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A Philosophical Analysis of Chet Bowers' Ethical Theory of EcoJustice: Shifting towards Uncertainty Thinking in Science Education

Michael Paul Mueller
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Michael Paul Mueller entitled "A Philosophical Analysis of Chet Bowers' Ethical Theory of EcoJustice: Shifting towards Uncertainty Thinking in Science Education." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

Barbara J. Thayer-Bacon, Major Professor

We have read this dissertation and recommend its acceptance:

Amadou Sall, Michael Bentley, John Peters

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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A PHILOSOPHICAL ANALYSIS OF CHET BOWERS' ETHICAL THEORY OF ECOJUSTICE: SHIFTING TOWARDS UNCERTAINTY THINKING IN SCIENCE EDUCATION

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Michael Paul Mueller
December 2007

Dedication

This dissertation is dedicated to my loving wife and sons.

Acknowledgements

I want to thank Dr. Barbara Thayer-Bacon for her guidance throughout my doctoral preparation and the dissertation. Her courses enlarged my thinking and helped me to recognize that the Earth has a significant story that is inseparable from our stories. She is an inspirational teacher who cares a great deal for the welfare of all of her students. I also want to thank my committee members, Dr. Michael Bentley, Dr. John Peters, and Dr. Amadou Sall for their participation in my intellectual development and dissertation. Finally, I want to thank Dr. Arthur Stewart, who is largely responsible for fostering my understanding of evolutionary ecology science and how scientists think with uncertainty. A Native American proverb notes: "we do not inherit the Earth from our ancestors, we borrow it from our children." May our children continue to inspire projects for the Earth.

Abstract

The purpose of this study is to analyze Chet Bowers' ethical theory of ecojustice as the basis of an ecological philosophy of education that recognizes Earth's uncertainty. Bowers' main thesis is that the commons, or what were once shared by members of the community, should be strengthened by education reforms based on ecojustice criteria. He argues for certain ideologies of the local authority of the commons, "Western" science and scientists, and the "ecological crisis." I argue that these certainties are uncertain, which justifies part certainty as deciphered by local people in places, in relation to others. Further, I develop a theory of ecological pragmatism, or thinking with uncertainty, grounded by the classical American pragmatist theory of John Dewey and other scholars. My expectation is to empower science teachers and their students to become informed, and share some of the responsibility for participating in local decisions as stakeholders and advocates for local communities, cultural diversity, and Earth's diverse ecosystems.

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Chapter 1: Chet Bowers' EcoJustice Philosophy

As a teacher educator in East Tennessee, I begin each semester with a "culture and community project" and ask my students to define the terms *culture* and *community*. I inform them that we will eventually define these terms, but that the authentic meanings cannot be found in the dictionary, encyclopedia, internet websites, and other sources. To be sure, we find and read aloud many definitions from various sources. Again, I tell my students that the meanings have yet to be found. At first, they think I'm joking because we have exhausted definitions from every available source. Initially, they do not realize that they are surrounded by meanings, and that getting to the source of these definitions will require that they explore the local community and ecosystems where they live. Thus, I partner students from nearby neighborhoods and ask them to talk face-to-face with elders, neighbors, farmers, business owners, teachers, and parents about the place that exists under their feet. With a great deal of uncertainty in mind, my students venture out into the community and into the woods, and attempt to get-to-know themselves again.

Meanwhile, in class, we discuss the significance of *places*. We begin by analyzing the local issues in my students' towns (for instance, methamphetamine "meth" problems). We discuss why we should take an interest in the place, become informed, and share the responsibility for setting things right when times are out of joint (Dewey, 1935). Next, we study how to interpret the "cultural heritage" of the landscape from walks in the woods, identifying plant species, the age of trees, patterns in nature, and the marks of earlier settlers and the Cherokee (Wessels, 1999, pp. 59-81). Further, we invite several local ecologists and a historian to give talks on the health of local ecosystems and explain

Appalachian weather folklore. We debate the significance of local knowledge in schools and how formal education may "cause students to worry about how they will make a living before they know who they are . . . and deaden their sense of wonder for the created world" (Orr, 1994, pp. 24-25). And finally, we consider existential questions of being in nature, from childhood to the present. We relate personal stories of how the natural environment impacts who we are and what we aspire to be. These conversations provide many opportunities to envision how places foster robust definitions of culture and community.

After four weeks of culture-community-nature interactions, my students are ready to present their projects in class. Rather than concentrate on generalized definitions of culture and community, I spend my time listening and learning the meanings from them. Each time, I am amazed at the number of hours my students put in outside of class, talking face-to-face with local people, visiting the library and historical sites, taking photos and interview notes, and hiking through the woods. As a teacher educator, my personal views of pluralistic Appalachian culture and community are continuously strengthened and I am convinced there are no absolutes. My students describe the early Appalachian settlers, Cherokee artifacts, civil war battlegrounds, the *homesteaders* (i.e., settlers under the Homestead Act), secret prison camps, slave graves, family game nights, "haint" tales (i.e., ghost stories), "bush hoggin" (i.e., mowing the yard), pumpkin festival, burned down city halls, old school buildings, haunted churches, the abandoned railway, favorite food diners, swimming holes, state parks, waterfalls, and bluegrass music. They explain how the interstates and U.S. highways bypassed their small towns – with devastating consequences – and how the Wal-Marts, and other big business, put their family-owned general stores out-of-business. My students' presentations are accompanied by PowerPoint, photo albums, scrap books, historical books, and other interesting artifacts, which evoke many interesting questions and conversations revealing community similarities and cultural pluralism.

My final assignment for my students is to learn an intergenerational skill from someone considered an "elder" in the community and then give something back in return. When my students discuss these final assignments, I am always amazed by the outcomes. My students describe how to bake a chocolate pie, pecan pie, fudge, and biscuits; make homemade jelly/jam and cook grandma's famous chicken and rice casserole; make a quilt, butterfly handkerchief, popsicle airplanes, and crochet a blanket; and tell a historical story, plow a field (the old-fashioned way), install a vehicle light, play the piano, and clog (i.e., a form of tap-dancing). Usually, students bring in food, crafts, quilts, stories, and other artifacts, to share with the class as they describe what they gave back in return: mow a lawn, paint a fence, organize a room, clean a garage, pick up grocery items, teach a class, and rehabilitate a three-year old quarter horse named Shilo. One student describes taking her grandmother dancing one evening at a local nightclub! And another student, after talking extensively with an 82-year-old woman in the hospital, finds a newspaper photograph of when she was the 1940 Beckley West Virginia Princess!

In the process of this assignment, my students realize the significance of their embodied experiences that go beyond the generalized definitions found in various sources. One student explains to the class that the elderly woman, who taught her how to crochet, told her that in her day, if she didn't know how to crochet, she wouldn't have any clothes. Another student says, "Maybe I can pass what I've learned to my sons and so on and so forth." Still other students comment that they now recognize how much local knowledge could be lost if ignored in the schools—that community is an integral part of cultural life. In essence, my students' ways of knowing the authentic meanings of culture and community come into focus, even though their individual definitions are never exactly the same. By engaging my students in these projects, I have become keenly aware that it is the interrelationships that are fostered, the differences and similarities that are recognized, along with the cultural pluralism and the natural environments that are conserved, that help my students to think with uncertainty in mind.

In this dissertation, I will defend the claim that we should embrace and value *uncertainty thinking* (Brewer & Gross, 2003) in science education to help teachers and students to participate fully in their community, conserve diverse cultures and the local ecosystems, dig deep roots, become informed, and make sound decisions that affect all of our lives (c.f., the glossary at the end of this chapter).

Hereafter, I discuss the large part of the picture, Chet Bowers' (1993, 2001, 2004a) insights that have influenced my work with students. The key point of this chapter is to show that Bowers' (op. cit.) *ecojustice* philosophy and education is a fruitful departure point for my philosophical work. The purpose of this dissertation is to analyze Bowers' (op. cit.) ecojustice philosophy, provide some of the groundwork for ecojustice, and work towards the development of a theoretical framework of uncertainty thinking for science education. Near the end of this chapter, I will situate Bowers' (op. cit.) philosophy within the larger spectrum of ecological scholars, defend my philosophical methodology, and connect with other scholars who have informed my thinking. A dissertation roadmap will outline the remaining study. Now, let's turn to ecojustice.

EcoJustice Philosophy

Our students will live in a world that is much different from the one in which their teachers were educated. Education during these times of uncertainty will challenge teachers to help students mediate the inherent tensions between their cultural ways of knowing and various forms of cultural and environmental enclosure (Bowers, 2001, 2004a, 2006). In this regard, Chet Bowers' (op. cit.) ecojustice philosophy plays a vital role in my own intellectual understanding, helping me to see the significance of conserving my students' cultures and intergenerational knowledges. Today, there are many distractions (e.g., television, internet, cell phones…) that come between individuals and an understanding of who they are and where they live. Without opportunities to analyze cultures with diverse others, we may not understand why many different views help to make more informed decisions. For diverse perspectives are influenced by many factors: shared views, fundamental beliefs and values, expectations, personal experiences and narratives. And, diverse perspectives help enlarge our own views. By learning to appreciate this cultural diversity, prospective teachers are more likely to work to conserve their own students' cultures and place-centered knowledges. They will help to foster intergenerational skills (e.g., cooking, repairing, and gardening) that could be lost when youth are so consumed by modern technology. As Earth's climate abruptly changes, intergenerational knowledges will be indispensable for the rapidly increasing human population that will need to adapt to fewer agricultural and natural resources. Unfortunately, with more people and a lack of sufficient resources on the horizon, the population may be prone to an inevitable collapse (Diamond, 2005; Morrison, 1999). A successful strategy for minimizing the consequences of population collapse is fixing environmental problems when they are small. The idea is that smaller problems are less difficult to work, on a precautionary basis, than if they escalate to levels beyond control. Now, more than anytime before, youth will need to be prepared to share with and rely on each other. Ecojustice educators will play a vital role in fostering these relationships.

Moreover, in response to Earth's changes, many species are now rapidly shifting geographic boundaries (Pennisi, 2007; Schwartz et al., 2006). Predicting which species should receive special conservation efforts and resources will require nothing short of the plurality of ways that humans come to know and express themselves in science. In previous geological times, Earth's variability determined where forests, mountains, rivers and wildlife have been located. Now that humans have ferociously intervened, we have an ethical responsibility to serve as stewards, to foster place-centered knowledges, and to participate fully in the decisions to conserve cultural pluralism and the Earth's wild ecosystems. Bowers' (2001, 2004a, 2006) *ecojustice education* will provide the basis for helping science teachers and students to navigate these choices before us.

Bowers (1993) defines the authentic meaning of culture in a way that is similar to what we explore in my teacher education courses. He notes: "anything that humans do, including those activities and artifacts that survive over time, can be understood as representing the influence of culture" (p. 19). Bowers (op. cit.) points out that some cultural beliefs and practices passed on through schooling are responsible for worsening "the ecological crisis" (pp. 1-33). He notes that, "if the thinking that guides educational reform does not take account of how the cultural beliefs and practices passed on through schooling relate to the deepening ecological crisis, then these efforts may actually strengthen the cultural orientation that is undermining the sustaining capacities of natural systems" (1993, p. 1). With Bowers' (op. cit.) help, I will explain further how these cultural assumptions are carried forward in schools.

Cultures and environments have a "memory effect." I was first introduced to this concept when I attended a global warming seminar at the University of Tennessee in Knoxville. The scientists displayed graphs and charts indicating that the trends of global warming would continue even if every polluter in the world was instantly stopped. They referred to this phenomenon as an environmental "memory effect." For me, thoughts of a smoky restaurant bar where I worked as a teenager came to mind. After the night comes to an end and the smoking stops, it definitely takes time for the smoke to clear, and the smoky scent and residue remain. The metaphor of "memory effect" can aptly be applied to cultural memories as well. For instance, despite the efforts to overcome racism for more than sixty years the residues of intolerance can still be found in the cultural memories of U.S. society in the year 2007.

Cultural memories are encoded by people who live during that period of culture; these memories are lived and passed on. Root metaphors likely are inculcated in, and further support, these memories; they are evident in, and even stabilized by, vernacular languages. Similar to an acorn that grows into an oak, the metaphorical nature of language carries cultural meanings through the cultural memories of many generations of people that can be traced back to the ancient rootstocks. Cultural memories can reinforce the cultural patterns of thinking that emphasize certain structures and reduce others. For instance, the Euro-Western patterns of thinking that legitimize "what counts" as the nature of scientific work has been historically and unconsciously upheld by the root metaphors of *individualism* (i.e., privileging self-interest), *anthropocentrism* (i.e., privileging humans), *emancipation* (i.e., privileging independence), *scientism* (i.e., privileging scientific meta-narratives), and technological change equated with progress (Bowers, 1993, 2001). That some root metaphors are upheld means others are marginalized. More and more scholars are writing about the root metaphors historically associated with women, the poor, ancient peoples, and non-Westerners that have been delegitimized, deemphasized, and devalued (Code, 2006; Martin, 1982, 1985; Seigfried, 1996; Shiva, 1997, 2001, 2005; Thayer-Bacon, 2000, 2003).

The root metaphors (mentioned above) in the Euro-Western cultural memory were amplified during the Industrial Revolution, a period of economic and social changes starting around 1760 in England. During the Industrial Revolution, manual labor was displaced by machines that were enabled by rapid and continuous scientific and technological advancements. These advancements were equated with progress. This progress led to the power-technologies, such as the increasing coal-dependent steam engine that rapidly filled the surrounding skies with smoky pollutants. In England, the increased need for coal meant more profits and further amplified the impact of progress. Referred to as the "father of English Geology," William Smith (1769-1839) developed a way to predict, draw, and map the coal below the surface of the ground to further exploit it (Winchester, 2002). Winchester (op. cit.) notes the patterns of thinking that lead up to the Industrial Revolution and legitimized the destruction of the ground:

> . . . there was no stopping it. Wherever in the country coal was exposed at the surface—near Gateshead, close to Mansfield, outside Sheffield, in South Wales, near the Scottish town of Lanark—men clawed hungrily for it. It was convenient if the coal remained close to the surface: It was easy to work, and cheap. But it

> became so important a source of energy and heat that, by the fifteenth century, if a coal seam happened to plunge deep into the ground, then, discounting all risks in the name of profit, they promptly dug after it (pp. 45-46).

Smith's geology was followed by a set of scientific movements that influenced Charles Darwin's theories of evolution and natural selection, and that would eventually provide the overarching theoretical frames for biology. Thereafter, a privileged scientific lens for viewing every aspect of cultural life developed concurrently with the Industrial Revolution, and may inadvertently be taken-for-granted by a few scientists today (Bowers, 2002, 2003, 2004b). This lens may even privilege the construction, deconstruction, reconstruction, and transformation of every aspect of cultural life, and is implicit in education reforms that emphasize competition for economic self-interests.

In 1974, Chet Bowers wrote his first book, *Cultural Literacy for Freedom*, emphasizing the significance of the cultural aspects of ecological literacy in public schools and universities. He explained that, at the time, he used an emancipatory liberal framework as a basis for promoting cultural and ecological sustainability (Bowers, 1996). Several years later, he noticed how various environmental groups misused the environment for short-term economic gains and realized that liberalism actually justified, through the root metaphors of individualism and technological progress, the further degradation of the environment. Thereafter, Bowers' (1993, 2001, 2004a) critiques of today's prevailing cultural views have fallen into three categories: the emancipation theories of education, educational computing and technology, and science.

Since Bowers (2001, 2002, 2003, 2004b) is a prolific scholar, I have narrowed my interests to his critiques of the cultural root metaphors (or ideologies) of science, and proposals for how ecojustice education may be used in science education. These cultural assumptions are particularly interesting because of my work with science teachers. Because science teachers work with students to understand the natural world, they need opportunities to think through the ideologies that are encoded and reproduced through language that is deeply embedded in the dominant culture and reifies certain cultural ways of knowing, along with certain practices, over others, which provides a frame of reference for viewing the natural world. Science education has not historically provided these kinds of opportunities for prospective science teachers. Yet these cultural root metaphors legitimize certain educational practices that may be responsible for deemphasizing and ignoring the ecological realm, and carry forward the "double binds" of the Euro-Western cultural memory (see Bateson, 1972/2000, pp. 271-278). For example, critical theory, while advancing an anti-racist and anti-classist agenda, does not provide an adequate understanding of how to conserve relational knowledges, intergenerational knowledges, indigenous knowledges, and traditional ecological wisdom that may be needed to decrease *consumerism* (i.e., the increasing consumption of goods). For Bowers (2001), critical theory is noted as "all patterns of human existence, regardless of cultural group . . . made explicit and . . . 'interrogated' in order to emancipate individuals" (pp. 50-51). He explains that critical pedagogues call for the transformation of the "political processes that subjugate individuals" into the "politics of liberation" (p. 51). Bowers (op. cit.) contends that the "politics of liberation" are short-sighted if they deemphasize or ignore the authority of the parents, the community, or the ecological realm. Keeping one eye open to liberation while keeping the other eye closed to what students are being freed from may intensify ecological declines, which Bowers (op. cit.) equates with the deepening ecological crisis.

Bowers (1995) argues that "when framed in terms of what the ecological crisis really is, namely, a worldwide crisis that challenges the foundational beliefs of every cultural group, the range of issues needing to be addressed by educational philosophers becomes nearly overwhelming" (p. 311). He explains that we should pay particular attention to the "assumptions, values, and analogues taught as part of the explicit and implicit curricula—in the public schools and teacher education programs" (p. 315). He notes that educational theorists will play a vital role in analyzing the educational implications of the ecological crisis:

> The threat our particular form of modernization poses for the Earth has led to a number of distinct discourses that also need to be sorted out by educational theorists. Ecofeminists, social ecologists, deep ecologists, and the emerging discourse that goes by the name of ecosophy represent what can be interpreted as new expressions of grounded philosophical inquiry. Each discourse represents an attempt to recover or constitute metanarratives for clarifying both the root causes of our environmental dilemmas and the directions for future cultural development (p. 316).

Bowers (op. cit.) notes that we should look to countries like Chile, Tunisia, and Kazakhstan, as part of the worldwide environmental movement, where local people are using democratic practices to make decisions that affect local bioregions. He says that most post-colonial societies are engaging in grass roots environmentalism to solve local problems that would not be possible without this democratic engagement.

Bowers (1995) wants formal education to be framed by the ecological crisis. He says that teachers and students can learn a great deal by examining their own cultural assumptions and the assumptions of traditional ecologically-centered cultures. “Education needs to be understood as a process of conserving cultural patterns,” he continues, “that enable people to meet their material, communal, and spiritual needs without further degrading the habitat” (p. 318). He points to the common characteristics of traditional ecologically centered cultures including the themes of harmony with nature, cyclical notion of time, and the “spiritual languages of art, music, dance, and narrative which are essential for connecting the person to a larger symbolic universe” (p. 320). He also includes the characteristics of marginalized minority cultural groups—“American Indian, Hispanic-American, African-American, poor rural whites, and religious communities who have chosen to live apart from the materialism of mainstream culture” (p. 321). Bowers (op. cit.) wants us to view the ecological crisis as a significant issue, take seriously the cultural patterns of thinking that contribute to an ecologically sustainable lifestyle, and introduce these ways of knowing as educational reform.

Bowers (1996) defines the concept of *ecological literacy* in schools as “awareness of how the assumptions, values, technologies, and categories of thinking of a culture influence how humans relate to the environment” (p. 1). He explains that the following ideologies have a profound impact on the thinking patterns and behaviors of teachers and students and contribute to the ecological crisis:

> (a) that change and experimentation with the foundations of culture are inherently progressive in nature, (b) that an anthropocentric interpretation of the Earth’s ecosystems represents the highest expression of enlightened thinking,

> anthropocentrism as the highest expression of Enlightenment thinking, (c) that individual autonomy in the areas of thought and values represents the fullest realization of human potential, (d) that science and technology are the twin engines of human progress, and (e) that the Western form of modernization represents the most advanced stage of human development and should be promoted throughout the world (pp. 1-2).

In contrast, Bowers (op. cit.) provides the ideologies of more ecologically informed cultures including the Kwakiutl of the Pacific Northwest, the Balinese of South East Asia, and the Ladahkis near the Himalayas. He explains that the educational approach valued by these cultures is centered on the cultural transmission of ceremonies, the arts, and narratives. Ecologically oriented peoples depend on intergenerational knowledges that provide the moral framework for sustainable lifestyles (Bowers acknowledges there are exceptions). Their oral narratives are centered on the interconnectiveness of all things and emphasize human relationships with the rest of the biotic community. Bowers (op. cit.) explains that communication within these ecologically-centered cultures is regarded as an integral part of moral and environmental education. He believes that the difficulty of Euro-Western cultures to understand an ecologically sustainable lifestyle can be attributed to (a) the early Biblical creation stories that emphasized anthropocentrism, (b) the emergence of science as the most rational way to understand the natural world, (c) and the transmission of cultural patterns of thinking that undermine the significance of the natural environment in our everyday lives.

Bowers (1996) wants teachers and students to become aware of the orientations that view intergenerational knowledges as problematic. Moreover, he wants teachers and students to understand the significance of culture/nature relationships and the relationships of mentoring, nurturing, playing, oral narratives, and other community ways of knowing, that are so often excluded in the school curriculum. He works towards an ecojustice perspective that serves ecological literacy by promoting "habitat *restoration*, environment *preservation* and *conservation*, as well as by cultural groups that have developed along more ecologically sustainable pathways" (p. 60, emphasis in original). At the center of this perspective is an awareness of the cultural assumptions that are encoded and reproduced through metaphorical language. And, Bowers (op. cit.) wants educational reformers to think in terms of a more ecologically balanced approach to education, community, economy, science, and technology.

In the preceding segment, I provided a large part of the picture, Bowers' (1993, 1995, 1996) insights that have influenced my conversations with prospective teachers, resulting in some interesting culture and community projects. In the future, I will enjoy developing new courses in science education that engage my students in an analysis of the cultural thinking patterns, embedded in language, that intensify ecological declines. These courses will focus on whether science and science education carry forward the cultural assumptions that contribute to the enclosure of cultures and the wild ecosystems. En route, Bowers' (2001, 2004a, 2006) ecojustice education will be used to help science teachers and students to deal with the various forms of cultural and environmental enclosures (e.g., consumerism, monoculture, globalization). At this point, I will discuss how Bowers' (op. cit.) ecojustice philosophy fits within the range of ecological works.

Why Explore EcoJustice Education

An essential characteristic of ecojustice education (Bowers, 2001, 2004a, 2006) is the conservation of cultural diversity and biodiversity. Conservation decisions are framed by the authority of the community and the needs of the local ecosystems. While traditions are highly valued by ecojustice education, they may be oppressive and should be changed without increasing humankind's destructive impacts (i.e., ecological footprint). Bowers (op. cit.) notes that traditions should always be framed by the wider spectrum of traditional ecological wisdom (TEKs), or place-centered knowledges, whenever possible. Moreover, Bowers (op. cit.) argues that the conservation of civil liberties, species and habitats, oral narratives, the arts, ceremonies, and intergenerational ways of living within the local ecosystems are much different from the political uses of the terms "conservative" and "liberal." He explains that both political platforms carry forward the cultural views (e.g., anthropocentrism and hyper-consumerism) that developed concurrently with the Industrial Revolution. It is a mistake to misinterpret Bowers' (op. cit.) ecojustice philosophy as endorsing a neo-conservative or neo-liberal political agenda—he also does not seek to renew a tradition of philosophical romanticism. The educational projects that I will discuss in this dissertation, including my work with students, should serve to reinforce that ecojustice does not imply impractical romantic ideals and attitudes. However, as Dilafruz Williams (2002) points out, the fact that people no longer stay in places presents a challenge for renewing the local democratic energies of place-centered knowledges. "Commitment to community and place" (Williams, 2002, p. 8) requires that conservation in the ecojustice sense of the word is careful socio-cultural and historical environmental activism where the focus is on strengthening TEKs.

In studying Bowers' (2001, 2004a, 2006) ecological perspectives, I do not wish to minimize the contributions of other environmental philosophers. Other scholars' works that I have reviewed include the following: *environmental ethics* (e.g., Peter Singer, J. Baird Callicott, and Holmes Rolston III), *deep ecology* (e.g., Arne Naess, George Sessions, and Warwick Fox), *ecofeminism* (e.g., Karen Warren, Carolyn Merchant, and Vandana Shiva), and *social ecology* (e.g., John Clark and Gary Snyder). The selected authors were reviewed in an environmental philosophy anthology edited by Zimmerman et al. (2001). David Orr (1994) also provides many interesting essays on the dangers of education and is often cited for his statement that "all education is environmental education" (p. 12). These scholars have not provided as many details as Chet Bowers' (2001, 2002, 2003, 2004b) works that specifically propose how teachers and students can deal with the cultural patterns of thinking deeply embedded in science and science education, which may lead to cultural and environmental enclosures, which is why I turn to Bowers' (op. cit.) works in chapter two.

Bowers (2001, 2004a, 2006) and other educational philosophers have written about the importance of ecological awareness in schools. Barbara Thayer-Bacon (2000, 2003) provides theories of relational thinking aimed at healing the culture/nature split. She addresses anthropocentrism, anthropomorphism, ecological feminism, and Native American and Buddhist views, through a pragmatic and postmodern lens. She wants to help teachers and students understand the importance of multiple perspectives and multidimensional thinking in schools. Her works have been very influential in my own thinking and are used throughout this study. Another scholar, Nel Noddings (2003, 2006) addresses the aims of happiness and critical thinking in schools with chapters on places, animals, and nature. She wants to help teachers and students think about empathy and care for animals, plants and ecological places, and yet she does not go far enough to address anthropocentrism that emerges in existentialism. Gregory Smith (2002a, 2002b, 2004) and Dilafruz Williams (Smith & Williams, 1999) have written several articles and books on environmental schools. These two educators emphasize a holistic service-learning curriculum focused on care, the community, and the environment as the overarching theme for all studies at an environmental middle school in Oregon. Similarly, David Sobel (1996, 2005) has written several books that focus on environmentalism and place-based projects in schools. Although these scholars offer many interesting perspectives, they do not provide in-depth critiques of the cultural assumptions linked with science and science education. Another scholar taking up place-based education, David Gruenewald (2003a, 2003b, 2004), too, has addressed ecojustice. His work, though, relies heavily on critical pedagogy, which limits how teachers and students should decide what's worth conserving in the commons, how to act on those decisions, and does not provide an adequate foundation for how places exist in relation to others.

Other scholars overemphasize science in their philosophies. The Harvard biologist E.O. Wilson (1998, 2002, 2006) provides many convincing arguments that support ecological declines and some excellent recommendations for restoring green corridors. However, he does not spend much time discussing the limitations of science. Earlier scientists relied on equal measures of science and non-science ways of knowing. Rachel Carson (1955/1983, 1962/1994) and Aldo Leopold (1949/1968) have been credited with the careful observations and environmental works that were influential to the modern environmental movement. Carson (1962/1994) is most cited for calling attention to the toxic affects of the insecticide *dichlorodiphenyltrichloroethane*, or DDT (hence *Silent Spring*), and Leopold (1949/1968) for his *land ethic* (i.e., an enlarged sense of community that includes the Earth's natural systems). Finally, the naturalists and transcendentalists (i.e., to think beyond nature) Ralph Waldo Emerson, Henry David Thoreau (1962), John Muir (1987/1997), and more recently Terry Tempest Williams (2004) provide interesting observations of the world through essays, poems, drawings, and nature writings often based in science but filled with ecological and spiritual transcendence.

Although these scholars all share a love for the natural world and provided many interesting ecological perspectives, Chet Bowers' (2001, 2004a, 2006) ecojustice education remains an appealing prospect for mindfully conserving and sustaining the cultural and environmental commons, and helping teachers and students deal with the cultural assumptions that may be carried forward in science education. While a few science educators (Aikenhead, 2006; Glasson et al., 2006; Tilgner, 2005) bring attention to TEKs, ecojustice education highlights TEKs as legitimate expressions of science and emphasizes the moral reciprocity of ecologically informed cultures. Ecojustice education emphasizes peoples' place-centered awareness, intergenerational know-how, face-to-face conversations, mentoring relationships, ceremonies, the arts, and ethical reasoning as part of the process of doing science. The central theme of ecojustice education is revitalizing neighborhoods and the local ecosystems as opposed to memorizing facts/concepts. Moreover, ecojustice education prompts science teachers to ask questions that may be considered outside the scope of science teaching, such as: Is it safe for students to walk or ride a bike to school? Might students be involved in working with the community to plant native grasses, to establish wildflower gardens, and to reduce irrigation? Ecojustice education cultivates important relationships with the community. Most importantly, ecojustice pedagogy is responsive to specific geographic locations and local peoples. And, success is measured by the renewal of cultural pluralism and the biodiversity of Earth's wild ecosystems rather than IQ tests or adequate yearly progress (AYP).

A significant challenge for ecojustice education (Bowers, 2001, 2004a, 2006) is that of breaking down the phrase "ecological crisis"—a position statement which may limit who gets to participate in reducing humankind's devastating impacts. This phrase is problematic in environmental and ecological philosophy, in general. Many people still look to the experts (i.e., scientists and technologists) to "solve" whatever form the ecological crisis may take (e.g., global warming, endangered polar bears, rising seas…) and perhaps, fail to recognize that they need to play a vital role as stakeholders who advocate and care for the community and local ecosystems. Further, there is a great deal of ambiguity with respect to the scale and significance of the ecological crisis assumed in Bowers (op. cit.) works. It is well-known, at least within the scientific community, that the scale and significance of environmental declines cannot be proven by science and remains highly uncertain because we have limited perspectives, according to the report from the International Panel on Climate Change (IPCC, 2001), the National Research Council (NRC, 2001, 2002), and other scientists (Grimm, 2006; Pollack, 2003/2005). While ecojustice education was originally intended to help science teachers and students to recognize the harmful assumptions carried forward with *positivistic* forms of science (i.e., all knowledge based on empirical experiences), Bowers' (2001, 2006) ecojustice does not go far enough to provide other science narratives, with the exception of TEKs.

Positivism may privilege certainty, and yet since at least the times of Albert Einstein, working with uncertainty is acknowledged as an essential aspect of doing scientific work.

I will eventually argue that uncertainty thinking is a natural extension of ecojustice education which values local knowledges, beliefs and values, expectations, personal experiences and place-centered narratives. As ecologists and policymakers have worked together, they have discovered that diverse knowledges are needed to evaluate multiple routes of action that result in multiple uncertain ecological outcomes projected with some confidence (Aslaksen & Myhr, 2007; Brewer & Gross, 2003; Clark, 2003). My theoretical contribution will be showing how ecojustice scholars will benefit from preparing science teachers and students to think with uncertainty in mind. At the same time, I will counter a performance contradiction for ecojustice (Bowers, 2001, 2006) when asking teachers and students to think through the cultural views linked with science while the assumptions associated with the ecological crisis remain hidden.

Philosophical Research in Science Education

In science education, many researchers value the more popular quantitative and qualitative approaches. These empirical approaches are considered "what one does" when they are a scholar in the field. Empirical research (i.e., the kind that requires rigorous evidence) is often described as "scientifically-based educational research" (Eisenhart, 2005; Eisenhart & DeHaan, 2005). However, educational philosophy is not mentioned as a research type in these educational reforms. Further, the U.S. Department of Education has prioritized funding for projects that are "scientifically-based." This situation empowers empiricists, but not philosophers. Because of a general misunderstanding and the pervasive shortage of research funds, many science educators deemphasize or ignore altogether philosophical works. However, philosophical research is gaining ground on traditional empiricism. New journals in science education (e.g., *Cultural Studies of Science Education*), specifically designed for theoretical conversations and cultural studies, have emerged in the last couple years.

Despite the underutilization of philosophy in the past, a significant way to determine what *should* be the case in science education theory, research, and practice is philosophical research (Thayer-Bacon & Moyer, 2006). Educational philosophy helps us to become consciously aware of the cultural assumptions we take-for-granted, and offers other perspectives, possibilities and potentialities, that help us to locate ourselves in relation to others in the world.

Philosophy should not be judged on scientific standards and vice versa (Thayer-Bacon & Moyer, 2006). Philosophical research differs from scientific research, in terms of objectives and goals. While scientific research emphasizes facts, logic and empirical verification, philosophy makes the case for what should be, ideally, warranted by logic and fruitfulness of the argument, as well as intuition, imagination, emotion, and communication and relating skills (Thayer-Bacon, 2000; Thayer-Bacon & Moyer, 2006). Philosophers don't try to make a case based on their personal opinion, rather, they make a case based on what is good, right, or just, for all people, across times and cultures. John Locke, for example, argued that people should be treated with dignity and respect, and Plato argued that women are just as capable as men to run a country/state (Thayer-Bacon & Moyer, 2006). Philosophical and scientific arguments both are continually open to reexamination and reinterpretation, and must withstand the test of time. Not all philosophers agree on the role of philosophy, what limits philosophy, or how to make a good, strong argument (similar to today's scientific work). Despite these considerations, philosophers agree that working with ideas is a way to establish normative claims.

Philosophical Methodology

For this philosophical study, I use a pragmatist/postmodern argumentation style. American pragmatism was initiated by the contributions of Charles S. Pierce, William James, John Dewey, and others (Seigfried, 1996; Thayer-Bacon, 2000, 2003, 2006). Pragmatists believe there is a direct link between thought and action, that existence and time are relational and fluid, thought is socio-cultural and historically contextual, and universal truths are problematic. Pragmatists almost always focus on their experiences and the experiences of others to provide the justifications for philosophical claims. Historically, pragmatists believe that knowledge is socio-culturally constructed and reconstructed in relation to momentum, fluidity, relationality, and potentiality. Richard Rorty (1979), Barbara Thayer-Bacon (2000, 2003), and Cornel West (2004) are examples of philosophers who have used a pragmatist argumentation style.

Pragmatism will help me to find the disconnections between thought and action in Bowers' (2001, 2002, 2003, 2004b) critiques of the cultural views of science. In the past, Bowers' (1995, 2001, 2004a) works have been criticized for a lack of pragmatic supports and educational applications (Desmond et al., 2003; Edmundson, 2001; Prakash, 1995). In chapter three, I will connect with other scholars to analyze Bowers' (op. cit.)

justifications for ecojustice education (i.e., groundwork for ecojustice). As noted above, empirical research is privileged to philosophical study in science education. Pragmatic warrants should serve to help science educators to make more sense of ecojustice education, and hopefully to take it seriously in science teacher preparation. There is a direct link between Bowers' (2001, 2002, 2003, 2004b) critiques, ecojustice education, and my theory of uncertainty thinking that I will explore further in this study. If Bowers (op. cit.) provides some of the "thought" side of the coin, I will provide some of the "action" side, particularly when it comes to ideas such as Darwin's theory of evolution and natural selection. As an "ecological pragmatist," I will enhance Bowers' (op. cit.) ecojustice education by showing how ecologists, wildlife biologists and other scientists use evolutionary ecology and other forms of uncertainty thinking to do their work.

Postmodernism is used to analyze notions of truth embedded in the institutions that conserve and sustain them. Postmodernists believe there is a direct link between power and knowledge, power is repressive and negative (as well as generative and productive), and power is embedded in historical contexts (Thayer-Bacon, 2000, 2003, 2006). Research questions are typically designed around issues of power and the role of the philosopher is to focus on the parts of the whole, such as the means of knowledge, discourses, objects, and how they are legitimized and situated. A postmodern approach embraces and values pluralism (i.e., human diversity) and qualified relativism. Thayer-Bacon (2003) defines *qualified relativism* as "acknowledging our own particularities and situatedness, which we learn about through our social interactions with others not like us" (p. 64). Qualified relativism opens the possibility of a view from pluralistic social communities in relation to others. The aim of postmodern works is to find cracks and fissures in taken-for-granted shared assumptions for the purpose of illuminating possibilities and potentialities. Michel Foucault (1977/1995) and Patti Lather (1991a, 1991b) are examples of philosophers who have used a postmodernist or poststructuralist argumentation style. And, feminist theory which traditionally analyzes power relationships and the structures typically associated with women has contributed significantly to postmodernism (Code, 2006; Thayer-Bacon, 2000, 2003).

Postmodernism will help me to explore the direct links between power and knowledge in Bowers' (2001, 2002, 2003, 2004b) notions of the ecological crisis. Specifically, I am concerned with how the presumed ecological crisis privileges people who are assumed to be more certain (e.g., mathematicians, scientists, engineers…). Subsequently, people who may be assumed less certain (e.g., women, children, theists…) are also assumed to be inferior and not taken as seriously. People who are not taken seriously may be excluded from the ecological decisions that affect the community and local ecosystems. Often people who are least taken seriously are the most impacted by local decision-making (e.g., locating a landfill in impoverished neighborhoods). Thinking with universalized certainty is an illusive device that helps humans to make sense of the world, and yet contributes significantly to negative ecological impacts (Morrison, 1999); absolute certainty should not be privileged as a way of knowing in ecojustice education. Postmodernism will help me to develop a theoretical framework of uncertainty thinking that will benefit both ecojustice and science education.

Now, I detail my philosophical methodology by connecting with scholars that have influenced my thinking. My philosophical perspective starts with Aristotle (Barnes, 1982; Kaufman, 1998; Saunders, 1992) who believed that ideas needed to be grounded in empiricism, or sensation and experience. While Aristotle privileged an interdisciplinary approach (i.e., philosophy, science, and the arts) to understanding the natural world, he had a tendency to deemphasize or ignore Earth's complexity and instability. In this way, he was heavily influenced by the certainty thinkers (i.e., Socrates, Plato, Euclid), who have had much more of an impact in the physical sciences, such as chemistry and physics (Bowler, 1992). Although Aristotle knew there were dangers with generalizations, and he knew that the Earth was changing rather than eternally fixed (i.e., Plato's view), Aristotle would take what he found in the natural world (as well as local stories from fisherman, herdsmen, beekeepers) and try to rationalize and categorize it (Barnes, 1982). Thus, I reject Aristotle's notion that the ecological world exists "out there" to be contemplated.

I agree with John Dewey's (1910/1997, 1925/1971) insights that all aspects of cultural life cannot be separated from the natural world. By this statement, he meant that there is a false dichotomy between the knower and that which is known. He resolved this dichotomy by claiming that learning involves doing something to the thing and in the process, and it does something back to us through reflective inquiry. Dewey (1916/1966) argued that "since growth is the characteristic of life, education is all one with growing; it has no end beyond itself. The criterion of the value of school education is the extent in which it creates a desire for continued growth and supplies means for making the desire effective in fact" (p. 53). These perspectives helped Dewey (1938/1963) advance the field of philosophy of education and argue for an education of *connectiveness in growth* (i.e., fluidity and plasticity). Dewey (op. cit.) was deeply embedded in the cultural memories of the day, and was particularly fascinated with Charles Darwin's *Origin of Species,* a popular book of the Victorian era. However, the *Origin of Species* largely ignored the contributions of Indigenous peoples and women in science. These limitations, in turn, are reflected in some of Dewey's (op. cit.) works. Despite Dewey's (op. cit.) limitations, ecologically influenced scholars have amended and extended his ideas in education.

Another early twentieth century scholar, William James (1901) also advanced the field of philosophy of education by recognizing the importance of multiple perspectives. James (op. cit.) used the notion of *radical pluralism* to mean that all things are relational, and yet nothing includes everything else simultaneously (Thayer-Bacon, 2003). His contributions of pluralism and relativism have been acknowledged in the development of postmodern thought. Yet James (1901) was also limited by a view of the natural world that was largely influenced by Euro-Western thought. It would have been a feat in itself, both for William James (op. cit.) and John Dewey (1938/1963) to be aware of all of the double binds linked with Euro-Western thinking during a time when ecological denigration was not well known. Both of these scholars would have benefited from acknowledging the relational views of Indigenous peoples and women. Feminist scholars (Martin, 1982, 1985; Okin, 1979; Seigfried, 1996; Thayer-Bacon, 2000, 2003) have troubled these early pragmatist's views by including the root metaphors that have been associated with women including childrearing and parenting. Barbara Thayer-Bacon (op. cit.) has been particularly influential in my understanding of this feminist scholarship.

Thayer-Bacon's (2000, 2003) notions of *individuals-in-relation-to-others* and *relational (e)pistemologies* help us to understand how human beings are embedded, embodied, and engaged within ecological and spiritual situations that are social, cultural, and historical. In her theory of *constructive thinking*, Thayer-Bacon (2000) argues that rationality may be over-emphasized by scientists as the exclusive tool of inquiry in order to reduce personal bias and assumptions that may interfere with objectivity. She reminds us that the nature of science and scientific inquiry in education go beyond the exclusivity of traditional Euro-Western thought and include the larger spectrum of expanded and enhanced constructive thinking – embracing, in addition to logic, emotion, imagination, and intuition, if we wish to care for and connect with the students' ecologically situated lives. She reminds us that students are individuals-in-relation-to-others; they are embedded, embodied, situated and constructive thinkers.

In *Relational (e)pistemologies* (2003), Thayer-Bacon draws on aspects of William James and John Dewey's classical pragmatist theories. In particular, she describes James' truths, radical empiricism, radical pluralism, and Dewey's warranted assertions and notions of democracy. She illustrates relational epistemologies including social relations, w/holistic relations, ecological relations, and scientific relations. She reminds us that relational epistemologies are socio-culturally and historically constructed by embedded, embodied knowers in relation with each other. She encourages us to embrace and value a multidisciplinary approach to education by recognizing the importance of pluralism, diversity and biodiversity. She redirects our attention to interrelational human knowledges and experiences that are reflective, reliant, and reciprocal of the Earth.

Further, Thayer-Bacon (2000, 2003) pays careful attention to many different voices (past, present, future, contrasting, consonant…), and includes them throughout her philosophical works before critiquing them. This philosophical approach is described as *caring reasoning*, meaning that we should try to pay attention to others before judging. In many ways, this philosophical approach provides for "blind" reviewers a way to move beyond the well-established "norms" that may limit their understanding of the argument.

To embrace and value this type of constructive scholarship takes much empathy, care and imagination. Philosophical conversation can run contrary to accepted conventions, and caring reasoning in these cases may help reviewers go beyond deciding the worth of various authors' contributions based on whether they fit in. Caring reasoning also can help ecojustice educators connect with others and avoid us-versus-them mentalities.

There are many ways in which we can connect with others. Goldberger et al. (1996) emphasize legitimizing the other in belief, without doubt, at least initially. Through connected knowing, we try to give the other an attentive ear and affirm their position without judging. The connected knower uses a great amount of empathy to understand the other, walk in their shoes, see it through their eyes, and preserve their life space. To the connected knower, pluralism, multiculturalism, multiple voices, inclusion, biodiversity, and open-mindedness are all essential structures to survival on the Earth. Connected knowing reminds us to view a situation through as many different lenses as possible and embrace and value their contributions even if we disagree. These diverse perspectives secure diverse selves-in-relation-to-others within dynamic places and must be conserved. In other words, these diverse perspectives help us to think about our roots. If we do not recognize our rooted selves-in-relation-to-others, we may simply deemphasize or ignore ideas that do not align with the accepted paradigms or status quo.

Relational individuals should never loose (i.e., decontextualize) themselves in the process of participating more fully in cultural and environmental situations and decisions. When educational situations are conceived in general, they may be used to inform, but not to universally represent situated peoples' thinking patterns or collaborative behaviors. Lisa Delpit (1988) and Elizabeth Ellsworth (1989) note that the emancipation projects of constructivism and critical theory are never justified for all peoples and places. Sometimes, these educational frames deemphasize or ignore the intergenerational knowledges and community authority that has been keenly developed over thousands of years of generational experiences of living within the limits of the local ecosystems encoded and reproduced through oral narratives, the arts, ceremonies, relationships, and spirituality. Perhaps these educational theories have historically and mistakenly neglected the ecological realm and seem to privilege the construction and transformation of every aspect of cultural life; it is always worthwhile to think carefully of developing theories.

Summary

Education is mistakably ecological. To demonstrate this point, I began with a description of a culture and community project that I use to help my prospective teachers foster interrelationships, discuss differences and similarities, and conserve cultural pluralism and the natural environment. This project helps my students to situate themselves, to think with uncertainty in mind, and to mediate the tensions between their ways of knowing and various forms of cultural and environmental enclosures.

My work aligns with Chet Bowers' (1993, 1995, 2001) works that emphasize ecological literacy—albeit, I will expand this notion to integrate ecological philosophy and ecology science. Bowers' (op. cit.) philosophical works hold the basic assumption that all knowledge and language is informed by root metaphors, which "think us," as we think them. The metaphorical nature of language is carried forward in the cultural memories of peoples and reflective of places. Bowers (op. cit.) notes that the ecological crisis challenges the fundamental beliefs and values of every cultural group, and that presents a significant challenge for ecological philosophers—he encourages local democratic decision-making to benefit the bioregion. Bowers (op. cit.) wants teachers and students to recognize how assumptions, values, technology, and cultural ways of knowing, influence how humans relate to the ecological world. He emphasizes the significance of cultural/nature relationships, mentoring, nurturing, playing, stories, and other community ways of knowing, that could be integrated into the school curricula. Equally, if not more importantly, he argues that the school curricula should embody a balanced approach to education, community, technology, and science.

Likewise, Bowers (1995) wants teachers and students to look to the ecofeminists, deep ecologists, and social ecologists – environmentalists – who argue for the conservation of the non-commodified aspects of community life. He advocates that what needs to be conserved and sustained be framed by the authority of the community and the needs of local ecosystems. He notes that some traditions are oppressive and should be changed, yet without further devastation to Earth's ecosystems. I pointed out that shifting communities requires ecojustice education to be deeply cognizant of the local traditions and interrelationships of people in places. My future work will continue to be informed by ecojustice philosophy and by other scholars that I will discuss in this study.

Roadmap for the Dissertation

My goal is to analyze Bowers' (2001, 2002, 2003, 2004b) philosophical works that address the cultural views linked with science using a pragmatic/postmodern argumentation style, to pay careful attention to the ideologies of the ecological crisis. In chapter two, I will take up a thoughtful description of Bowers' (op. cit.) ethical theory of ecojustice and several critiques of the cultural views of science. He will argue that the commons must be revitalized to prevent further enclosures of cultures and environments. Likewise, he will discuss how educational research has been patterned after the rigors of scientific work for many years, how Charles Darwin's theory of evolution and natural selection have become powerful metaphors in education, and how these theories may inadvertently perpetuate the notion that change is inherently progressive.

In chapter three, I will connect with other interested scholars to think carefully about Bowers' (2001) ecojustice-centered recommendations for science education. Several scholars (Brickhouse & Kittleson, 2006; Desmond et al., 2003; McLaren & Houston, 2004; Prakash, 1995) will raise concerns that ecojustice lacks pragmatic warrants and does not adequately address the notion of local authority of the commons. Likewise, I will discuss Bowers' (2001, 2002, 2003, 2004b) ideologies of scientists and "Western" science by connecting with Nancy Brickhouse and Julie Kittleson (2006) and E.O. Wilson (2002, 2006). My expectation is that chapter three will provide a better understanding of the emerging theories in evolutionary ecology (Pennisi, 2007), which counter reductionist conceptions of Darwin's theory of evolution and natural selection. An analysis of the notion of deepening ecological crisis will conclude chapter three.

In chapter four, I will work to develop a theoretical framework of uncertainty thinking, which includes place-centered science education for ecojustice and activism. Uncertainty thinking in ecojustice-centered science education will acknowledge the significance of high uncertainty in today's environmental sciences (Pollack, 2003/2005).

With uncertainty in mind, I will argue to reposition science teachers and their students as citizen-scientists (Feynman, 1998; Roth & Barton, 2004; Wilson, 2006), as legitimized stakeholders (Aslaksen & Myhr, 2007; Ravetz & Funtowicz, 1999), and as advocates who care for affected parties in the local community and ecosystems (Thayer-Bacon, 2003). I will show how uncertainty thinking will help science teachers and students to assess ecological vulnerabilities, analyze scenarios, and work with multiple perspectives. Uncertainty thinking is a natural extension of ecojustice-centered education and will do much to empower people in local communities to share some of the responsibility for becoming informed, participating more fully in local ecological decisions, and working as advocates and caring for other people and the Earth's natural systems. Ecojustice and place-centered science education will provide the basis for educational implications in chapter five, where I will offer new directions for further ecojustice-centered projects.

Glossary

1. *Bioregion* is equated with the World Wildlife Fund's (WWF) (http://www.worldwildlife.org/science/ecoregions.cfm) term *ecoregion*: "…a large area of land or water that contains a geographically distinct assemblage of natural communities that (a) share a large majority of their species and ecological dynamics; (b) share similar environmental conditions, and; (c) interact ecologically in ways that are critical for their long term persistence." Bioregions may be based on the location of watersheds, and I extend the above definition to

include the places where humans live. For my purposes, bioregions are where humans, animals, and plants, are situated within particular environments.

2. *Certainty thinking* refers to the ways in which people use science to rationalize the Earth in certain ways (e.g., Linnean system of biological classification). Although there is nothing wrong with trying to be objective, it is misleading to think that the Earth is any certain way, stable, non-complex. Historically, the false notions of certainty have been used to influence governments and garner public and private financial supports for research programs (Bowler, 1992; NRC, 2002). The human need to rationalize the ecological unknown has been traced back as far as 2.5 million years to *Homo habilis* (Morrison, 1999), and more recently from the ancient Greeks, to the early naturalists, and mid-19th century positivism (Abram, 1996; Barnes, 1982; Bowler, 1992; Chalmers, 1976/1982/1999; Thayer-Bacon, 2000, 2003). Certainty thinking anticipated and continues to inadvertently perpetuate the modern day ecological declines and the crisis viewpoint.
3. *Ecology* is the study of the interactions between organisms and their natural environments (Bowler, 1992).
4. *Ecosystems* are the collective community of species and habitats and the interactions therein (Bowler, 1992).
5. *Environmental education* is the study of environmental principles and personal conduct knowledge (Coyle, 2005).
6. *Epistemology* is the branch of philosophy that works to understand the origins, nature, and extent of human knowledge (i.e., Truth). Contemporary postmodern philosophers (Code, 2006; Thayer-Bacon, 2000, 2003) propose that knowledge is

contextual, intersubjective, and interrelational. I routinely use terms like "epistemic" and "epistemological," that derive their meaning from *epistemology.*

7. *Evolution* is the study of genetic variations across generations via mutation, natural selection, and genetic drift (Bowler, 1992). Three main tenants of Darwin's theory of evolution include, (a) individuals within a population will vary with respect to many traits (morphological and physiological), (b) the probabilities of survival and reproduction are effected by the traits and the environment, and (c) the traits have a heredity component (mutation, natural selection, and genetic drift) (National Academy of Sciences, 1998).
8. *Metaphorical thinking* is the ability "to be able to recognize root metaphors, processes of analogic thinking, and the image words (iconic metaphor) that reinforce a taken-for-granted acceptance" of the interpretative frameworks of the cultural milieu (Bowers, 2006, p. 45).
9. *Science education* is the study of scientific principles, processes, and how to use science in everyday life (NRC, 1996).
10. *Uncertainty thinking* is the epistemic-scientific practice of acknowledging the ambiguity and variability of environmental processes and events when engaging in ecological risk assessments, projections, and decision-making (Brewer & Gross, 2003; Clark, 2003). Thinking with uncertainty is highly valued by a post-normal science perspective (Aslaksen & Myhr, 2007; Ravetz & Funtowicz, 1999) that includes scientific evidence, fundamental beliefs and values, expectations, personal experiences and place-centered narratives as equally legitimate and viable sources of knowledge.

Chapter 2: Chet Bowers' Ethical Theory of EcoJustice

The first chapter provided the large part of the picture for Chet Bowers' (1993, 1995, 2001) philosophical works, which have influenced my work with prospective teachers. The basic assumptions of Bowers' (op. cit.) works were discussed including how cultural memories and the metaphorical nature of knowledge and language may contribute to ecological declines—cultural knowledge and language "think us," as we think them. I explained that education has historically deemphasized or ignored the ecological domain, as well as the assumptions of science and technology. Moreover, I described Bowers' (op. cit.) movement towards *ecojustice education*, which serves ecological literacy. Ecojustice values traditional ecological knowledges (TEKs), local knowledges and skills, mentoring and nurturing relationships, personal experiences and oral narratives. Ecojustice education frames what should be conserved and sustained by the authority of the community and the needs of the natural systems. Traditions are valued highly by ecojustice, and yet some are oppressive and should be changed without further taxing the Earth's wild ecosystems.

This chapter is focused on describing how Bowers (2001, 2004a, 2006) warrants an ethical theory of ecojustice. I will provide Bowers' (op. cit.) most recent definition of what he means by *ecojustice* and how that relates to "educating for the commons." Ecojustice deals with reducing the impact of the industry/consumer-dependent culture while ensuring that people do not live in poverty and have equal opportunity, by revitalizing the cultural and environmental commons (http://www.ecojusticeeducation.org/). I will provide the overarching criteria for educational reforms based on ecojustice. After discussing Bowers' (op. cit.) justifications for the revitalization of the commons, I will describe two dimensions of what Bowers (op. cit.) calls *ecojustice education*—elements of curriculum and implications for practice. And finally, I will describe Bowers' (op. cit.) ecojustice agenda for educational reforms. In the process, I will point out Bowers' (op. cit.) assumptions that lack sufficient warrants or need further clarification. By the end of this chapter, readers should be familiar with an ethical theory of ecojustice and educational implications for science education.

Educating for the Commons

Although environmental education (EE) has come a long way since the 1970s, a recent environmental literacy report concluded that there is a decreasing emphasis on EE in public schools and when EE issues are represented in the curriculum, they seldom go beyond environmental catastrophes (Coyle, 2005). Conceivably, EE in schools represents one of the most inclusive and multidisciplinary ways to foster ecological awareness and a sense of places (*environmental education*, *evolution*, and *ecology* have overlapping features as parts of the general domain of *science education*). Adversely, as economic interests have intensified, a sense of places is becoming less relevant to measuring how well students are being prepared to enter the workforce. Prioritizing financial success as the implicit goal of public schools leaves little time for teachers to foster a sense of places. Chet Bowers (2006) argues that the phrase "environmental education" may carry forward taken-for-granted cultural assumptions that limit how it is perceived in schools. Historically, the term "environment" has been assumed "as needing to be brought under human control, as an economic resource to be exploited, as separate from culture, as an external phenomena that can be objectively observed and judged" (p. 4). Bowers (op. cit.) proposes a shift to phrases such as "commons education" or "educating for the commons," which he equates with *ecojustice education*.

The *commons* can be defined as the non-commodified aspects of cultural life and the environment that were once available to all people. Bowers explains further,

> The commons represent both the natural systems (water, air, soil, forests, oceans, etc.) and the cultural patterns and traditions (intergenerational knowledge ranging from growing and preparing food, medicinal practices, arts, crafts, ceremonies, etc.) that are shared without cost by all members of the community; nature of the commons varies in terms of different cultures and bioregions; what has not been transformed into market relationships; the basis of mutual support systems and local democracy (http://www.ecojusticeeducation.org/).

This definition corresponds with historical accounts offered by other scholars (Shiva, 1997, 2005; Snyder, 2001). The term "commons" is formed of "*ko,* 'together,' with (Greek) *moin,* 'held in common'" that accurately depicts the way that the natural land was accessed by local people during periods of common usage (Snyder, 2001, p. 475).

The problematic nature of the commons was popularized in 1968 by Garrett Hardin's "The Tragedy of the Commons" that claimed when there are open rights to resources people will typically maximize their self-interests, overshooting the limits of the local ecosystems. Environmentalists (Bowers, 2006; Snyder, 2001) argue that Hardin's claims were based on an ethnocentric perspective of the commons (i.e., Euro-Western lens). Moreover, Gary Snyder (op. cit.) notes that the world's natural commons were almost always overseen by village councils dating back to Neolithic times. In the U.S., the common lands (i.e., environmental commons) disappeared rapidly when the native inhabitants were displaced by the Europeans. The early European farmers, miners and ranchers did not have the Native American knowledge or ethics to take care of the land (i.e., cultural commons). Eventually, the development of the Forest Service, the Park Service and the Bureau of Land Management were created to publicly manage the lands that remained. Since the European colonization, the common lands have remained either privatized or publicly managed, but never returned to be shared by humans and non-humans. Understanding the role of the commons in providing social services is a step towards integrating ecology with economy.

By conserving cultural diversity and sustaining the human relationships of the cultural commons (and reducing industry/consumer dependence), we contribute to sustaining the plants, animals, air, water, and soil of the environmental commons (Bowers, 2004a). The commons may be a refuge for people "who possess the skills that have been marginalized by the industrial culture, who find that work is no longer available due to automation and outsourcing, and who want to base their lives on meaningful social relationships and community-enhancing activities" (p. 52). Bowers (op. cit.) argues that we share an ethical responsibility to revitalize the commons and preserve cultural diversity and biodiversity for future generations. He encourages scholars to pay careful attention to the inherent tensions between the commons, various forms of cultural and environmental enclosure, and to frame conversations of equal opportunity by what the local ecosystems can sustain. Bowers makes the case for shifting toward ecojustice education by making explicit the harmful assumptions carried forward in the emancipation theories, educational computing and technology, and science, which limit the conservation of cultural diversity and devalue human relationships, which degrade the environmental commons. His main thesis is that the commons should be strengthened by educational reforms that revitalize what was once available to all people. He notes that currently, "the knowledge, skills, patterns of social interaction that contribute to participating in intergenerationally connected and morally responsible communities are not learned in public school and university classrooms" (2001, p. 20). However, teachers should help students recognize the differences between sustainable and unsustainable assumptions, as part of the movement to revitalize the commons.

Criteria for Basing Educational Reforms on EcoJustice

Central to Bowers' (2001, 2004a, 2006) main thesis is the assumption that cultural knowledge and language carry forward root metaphors that encode and reproduce cultural ways of knowing and human relationships with the Earth's natural environments. This assumption has been influenced by the works of Peter Berger, Thomas Luckmann, Alfred Schultz, Gregory Bateson, Friedrich Nietzsche, Michael Foucault, Edward Shils, Vandana Shiva, and Helena Norberg Hodge. These scholars argue that culture plays the strongest role in peoples' thinking patterns, behaviors, and relationships with each other and the Earth. Most influential in Bowers' (op. cit.) works has been Gregory Bateson (1972/2000), who argued more than thirty-five years ago that the cultural roots of the ecological crisis and the rash of increasing environmental problems could be attributed to unrestrained technological change, population increases, and errors in cultural patterns of thinking. Bateson (op. cit.) argued that all three fundamental variables intensify the ecological crisis: “the increase of the population spurs technological progress and creates that anxiety which sets us against our environment as an enemy; while technology both facilitates increase of population and reinforces our arrogance, or ‘hubris,’ vis-à-vis the natural environment” (p. 498). Bateson (op. cit.) believed that the only conceivable reversal would be a change in cultural attitudes toward the natural environment.

The metaphorical nature of language observed in Bateson’s (1972/2000) writings provides an understanding of how language both illuminates and hides particular cultural assumptions. Bowers (2006) describes how metaphorical thinking is similar to a map that marks territories that we pay attention to: if the map does not mark animals on the verge of extinction, these aspects of Earth’s wild ecosystems may go unnoticed and unchecked. Bowers (op. cit.) notes that cultural assumptions work the same way, they may be taken-for-granted if unnoticed, for even the most educated scholars. Bowers (op. cit.) notes that Friedrich Nietzsche pointed out that it is impossible to consider new information without a frame of reference. The familiar provides metaphorical thinking conceptualization(s) for framing what the new is like, which is culturally interpreted based on the taken-for-granted assumptions that we seldom pay attention to. The main point is that teachers are constantly exposing students to new concepts, words, models, and experiences that embody the highlighted expressions of peoples and places (i.e., selective attention).

Thus, Bowers (2001) argues that many well-intentioned educational theories and social justice reforms fail to recognize the deeply embedded cultural assumptions which contribute to the ecological crisis. For a long time now, a focus on social justice has deemphasized or ignored the ecological realm (i.e., selective attention). However, Bowers (op. cit.) notes that "any definition of social justice that does not take account of how human demands on the natural environment are affecting the lives of future generations is fundamentally flawed" (p. 3). He explains that social justice is inseparable, even deeply embedded in, the ecological domain. In contrast, ecojustice takes seriously the concerns of extreme weather patterns associated with global warming, fossil fuel dependency, human illness and death associated with synthetic chemicals, the loss of jobs and a vital food source with the decline of marine ecosystems, the loss of tens of thousands of species, and the loss of twenty billion tons of topsoil yearly. Ecojustice takes seriously the increasingly consumer-dependent lifestyle in the U.S., promoted at the expense of other cultural ways of knowing and the ecologically informed thinking patterns of Native Americans. Ecojustice makes explicit the deeply embedded root metaphors that are carried forward in the assumptions of Euro-Westerners that developed concurrently with the Industrial Revolution, the double binds associated with thinking that change is equated with inherent progress, and the commodification of many aspects of cultural and community life. And ecojustice addresses poverty at a local level, the resistance of environmental injustices by marginalized communities, the necessity of intergenerational knowledges, the value of renewing marginalized talents and skills, and the interrelationships between the family, the community and natural environments. Thus, ecojustice may be the more encompassing challenge in educational reform.

Bowers (2001, 2004a, 2006) equates these aforementioned conditions with *the* "ecological crisis"—a supposition that lacks sufficient warrants and takes advantage of the high uncertainty of the scientific studies of environmental scientists (chapter three). Despite that limitation, Bowers (op. cit.) argues that science education has historically taken-for-granted particular cultural interpretations of science (e.g., that science is the highest form of knowing, inherently progressive, cultural neutral…), which is apt. Moreover, science education has historically taken-for-granted the generally accepted scientists' versions of reality (e.g., Bering Strait land bridge theory), which undermine the thinking patterns and behaviors of less consumer-dependent cultures (e.g., Dakota Sioux). In turn, the root metaphors (e.g., anthropocentrism, consumerism, individualism…) that reify thinking patterns and behaviors may contribute to humankind's devastating impacts. Moreover, science educators may favor certain methodologies and research paradigms based on the generally accepted versions of "what counts" as the most legitimate science. Thus, Bowers (op. cit.) argues that the commons are strengthened when science teachers and students have opportunities to analyze these assumptions and revise them if needed.

There are six criteria that Bowers (2006) recommends for educational reforms that are focused on ecojustice:

1. The understanding of local and global ecosystems as essential to human life, as well as the recognition of the deep cultural assumptions underlying modern thinking that undermines those systems.
2. The recognition and elimination of environmental racism, such as the dumping of toxins in the communities of economically and socially marginalized peoples.
3. The recognition of how Western patterns of hyper-consumerism reproduce the exploitation in the Southern hemisphere by the North for resources—both natural and human.
4. The recognition and protection of the cultural commons; that is, the intergenerational practices and relationships of non-monetized mutual aid

(relationships that do not require the exchange of money as the primary motivation for the relationship). An ability to think critically about what aspects of the cultural commons are being enclosed—that is, being integrated into a money economy.

5. The recognition, protection, and establishment of Earth democracy—that is, the decision making practices established to ensure the renewal of water, soil, air, plant life, and other living creatures in natural systems, and necessary to socially just communities. Earth democracies are sustained by virtue of the spirituality and wisdom in many tradition and indigenous cultures that have created sustainable communities in balance with natural systems over hundreds of years.
6. The recognition and emphasis that local knowledge and practices should leave future generations a viable and healthy environment (pp. 94-95).

By *Earth democracy*, Bowers (op. cit.) means Vandana Shiva's (2005) philosophical work that emphasizes that "all species, people, and cultures have intrinsic worth" and are not subject to exploitation, patents, and intellectual ownership rights (p. 9). Over the past thirty years, Bowers (http://cabowers.net/) has worked towards the development of ecojustice philosophy and educational implications with over 95 articles and 19 books. My focus is narrowed to how Bowers' (2001, 2004a, 2006) supports his central claim (i.e., strengthening the commons should be the major goal of science education). Bowers (op. cit.) general argumentation pattern, noted above, can be found in any of his critiques of the emancipation theories, educational computing and technology, or science. I will focus on Bowers' (2001, 2002, 2003, 2004b) critiques of the cultural views of science to show how science education may carry forward unsustainable assumptions.

Justifications for the Revitalization of the Commons

The primary goal of science education should be to revitalize the commons by teaching sustainable assumptions and making explicit the root metaphors that reify thinking patterns and behaviors that contribute to accelerated ecological devastation (Bowers, 2001, 2004a, 2006). Fostering a sense of peoples and places is the meaningful purpose of Bowers' (op. cit.) ethical theory of ecojustice, which reduces human impacts. Empowering science teachers and students to become informed and to participate fully in the democratic decision-making process is the shape and scope of an ethic of ecojustice. According to Bowers (op. cit.), ecojustice emphasizes a multidisciplinary approach to community reliance and mutual support networks within the educational milieu. He notes that science education has been reduced to environmental projects, such as recycling programs, monitoring the health of local streams, and the mapping of green spaces in the community. An expanded version, including his ethic of ecojustice prepares science teachers and their students to consider the implicit impacts of the cultural messages communicated by the media, super-sized houses and modern modes of gas-guzzling transportation that supports the false guarantee of satisfaction and happiness of living a lifestyle reliant on consumerism (i.e., practice of increasing consumption of goods).

Because addressing the symptoms of environmental declines is fundamental to reducing humankind's negative impacts, the symptoms must be made explicit in science education (Bowers, 2006). Instead of an exclusive focus on plants, animals, rivers, forests, and mountains, there must be an emphasis of how the accepted cultural narratives of science legitimate certain ways of knowing and human relationships with the natural environment. For example, the taken-for-granted assumptions of plentitude and progress will show that more and more people do not have enough and that things are not shared equally between the rich and the poor. Unfortunately, the impoverished do not have the same access that the affluent have to natural resources that were once shared in common. Bowers (op. cit.) notes that “helping students understand that the prejudices and narratives that legitimate the privileged status of some individuals and groups are also part of the commons of some cultures will help them to avoid romanticizing the commons” (p. 14). Consequently, the commons are located where we actually live and work (e.g., schools, community centers, public streets, city parks…), which is the foundational context for science education focused on reducing peoples’ adverse ecological practices.

Because people rely on the environmental commons for their survival, they must understand that the enclosure of the commons may result in devastating life changes, which emphasizes a personal responsibility to the things shared in common with others. Because the commons will differ from locality to locality, the local authority serves as the way of analyzing the potential outcomes of decisions based on multiple perspectives. However, Bowers (2001) argues that this shift from the abstract to an emphasis of locality does not call for “cultural relativism” (p. 23). That is, he does not want “cultural relativism” to replace the basic human rights that should be universally respected. For example, Bowers wants eco*justice* to be expanded to include:

> . . . rights of future generations to experience life in an uncontaminated environment, the need for cultures to sustain patterns of moral reciprocity along with knowledge and activities that result in a more ecologically sustainable footprint, and the need for more ecologically centered cultural groups to assess

> which technological and linguistic innovations can be assimilated and which must be rejected (p. 33).

Bowers (op. cit.) argues that appropriate responses will be deciphered by looking to the ways in which ecologically informed cultural groups have survived over thousands of years. While he mentions exceptions (1996), he assumes that TEKs are sustainable and will work with today's society when the human population is much greater than it was thousands of years ago, which remains unclear and unfounded (chapter three). It is worth noting that Bowers (2006) notes that who is privileged to make local decisions and who has to live with the consequences of those decisions is integral to eco*justice*.

Because what constitutes the commons depends on the bioregional location, the renewal efforts will take different forms, which depend on the authority of local peoples (Bowers, 2001, 2004a, 2006). Renewing the commons means placing an emphasis on what can be conserved and shared with others, which lies outside the realm of the market. Enclosures occur when aspects of what was once held in common becomes privately owned, privileging particular peoples (e.g., affluent homes that surround lake access). Another example of enclosure is when contributions to scientific work are favored for people with high amounts of expensive education or gendered ways of knowing. Mentoring relations may be enclosed when certain people cannot afford to pay for tuition and books. Science teaching may be enclosed when specialized certifications and specified subject knowledges are required to participate. Bowers (op. cit.) notes that all enclosures favor certain peoples and marginalize others. Enclosures may go unrecognized until it is too late to make the necessary decisions to resist them. For example, when new forms of technology are introduced and embraced, others must adapt or be left behind.

Inevitably, enclosures may exclude the people who cannot afford to participate fully in the democratic practices of the local community.

New technologies may be favored because they are seen as inherently progressive (Bowers, 2001, 2004a, 2006). When local people rush out to get the latest technologies, aspects of the local community may become increasingly deemphasized and enclosed. Bowers (op. cit.) notes how elders in the community have valuable knowledges and skills that may be considered irrelevant when they are deemphasized or ignored. These knowledges and skills that elders have are essential to developing the mutual relationships of the community that reduce humankind's negative impacts on Earth's wild ecosystems. For example, Bowers (op. cit.) notes that sharing a meal prepared by grandparents or face-to-face conversations with local peoples is when the commons are renewed, when intergenerational knowledges and skills are passed along, and when social bonds and personal relationships are strengthened. These community relationships tax the natural environment much less than industrial fast foods and cellular/email conversations. The biggest difference is that the latter experiences have to be purchased with a commensurate environmental fee, which may be much greater and go unnoticed. And, the latter experiences may also have to be purchased with a commensurate human fee, such as poor diets and a lack of physical stimulation that results from sedentary lifestyles.

Bowers (2006) notes that what is healthy for human bodies may be deemphasized or ignored because the cultural narrative of progress reinforces a more solitary existence by glorifying the technological conveniences of life. He explains that this existence,

> . . . in turn, reduces the opportunity to learn how to use the collective knowledge of the community in growing vegetables and in preparing healthy meals, in

> learning about the activities in the community that are a source of physical exercise—such as helping others who need house repairs, participating in community gardening projects, helping to restore degraded habitats, taking walks with others, participating in local arts programs, and so forth (p. 19).

Typically, collective knowledges and skills are associated with people who share with each other to meet basic material needs. Historically, racial/ethnic minorities have lived in poverty in the U.S. and collective knowledges and skills emerged as a way to survive. Thus, the devaluation of collective knowledges/skills may have been a casualty of racism. Bowers (op. cit.) notes that the lack of knowledge of how to rely on local resources and intergenerational knowledges is yet another expression of enclosure of the commons.

By emphasizing many contemporary examples of how the commons are enclosed, Bowers (2006) avoids charges of romanticism. He explains that differences in thinking patterns will lead to different forms of enclosures, depending on the cultural community. However, the expanding Euro-Western market has an extensive marginalizing affect when less consumer-dependent lifestyles are lost. Examples, Bowers (op. cit.) explains, include the environmental ethics embraced by Western Apache youth that are being enclosed by increasing market reliance and the Mexican compesinos displaced from their land because of economic policies dictated by the North American Free Trade Agreement (NAFTA). He also points out that the urban and rural areas of North America where credit card spending has increased the rate of bankruptcy is another form of enclosure. For instance, the decrease of mutual support networks and community reciprocity is linked with the rapid increase of mega-supermarkets and fast foods. These conveniences are now privileged, and yet pale in comparison with the "complex set of interdependent social relations . . . which lead to meals that are nutritious and a source of enjoyment—perhaps even aesthetically pleasing" (p. 21). Opportunities to foster social relationships may be missed when people scurry by local farmer markets and home-prepared meals with friends and family. These social opportunities are where personal experiences may be shared (e.g., such as interesting recipes and how to grow varieties of fruit), which increases self-reliance and mediates the enclosure of the commons.

The acquisition, preparation, and sharing of foods fosters mutual support networks, community trust, and a sense of moral reciprocity for citizens (Bowers, 2006). These kinds of community relations promote a healthier diet, physical fitness, interdependence, intellectual stimulation, collectively-centered activities, happiness and personal responsibility—measures of success when focused on local peoples and places. Bowers (op. cit.) notes that the typical measure of quality of life in the U.S. is now focused on the need for a high salary and ability to purchase lots of things, as compared with turning to the community and natural environment for satisfaction and happiness. Thus, Bowers' (op. cit.) justifications for ecojustice support the notion that the commons will be strengthened by science education that prepares science teachers to teach sustainable cultural assumptions. Ecojustice is undermined when unsustainable cultural assumptions are taken-for-granted in science education.

The Limitations of Science in Contributing to EcoJustice

Concerns have been raised that some of the cultural dimensions of science, which contribute to the globalization of the consumer lifestyle, may be leading humankind down a road of ecological catastrophes (Bowers, 2001). Bowers (op. cit.) believes that the slippery scientific path provides significant contributions to our understanding of the "scale of the ecological crisis," along with increasing the conveniences of life, yet on the negative side, the scientific path continues to favor certain ways of knowing over others. In particular danger of cultural enclosures are the TEKs of many Indigenous cultural groups. It follows that an ecojustice ethic is most aligned with the ecologically informed patterns of thinking and behaviors of peoples who are aligned with the natural world. However, these morally reciprocal ways of knowing may be compromised by science when educational researchers privilege science-based methodologies and when theorists privilege extrapolations of science to provide the foundation of educational reforms. Educational research and theory may reify the cultural myth that science is the highest form of knowing and should be used to determine "what counts." Thus, educational extrapolations of scientific research and theory may be privileged to provide an ethical framework guiding questions of how we should treat others and the local ecosystems. The problem is not with science, but with the cultural views (i.e., narratives) of science that legitimize particular cultural attitudes towards others and the natural environment.

There are three main areas (i.e., scientifically-based research, chaos/complexity, and Darwin's theory of evolution and natural selection) where Bowers (2001, 2002, 2003, 2004b) identifies cultural narratives of science that undermine ecojustice theory. Because similar assumptions are identified in all three areas of science and each of these topics covers vast terrains of knowledge (e.g., evolution has become the central organizing principle of biology and provides a unifying theory for biodiversity), and because Bowers (op. cit.) provides the most details on educational reforms patterned after

Darwin's theory, I will focus on Bowers' (op. cit.) critiques of the cultural narratives of evolution and natural selection that further justify the movement towards ecojustice.

Bowers (2001, 2002, 2003, 2004b) makes the case that the environmental ethics of cultures have been derived from the long history of mythopoetic narratives, which originated from the long history of morally reciprocal relationships between humans and the natural world. Bowers (op. cit.) points out that a comparative cultural/historical analysis reveals that *cooperation*, in contrast to competition, was embraced and valued by most ecologically informed cultures (e.g., Indigenous cultures of the Pacific Northwest), which helped them to become better adapted and survive over thousands of years. The mythopoetic narratives of ecologically informed peoples are reflective of thousands of years of intergenerational knowledges and living within the limits of local ecosystems. However, Bowers (op. cit.) notes that these ecologically informed traditions had to be overturned in order for new cultural narratives to become legitimized and valued.

Bowers (2001) turns to Kirkpatrick Sale's (1995 as cited in Bowers, op. cit.) descriptions of three traditions of community that had to be overturned in order for the Industrial way of life and consumerism to emerge: "self-sufficiency, mutual aid, and morality in the marketplace" (p. 34). Self-sufficiency includes knowledge and skill of food, clothing, and the ability to participate in decisions regarding common resources. Mutual aid is multidimensional and integral to self-sufficient communities, including interpersonal relationships regulated by the moral imperatives of others and the needs of the natural systems, which are expressed in the intergenerational sharing of knowledges (i.e., to avoid short-term mistakes from the lack of long-term experiences). Morality in the marketplace is the recognition that market relationships should not be privileged to decipher human interactions and values, which provide the frameworks for the human-nature relationships found in mythopoetic narratives. For example, Bowers (op. cit.) notes the Luddites who attacked the factories of Manchester and other Midland towns to protest the new technologies and systems that reduced work to a mechanistic process, which made their highly sophisticated technical skills irrelevant.

Moreover, Bowers (2001) aligns with Hannah Arendt to make the case that,

> . . . the authority of tradition in peoples' lives (which, as Hannah Arendt points out, is profoundly different from the authoritarianism of external control) had to be overturned at an ideological level as part of the convergence of cultural changes that promoted the modernizing process (p. 37).

Bowers (op. cit.) notes that as people (e.g., Luddites and Native Americans) embraced their cultural ways of knowing and living, they were indoctrinated into an ideological divide that equates their traditions with backwardness and oppression. The new cultural narrative (i.e., meta-narrative) emphasizes that every cultural change should be equated with how a society "advances"—evidenced by the ways some cultures are conceived (e.g., "developed" versus "underdeveloped"). Unfortunately, older traditions are now seen as oppressive, backwards, illegitimate, and less-than-modern. An example includes how almost every aspect of cultural life is now at risk of being commodified or manufactured, which "required a change to a consciousness free of the influences of traditional values and ways of thinking that foreground the reciprocal nature of communal relationships and responsibilities" (p. 38). Bowers (op. cit.) points out that Susan Bordo, Vandana Shiva and Andrew Kimbrell are several examples of the expanding literature that describes how the industrialization process advances by deemphasizing or ignoring the alternate traditions that embody morally coherent and noncommodified relationships with others and the Earth's wild ecosystems.

Bowers (2001) equates the word *tradition* with the word *culture*. He notes that people are embedded in their cultural traditions, described as "organic" in Edward Shils' (1981 as cited by Bowers, op. cit.) analysis of cultural traditions. He notes that traditions can be thought of as "organic—like a plant with branches that are in various states of growth and decay and with largely unseen roots extending to various depths that also include the mix of the new and the no longer vital" (p. 40). Bowers (op. cit.) extends this metaphor to show that most traditions change very slowly, with exceptions that change faster (e.g., privacy, craft knowledge, noncommodified relations…) before people may be aware of the consequences of these changes. He notes that some traditions should have never been constituted (e.g., racism, sexism, environment exploitation) and that social/ecojustice criteria should be the basis for assessing what needs to be renewed. Because renewed traditions are not static and develop concurrently with cultural groups, they will be perpetuated by those who wish to keep their identity/characteristics. Thus, racial/ethnic groups will hold tightly to their cultural narratives as traditions modify them. He points to the "organic science" still valued by Native Americans and shared through intergenerational experiences (p. 42). Organic sciences are the local knowledges of the bioregion that helped peoples to survive and adapt over thousands of years (i.e., Northern Indian women's knowledge of 150 species of plants for healthcare and child rearing, Indigenous cultures in the Andes with 3,500 varieties of potato and 1,500 varieties of quinoa, the practice of intercropping used by Indigenous cultures worldwide).

Organic sciences embrace and value the local contexts of embedded and embodied peoples' knowledges and skills (Bowers, 2001). Bowers (op. cit.) notes that organic sciences are needed during these times of ecological uncertainty—the interweaved mythopoetic narratives of "tradition, intergenerational responsibility, mutuality within the community, and a clear understanding of human dependency on ecosystems that are subject to rapid and unpredictable changes" (p. 44). He argues that these forms of intergenerational knowledges are more democratic than the "forms of social organization connected with the history of mechanistic science" (p. 45). It takes thousands of years of negotiated mythopoetic narratives to develop intergenerationally connected knowledges and skills, which minimize the practices that do not sustain life over the long haul or conserve natural resources for future generations. Bowers' (op. cit.) claims correspond with the work of other scholars (DeLoria, 1997; Shiva, 1997, 2005; Thayer-Bacon, 2000, 2003), who emphasize that TEKs are legitimate science. However, Bowers (op. cit.) claim that TEKs are generally a certain way may be unwarranted.

Keeping in mind that there are many different cultural narratives of science; Bowers (2001, 2002, 2003, 2004b) points out the dominant interpretations underpinning scientifically-based educational research and extrapolated to develop educational theory. The assumptions taken-for-granted by educators (e.g., William E. Doll, Jr and Donald Oliver) are the views that constant change is inherently progressive and self-organizing (i.e., societal advancement) and that the modern mind is more evolutionarily advanced. These educational reforms reinforce that *the* scientific method or science inquiry process is assumed to be the highest form of knowing the natural world. Bowers (op. cit.) points out that *the* acclaimed scientific process still does not prepare scientists to think through the moral and ethical consequences involved when doing scientific work. Likewise, the science method promoted in many schools fails to recognize the impacts of scientific work on society as a significant part of the science inquiry process. Bowers (op. cit.) explains that scientists deemphasize such issues, in light of the possible financial gains, publications and prestige to scientists who discover new phenomena or research methods.

Bowers (op. cit.) examines scientifically-based educational research further by pointing to the more recent developments of genetically modified foods, along with the Monsanto Company's terminal seeds, which are profitable for some, and at the same time, come at the expense of farmers' reliance on commodified seeds rather than the non-commodified and traditional practices of saving seeds annually. Bowers (op. cit.) links the reliance of farmers on the commodified seeds with the reliance of teachers on scientifically-based or evidenced practices in education, noting how science is used to provide the legitimized basis for teacher decision-making. In other words, scientifically-based educational research is perceived to be the highest form of knowledge to inform education practices. Bowers (op. cit.) warns of the dangerous consequences that have followed, such as the conceptualization of the brain as a computer by educators and scientists, the reliance on prescription drugs (e.g., Ritalin) to modify behaviors and learning, and the failure of researchers to place scientific works within the larger context of cultural pluralism.

While science contributes to our understanding of the natural world, Darwin's theory of evolution has been wrongly equated by nonscientists with linear progress, which leads to thinking that the natural sciences are the most evolutionarily advanced. Bowers (op. cit.) asserts that educational theory should not be reduced to the underlying assumptions and extrapolations of Darwin's theory of evolution (see the three main tenants of Darwin's theory of evolution under the term "evolution" in the glossary). Unfortunately, Bowers (op. cit.) argues that many of the academic domains (e.g., architecture, economics, computer technology…) now use the assumptions underpinning Darwinian evolution to describe progressive changes through the vehicle of natural selection. In other words, evolutionary changes are now being equated with progress, aligned with the Euro-Western ways of knowing, assumed more advanced and complex. Bowers (op. cit.) warns that the influence of scientists who make daily discoveries linking genes to illnesses and character traits will be hard to ignore. Darwin's theory of evolution does not seek to explain education and should not be used to reify the cultural myth of linear progress, now being used to theorize how scientific and technological changes, such as genetically modified organisms (GMOs) will inevitably replace the natural flora and fauna.

The use of scientific inquiry, outside the science domain, to perceive, explain and describe all aspects of cultural life is called *scientism* (Bowers, 2001, 2002, 2003, 2004b). Bowers (op. cit.) describes how several scientists (e.g., E.O. Wilson, Carl Sagan, Richard Dawkins) have explained the domain of science as a superior, legitimate and exclusive way of knowing—an epistemological stance used to judge "what counts." He notes how scientists have used scientism extrapolated from Darwin's theory of evolution and natural selection to explain the interplay between genes and culture. He explains that scientists privilege the scientific approach to understanding the natural world, as the highest and most legitimate source of knowledge, creating a pre-scientific and scientific dichotomy.

Bowers (2002, 2003) explains that this ethnocentric outlook of pre-scientific cultures (i.e., prior to the development of Western views of science) suggests they are backward and less developed. Bowers (op. cit.) uses the term "Western" science in a metaphorical way, which may suggest that he assumes most North American and European scientists privilege the same assumptions, which is unclear and lacks sufficient warrants (chapter three). He notes that this outlook conflicts with the long histories of Indigenous cultures that live well with their land—a more *ecologically* advanced ideology, because TEKs include moral and ethical considerations whereas what is generally accepted with science is cultural neutrality. Bowers (op. cit.) notes how problematic it is when all aspects of complex cultural life are reduced to the explanations of the roles that genes play. Bowers (op. cit.) says that several scholars (e.g., Daniel Dennett, Richard Alexander, Richard Dawkins) are now using the assumptions extrapolated from Darwinian evolution, linked with the process of natural selection, to warrant a range of activities from genetic engineering to robotized humans.

Another problematic idea associated with the process of natural selection is equating progress with the legitimization of monoculture (i.e., one right way of knowing). According to Bowers (2002, 2003, 2004b), scientists such as E.O. Wilson reinforce the cultural view of monoculture when advocating science as an exclusive source of values, which undermines TEKs sense of moral reciprocity with the natural environment. Bowers (op. cit.) questions whether science (as *the* privileged source of knowledge) is the best suited ideology to decipher ecologically aligned ethics when many scientists seem to be unconsciously accepting the taken-for-granted assumptions which are increasing the ecological impact of humans on the natural world. The following passage, worth quoting, clearly emphasizes Bowers' (op. cit.) concerns with regards to scientists:

> . . . the historical record of scientists as exemplary moral agents and futuristic thinkers is mixed. We are all aware of how their research and, in many cases, personal sacrifices have improved the quality of human life and expanded our knowledge of the physical world. But like Janus, the two faced Roman god that looks in opposite directions, the history of the scientific community also has a Janus face. That is, scientists as a community of scholar/researchers have made contributions that have been constructive, and contributions that have been destructive—even environmentally destructive (p. 15).

Bowers (op. cit.) explains that in the past, scientists created weapons of mass-destruction, were major contributors to racist theories of intelligence, were significant contributors to the eugenics movement, introduced thousands of chemicals into the environment without considering the consequences and continue to investigate the uses of genetic engineering, which places the scientist in a position of determining what constitutes normality.

It is worth noting that Bowers (2004b) believes E.O. Wilson has good intentions and cares a great deal about the natural environment, however, Wilson's reliance on scientism undermines any major score to conserve biodiversity. Bowers (op. cit.) explains that Wilson shares with most scientists (i.e., Westerners), a failure to recognize the consequences of science on the cultures of the world (which discounts TEKs as science). Bowers (2003) highlights how different an environmental ethic predicated on natural selection is from one that is historically supported and derived from the experiences of diverse ecologically informed cultures (i.e., organic science). Bowers (op. cit.) explains that “while natural selection explains much about the development of biological processes, it does not explain the origin of the mythopoetic narratives of different cultures” (p. 78). He explains that cultural misinterpretations extrapolated from Darwin’s theory of evolution may lead educational scholars into believing that certain moral choices and greater reproductive success are the result of the process of natural selection. He is nervous that the prevailing evolutionary mode of thinking (in relation to cultural development) will prevent scholars from seeking alternatives to the destructive lifestyles being globalized.

Thus, Bowers (2003, 2004b) questions whether the assumptions implicit in evolutionary thinking can be used to address the ecological crisis. He questions whether the current accounts of evolution avoid the reductionist language of social Darwinism (i.e., equated with *scientism*; the 19th century lens used to investigate matters of society). Bowers (op. cit.) argues that an evolutionary extrapolated framework for understanding the educational issues associated with the ecological crisis may undermine the potential of human decision-making (e.g., ecological decisions reduced to computer projections). Bowers (op. cit.) clarifies further how the futuristic thinkers merge the categories of technology and biology, embracing natural selection as the point of departure for their predictions of where the world is headed—cultural globalization, human-machine hybrids and global computerized brains. For these technocratic thinkers, cultural diversity and biodiversity may be a thing of the past. Thus, Bowers (op. cit.) questions whether the technocratic minds of future humans will have the ability to think through the diversity of challenges that the ecological crisis embodies. He warns that the digitalization of the human mind (i.e., internet, email, cell phones…) will also lead to the enclosure of very important aspects of cultural life, not limited to face-to-face communications and the social context of conversations. Thus, ecojustice confronts the enclosures of the commons and protects the *weakest* and *most vulnerable* cultures that have a lesser impact on the Earth's wild ecosystems. Next, Bowers (op. cit.) offers educational implications in the form of *ecojustice education* to help teachers and students to analyze the assumptions linked with science and to revitalize the commons.

Elements of EcoJustice Curriculum

Chet Bowers' (2001) most specific ecojustice curriculum reforms are presented in *Educating for Ecojustice and Community*. Bowers (op. cit.) believes *ecojustice education* will empower marginalized peoples through the democratic decision-making process. Moreover, he advocates a democracy for ecojustice "that recognizes individualized perspectives and talents as being embedded in distinct cultural approaches to community" (p. 150). Bowers (op. cit.) explains that the overarching aim of the democratic decision making process will be to include all the stakeholders affected by local decisions. He notes that the aims for ecojustice education are aligned with the community-based initiatives written by the American Association for the Advancement of Science (AAAS).

Any good ecology curriculum begins with finding out what the students already know about their interdependent communities, along with the impact of these communities in relations with the natural environment (Bowers, 2001). Bowers (op. cit.) explains that students' responses "need to be considered in relation to how the distinction between high- and low-status knowledge affects racial, gender, and class relationships"

(p. 153). Students' responses should reveal the cultural assumptions embedded in their community, which will foster an understanding of how cultural patterns of domination privilege certain groups over others. Students' responses will trigger conversations of how students can participate in the renewal of the intergenerational knowledges and skills. The differences between the students' cultural narratives and the mainstream meta-narratives may serve as the context for conversations about the value of high- and low-status knowledges and skills, and the many social issues that cut across cultures. Integral parts of ecojustice curriculum will include the cultural resources that are available within the local community, such as cultural relationships and skills that can be explored through comparative cultural studies and community surveys. A survey of the local community is a great activity that can be used to identify both commodified and non-commodified aspects of cultural and community life. Bowers (op. cit.) notes that secondary students and university students might be led through a comparative study of community based cultures that embody a less negative impact on the Earth's ecosystems.

Next, Bowers (2001) describes how an exploration of traditions (i.e., the entire scope of cultural and community practices) can be emphasized by focusing on students. An examination of traditions should include an analysis of what it would be like to live without traditions. A cultural survey of the local community can be used to analyze the forms of media that promote constant change and innovation as expressions of inherent progress and growth (e.g., AYP). Students should understand the traditions of the community, the nature of traditions, the difference between traditions and fads, and how traditions do not stifle change or innovation. Bowers (op. cit.) explains how students can be engaged in the traditions of communities aligned with taking care of and connecting with the natural environment (e.g., gardening, sports, craft knowledge, volunteerism…).

Another element of ecojustice curriculum is how technology amplifies and reduces certain aspects of cultural life (Bowers, 2001). Bowers (op. cit.) explains that technology may be the greatest impediment to ecologically sustainable ways of living (with the exception of ecologically informed designs). People who do not have access or do not embrace technological advancement continue to be marginalized. Science teachers and students should focus on the culturally mediating impacts of technology, the cultural biases of technology, and how technology is embedded in their everyday experiences. Likewise, Bowers (op. cit.) wants teachers and students to recognize that science and technology are not inherently destructive—the problem lies with the way in which science and technology may displace human relationships and cultural values.

Ecojustice curriculum should provide a balanced lens for analyzing science, the achievements and inappropriate uses, and the knowledge to help teachers and students to democratize science (Bowers, 2001). Examples of Indigenous practices, along with other local knowledges (e.g., Appalachian) should be woven into science education to reinforce cultural differences. Moreover, the history of scientific thought might include: "the systematic exclusion of women from science" and other viable eco*justice* topics (p. 174). Bowers (op. cit.) explains that social justice issues, typically encountered when pursuing a career in science are better framed by ecojustice education. Thus, science teachers and students should not be limited to a scientific method that may exclude the cultural impacts of scientific work. Science teachers and students should recognize the forms of human knowledges and experiences that are privileged by *the* scientific method, the moral norms that are beyond the explanatory power of science, how science contributes to technology and consumer dependence, when scientism is engaged to advance or damage ideologies, and what can be legitimately explained by Darwin's theory of evolution, natural selection, as well as when extrapolations of evolutionary thinking become problematic and legitimize colonization. These topics will allow science teachers and students to develop a balanced perspective of the limits of science, and ultimately, to participate in decreasing the rate of environmental declines. Finally, Bowers (op. cit.) wants teachers and students to analyze the language of the community that carries forward taken-for-granted cultural ways of knowing through the socialization process.

Implications for the Practice of EcoJustice Education

The main point in enacting ecojustice curriculum is to develop an adequate understanding of society's underlying cultural assumptions and to become aware of the cultural patterns of thinking that contribute to ecological declines, which "cannot be turned into a rigid set of prescriptions—no matter how well intended" (Bowers, 2001, p. 186). Bowers (op. cit.) explains that the teachers' primary responsibility will be one of mediation that is "responsive to the cultural patterns enacted in the relationships that make up the complex ecologies of the classroom and the larger communities" (p. 187). Teachers should be actively involved in the decision making of local communities, which is a significant part of mediating the meta-narratives of the U.S. cultural milieu. Responsible decisions for the prospects of future peoples will set ecojustice education apart from other approaches.

In the classroom, the science teacher should be viewed as the "significant other" (Bowers, 2001, p. 189). Bowers (op. cit.) clarifies the notion of a significant other by evoking Martin Buber's I/Thou perspective that embraces and values "confirmation, acceptance, trust, and the other qualities of relationship essential to a continued dialogue" (p. 194). The teacher, as the significant other, should embody these qualities. Students must be able to depend on the "significant other" relationship, established with the teacher, when they are guided through discussions that make explicit the aspects of the dominant culture that are largely taken for granted. The science teacher will have the primary responsibility of developing an understanding of the connections between language and the underlying cultural assumptions of everyday life. Thus, the teacher should know when to make explicit the metaphorical nature of language, which is defined as "primary socialization":

> . . . decisions on the teachers' part about whether the language made available enables students to conceptualize and articulate the patterns of their own experiences and to connect these patterns to different frames of cultural experience—personal, family, community, intercultural, and global trends (p. 196).

Bowers (op. cit.) explains that if the curriculum frameworks are too abstract from the students' everyday experiences, students will interpret it to mean that their experiences (i.e., local knowledges and skills) are insignificant to the majority's meta-narratives. Adversely, teachers are now educated in teacher education programs that may not expose them to the deeply embedded cultural assumptions they take for granted. This lack of exposure may limit how well science teachers can help students analyze cultural assumptions. Thus, ecojustice ought to play a vital role in science teacher preparation.

Bowers (2001) recommends that science teacher educators and prospective science teachers develop an understanding of the "ecology of the classroom" (p. 199). Ecology of the classroom is defined as the "languaging patterns in primary socialization and the patterns of communication [i.e., meta-communication] that signal the ongoing shift in attitudes about relationships among students and between students and the teacher" (p. 199). Meta-communication is defined as the "use of social space, or proxemics; what is popularly referred to as body language, or kinesthetics; and tone, rhythm, and pitch of voice, or prosody, to communicate about relationships" (p. 200). Focusing on students' social space, body language, and the tones that communicate the dynamics of relationships and the classroom space might be used in a way that respects cultural traditions, beliefs and values, and embodies the root metaphor *ecology*.

An EcoJustice Agenda for Science Education Reform

Chet Bowers (2004a, 2005a, 2006) asserts that teacher education institutions that take ecojustice seriously will provide a balanced view of science and technology by analyzing the metaphorical nature of language emphasized in the university. He explains that faculty and students should be exposed to the double binds of the current patterns of thinking that developed concurrently with the Industrial Revolution. He believes this exposure should be accomplished by showing interdisciplinary linkages between the root metaphors of the past, and those of the present, the ecological technologies of the past, and the modern technologies, non-commidified aspects of community, and the aspects of the consumer culture being globalized, and by analyzing the view that whatever leads to change is inherently progressive. Bowers (2004a) explains that we can live as individuals transforming the world or we can teach and learn about our cultural patterns of thinking, embrace and value the practices of less consumer dependent cultures, and help to revitalize the cultural and environmental commons, which will have a less damaging impact on the bioregion—we have a choice before us.

Commons revitalization projects are valuable to all members of the cultures, as well as the water, air, woodlands, pastures, plants, animals, and other characteristics of the natural systems (Bowers, 2004a). The commons are embraced and valued by teachers and students who seek out the "symbolic aspects of the culture: narratives, knowledge of the cycles of natural systems, spoken and written symbol systems, craft knowledge, music, dances, moral norms and patterns of reciprocity, knowledge of the medicinal characteristics of plants, and so forth" (p. 49). Revitalization will vary depending on the school's location, place-centered experiences and local knowledges/cultural traditions.

Bowers (2004a) emphasizes comparative cultural studies of how TEKs have much less of a negative human impact on the commons (i.e., what he encourages here is modes of community reliance, not going back to pre-20th century Indigenous practices). He urges science teachers and students to consider a sense of reliance and community, along with the ways to live a productive life with less money and goods. He identifies an ecojustice agenda as one that protects, conserves and sustains cultures and environments. He explains that ecojustice conserves the "cultural traditions that enable people to reduce their dependence on a money economy as well as the size of their ecological footprint"

(p. 56). He wants educators to engage in ecojustice education reforms that foster greater cultural and environmental awareness, provide opportunities to look at the world through local values, intergenerational knowledges, community-based ways of living, community reliance and acknowledge the consequences of globalization (i.e., Earth democracy). Ecojustice education reforms will help teachers and students recognize the significance of other cultural ways of knowing that contribute to the revitalization of the commons.

Bowers (2004a) recommends that the overarching questions of what need to be conserved and sustained should remain visible in educational reforms. He points to the conservation principles of The Nature Conservancy (http://www.nature.org/) and Conservation Land Trust (http://www.lta.org/) for examples of how we might expand the commons. Moreover, Bowers (2005a) encourages teacher educators to consider the works of environmental conservatives including Wendell Berry, Aldo Leopold, and Vandana Shiva, and for an alternate perspective, the classical liberal thinkers including John Locke, Adam Smith, John S. Mill, and Herbert Spencer (i.e., social Darwinism). He believes that discussions of these scholars' works will provide teachers and students with an adequate understanding of the "current efforts to overturn the traditions that genuine conservatives have historically viewed as essential to the civil rights of the current and future generations" (p. 2). He explains the importance of an involved teacher to help students mediate Euro-Western worldviews and to navigate the underlying assumptions. Bowers (op. cit.) encourages teachers and students to work together to understand the various ways in which cultural groups acquire, encode and reproduce intergenerational knowledges and skills. Teachers and students should work together to accomplish the aims of an ecojustice agenda in their classrooms, communities and bioregions. Together, they should value a responsible knowledge of local peoples/ecosystems and engage in ecojustice projects that revitalize the commons to make informed democratic decisions.

Summary

Readers should now be familiar with the potential of Chet Bowers' (2001, 2006) ecojustice philosophy and education. Chapter two provided a more detailed description of Bowers' (op. cit.) ideas of "educating for the commons," ecojustice philosophy and critiques of the cultural views of science, as well as educational implications for science education reform. Central to Bowers' (op. cit.) philosophy is the key assumption that knowledge and language carry forward root metaphors. Bowers' (op. cit.) main thesis is that the commons are strengthened by educational reforms that revitalize what was once available to all people. Bowers (op. cit.) argues that cultural biases, subjectivity, and morals and ethics, make an understanding of cultures different from an understanding of the natural world. He explains that scientists may lack the academic preparation to respond to the moral and ethical issues, along with cultural consequences, involved in scientific research. He argues that scientism, the view that a scientific lens can be used to investigate all aspects of cultural life, reinforces the notion that the thinking patterns of the natural sciences are more evolutionarily advanced. The prevailing cultural assumptions drawn from Darwin's theory of evolution, linked with the process of natural selection as a way to explain human choices, reinforces linear time, increasing complexity, and the view that change is equated with inherent progress. If not constrained, these assumptions would reinforce the idea that human choices are framed of natural selection, which undermines TEKs. In contrast, Bowers (op. cit.) notes that his ecojustice perspective protects the weakest and most vulnerable cultural groups, which carry forward the least damaging human impacts on the Earth's natural systems.

Bowers (2001, 2006) discusses the implications of his ecojustice philosophy for science education, writing about the elements of the curriculum and implications for practice. He wants teachers to find out what students already know and elicit their everyday experiences to provide a frame of reference to analyze cultural assumptions. He advocates relying on local resources, community surveys, and comparative cultural studies. He emphasizes the importance of understanding cultural traditions, the ways in which people renew marginalized skills, and how students can carry forward cultural practices that have the least impact on the natural systems. Bowers (op. cit.) advocates a balanced view of science, an understanding of the history of scientific thought, and the teaching of a science process that includes the consequences of scientific work on community life. Bowers (op. cit.) notes that ecojustice education will be enacted in various ways, depending on location and believes that ecojustice education will enhance local decision-making. Teachers should be viewed as the "significant other," the cultural mediator, who makes explicit the root metaphors of language when appropriate, which is primary socialization. Bowers (op. cit.) proposes that science teacher educators and prospective teachers consider what he calls the "ecology of the classroom," the meta-communication and an understanding of the dynamics of relationships in order to respect students' cultural traditions and beliefs.

An ecojustice agenda for science education reform is the final component of Bowers' (2001, 2006) ecojustice philosophy. An ecojustice agenda, similar to the characteristics of reforms based on Bowers (op. cit.) ecojustice philosophy, is specific to science teacher education. Bowers (op. cit.) wants educators to cultivate a greater cultural and environmental awareness, to help students look at the world through a local lens and to renew intergenerational knowledges. He wants educators to conserve an Earth democracy, study the consequences of cultural and environmental enclosures and the locally defined authority of cultural groups. Bowers (op. cit.) encourages teachers and students to work together to engage in the competence of local ecosystems and ecojustice projects that renew the commons.

Bowers (2001, 2006) contributes many interesting perspectives for science education. His proposals should help science educators develop projects that are centered on revitalizing local knowledges and community reliance. However, there are several problematic assumptions that need to be resolved before ecojustice will work for science education. Although Bowers (op. cit.) acknowledges that the Earth's wild ecosystems are highly uncertain, he inadvertently perpetuates certainty notions of Earth-in-crisis, science/scientists, TEKs. While Bowers (op. cit.) recognizes that capitalism and environmental politics are linked with revitalizing the commons, he does not go far enough to address these issues. Ecojustice is subject to the criticisms that it lacks sufficient pragmatic justifications and does not provide an adequate understanding or balanced view of the ways in which scientists use Darwin's theory of evolution and natural selection to conserve and sustain the commons. I will respond to Bowers' (op. cit.) work in the next chapter.

Chapter 3: Groundwork for EcoJustice

In chapter two, I described Chet Bowers' (2001, 2006) main thesis of strengthening the commons and educational implications for science education. I provided criteria for educational reforms based on ecojustice and explained how assumptions deeply embedded in science may carry forward the double binds, or general misunderstandings, of Euro-Western thought. Now, readers should recognize that science both contributes to our understanding of ecological declines and increase the conveniences of life, and yet science should not be exclusively privileged to understand the complexity of cultural life. Because of the natural sciences' favored status, educational research may be patterned after and educational theories might be extrapolated from it, which deemphasizes cultural ways of knowing that are not generally accepted as science. Education may also reinforce cultural interpretations of Darwin's theory of evolution and natural selection that are not representative of how these theories are generally understood within the field of ecology. Bowers (op. cit.) wants science teachers and students to analyze the cultural views of science and to look to the traditional ecological knowledges (TEKs) or "organic sciences" of peoples who lived for thousands of years within the limits of the Earth's wild ecosystems, for metaphorical examples of how to revitalize the commons. He does not propose that we go back to the past, but rather embrace and value the importance of community reliance. Ecojustice will spark new conversations in science education, and ecojustice education and agenda for science education represent interesting departure points for my work.

While Bowers (2001, 2006) contributes interesting ideas, he perpetuates several assumptions that need to be resolved before ecojustice is a constructive option for science education. In this chapter, I will respond, and connect with other scholars, to evaluate Bowers' main thesis to revitalize the commons. Three major assumptions were pointed out in chapter two that will serve as the structure for this chapter. First, Bowers (op. cit.) assumes that the local authority of the commons is a certain way universally (most aligned with TEKs). Second, he assumes that science (i.e., "Western") and scientists are a certain way. Third, he assumes the Earth (i.e., *the* ecological crisis) is a certain way. As I am shifting towards a theory of uncertainty thinking for ecojustice and science education, I will break down these assumptions. My expectation is that this chapter will bring clarity to ecojustice.

The Local Authority of the Commons

The commons are represented as the non-commodified aspects of cultural life and the environment that were once available to all humans (Bowers, 2001, 2004a, 2006). The cultural dimensions of the commons include the thinking patterns and traditions shared by all members of the community (e.g., local decision-making). The natural dimensions of the commons include the shared water, air, forests, the oceans and lands. Vandana Shiva (1997, 2005) and Gary Snyder (2001) support this definition and add that the common lands were displaced by the early Europeans in the U.S., which were almost always guided by the authority of local village councils dating to Neolithic times. The early European farmers, miners, and ranchers did not have the shared TEKs needed to take care of the common lands. Today, common lands are managed by the government.

Bowers (2001, 2004a, 2006) argues that the commons will differ depending on location and should be revitalized according to the local authority of the community and the needs of the Earth's wild ecosystems. Because people depend on the environment where they live for their survival, people must recognize potential enclosures and make appropriate decisions to protect the commons. Enclosures represent the ways that the cultural, the community, and the environmental aspects of the commons are turned into market commodities—when things are no longer shared. Bowers (op. cit.) argues that the democratic decision-making process to protect the commons must include multiple perspectives, and yet he argues that the commons are not subject to "cultural relativism" (2001, p. 23). He rejects cultural relativism because it seems to threaten *the* basic human rights that should be universally respected. As part of eco*justice*, these human rights are expanded to include the rights of future peoples to live in uncontaminated environments, rights to sustain patterns of moral reciprocity and knowledges/skills that reduce human impacts on the environment, and rights for ecologically informed groups to determine which technological and linguistic innovations are embraced and which are rejected. Because Indigenous people have survived and adapted to Earth's changes over thousands of years, Bowers (op. cit.) argues that TEKs provide the strongest metaphor for commons revitalization today. It follows that the metaphor of local authority and TEKs of village councils dating back to Neolithic times should be favored to make decisions.

Ecojustice philosophy can be criticized for the lack of specific pragmatic warrants for renewing and revitalizing the commons (Bowers, 2001, 2004a, 2006). In 1995, Madhu Prakash raised this concern, warning Bowers of the lack of pragmatic supports for ecological education and literacy. Prakash (op. cit.) urged ecological scholars to highlight pragmatic projects focused on the places where people live. In her work, she provides examples of the environmental projects currently underway in many parts of the nation. She argues that these kinds of warrants help to ground ecological philosophy. Prakash (op. cit.) elaborates:

> Our philosophical discussions of nature are thoroughly dislocated or disembedded from the local spaces we inhabit. We analyze an abstract earth from a lofty academic tower. Following professional norms, we write principally as disembodied intellectual voices, and not as persons engaged in conversation with neighbors, families, and friends. Speaking impersonally through the loudspeakers to other uprooted global citizens or all-purpose intellectuals, our writings say little or nothing about our own personal attempts at living and working, teaching and learning in ways that make more moral/ecological sense without our own local communities (p. 333).

Prakash (op. cit.) concludes by discussing her own experiences with students in Pennsylvania. She provides numerous examples of how her students analyze their own taken-for-granted assumptions and learn from the more ecologically informed traditions of sustainability. She warns that "ecological perspectives are only educative when they continuously connect us to the natural world we know and cherish" (p. 337). Prakash (op. cit.) encourages her students to learn to value places through affection, loyalty, and care.

Other scholars (Edmundson, 2001, 2004; Martusewicz, 2005a) have also suggested that perhaps the reason that ecojustice has been deemphasized or ignored is because of the lack of pragmatic justifications. I agree with these scholars and add that science educators may not take ecojustice seriously without pragmatic warrants. My suspicion is that pragmatism is necessary for ecojustice to work in science education. Because the commons vary depending on the particular bioregion where science teachers and students are located, they will need many different examples of which traditions are being renewed and which traditions are being revitalized. The latter are particularly important for educators based in geographic places where TEKs can no longer be found. Each place will have different social, historical, and political contexts that play a vital role in the local authority of the community. Although Bowers (2001, 2004a, 2006) acknowledges that these contexts are important, he offers few local experiences to ground his claims for renewing and revitalizing the cultural and environmental commons. Because he favors the metaphor of TEKs, he assumes that they are essentially universal. A strong case can be made that Bowers' (op. cit.) human rights that should be universally respected are found in the metaphors of ecologically informed peoples worldwide, which he equates with TEKs and the racial/ethnic traditions of moral reciprocity and reliance. Reducing the renewal and revitalization of the commons to these "certainty" metaphors may not uphold the cultural diversity and the recognition of Earth's biodiversity needed. Ecojustice warrants millions (or more) of small ideas rather than one big idea. However, with this much cultural diversity (all working towards sustainability), there must be a way for local people to decipher which ideas work best for their particular situations.

The Political Contexts of Commons Renewal and Revitalization

In several responses to ecojustice philosophy, Peter McLaren and Donna Houston (McLaren, 2006; McLaren & Houston, 2004) charge Bowers with dismissing the political contexts and sociopolitical possibilities of critical theory. McLaren and Houston (op. cit.) recognize the significance of including ecological justice in critical pedagogy, and yet caution against moving away from the radical aim of transforming oppressive social and economic conditions, the contextualized dialogues of environmental conflicts, and the historical production of environmental injustice shaped by capitalism and globalization. However, they are concerned that Bowers' ecojustice philosophy attempts to escape the political context and warn against situating place-based critical pedagogy "under an encompassing category of ecojustice" (p. 30). They provide an example of an urban school project in Los Angeles that was tattered by political maltreatment and pressing human/environmental hazards. McLaren and Houston (op. cit.) argue that environmental justice issues "do not *take place* just anywhere," and thus, the connections between the politics of the terrain and environmental injustice are salient (p. 32, emphasis in original). The places where environmental injustice occurs are most often the "poorest and least-white places with the worst and most deadly pollution" (p. 32). McLaren and Houston (op. cit.) argue that the dialectics of environmental injustice provide a lens into how global capitalism degrades the Earth. Examples include industrial and military wastes, land development and resource extraction and the exploitation of plants and animals. McLaren and Houston (op. cit.) argue that understanding the ecological crisis as a social and historical process shows how Earth's wild ecosystems are in constant change and that political alternatives are definitely possible, which counters issues of human-centeredness (i.e., anthropocentrism) and the exploitation of Earth's natural resources.

Moreover, McLaren and Houston (2004) argue that "initiatives undertaken by critical educators cannot ignore the relationship between capital and the abuse of environmental and human rights, including the right to a healthy school environment, equitable access to green-space, and ecologically sustainable communities, or the plight of those activists who expose this connection and organize for change" (pp. 34-35). McLaren and Houston (op. cit.) propose a pedagogical movement founded on Marxism, and explain that Marxism does not advocate anthropocentrism but rather "views humans as dialectically and spiritually linked to natural processes in a mutually transformative capacity" (p. 35). Because all forms of social oppression are lived, experienced, and function within a class-based and far-reaching capitalism, they propose "an ecosocialist focus on the dialectics of justice can help us replenish the soil of universal human endeavor by bringing to the attention of students the intractable connection between capitalism and ecological devastation" (p. 36). McLaren and Houston's (op. cit.) key point is that ecojustice does not escape politics and should include an exploration of politics, economics, student histories, similar sites of environmental injustice, and environmental activism. The encompassing challenge is to work towards:

> . . . a society of associated producers who collectively control production instead of being controlled by it, brought about when the working class transforms itself from a class "in itself" to a class "for itself." The objective is to create a society in which we are free from physical need so that we can engage in work free from

coercion and obligation. Only then can we inhabit a society in which our human sociality and creativity can flourish (p. 41).

Ecojustice pedagogy should be grounded in the places in which people are engaged in environmental activism. However, McLaren and Houston (op. cit.) warn that such a dialectics of justice should not dismiss the "transformation of the collective historical conditions of injustice produced by capital and its value forms under a rubric of a 'new' green paradigm or recently reimagined ecological 'past'" and assert that "critical and revolutionary educators must carefully interrogate the claims that 'greening' their respective traditions register" without loosing sight of their radically revolutionary transformative agendas (p. 41).

David Gruenewald (2003a, 2003b, 2004, 2005) concurs with McLaren and Houston and offers an educational framework (i.e., "Critical Pedagogy of Place") that he believes adequately synthesizes the crucial elements of Bowers' ecojustice theory and McLaren's transformative agenda. He remains open to the possibility of finding common grounds between the ethical theory of ecojustice and the liberatory pedagogy of critical theorists. Gruenewald (2003b) argues that Bowers lays the groundwork for bringing together the "dissident ecological traditions" of environmental justice, ecofeminism, social ecology, and TEKs (p. 6). However, he argues that there are issues for ecojustice theory that remain unresolved, such as developing an educational framework that both ecological educators and critical pedagogues can use to interrogate the "intersection between urbanization, racism, classism, sexism, environmentalism, global economics, and other political themes" (p. 6). He explains that different social experiences (i.e., race, gender, class) and geographic locations means that people will perceive and prioritize environmental issues differently. For example, Gruenewald (op. cit.) notes that resource exploitation and environmentalism ranked higher for radical middle-class whites around Earth Day in 1970, whereas for blacks, the issues of unemployment, poor housing, racial discrimination and deteriorating cities were more relevant priorities. Gruenewald's (op. cit.) main point is that environmental concerns shift with geographic location and necessitate a critical pedagogy of place that interrogates peoples' particular situations and the interrelationships that bridge the cultural and ecological milieus.

Responding to the aforementioned scholars, Bowers (2004c, 2005b) seems nervous that integrating McLaren's critical theory perspectives with ecojustice theory will hide the cultural patterns of thinking and behavior linked with ecological declines. Bowers (op. cit.) argues that McLaren and Houston's ecosocialist focus and Gruenewald's place-based critical pedagogy do not adequately address how teachers and students should effectively confront cultural assumptions that may lead to cultural and environmental enclosures. Since McLaren and Houston are not explicit about which assumptions should be carried forward, Bowers (op. cit.) assumes that they mean emancipation from all cultural ways of knowing. Bowers (op. cit.) argues that Gruenewald's place-based critical pedagogy privileges the ideologies of anthropocentrism and universalism linked with McLaren and Houston's perspectives. His final concern is that blended approaches (i.e., critical pedagogy of place) may lead science education researchers, theorists, professors and teachers in a variety of directions not intended by his ethical theory of ecojustice to revitalize the commons.

Already, the distinctions between Bowers' ecojustice theory and Gruenewald's critical pedagogy of place are becoming convoluted in science education research

(Glasson, Frykholm, Mhango, & Phiri, 2006; Lim & Calabrese Barton, 2006). Because educational theories are generally used to develop a cohesive framework for empirical investigations, they are seldom critiqued. In science education, theoretical frameworks are rarely supported in the research literature spanning hundreds of reviewed studies (Abd-El-Khalick & Akerson, 2006). Thus, the underlying and problematic assumptions may be inadvertently perpetuated and favor certain kinds of outcomes. Correspondingly, the philosophical frameworks offered by Bowers and Gruenewald remain blurred and may not be supported by empirical research in science education. Efforts to bridge ecojustice and other social justice theories is a step in the right direction, however, there are cultural assumptions that remain unresolved in critical pedagogy of place. As science education needs to be well-guided by theoretical frameworks that reduce human impacts, ecological philosophers must dig deeper to make explicit these underlying assumptions.

Most concerning is the universal ideology (i.e., oxymoron) perpetuated by McLaren (2006) and Gruenewald (2005) that "critical" is an *inclusive*-oriented direction. While critical inquiry may be appropriate for reflecting on oppressive human conditions, it privileges the evaluator's inclinations as *the* standard for comparison. This condition suggests that the critical inquirer knows everything there is to know of other's situations. But, the evaluation of projected ecological outcomes necessitates the full inclusion of many diverse perspectives, including contrasting perspectives (i.e., past, present, future), which compels us to suspend critical judgment and doubt. If we start from a position of judgment and doubt, we might not give other people and the Earth the full attention that they deserve, to be legitimately considered (Ellsworth, 1989; Thayer-Bacon, 2000, 2003). Withholding judgment and doubt may be compromised by positions of critical inquiry, which limit how much attention we pay to the complexity of other people and the Earth. An inclusive-oriented direction embraces and values multidimensionality and the needs of the Earth's wild ecosystems, which are constantly changing and irreducibly complex. Because of these uncertainties, the inclusion of diverse knowledges, beliefs and values, personal expectations and narratives are needed to engage in democratic decisions. Democratic decisions offer all affected stakeholders an equal opportunity to participate, which is likely to be strengthened when peoples views-in-relation-to-others are affirmed.

However, there is merit to what McLaren and Houston (2004) and Gruenewald (2003a, 2003b, 2004, 2005) are trying to address when emphasizing the need to consider politics and capitalism in educational reforms based on ecojustice criteria. The political context of peoples and places warrants which perspectives are accepted and which are rejected. But the versions of critical theory represented by the above scholars do not adequately address how the American public might resist the politics of capitalism and globalization. Imagine all the ways that a single person defeats any effort to protect the natural world by not knowing where their money is invested (assuming they are lucky enough to be one of the relatively few "haves!"). The majority of us are implicit stakeholders in many companies, and we invest our dollars, which is the result of having a salary, retirement accounts, vehicle insurance, health and dental insurance, banking accounts, bank loans, and credit cards—through systems that are driven by returns, rather than by concern for environmental destruction. These things are unavoidable for many people in the Euro-Western and now Eastern (e.g., China, Thailand, Burma, Japan…) worlds. According to the surfer and songwriter Jack Johnson (2003),

Well, it was you, it was me, it was every man, *We've all got the blood on our hands.*

We only receive what we demand,

If we want hell, then hell's what we'll have.

Replace the word *man* with *human*, and Jack Johnson's song lyrics accurately describe the dilemma facing the vast majority of people today who are concerned about the Earth.

The environmental columnist Curtis White (2007b) notes, "environmentalists are, on the whole, educated and successful people, many of whom have prospered within corporate capitalism. They're not against it." (p. 28). It is counterintuitive to think that the majority of environmentalists will resist or reject current forms of capitalism, which are needed to protect the Earth's *natural capital* (i.e., nature's services such as pest control, the pollination of crops, water purification, erosion prevention; c.f. Herman Daly, 2002). More likely to occur is what Curtis White calls the "so-called greening of corporate America" which resembles something more like our current predicament (p. 28).

> For environmentalism, confronting corporations and creating indignant scientific reports about pollution is the easy stuff. But these activities are inadequate to the real problems, as any honest observer of the last thirty years of environmental activism would have to concede (White, 2007b, p. 28).

When it comes to environmentalism, *actions speak louder than words*. These actions begin with our own lifestyles and extend outward to include our neighbors, community, and the Earth's wild ecosystems. Ecojustice ought to be focused locally and relationally.

The local forms of community reliance and mutual support systems discussed by Bowers (2001, 2004a, 2006) do have political contingencies, and yet they also have the potential to help people reduce their reliance on the market—at least on a local scale, which may be the only avenue to doing what is advocated by the above critical theorists. Gruenewald (2003a, 2003b, 2004, 2005) should be credited for attempting to resolve the long-standing dualism between Peter McLaren and Chet Bowers, which means bridging social- and ecojustice perspectives. It is naïve to think that critical theorists in the traditions of Peter McLaren (2006) are advocating educational philosophy that harms rather than heals, and yet they deemphasize or ignore the ethical and moral imperatives supported by ecojustice theory that provide metaphors for resolving the very difficult issues surrounding capitalism and globalization. Perhaps the morality that stirs a less consumer dependent lifestyle is one of few options for reducing humankind's impacts. Bowers (op. cit.) argues that the metaphor of TEKs provides these possible routes.

The Urban Community: Sources of Conflict and Oppression

A problem for ecojustice based on the local authority of the community and the needs of the natural environment is that TEKs no longer exist in many parts of the U.S. Will the relational perspectives of the vast majority of people who actually live in urban communities (e.g., New York City, Los Angeles, Chicago, Minneapolis…) be considered legitimate contributions when compared with more ecologically informed perspectives? Nancy Brickhouse and Julie Kittleson (2006) argue that the conceptions of community and moral imperative written in Bowers' *Educating for Ecojustice and Community*, "could not exist in urban areas, where living on local resources is not possible" (p. 198). They explain that Bowers places too little emphasis on the realities of urban cities, and they argue that there are few people left who could teach (or would even want to renew) the skills and various forms of customs and local knowledges advocated by Bowers. They claim that Bowers excludes urban dwellers from his visions of community and ecojustice.

One environmental problem with regards to metropolitan areas is urban sprawl (i.e., spread of a city into neighboring rural areas). Describing one possibility to resolve urban sprawl, Brickhouse and Kittleson (2006) note that Japan is “seventy percent forested, with the human population concentrated mostly in cities” and multi-person dwellings. They note that it would be “interesting to see how Bowers would envision ecojustice education for cities that could also contribute to ecological sustainability” (p. 199). While Bowers’ response may trigger some interesting conversations on urban sprawl and sustainability, it is unfair to use Japan’s forestry policies as a viable example for preserving forested areas. Brickhouse and Kittleson (op. cit.) fail to recognize:

> Japan’s thirst for wood products for international markets has been primarily responsible for encouraging the destruction of 80 to 90 percent of the tropical forests in Sri Lanka and Southeast Asia over the last forty years. Japan is also a leading exploiter of the old-growth forests of Central and South America (including Brazil, Peru, and Chile) and the United States (including Southeast Alaska) (Sessions, 2001, p. 238).

While Japan is a significant player in the world-wide destruction of old-growth forests, it is important to note that North America’s clear cutting of old-growth forests along the western coast, from California to British Columbia to Alaska, is another serious issue. Eastern countries such as Japan, China, and others have rapidly increased their ecological footprint and might not offer the strongest examples of ecological sustainability.

Then again, local examples are emerging in U.S. cities such as New York, where multiple family housing units are constructed based on codes for ecological components. The Sundance Channel recently broadcasted an episode on how builders are turning to geothermal heat, voltaic solar panels, and construction materials made from waste (e.g., high-strength concrete, insulation, building lumber…). Engineers and contractors explain that ecological designs offer less expensive housing options for people who do not have much disposable income, which strengthens the commons. These ecologically designed buildings offer community revitalization components (basketball courts, gardens, etc). Brickhouse and Kittleson's (2006) argument is well-intended, but there are many examples that can be found in local communities where people in the U.S. are taking the initiative to move society in a different direction. These examples must be highlighted by scholars interested in ecojustice because local science teachers and students can relate better with ideas that are closer to the places where they live. My suspicion is that pragmatist philosophy will do much to emphasize local situations.

Further, Brickhouse and Kittleson (2006) point out that Bowers' visions of cultural renewal and commons revitalization do not adequately address how to deal with sources of conflict and oppression in urban places. They argue that Bowers "glosses over this problem and suggests that social justice would be a natural outcome of ecojustice" (p. 201). They point out that marginalized peoples (most often victimized by environmental hazards) would benefit significantly from an ecojustice curriculum that teaches them how to resist these hazards and live in a more ecologically sustainable way. A major dilemma for ecojustice is that individuals may have a high price to pay if they deviate from the values and customs of their community. Thus, Brickhouse and Kittleson (op. cit.) identify the difficulty of urban dwellers to break away from the *status quo*.

This dilemma is taken seriously when Bowers (2001) argues that teachers need to be actively involved with students to negotiate the dominant cultural milieu or meta-narratives that implicitly reinforce activities such as consumerism. Because students are embedded in the *status quo* (e.g., MTV), they need guidance to negotiate the implicit assumptions underpinning accelerated ecological declines. For example, in Phoenix, Arizona, where I worked as a high school science teacher, there were times when I had to actively help my students to resist community influences (e.g., gangs, drugs, alcohol...). There are many reasons why an insightful adult should be purposely involved with youth to help them evaluate the mythopoetic narratives of the consumer-dependent culture.

The Arizona school district where I worked expected the teaching and learning of a particular form of generally accepted science that was privileged on school wide exams. I was fortunate to recognize my students' traditional cultural knowledges (e.g., Mexican American and Native American) and multiple community affiliations early in my career. As my students shared their beliefs and values with me, I listened and integrated their community-centered perspectives within the scientific framework of the classroom. Because homework was kept to a minimum, students had more time to spent with their family and community (in retrospect, the conservation of time for renewing family and community knowledges may have reduced my students impacts on the environment). Eventually, I incorporated community-focused science projects that provided opportunities for my students to collaborate with working scientists, parents and siblings. Together, we co-constructed new ways to learn science including community-centered astrogeology projects (e.g., Mueller & Valderrama, 2006), astronomy night events, and an expedition team to hike Arizona's unique landscapes.

I wrote several small grant proposals to fund the hiking trips to The White Tank Mountains, Estrella Mountains, Superstition Mountains, Oak Creek Canyon, and the Prescott National Forest to collect rocks and other specimens (e.g., insects and animal bones) for our classroom. Initially, I did not think students would want to give up their Saturdays to venture into the desert and woods. Soon thereafter the expedition team grew to more than thirty-five students!

My colleagues joined the weekend trips, and together we found these trips provided many opportunities to talk with students about their cultural and community interests and life aspirations. Likewise, parents and community businesses pitched in to help make these trips possible by providing food, drinks and travel supports. Local fire-fighters provided free first-aid courses and trained several students as certified first responders and wilderness guides. I also taught students how to navigate the trails. Eventually, students planned our trips and guided our expeditions.

While hiking Arizona's landscapes, students taught me about the native species and desert habitats by capturing and releasing *tarantulas* and *giant hairy scorpions* (I'll admit that I was shocked to see my students gently place these creatures in their bare hands). They taught me how to identify the smell of rain in the leaves of the *creosote* bush, one of the most common desert shrubs in Arizona, and the uses of other native plants. My Navajo (or Dine´) students taught me the word *Hozho* meaning balance, beauty, harmony, happiness, and the interrelatedness of all things in Earth's ecosystems. It did not take me too long to realize that in some cases, the science assumptions portrayed in the school's textbooks and curriculum undermined my students' legitimate ways of knowing. My students helped me to become cognizant of the plurality of creative ways in which science is legitimately expressed.

My experiences are not the only exception that counter Brickhouse and Kittleson's (2006) claims that few urban dwellers can teach or would want to renew the TEKs and other racial/ethical narratives of community reliance advocated by ecojustice. There are other examples where people continue to renew and revitalize the community narratives of reliance, mutual support and moral reciprocity that can be found in urban cities such as Detroit, Michigan (Martusewicz, 2005a, 2005b). My work with prospective teachers in rural Appalachia, Tennessee, is yet another justification that local knowledges and skills advocated by Bowers (2001) are renewed and strengthened when embraced. Thus far, I have shown several examples of scholars who criticize Bowers (op. cit.) for advocating romantic visions of the past. Marginalizing the local knowledges and skills typically associated with Indigenous cultures, racial/ethnic minorities, and the poor is racism, and undermining the gendered knowledges and skills associated with women is sexism, which may be disguised by the illusion that progress and growth are inherently good. People find a great deal of pleasure in cooking a meal, making crafts, washing dishes by hand, taking care of pets, working in the yard, talking with neighbors, and hiking through the woods—all renewed and revitalized daily. A challenge for teachers interested in ecojustice and neighborhood revitalization projects will be helping young people to find the virtue, aesthetics and embodied experiences in doing these things.

How teachers and students should confront conflict and oppression has remained a common concern of scholars interested in ecojustice philosophy for a few years now

(Desmond et al., 2003). I anticipate that with the world's constant changes, this issue will remain a central concern for scholars (thus, the need for more pragmatic-based warrants). At the 2003 American Educational Studies Association conference in Mexico City, Mexico, Desmond et al. (op. cit.) raised similar concerns aforementioned. In a paper titled "Ecojustice Pedagogy: Making It Real," they describe the implementation of Bowers' ecojustice works in a *Sense of Wonder Camp* for young girls, ages eight to thirteen (the theme based on the writings of Rachel Carson). They use ecojustice education to engage campers in conversations of the root metaphors *ecology*, *community*, *relationship*, *power*, and *harmony*, to foster a sense of gendered self and empowerment. The meaningful purpose of the camp is to develop a sense of wonder, within each child, in the natural environment, and to help young girls discover ecology. Camp leaders guide youth through a series of questions to improve their personal relationships with other people and local ecosystems. Desmond et al. (op. cit.) describe how ecojustice education was successfully implemented in the curriculum, with one significant exception. They note that the girls had trouble with developing a sense of "being" (i.e., becoming) a young woman in society and in the ecological world. They argue that ecojustice education neglects "the importance of the agency of self within groups, especially as it applies to social justice and the categories of gender, race, and ethnicity" (p. 8). While Desmond et al. (op. cit.) agree with Bowers' critiques of critical theory, they explain that ecojustice education "needs to include a process of critical inquiry to address the social injustices that occur within traditional groups based on race, ethnicity, gender, and religion as well as those that result from environmental injustices" (p. 8). Desmond et al. (op. cit.) point out that intergenerational knowledges, cultural rituals and other community traditions need to be explored in ways that do not restrict or oppress the self in relation to the community and the natural world.

Oppressive conditions are being taken seriously by ecojustice scholars as they encourage and engage in local projects and further clarify ecojustice education with pragmatic justifications (Martusewicz, 2005b; Edmundson, 2001, 2004). To further discuss these issues, there is a journal called the *EcoJustice Review*, a resource website (http://www.ecojusticeeducation.org/), yearly ecojustice conferences, and interactive sessions held at the AESA and the American Education Research Association (e.g., AERA's Division B has created a new section called "Moral and Ecological Perspectives" where ecojustice works are now being encouraged to open up conversations on the questions related to the cultural, ethical, and ecological issues facing our communities, personal communication, R.A. Martusewicz, June 5, 2007).

However, Bowers (2001, 2004a, 2006) perpetuates the notion that ecologically informed peoples are a certain way (i.e., that environmentalism embodies certain virtues). Because "cultural relativism" has been rejected, there is a way advocated by ecojustice theory for approaching the revitalization of the commons most aligned with the moral structures and community reliance of Indigenous cultures and racial/ethnic minorities. While very few scholars will argue against fostering moral reciprocity and mutual support systems, ecologically informed thinking patterns and traditions are not universal. Because there are so many different cultural and environmental places and combinations thereof, the revitalization of the commons is dependent on the locality of Earth's diverse ecosystems and the local authority of diverse communities, which are not a certain way. Thus, the local authority of ecologically informed peoples remains highly uncertain, which aligns with the Earth's changes and complexity, which are inherently uncertain. Identifying some sort of "cultural relativism" is necessary for the relational perspectives of the local authorities to participate fully in the decision-making of the community.

In *Relational (e)pistemologies* (2003), Barbara Thayer-Bacon argues that (e)pistemological fallibilism (i.e., impossibility of ascertaining knowledge with certainty) is equated with epistemological pluralism (i.e., impossibility of attaining universal Truth). She claims that "democratic communities always-in-the-making are what protect us from fears of vulgar relativism [i.e., anything goes], as we openly argue and discuss and debate our concerns within our own communities as well as among other communities, even communities we can only imagine" (p. 49). She posits a theory of *qualified relativism* justified by relational (e)pistemologies (i.e., truth[s] based someplace[s]). Because she acknowledges an "ever-changing world in which we are active participants," she offers truths that are justified by as much evidence as we can muster, with the understanding that human constructed criteria and standards are subjective, fallible and corrigible (p. 48). Thus, truth is dependent on the authority of peoples- and places-in-relation-to-others. Addressing what constitutes good evidence is the goal of relational philosophies that recognize the world's constant changes and irreducible complexity. What is right today may or may not be right tomorrow (i.e., contradictions are necessary). It is impossible to have ecologically informed thinking patterns and behaviors that transcend the strong contextualities of particular peoples in specific places. That is, particular contexts are the cultural and environmental interrelationships between the knower and known (i.e., *culture* is both the interweaving of thoughts and experiences). Qualified relativists argue for a *both/and* logic that justifies a position from somewhere rather than everywhere, which warrants that thinking patterns and experiences are both particular and universal. Thinking in terms of qualified relativism helps to amend and extend Bowers' local authority of the commons because it acknowledges that ecological decisions that affect the community and the needs of natural systems needs multiple, contrasting perspectives.

The metaphors used by Bowers (2001, 2004a, 2006) are unclear and may or may not represent the most appropriate concepts for renewing and revitalizing the commons. Qualified relativism helps the authority of relational communities evaluate what should be renewed and what should be rejected. However, some scholars might respond that qualified relativism provides the justification for just about anything that reduces humans' impacts on Earth's wild ecosystems. For example, local peoples may decide to kill particular racial/ethnic peoples to conserve the environmental commons, which actually occurred during World War II and was justified by the Nazi's, in the name of "environmentalism" (Bowler, 1992). However, an example of qualified relativism can be seen in how the Allies responded to the holocaust, based in part on environmentalism. Another example might involve people who decide to rely on the marketplace to produce vehicles with higher MPG to reduce accelerated ecological declines rather than walking. Qualified relativists might seek this temporary solution for people who must drive, to counter the production of low MPG vehicles that are worse for the natural environment. Other qualified responses might seek alternate modes of transportation depending on the relevant contexts where people live (e.g., bikes, trains, boats…). In particular locations, different modes of transportation are warranted, such as the Grand Canyon where mules help people move up and down the canyon walls. A mule transport is less taxing on the environment when compared with the fuel used by a helicopter. However, helicopter transport is necessary when an injured person needs to be airlifted to a hospital. Thus, the authority of a community, based on qualified relativism, might warrant particular modes of transportation by including the perspectives of both helicopter and mule advocates.

It remains unclear whether Bowers (2001, 2002, 2003, 2004b) offers "organic sciences" (i.e., TEKs) as an alternative to the sciences generally taught in U.S. schools. However, he claims that the metaphor of TEKs is the superior metaphor for making democratic decisions over what is now generally accepted as the ecological sciences. This hierarchy may perpetuate a false dichotomy between what is generally accepted as "science" and what is legitimized as organic science. Organic science is now recognized as legitimate science in fields such as *ethnobiology*, or the "the scientific study of dynamic relationships among peoples, biota, and environments," which includes a diversity of scholars from the fields of Earth systems, population biology, ecology, mathematical biology, cultural anthropology, archaeology, geography, pharmacology, nutrition, conservation, and sustainable development (NSF, 2003, p. 1). Unfortunately, ethnobiological research is difficult because there are fewer funds available for multidisciplinary fields of science (NSF, 2003) and because TEKs are difficult to access, which resulted from the mistreatment of Indigenous cultural groups worldwide. Scientists and other scholars constrained by the "publish or perish" mantra of research institutions inadvertently perpetuate the avoidance of scientific work that is difficult to access and that does not garner adequate research funds. Fostering the needed relationships with Indigenous communities and accessing the types of comparative cultural studies advocated by ecojustice education is both challenging and vital work.

Comparative cultural studies provide exceptions to the metaphors used by Bowers (2001, 2004a, 2006). Bowers (op. cit.) does note that there are exceptions, but does not say whether they should be included in ecojustice education. Exceptions when Indigenous cultures did not treat their land with responsibility and did not live in harmony with the plants, birds, and sea, are noted in *Collapse* (2005) by Jared Diamond. Diamond (op. cit.) provides a rich description of the variables that contributed to the collapse of societies over the last 13,000 years: deforestation, soil problems, reckless use of water, depleting fisheries and overhunting, introducing invasive species, and human population growth. Likewise, economic and military variables can lead to the collapse of a society. Diamond (op. cit.) describes many societies – the Polynesians, Anasazi, Maya, Norse, and others – that took advantage of the natural environment too quickly and intensely, or were not able to adapt to the Earth's changes. His perspectives on the misuse of the environment serve as important historical and relational examples for science education that were unavailable to the ancient peoples.

Diamond's (2005) perspective on what happened to the Polynesians on Easter Island is particularly instructive. Diamond (op. cit.) explains that paleoecological records (e.g., pollen grains and fossils) indicate that subtropical trees and shrubs were abundant when the early Polynesians first arrived on the island. They made canoes from the wood of palms and were able to hunt porpoises from the sea. Moreover, they ate chickens (which were brought with the Polynesians) and many different types of sea birds on the island. As the human population increased, the Polynesians depleted the islands' trees for firewood and competed with each other for dwindling resources. Food sources became less abundant: shellfish were overharvested, and invasive species, including rats, prevented the new growth of palms. Without trees, the soil eroded rapidly and was dried by the sun. The insects, birds and foods from the sea were no longer available. One can only imagine the human tragedy that ensued as the Polynesians began to eat each other.

These exceptions help the local authority of the community (based on qualified relativism) to analyze whether ecologically informed patterns/practices are a certain way. Having multiple and dissenting perspectives helps the local authority of the community analyze the larger picture of possible outcomes of particular decisions. During these times of ecological uncertainty, the authority of the community-in-relation-to-others (Thayer-Bacon, 2003) recognizes that there will be unorthodox ways to revitalize the commons. Moreover, qualified relativism protects ecojustice educators from romanticizing TEKs while working towards the metaphors of community reliance and moral reciprocity of TEKs. Reducing the rate of ecological declines and fostering a sense of diverse peoples and places is the multidisciplinary approach to community reliance and mutual support called for Bowers' (2006) criteria for educational reforms based on ecojustice. Qualified relativism helps science teachers and students to become informed and to participate fully in the democratic decisions where ecological informed peoples are thought to be extinct.

The Meta-narrative of "Western" Science

Chet Bowers (2001, 2002, 2003, 2004b) argues that the mythopoetic organic sciences, rather than the meta-narratives of mechanistic-based science, are the stronger conceptualization for democratic decision-making because of the time tested experiences and oral narratives that helped Indigenous cultures to survive and adapt for millennia. While Bowers (op. cit.) notes that science is multifarious, he perpetuates the notion that "Western" science is a certain way. Thus, the cultural views of science (or metaphors) that he critiques are assumed to be the most widely accepted and legitimized ideologies by Euro-Western scientists, such as E.O. Wilson, Richard Dawkins, and Carl Sagan. While the assumptions of Darwin's theory of evolution and natural selection that Bowers' (op. cit.) argues are extrapolated and reinforced by educational theorists and researchers are essentially correct, he fails to offer the authentic narratives of evolutionary ecologists. The cultural interpretations that Bowers (op. cit.) notes in educational theory and research are not warranted by the natural sciences, with few exceptions that I will now discuss.

A likely challenge for educators will be integrating ecojustice within the current structure of the national standards-based education movement (NRC, 1996). Brickhouse and Kittleson (2006) argue that ecojustice education cannot work in science education unless there is an emphasis on the major aim of acquiring scientific competencies. They explain that science education cultivates "a strong understanding of the content and methods of the sciences and the ways in which this knowledge is constructed, mediated, and used within a variety of science-related communities" (p. 192). They note that the science set up to be critiqued by Bowers is aligned with positivism that is largely a myth. They turn to the feminist philosopher of science, Donna Haraway (1991 as cited in Brickhouse & Kittleson, op. cit.), to highlight visions of inclusive and situated science that work against the cultural views described by Bowers. Brickhouse and Kittleson (op. cit.) explain that Haraway's visions look critically at who gets to participate in science, and create "transformative relations within and between communities" (p. 203). They argue that Bowers' critiques of science fail to recognize the progress made by feminist philosophers such as Haraway. Likewise, they argue that Bowers has given up on science altogether: they remark "to give up on science entirely is to give up too much" (p. 202).

Brickhouse and Kittleson (2006) are essentially correct in pointing out that Bowers does not talk much about the benefits of Euro-Western meta-narratives of science in his critiques (2001, 2002, 2003, 2004b). However, it is unfair to charge Bowers with completely abandoning science, excluding women's voices, and dismissing feminist philosophy of science. In *Educating for Ecojustice* (2001), for example, Bowers discusses the beneficial roles of science (e.g., ecological awareness and the conveniences of life); he takes seriously the writings of Rachel Carson (p. 31); emphasizes Vandana Shiva's ecofeminist works (p. 38, 44, 62, 100), and emphasizes the importance of learning about the exclusion of women in science (p. 174). Unfortunately, Bowers' (op. cit.) main thesis might have been missed and I make this distinction so that other science educators will not be turned away from ecojustice education. He wants science teachers and students to wrestle with the root metaphors (including patriarchy and scientism) carried forward in the ideologies of science and science education, to prevent the enclosure of the commons, by making explicit the double binds that may influence ways of thinking and behaving.

Further, Brickhouse and Kittleson (2006) misinterpret ecojustice education as an "exclusive focus" on local knowledges that deny students the opportunity to work with the "broader discourse of powerful science-related communities" (p. 193). They point to several science educators (e.g., Gloria Snively, John Corsiglia, William Stanley, and Glen Aikenhead) who teach "non-Western scientific and cultural knowledge" alongside the

Western perspectives to help Indigenous students better navigate the dominant paradigm (p. 196). Brickhouse and Kittleson (op. cit.) elaborate:

> Educators particularly concerned with the position of science in the education of children living in indigenous communities have not abandoned teaching Western science; in fact, they have found that this kind of science education is well-regarded by the communities in which they work (p. 196).

While Bowers (2001) might agree with the importance of teaching TEKs as part of the generally accepted and legitimized science education, I remain unconvinced that "Western" science is so well-regarded by Indigenous peoples. Here, I should clarify that when scholars use the term "Western" science, they typically refer to the science that spans cultural milieus (i.e., international scientific collaborations that encompass scholars from Asian, Indian, European, and other cultures, who work together using an agreed upon scientific approach to discuss anything from native herbals to water-use/policies…). However, the term "Western" science privileges European and North American views, which tends to hide the contributions of the Ancient Greeks, the Chinese, and the Islamic scientists and philosophers, as well as Indigenous ways of knowing that have never been fully acknowledged as part of the "Western" scientific regime. Although Bowers (op. cit.) notes that organic science is legitimate science, he perpetuates the superiority of the Euro-Western meta-narratives by using the term "Western" science—when science is the cumulative knowledge of culturally diverse and creative peoples within different places. If the term "Western" science is used, then it should be qualified as the plurality of ways that humans come to know and express themselves in science (Mueller & Bentley, 2007). Science education has a long history of delegitimizing and devaluing the TEKs, the intergenerational knowledges and the relational epistemologies of Native peoples (Bowers, 2001, 2002, 2003, 2004b; Deloria, 1997; Shiva, 1997, 2005; Thayer-Bacon, 2000, 2003). These category mistakes are tough to avoid, and yet vitally important to make explicit for ecojustice, to be successful.

As Brickhouse and Kittleson (2006) aptly note, ecojustice education will not be successful in science education unless the major competencies are adequately addressed. Because today's science education is largely guided by the national science education standards and by psychological studies of how students' learn science, there is an increasing emphasis on brain research, constructivism, and standardized facts/concepts (National Research Council, 1996, 2005). The national science education standards guide the most accepted and NSF funded science-education research projects. Thus, science educators are legitimately concerned with the roles that science will play in ecojustice. But this concern should not justify endorsing the national and state priorities linked with high-stakes testing, or justify deemphasizing or ignoring the national science education standards. There have always been standards to guide the role of science in science education, and there always will be the *status quo*. Bowers (2001, 2004a, 2006) seems nervous that one-size-fits-all mentalities are destructive for science education. On this point, Brickhouse and Kittleson (op. cit.) would agree; there is no single way to do science. Moreover, other scholars (Prakash and Stuchul, 2004; Gruenewald, 2004; Mueller & Bentley, 2007; Noddings, 2003, 2006) are now pointing out the problems with portraying the U.S. standards for science education as "world class" standards. The key emphasis of ecojustice education is to help science teachers and students renew and revitalize the authority of the local commons in order to become empowered stakeholders and decision-makers. Thus, ecojustice education will vary from place-to-place.

In more recent works, Bowers (2006) is addressing the changing roles of the environmental sciences in ecojustice (*Transforming Environmental Education*). For instance, Bowers (op. cit.) notes:

> In the Northwest, the focus may be on changes in the nearby stream beds that limit the ability of salmon to reproduce themselves, how the clear cutting of forests reduces the habitat needed by different species of birds and small mammals, and how the dams and changes in water temperature impact the number of salmon that return to spawn. Across what was formerly the great plains covered with native grasses, the focus now may be on the loss of species that result from the use of herbicides, the impact of irrigation on local aquifers, and the farming techniques that contribute to the loss of topsoil. In other bioregions, the main focus will reflect essentially the same relationships: namely, how the manifestations of the industrial culture, with its reliance upon toxic chemicals and more efficient technologies, impacts the local environment (p. 85).

Engaging science teachers and students in these kinds of place-centered science projects will begin to foster an understanding of how humans impact the natural environments. However, ecojustice education also must include the conceptualizations of Darwinian evolution and natural selection. While Bowers points to the effectiveness of these theories in the natural sciences, he does not go far enough to explain that Darwinian evolution, for example, does not always end with increased natural complexity. Genetic variations may arise that are devastating for the continued success of a species within a changing environment, and species have gone extinct as a result (e.g., the polar bear). Moreover, the ironies of Darwinian evolution and natural selection and its role in ecology must be well understood by prospective science teachers (i.e., evolutionary ecology).

The emerging explanations of geographical coevolution (e.g., interactions between birds and trees) within various ecosystems structured as "geographic mosaics" serves as an example that can be used to understand how the forces of natural selection are place-dependent (Pennisi, 2007). Interestingly, "ecologists have found that, in organisms from birds to bacteria, coevolution is not a sure thing": it depends greatly largely on the intensity of coevolution specific to place (p. 686). Pennisi (op. cit.) explains that John Thompson of the University of California, Santa Cruz, developed the theory of "geographic mosaics" to explain these geographic variations. *Geographic mosaics* theory posits that "the survival advantage provided by coevolution was inconsistent because environmental conditions, and hence the forces of natural selection, differ from place to place" (p. 686). Thompson predicted that if researchers looked at different populations of interacting species, "they should discover 'hot spots'—with intense interactions between partner species and rapid coevolutionary change—and 'cold spots'—areas where the two species have little influence on each other's evolutionary trajectories" (p. 686). Environmental factors and species migrations work together to either speed up or slow down coevolution, respectively. Some relationships are relatively easy: the Clark's nutcracker in north-central Nevada thrives with pine trees by eating some seeds, and hiding others in the ground, which become successful seedlings. Other relationships with the nutcracker are more difficult because of competitors, such as squirrels, so pine trees in the Rocky Mountains defend their seeds with long, heavy cones with thick scales and fewer seeds. At first, researchers were skeptical of Thompson's theory. However, over the last six years there have been an increasing number of warrants to support the idea. Pennisi (op. cit.) quotes Craig Benkman from the University of Wyoming in Laramie: "in retrospect, this idea seems self-evident, but at the time 'people generalized [what they found] from one location and extrapolated to everywhere else for that species'" (p. 686). She explains that 40 years ago, very few biologists appreciated the complexity of coevolution. Today, biologists are excited to discover how species within various geographic locations may have different adaptations.

There have been some very interesting developments for geographic mosaics (Pennisi, 2007). Third-party interferences are being observed, such as the squirrels mentioned above, which do little to propagate the Rocky Mountain pines (p. 687). In contrast, the nutcrackers are very good partners with the Rocky Mountain pines, "a single bird can carry off up to 98,000 seeds a season, sometimes as far as 22 kilometers" (p. 687). Interestingly, the presence of squirrels determines whether the geographic mosaics are hot spots or cold spots. When squirrels are absent, the birds prefer the easily accessible seeds and the pines that thrive are the ones with thinner scales and more seeds—a hot spot for coevolution. When squirrels are present, the pines retain their difficult-to-access cone shapes, resulting in more difficult interactions with the nutcrackers.

Moreover, three-way interactions can lead to the formation of new species (Pennisi, 2007). In Idaho forests, for example, the South Hill crossbill is a new species that has developed larger bills to access seeds in squirrel-populated locations. With break development, the crossbill's call has changed, lessening it's attraction to the same population in other geographic locations, resulting in genetic isolation and formation of a new species. Pennisi (op. cit.) also points out that a third species can impede coevolution. A good example is the correspondence between the toxins of the wild parsnip and the detoxifying capabilities of the parsnip webworm; these relationships differ depending on geographic location. In North America, the webworm quickly developed a relationship with the wild parsnip—both increasing the parsnip's toxicity and the webworm's ability to consume the plant. In North America, the wild parsnip is much more toxic than in Europe, where webworms have retreated to forage preferentially on other plants.

Pennisi (2007) refers to the justifications for geographic mosaics theory as *coevolutionary tales*—for example, the relationship occurring between garter snakes and toxic newts. At the University of Virginia, scientists have found "hot spots—where garter snakes are rapidly evolving resistance from snacking on newts—[and] cold spots, where the resistance to the newts has not evolved" (p. 687). These scientists now are looking at other predatory snakes to see if further evidence for geographic mosaics theory can be found. They are tracking the flow of genes into and out of geographic mosaics. Currently, the strongest evidence for geographic mosaics comes from the work of John Thompson and his colleagues who are monitoring how quickly bacteria evolve resistance to bacterial viruses, which in turn are able to evade resistance.

The ramifications of geographic mosaics may lead to better understandings of how to better protect local ecosystems borders from invasive species and how to make better predictions of species distributions and coevolutionary success (Pennisi, 2007). Pennisi (op. cit.) warns that the scientific evidence to date suggests that wildlife biologists and conservationists will need to be very careful about revitalizing ecosystems with particular species that have been extirpated for extensive periods of time. She explains that "conservation policies need to consider how species might differ genetically across space, and how the coevolutionary paths they travel might vary" (p. 687). The complexity, biodiversity, and ecological changes – as part of the geographic mosaics theory – are all very interesting to work with and will provide many new avenues for future works. This understanding will help teachers and students discuss why educational theory may or may not be extrapolated from scientific knowledges without significantly compromising the evolving nature of scientific theory.

Ecological philosophy, in general, must not deemphasize or ignore these kinds of developments in evolutionary and ecology science. Historically, ecological philosophy has attempted to generalize what was found in one place and make it so in many others. Yet arguing for what aspects of the local ecosystems should be legitimately conserved and sustained depends greatly on working with ecologists, evolutionists, and wildlife biologists (and others). In the next segment, I will discuss the increasing challenges and complexity facing environmentalists and conservationists, who consider (as the right thing to do) the reintroduction of native species back into places where they have been absent for long periods of time, which may have destructive effects for local ecosystems. Extending ecojustice philosophy and education, I will argue that evolutionary ecology better prepares science teachers and students to renew and revitalize the commons. Coevolutionary tales, which provide an understanding of local ecosystems, will help science teachers and students to contribute effectively to local ecological decisions. An integrated perspective of ecojustice education will strengthen its influence in science and science education, where the importance of thinking beyond what has been historically considered the boundaries of science is now consistently challenged. For my purposes, geographic mosaics and coevolutionary tales will help science teachers and students analyze the relationships between humans, flora and fauna within geographic locations.

How E.O. Wilson Might Respond to Bowers' Critiques

In chapter two, Bowers (2001, 2002, 2003, 2004b) was most critical of E.O. Wilson's perspectives that privilege Euro-Western assumptions linked with science. Bowers (op. cit.) argues that Wilson reduces all aspects of cultural life to the primacy of genes and privileges cultural assumptions extrapolated from Darwin's theory of evolution and natural selection to explain a wide range of human activities. As Bowers (op. cit.) notes, Wilson's philosophy can be considered a resource to study cultural root metaphors carried forward in science (e.g., scientism). Yet science, as one aspect of human thought, is expressed in many creative ways, and continues to prove indispensable for thinking and projecting the ways in which human activities are intimately linked with the changes and complexity of Earth's ecosystems. In this regard, E.O. Wilson's (2002, 2006) contributions are significant and will be used to extend ecojustice education for science education. Wilson's (op. cit.) philosophy can be used to discuss scientific principles and evidence underpinning current ecological declines and, ironically, how scientists think with both philosophy and science in mind. In this regard, Wilson's (op. cit.) philosophy-science writing serves as an impetus for the revitalization of the commons.

In *The Future of Life* (2002), Wilson helps science teachers and students to understand that,

> . . . biodiversity (short for biological diversity) is everywhere organized into three levels. At the top are the ecosystems, such as rainforests, coral reefs, and lakes. Next are the species, composed of the organisms in the ecosystems, from algae and swallowtail butterflies to moray eels and people. At the bottom are the variety of genes making up the heredity of individuals that compose each species (pp. 10-11).

Wilson notes that the equatorial rainforests of the Asian, African, and South American continents have the largest number of plants and animals species on Earth. Yet he points out that we do not have to visit these exotic places to find a "rainforest" of life forms living on the human body. Wilson (op. cit.) uses the term *bottleneck* to describe the environmental crisis we need to face, and get through, by aligning our short-term goals with the long-term future, and by embracing an environmental ethic to guide our species. He provides a description of the invasive species that humans brought with them as they migrated around the globe, which now constitute 50% of the species in places such as Hawaii. He lists various economically destructive invasive species (e.g., red imported fire ant, Asian subterranean termite, zebra mussel, purple loosestrife, balsam wooly adelgid). He notes reasons for amphibian declines, such as habitat destruction, atmospheric pollutants, pesticides and herbicides. Likewise, he notes that, today, only half of the original old-growth forests remain: gone are 60% of temperate hardwoods, 30% of conifer forests, 45% of tropical rainforests, and 70% of tropical dry forests. Wilson (op. cit.) paints a grim picture for many of Earth's inhabitants, which aligns with Bowers.

Wilson (2002, 2006) might argue that Bowers does not go far enough to explain how science provides an understanding of ecological declines. He might say that Bowers offers few scientific solutions to the environmental problems before us. Wilson (op. cit.) explains that the biosphere in terms of GNP might be valued at approximately thirty-three trillion U.S. dollars, if we replaced the services provided by natural capital (e.g., fisheries and forested watersheds that provide clean drinking water, bees that provide pollination service, etc). He points out that the more species that live together, the more productive and sustainable the Earth's ecosystems. When we drive biodiversity down, the ecosystems weaken. For the future of genetic engineering, more species means that more genes are available. Wilson (op. cit.) notes: "it is no exaggeration to say that the search for natural medicines is a race between science and extinction, and will become critically so as more forests fall and coral reefs bleach out and disintegrate" (p. 123).

On moral reasoning, Wilson (2002) might agree that it should play a central role in the ecojustice classroom, defined as "the vital glue of society, the means by which transactions are made and honored to ensure survival" (p. 151). He wants us to find common grounds for environmental conservation and economic progress. Wilson (op. cit.) notes "to lift a stabilized world population to a decent quality of life while salvaging and restoring the natural environment is a noble and attainable goal" (p. 157).

Wilson (2006) might argue that Bowers (2001, 2006) perpetuates the myth that people and places are interdependent (i.e., that the environment is dependent on humans). Bowers (op. cit.) emphasizes "moral reciprocity" (i.e., that the environment supports humans and so the environment must be supported by humans), which is misleading. Dispelling the myth, Wilson (op. cit.) describes how the loss of humankind would affect the natural systems:

> In two to three centuries, with humans gone, the ecosystems of the world would regenerate back to the rich state of near-equilibrium that existed ten thousand or so years ago, minus of course the many species that we have pushed into extinction (p. 33-34).

Turn that idea on its head and look at what humankind would do with the loss of insects, for instance, and soon the tragedy for humans becomes apparent. Without insects, flowering plants cease to reproduce, the majority of herbaceous plants go extinct, insect pollinated shrubs and trees linger for a few years, and go extinct.

Because Bowers (2001, 2006) does not discuss whether some species should not be conserved, it might be implied that he argues for the conservation of every species. Wilson (2006) contends that we should not become “conservation absolutists,” and he is comfortable with eradicating some insects (e.g., mosquitoes that transmit malignant malaria) and advises keeping their DNA for future study (p. 35). Moreover, while it may be wise to erase harmful organisms such as the invasive fire ant in the southern U.S., it would not be wise to do so in “southern Brazil and northern Argentina, where the ant is not imported but a native species, ecologically adjusted by millions of years of coevolution with other native species” (p. 36). Sorting out the advantages of geographic locations is the daunting challenge ahead of ecology scientists and others.

Finally, Wilson (2002) agrees that science teachers and students should help with the restoration of natural corridors (i.e., environmental commons). He argues that there is

> . . . a reasonable expectation that the study of biodiversity and concern for its welfare will be an increasing focus of education from kindergarten to twelfth

> grade and college, and beyond. What better way to teach science than to present it as a friend of life rather than an uncontrolled destructive force? (p. 188).

In short, Wilson's (op. cit.) ideas are complimentary to ecojustice education and provide a credible context for analyzing the double binds linked with scientific thinking.

The Ecological Crisis

What is *the* ecological crisis assumed by Chet Bowers (1993, 2001, 2006)? Breaking down the concept "ecological crisis"—*ecological* is derived from the word *ecology* or the study of the interactions (i.e., relationships) between organisms and their natural environments (Bowler, 1992; Wilson, 2002, 2006). However, *crisis* is more difficult to define, relatively ambiguous, with multiple meanings. A crisis depends upon particular situations and is context contingent. It is typically a turning point, a decisive moment, an incipient drastic change, or a "fork in the road." Locally, a crisis may be a moral dilemma, such as dumping chemicals into the creek versus paying for disposal. A crisis also may be induced by an emotionally charged event, such as a teen at the crossroads between obeying parents and the contradictory influences of friends. A crisis may result from too much to do over a limited amount of time, such as raising school district test scores within three years. Or a crisis may be connected to the beginnings of a paradigm shift, such as the Copernican Revolution. Moreover, a crisis may be deemphasized or ignored, such as when a teacher deemphasizes the teaching of evolution because it seems to conflict with personal values. A crisis may turn out well, such as when a fundraiser provides a kidney for a sick child. Or, it may turn out tragic, such as when the space shuttle lost a piece of material needed for safely reentering the Earth's atmosphere. The key point is that almost all crises depend on personal, social, cultural, historical, and environmental contingencies. And often, a crisis occurs when times are not as predictable as they were in the past.

Thus, crisis viewpoints are human constructed knowledge deeply influenced by personal and shared experiences, expectations, and fundamental beliefs and values. To have crises, there must be humans deeply embedded in situations to think it that way (Takacs, 2003; Thayer-Bacon, 2000, 2003). But, it might be said, that other-than-human-species can think of crises, for example, that a species of fish could experience a "crisis" related to an event such as a volcanic eruption. Because of the high uncertainty involved with interpreting the thought processes of nonhumans, we may not know if a species of fish is capable of thinking itself in "crisis" when confronted with threatening situations. The case can be made that because humans experience crisis when things become less predictable, that nonhumans experience similar phenomenon. But, there must be human interpreters to think it that way. When people think about crises, they think-in-place(s) and, consequently, most crises are position-dependent (e.g., many people do not view anthropogenic climate change as a crisis because it is not tangible enough in their lives). The meta-narrative of ecological crisis is no different—it is a *positioned* vantage point.

Because the ecological crisis is a positioned Earth viewpoint, the scale and significance of the ecological crisis is constrained to our limited human perspectives. Even with satellites and other scientific equipment that permit access to more data, the scale and significance must always be interpreted and often is accompanied with much uncertainty. For example, the scale and significance of Earth's abrupt climate changes are reported as highly uncertain in more recent scientific reports (International Panel on Climate Change, 2001; National Research Council, 2001, 2002, 2007). These documents stress the need for a better understanding of scientific uncertainty for policymakers and society in general.

In *The Open Space of Democracy* (2004), Terry Tempest Williams notes: "scale cannot be registered here in human terms. It is geologic, tectonic, and planetary" (p. 44). If people did not have very limited perspectives, there would be little need for multiple stakeholders with different perspectives to participate more fully in ecological decisions. My point is that the scale and significance of what is thought of as the "ecological crisis" (now described as a reality) can never be surmised in any certain way and is limited to what we now know. In other words, the notion of an ecological crisis is highly uncertain. Inasmuch as we think we know the Earth a certain way, we are in continuous momentum with the Earth, the ride of our lives around the sun at more than 18,000mph! The anticipation of the future, which is often highly uncertain, may evoke "crisis" thoughts, and yet crisis is a way of life. Dealing with crises is something we all learn to do.

Thus, it makes sense that Bowers (1993, 2001, 2006) warns that ecological decline is a major threat to cultural diversity and biodiversity everywhere—and yes, it always has been a threat. Bowers (op. cit.) emphasizes the collapse of fisheries, the pollution of oceans, the loss of erodable soils, and the loss of species and habitats. Moreover, he emphasizes the potential devastation to peoples' lives and livelihoods (e.g., food shortages and a lack of sufficient healthcare). These impacts are the consequences of too many people and a fixed supply of resources. For Bowers (op. cit.), the trouble lies with the root metaphors carried forward by the scientists and technocrats, the emancipation theorists, the corporations, and the hyper-consumerists. He equates these socio-cultural and environmental conditions with the metaphorical roots of the thinking that drives the deepening ecological crisis. However, Bowers (op. cit.) does not go far enough to explain that these same metaphors are taken-for-granted in the science he uses to support the ecological crisis position—assumptions that remain hidden, which make the ecological crisis an *ecojustice crisis*.

The EcoJustice Crisis

Bowers (1993, 2001, 2006) recommends that all education reforms be framed by the ecological crisis, which challenges the fundamental narratives of every cultural group. He wants philosophers and teachers to pay attention to the cultural roots of the ecological crisis that are implicitly passed forward as part of the school curriculum. On the ecojustice website (http://www.ecojusticeeducation.org), the ecological crisis is defined:

> The accelerating degradation occurring in natural systems that is undermining their ability to reproduce themselves at a sustainable level; caused in large part by human ignorance, greed, use of destructive technologies and economic practices, population pressures, and a lack of knowledge of how to live in sustainable ways.

These social, cultural and environmental factors all play a role in the accelerated devastation of Earth's wild ecosystems. Yet the human element is what makes all of the above a crisis situation. The "ecological" crisis is not so much ecological as it is human.

When linked with the Earth's wild ecosystems, the terms *crisis*, *tragedy,* and *catastrophe* are often used to cultivate environmentalism (Coyle, 2005; Sobel, 1996).

However, when considering the need for an adequate understanding of science, these phrases are too simple an explanation for why science teachers and students should engage in ecojustice activism. En route, ecojustice educators may bypass the brains of the science teacher and the student when crisis narratives are used to inspire changes, protection from enclosures, and the revitalization of the commons. Ecojustice educators may evoke feelings of anxiety, despair and hopelessness—not suitable for youth at any age, according to David Sobel (1996). Young people have enough problems to deal with, such as sexual and physical abuse, divorce, alcohol and drugs, peer pressure, bullying, gangs and street violence, to name a few. Sobel (op. cit.) explains that educators may perpetuate "ecophobia—a fear of ecological problems and the natural world. Fear of oil spills, rainforest destruction, whale hunting, acid rain, the ozone hole, and Lyme disease. Fear of just being outside" (p. 5). He argues that "what's important is that children have an opportunity to bond with the natural world, to learn to love it and feel comfortable in it, before being asked to heal it's wounds" (p. 10). And healing the Earth's wounds is the overarching goal of ecojustice activism for Bowers (2001, 2006). But, it might be argued, that children should be exposed to environmental perils to develop effective capabilities for dealing with them. Intuitively, these situations should be approached carefully.

Using the term "crisis" to stimulate ecojustice activism may be counterproductive for science teachers and students as they confront the accelerating ecological declines. Peter Corcoran (2004) warns: "the ecojustice crisis is particularly challenging to teach . . . because for so many teachers, and students, it induces despair and hopelessness" (p. 111). Likewise, Cornel West (2004) warns, "many [youth] lack the necessary navigational skills to cope with the challenges and crisis in life—disappointment, disease, and death.

This is why so many are enacting the nihilism of meaninglessness and hopelessness in their lives" (p. 176). My concern is that science teachers and students will uncritically accept the certainty that comes attached to the ecological crisis supposition, which reinforces contentment with learning scientific facts/concepts needed for the next exam and, consequently, not worry about knowing the people of the local community or the flora and fauna of the surrounding natural systems—taking an interest as stakeholders.

The problem with trying to prove scientifically the significance of the accelerating environmental declines is seldom recognized by science teachers and their students. But, it is conceivable, for example, that moving towards thinking that supports the belief that a more sustainable pattern of living and behavior is helpful to the individual, the community, and the Earth as a whole, is not dependent on the significance of declines. My point is that science teachers and students will take-for-granted that science can be used to prove what is significant and what is not significant. Likewise, environmentalists get caught in the trap of relying too heavily on the exclusive meta-narrative of reason and the high-status of science to justify their position statements (White, 2007a). Curtis White (op. cit.) notes: "quantitative reasoning has the unfortunate consequence of turning environmentalists into quislings, collaborators, and virtuous practitioners of a cost-benefit logic figured in songbirds" (p. 20). For ecojustice scholars, there is a real danger in relying too heavily on the legitimization of science as the highest form of knowing to support the crisis supposition. Accepting prima facie the assumption of ecological crisis undermines the meaningful purpose of analyzing the cultural views linked with science (Bowers, 2001, 2002, 2003, 2004b). That Bowers (op. cit.) relies on the meta-narrative of science to support the assumption of ecological crisis is ironic, when he also recognizes that previous unquestioned research led to eugenics and the sterilization and unearthing of Indigenous peoples, and now, genetic engineering and patents on natural organisms.

Ecological Crisis or Cultural Myth?

Without a careful analysis of the phrase "ecological crisis," science teachers and students are likely to trivialize anthropocentrism. An example is Peter Singer's term "speciesism," recently criticized by Nel Noddings (2003, 2006):

> To associate speciesism with racism, sexism, and classism is a powerful emotional move, but it may involve a category mistake. At least in principle, each of the big human "isms" applies to all the entities involved – all human beings. We usually think of racism in connection with the oppression of blacks by whites, but clearly, if power relations were reversed, the oppression of whites by blacks would still be racism. The same could be said of sexism and classism. Such a reversal is, however, meaningless with respect to species. All species give special consideration to their own, and we would not think of criticizing nonhuman animals for their preference, nor would it make sense to accuse them of speciesism. They are not capable of such discrimination (2003, pp. 134-135).

Noddings' point calls into question the anthropocentrism deeply embedded in phrases such as "ecological crisis" and "environmental racism"—the latter not wrestled with here. Although these phrases have previously served environmental scholars, they do not promote the careful study of the environmental sciences. Are the trees, hawks and soil really in "crisis?" If not carefully considered, the crisis supposition could be interpreted to mean that humanity's conservation choices are shared with the birds, insects, microorganisms and the soil—all complex components of the Earth's wild ecosystems. As noted by Wilson (2006) in this chapter, humans may not wish to save all life forms. He noted malaria-infested mosquitoes and invasive fire ants, and yet there are other pesky critters such as the protozoan *Plamodium falcipartum*, that causes malaria; and hookworms, and liver flukes, and organisms that cause river blindness, dengue fever, yellow fever, cholera, typhoid, leprosy, and tuberculosis. Perhaps not every species *should* be preserved!

I realize that the criticisms above could be applied to my use of the term "ecojustice." What is considered *justice* is also human constructed and positioned. For example, *social justice* focuses on how people are advantaged or disadvantaged and attempts to eliminate disparities that occur someplace(s) (Thayer-Bacon, 2000, 2003). Deciding which disparities to eliminate involves moral and ethical evaluation. Thus, *ecological justice* considers how Earth's wild ecosystems are advantaged or disadvantaged and attempts to eliminate disparities that occur someplace(s). Because rejecting unjust constructs is warranted, the case can be made that eliminating species and habitats in someplace(s) is entirely justified. Ecojustice is human preconceived when it comes to renewing and revitalizing the commons and runs the risk of privileging what is considered good for humans rather than for the overarching ecosystems. Because there is uncertainty between human sustainability and species conservation, I will uphold the tradition of using *ecojustice* to convey the constructed and positioned meanings of social and ecological justice for both humans and the Earth's wild ecosystems.

For the sake of argument, let's assume that environmental advocates do consider every species on Earth in decisions to revitalize the cultural and environmental commons. Would the other-than-human-species really have a "voice" in how these decisions are approached? For example, if eliminating a species someplace(s) means more outdoor experiences, and reduces consumerism, would it be appropriate to do so? Turn that idea upside down and we come back to Wilson (2006), who noted what might happen if there were no more humans for other species contend with: ecological bliss! Likewise, evolutionary ecology points out that conserving all components of the ecological world is not responsible stewardship from the other-than-human-vantage-point (Pennisi, 2007). The implicit danger of the crisis myth is that it carries the false assumption that science teachers and students can save every species and habitat. This point is evidenced by the fact that the universal assumption of *the* deepening ecological crisis is not dependent any particular place(s) in Bowers' (2001, 2006) works, because if it were, *the* ecological crisis would be compromised by nonhumans.

Obviously, the nonhuman species cannot talk to tell us what is on their minds. However, the Earth's natural history provides some clues. There are billions of years of significant geologic events in the exposed strata of rock formations around the world, showing fossilized evidence of previous global warming and cooling trends, rising and falling coastlines, volcanoes, earthquakes, tsunamis, hurricanes and meteorites that have been classified as natural phenomena. For example, Earth's climate changes have been effected by the changing shape of the ellipse of the Earth around the Sun, the tilt of the Earth that varies between 22° and 24° (dynamic seasonal changes), and the Earth's slow spin axis "wobble," which alters the timing of seasons. These natural changes intensify the unfamiliar terrain of more relevant changes occurring in the last several centuries (Pollack, 2003/2005, p. 52). Moreover, the science of climate change is influenced by plate tectonics (albeit, at the speed of fingernail growth), including the uplifting of mountains and constantly eroding topography of the planet. These natural processes both warm and cool the Earth, sometimes abruptly in the past, which led to movements in ancient civilizations (e.g., ancient Pueblo peoples). The assumption of ecological crisis may not be the best way to think about the Earth's natural processes and events. Life has, and will survive, no matter how insensitive humans are to the Earth. One of the best examples can be found in the world's undersea basements, where occur the highest mountains, the deepest valleys and the deadly toxic hydrothermal vents: the undersea volcanoes and thriving communities of life (Van Dover et al. 2002). On the Earth there are literally billions of organisms which do not rely on humans' needs for their survival (e.g., geothermic pools of Wyoming and Montana, rocks of the Mojave Desert, and icepacks of Antarctica and Greenland).

Interesting examples also can be found by looking to Earth's paleoecological records for evidence of earlier life forms -- fossil pollens, seeds, animal remains and charcoal. Analyzing paleoecological studies or "hindcasting" helps today's researchers think about the complexity of Earth's changes and the impacts of humans (Willis & Birks, 2006). What is thought to be natural and native is seldom straight-forward and depends on peoples' interpretations. For example, Willis and Birks (op. cit.) explain that "although it is not unreasonable to assume that an increase in aridity would result in more [forest] fires, several studies indicate otherwise. In the Alaska boreal forest, fires occurred more frequently under wetter climatic conditions" (p. 1263). They note similar conditions in the paleoecological record of wildland fires in the Northern Great Plains grasslands of North America and the tropical dry forests of the southern Ratanakiri Province in northeastern Cambodia. Essentially, modern conservation logic may be "clearly at odds with evidence from the paleoecological record" (Willis & Birks, 2006, p. 1263). The paleoecological evidence signifies that "low-intensity forest fires caused by humans may, in fact, conserve forest cover" (p. 1263). Willis and Birks (op. cit.) propose that the paleoecological record be used to provide insights to guide wildlife conservation.

Moreover, the thinking that accompanies the cultural myth of ecological crisis may not allow for ecological surprises! Christensen et al. (2006) explain that *ecological surprises* are expected where "a high degree of uncertainty exists in predicting the cumulative impacts of anthropogenic stressors on an ecosystem because stress-induced species tolerances result in antagonistic responses" (p. 2317). They point to several scientific studies showing that organisms and microorganisms can be surprisingly resilient and tolerant of Earth's changes and human activities. Currently, there is a significant lack of scientific investigations available to help understand the effects of multiple anthropogenic stressors on Earth's wild ecosystems. Future ecological studies will help scientists make better use of the currently unreliable "forecasts of the cumulative impacts of global change on biodiversity and related ecosystem processes" (Christensen et al., 2006, p. 2321). Christensen et al. (2006) also note that there will be many more unexpected ecological surprises in the years to come: some will be beneficial and others adverse, but all depend on the particular.

Not surprisingly, abrupt changes are now thought to have caused at least five previous mass extinctions and the emergence of many new life forms. Without this necessary evolutionary process, the dinosaurs may not have met their demise 65 million years ago, which subsequently allowed new species to survive and reproduce. The emergence and movements of species deserves philosophical consideration. Can the case be made that human beings are invasive species, for example? By today's science standards, an *invasive species* is identified as a non-indigenous species that expands beyond its native home range, which may be introduced by humans or by the variability of Earth's changes (Willis & Birks, 2006). With the reality of Earth's changes, we cannot know for certain which species will shift borders and, hereafter, every species could potentially be considered invasive if it moves in response to Earth's temperature changes. A double standard for humans that assumes that we all have unlimited access to Earth's vast topography has been privileged in response to Earth's previous climate changes. Ironically, the cultural myth of ecological crisis may disguise humans from being positioned as "invasive." There may be an explanation for why humans are favored for survival and reproduction, but if there is, Bowers (2001, 2006) does not offer it.

Thus, what is deemed okay for humans is not deemed to be okay for nonhuman species: humans are thought of as "special." Species movements in response to Earth's changes will require a different kind of thinking that helps to predict which species should receive special conservation effects and resources. This challenge will require nothing short of the plurality of ways that humans come to know and express themselves in science. The daunting task for ecologists and other environmental scientists is to understand the responsiveness of endemic species to Earth's changes and human activities (Schwartz et al., 2006). In previous geological times, Earth's natural events and processes were responsible for where forests, mountains, rivers and species would be located and relocated. Now that humankind has ferociously intervened, humans have an ethical responsibility to share some of the actions for setting things right, which involves making well-informed ecological decisions. Because these decisions will impact other humans, animals and plants in unexpected ways, many diverse perspectives are needed. But, it might be argued, that humans are entitled to equal ethical considerations and should not be obligated to do things differently than they were done for thousands of years. Previously, humans were expected to provide for the interests of their own species (i.e., to survive and reproduce). If alternate ethical considerations did not provide for the longer term potential of human survival, then why should they be conceived as appropriate today?

Although there is merit to the philosophical ideal that all species and habitats on the planet should be preserved and sustained, we live on a changing and complex Earth and do not expect to save every species and do not aim for such expectations. But, it might be argued, that aiming for such expectations is a legitimate goal for humankind. However, we cannot expect that things will stay the same when the Earth is in constant motion and the Earth's history indicates that things have changed significantly over time. If humans are considered equal members of the Earth's wild ecosystems, then humans are subject to the same expectations as other species. Ecojustice views humans as equal. Thus, for ecojustice, humans are not exempt from the possibility of extinction.

Nevertheless, I do not want to be misinterpreted as saying that cultural and environmental perils should not be addressed. The anthropogenic stressors to Earth's wild ecosystems must be taken seriously within science education (IPCC, 2001; NRC, 2001, 2002). Indeed, humankind has been scientifically linked with the recent rash of record-breaking hurricanes and cyclones, increasing ocean temperatures and changing ocean chemistry, glacial earthquakes and melting ice shelves, increasing lightning storms and wildfires, shifting seasons and invasive species, and loss of species and habitats. Instead, I am advocating that science teachers and students be prepared as careful thinkers so they will be empowered to effectively deal with the ecological world and be included as legitimate and effective decision-makers in their community. Science teachers and students might consider appropriate scientific questions as part of ecojustice education: What does the term abrupt climate change mean? How does geologically recent climate change compare with Earth's paleogeologic records? How will increased precipitation and clouds effect the changing climate? How will levels of freshwater change? Is the stratosphere and troposphere warming at the same rate as the Earth's surface? Moreover, science teachers and students might question whether the cultural myth of the ecological crisis favors who participates in ecological decision-making and who is excluded. They might ask: "who do we take the most interest in and who is marginalized by this selective attention?"

Marginalized by the Cultural Myth of Ecological Crisis

In the last segment, I connected with Brickhouse and Kittleson (2006) who noted that the positivistic form of science critiqued by Chet Bowers is a cultural myth today. While that may be true for people who understand the nature of science, the cultural residue of times past maintains that positivism is still alive and well in the public schools (e.g., the testing movement). The certainty associated with the cultural myth of ecological crisis may inadvertently perpetuate the idea that some people are less certain than others. Tackling the "ecological crisis" is equated with revitalizing the commons and there are tragic consequences for not doing it (Bowers, 2001, 2006). Ecojustice is limited in that there is a certain way to deal with the ecological crisis—the one that leads from *the* crisis. Certainty thinking goes against the evolutionary process—a plan which may not favor humans. I have already shown how the certainty implicit in the crisis myth negates Earth's story. Now, I will show how the crisis myth undermines other peoples' narratives.

Marginalizing Theists

In his famous essay "On the Historical Roots of Our Ecological Crisis" (1967), Lynn White notes the uncertain nature of tracing back the cultural roots of the "ecological crisis" and explains that humans have always had an impact on the natural environment, albeit some cultures in less exploitive ways than others. He positions most blame for the negative cultural views towards the environment on the "Judeo-Christian" doctrine of transcendentalism (i.e., Christ's ascension from Earth). Yet he notes exceptions such as Saint Francis of Assasi (1182-1228), who tried to establish the notion of humans-as-species—equal with the rest of the Creation. Saint Francis' doctrine was never fully established and White's (op. cit.) interpretation of "Judeo-Christianity" supposedly keeps humans epistemologically separate from the nonhuman world.

Correspondingly, Bowers (1996, 2006) argues that the roots of today's ecological crisis can be traced all the way back to the Creation and the old testament of the Bible. Although the Christian Bible has been interpreted by some theists to mean that humans have dominion over the Earth, not all Christians can be placed in this vast generalization. Cornel West (2004) explains that prophetic Christians have a moral obligation and responsibility to take care and respect the Earth, and other humans and other species. Peter Bowler (1992) notes "the Bible can also be interpreted as placing us in the position of stewards looking after God's creation – and the steward is not supposed to destroy the property entrusted to him [and her]" (p. 13). Bowler (op. cit.) explains that the "Medieval Europeans did not set out to destroy their environment, and the growth of industrial civilization has been accompanied by a lessening of interest in the Christian foundations of western culture" (p. 13). Linking the cultural origins of today's cultural myth of *ecological* crisis with the roots of Christianity is most likely guilt by association only. But, it might be argued, that the presumed ecological crisis was essentially anticipated by the early Hebrew roots of Christianity which set up an ideology of humans over nature. Perhaps, but the earliest mention of the word "ecology" is traced to the ancient Greeks, a time period that occurs thousands of years after the origins of Christianity.

In his book *Spell of the Sensuous* (1996), the phenomenologist and ecologist David Abram explains that it is unfair to position the human disregard for the needs of the *more-than-human-world* on the ancient Hebrews (i.e., Judaism). He argues that the term "Judeo-Christian" has been used recklessly by environmentalists. Abram (op. cit.) notes that "careful attention to the evidence suggests that ancient Hebraic religiosity was far more corporeal, and far more responsive to the sensuous earth than we commonly assume" (p. 240). He explains that the ancient Hebrews valued the ecocentric traditions of oral narratives, subjective spoken words and the breath/wind of speech/nature itself. Abram (op. cit.) notes that "*Elohim*, for instance, one of the most sacred names of God in the Hebrew Bible, could be shown to have the same numeric value as the Hebrew word for nature, *hateva*—evidence of the hidden unity of God with nature" (p. 246). Abram (op. cit.) notes that his account of the Hebrew origins of Christianity may "startle the various environmentalists today who charge that Hebraic religion expelled all divinity from the natural world" (p. 246).

Abram (1996) asserts that the ancient Greeks created a distance between humans and the more-than-human-world with the emergence of the Greek alphabet. He explains that when we *learn to spell*, the influence of the written or human world *casts a spell* on our own senses—how we view the natural world. He acknowledges the cultural myth of ecological crisis, but deemphasizes it, and in turn, provides us with the more encompassing challenge of learning to *speak* with the Earthly ecology. He elaborates:

> Although we may be oblivious to the gestural, somatic dimension of language, having repressed it in favor of strict dictionary definitions and the abstract precision of specialized terminologies, this dimension remains subtly operative in all our speaking and writing—if, that is, our words have any significance whatsoever. For meaning, as we have said, remains rooted in the sensory life of the body—it cannot be completely cut off from the soil of direct, perceptual experience without withering and dying (p. 80).

Abram (op. cit.) argues that "*all* phenomena are animate, actively soliciting the participation of our senses, or else withdrawing from our focus and repelling our involvement" (p. 81, emphasis in original). He explains that all human knowing and language are part of the essences that he calls the Earthly ecology.

As theists are part of the overarching project of ecojustice and environmentalism, scholars should not exclude them. E.O. Wilson (2006) notes:

> Meet on common ground. That might not be as difficult as it seems at first. When you think about it, our metaphysical differences have remarkably little effect on the conduct of our separate lives . . . . We would gladly serve on the same jury, fight the same wars, sanctify human life with the same intensity. And surely we also share a love of the Creation (pp. 167-168).

While many religious-minded folks are Heavenbound, the vast majority of people do not set out to intentionally harm the natural world because of their spiritual beliefs. Most spiritually minded people do not agree with exploiting the Earth's natural resources and their views can be respected while maintaining the integrity of an ecojustice agenda for science education. One of the implicit dangers of the presumed ecological crisis is that spiritualists may be written off because of their beliefs and values (cf. Bowers, 2006).

Marginalizing Women

As part of the definition of ecological crisis (http://www.ecojusticeeducation.org), Bowers explains that the accelerating degradation of the natural systems is caused in a large part by population pressures. In other words, Bowers (op. cit.) claims that the rapidly increasing population is partly responsible for the presumed "ecological crisis." The implicit assumption is that population reduction will slow down ecological degradation. Ecological degradation occurs in several ways, including cultural attitudes that degrade the Earth and human activities that lead to accelerated ecological declines.

Consequently, both cultural attitudes and activities towards reproduction may be viewed as problematic. Without careful analysis, this assumption may implicate those who do not take measures to control the reproduction of their bodies to curb population growth.

Reducing the birth rate is usually associated with the practice of limiting population growth, which is presumed to be a viable option for resolving overpopulation (Wilson, 2002, 2006). Abstinence, contraception, sterilization, abortion, and government mandates are some of the ways proposed. While population control is usually aimed at improving quality of life for a society, men are almost never the targets of birth control. Historically, women have been associated with the reproductive processes of society, such as birthing, child-rearing, and taking care of the home (Martin, 1985; Noddings, 2003, 2006; Thayer-Bacon, 2000, 2003). Unfortunately, the reproductive processes of society that prepare people for parenting are not afforded the same high-status as the school activities that prepare people for financial success. But, it might be argued, that financial means are necessary to provide for the needs of a family or reduce birth rates. While this point is valid, the emphasis is on the worker outside of the home and not on the worker inside of the home, which may be a man or woman. Ironically, when the blame for the "ecological crisis" is placed on population pressures, the reproductive processes of society are emphasized and implicated, which hides other relevant issues (e.g., consumerism, lack of mutual support systems, deemphasis of local knowledges).

If the reproductive processes of society are largely responsible for the presumed ecological crisis, then where are the discussions of the reproductive processes in Bowers' (2001, 2004a, 2006) ecojustice philosophy? The reproductive processes may not be deemed important enough to discuss, which begs the question of whether gender matters?

In other words, if the population pressures cause the degradation of the natural systems, which is part of the definition of "ecological crisis," then where are the justifications that controlling the processes linked with gender will reduce the presumed ecological crisis? Unfortunately, the issue of associating population pressures with the cultural myth of ecological crisis reinforces what Caroline Merchant (2001) describes as "The Death of Nature," which sanctioned the dominance and control of both women and nature.

For a long time now, men have assumed the rights to name the natural world and have historically used the terms linked with the female gender (Okin, 1979; Martin, 1985; Merchant, 2001; Thayer-Bacon, 2000, 2003; Warren, 2001). While it may seem at first glance to be an "ok" thing to be ideologically linked with the Earth, it has been oppressive for women as men took control of the natural world to dominate and exploit it (i.e., Aristotle and Francis Bacon's ideologies). Merchant (op. cit.) describes how Bacon (1561-1626) transformed the program of science advocating the control of nature using metaphors associated with the courtroom and witches, such as bondage, torture, and rape. She notes how these metaphors are inadvertently perpetuated today with the notions of the modern experimental method: "constraint of nature in the laboratory, dissection by hand and mind, and the penetration of hidden secrets—language still used today in praising a scientist's 'hard facts,' 'penetrating mind,' or the 'thrust of his argument'" (p. 279). Merchant (op. cit.) shows how the "new image of nature as a female to be controlled and dissected through experiment legitimated the exploitation of natural resources" (p. 280). She explains how Bacon's philosophy of science led to a new philosophy of mechanical world, which emphasizes order to mean "the predictable behavior of each part within a rationally determined system of laws" (p. 281). Thus, Merchant (op. cit.) argues that "rational control over nature, society, and the self was achieved by redefining reality itself through the new machine metaphor" (p. 281).

Mechanism, now assumed in our everyday, common sense of reality views nature, society, and the human body as mechanical parts that may need to be fixed. Merchant (2001) notes: "the 'technological fix' mends an ecological malfunction, new human beings replace the old to maintain the smooth functioning of industry and bureaucracy, and the interventionist medicine exchanges a fresh heart for worn-out, diseased one" (p. 281). Merchant (op. cit.) points out that mathematics is now used as the criterion for rationality and certainty, whereas nature has become the testing grounds to try out theory. Because nature is no longer conceived as an organic element, it can be manipulated, managed, and used according to what benefits human beings. Based on Merchant's work, the case can be made that the more recent ecological malfunction (i.e., ecological crisis) is perceived to be repairable by the rationality and certainty of mathematics and *man*kind. When the reproductive processes are implicated as part of the "ecological glitch," the mechanical assumption is that there is something wrong with the nature of the processes. The technological fix favors the mechanical measures to reduce the numbers of people living on the Earth. This fix is human prescribed. But, according to Merchant (op. cit.):

> External forces and stressors on a balanced ecosystem, whether natural or man made, can make some parts of the cycle act faster than the systems' own natural oscillations. Depending on the strength of the external disturbance, the metabolic and reproductive reaction rates of the slowest parts of the cycle, and the complexity of the system, it may or may not be able to absorb the stresses without collapsing. At various times in history, civilizations which have put too much

external stress on their environments caused long-term or irrevocable alterations (p. 284).

In other words, Merchant (op. cit.) does not attempt to undermine the Earth's natural narrative. She recognizes that the reproductive processes of society are equated with an organic theory of Earth, which identifies nature with the metaphor of a nurturing mother.

The Earth-in-crisis is a certainty way of thinking and the early scientists were provided almost exclusive opportunities to do work to resolve Earth's wild uncertainty. Because the Earth and women have been thought to be ideologically interchangeable, and because historically the male gender has been associated with rationality and certainty, the female gender and uncertainty thinking may be subjugated. More importantly, the male criterion may serve as the standard for how women enact scientific investigations.

Evelyn Fox Keller (1983) provides the story of Barbara McClintock, who emphasized subjectivity, imagination, and intuition as part of the process of science. Throughout McClintock's life, she struggled to be taken seriously by her colleagues, who based the criterion for good science on standards established by male scientists. Merchant (2001) notes: "the work of historians and philosophers of science notwithstanding, it is widely assumed by the scientific community that modern science is objective, value-free, and context-free knowledge of the external world" (p. 282). Essentially, people who are assumed to think with more generalized certainty are privileged over people who do not privilege decontextualized certainty in their approach to studying the natural world. Another example is the female ecologist Rachel Carson (1955/1983, 1962/1994), who did not privilege generalized and decontextualized certainty to do her work. Carson (op. cit.) did almost all of her scientific work *in* nature. Her works are grounded by the particular.

In contrast, the idea, that generalized and decontextualized certainty is privileged, is warranted by the public perception that the ailing mechanical world will be fixed by the certainties of modern science and technology. Many people have faith in science and technology for no other reasons than that the notions of "progress" and "growth" are assumed to be certainties. Ironically, certainty thinking is most definitely an impossible criterion for today's environmental scientists (IPCC, 2001; NRC, 2001, 2002, 2007). But, the evidence for the cultural residue of Earth-in-crisis-to-be-solved-by-certainty-thinkers can be clearly seen in the climate-change controversy in the United States. Today's International Panel on Climate Change (2001) wrestles with high uncertainty, and I will eventually point out how the uncertainty details are intentionally left out for policymakers (chapter four). The cultural narratives inspired by early scientists who used certainty thinking to garner funding both supports and influences governments, and continue to be privileged today. Interestingly, more women are now entering the environmental sciences and excel in ecological-oriented careers where thinking with uncertainty is highly valued (Coyle, 2005). The number of women going into fields (e.g., chemistry and physics) where thinking with generalized certainty is not as challenged is much lower.

Marginalizing the Impoverished and the Family

For wealthy people in the U.S. and abroad, it must be discomforting to know that the Earth's abrupt climate changes may force a return to the neighborhood commons (Bowers, 2001, 2004a, 2006; Grimm, 2006). Kurt Grimm (op. cit.) notes,

> In the affluent North, an infrastructure collapse linked to abrupt climate change would accompany and propel a return to locally based (i.e. bioregional) lifestyles. At the very least, this means a shift to living with larger uncertainties and risk than before, and adapting by becoming more interdependent with our neighbours, while becoming more skillful and resourceful in meeting our daily needs. In poorer regions and countries, these immediate impacts may be less profound because these societies are generally less dependent upon infrastructures (p. 79).

If Bowers (2001, 2004a, 2006) and other environmentalist scholars are right about revitalizing the commons, then perhaps notions of the ecological crisis will encourage affluent people to engage in a less consumer-oriented lifestyle, which involves *sharing*. For the impoverished, however, I'm concerned that ecojustice scholars are saying: "just keep doing what you're doing; the rich are on the way to meet you at the bottom!"

The problem is that reducing consumer dependence applies more for people who have money to spend than for people who do not have the means to engage in hyper-consumer-dependent lifestyles. As a person who grew up in a poor family, my experience is that the poor spend their money on the things that are needed to support basic needs. But, it might be argued, that ecojustice is centered on reducing market reliance for both the affluent and the impoverished. My point is that people with very little, spend the least at the market. Reducing consumer-dependence across the board is implausible because people with not enough are not capable of limiting their spending to support basic needs. I am not arguing that reducing market-reliance for all should not be the goal. Instead, it is more probable that consumerism will be reduced by starting with people who are capable.

Rolf Jucker (2004), for example, explains that people living in developing countries do not have the "difficult task of kicking the overconsumption habit" (p. 19). He argues that the rich elites and people living in the Euro-Western world need to lower their standards of living so that the world's people can share the natural resources of the Earth. For Jucker (op. cit.), the ecological crisis does not apply to the poor in the same way that it applies to the more affluent. However, when this same logic is applied to Euro-Western countries such as the U.S. (i.e., where many people are living in poverty), it becomes more difficult to decipher where the "ecojustice poverty line" exists. What about the "American Dream?"—live and let live? Will people who are already more reliant on others and the Earth want to maintain their lifestyles if more can be accessed? Unfortunately, this situation presents one of the greatest dangers of the certainty thinking of the ecological crisis myth. The resolution is not simple and may require more cultural mysticism that does not deem material things as status symbols. As the philosopher, Reg Morrison (1999) notes: "we might smooth out the gross disparity in wealth and food distribution, and thereby share what we have a good deal more equitably. And pigs might fly" (p. 46). Adversely, others may inevitably argue that sharing is irrational and naïve.

Another ecological philosopher, Vandana Shiva (1997, 2001, 2005) contends that previous scholars have used the ecological crisis supposition to criticize people living in the poorest nations for putting a strain on the world's natural resources. She argues that this criticism is oppressive for the poor, women, children and the Earth. She explains that poverty has been traditionally viewed through ethnocentric standards of living, which makes it seem as if anyone not living the "American Dream" is not living a decent life. She explains: "we need to move away from these restrictive and biased perceptions to grapple with poverty in terms of threats to a safe and healthy life either due to denial of access to food, water and shelter, or due to lack of protection from hazards in the form of toxic and nuclear threats" (2001, p. 293). For Shiva (op. cit.), poverty is "a denial of vital human needs" (p. 294). She explains that the view that the people living in the poorest nations are overpopulating the Earth and putting an unnecessary burden on the world's resources is unfair and takes the emphasis away from affluent peoples. She notes the "fact that the greatest pressure on the earth's resources is not from large numbers of poor people but from a small number of the world's ever-consuming elite" (p. 300). The focus on population takes away from acknowledging that people living in the poorest nations have unequal access to the Earth's resources and have a smaller ecological footprint.

Moreover, Shiva (2001) notes how "environmentalism is increasingly used in the rhetoric of manager-technocrats, who see the ecological crisis as an opportunity for new investments and profits" (pp. 300-301). She explains the World Bank's Tropical Action Plan, the Climate Convention and the Montreal Protocol are now being used to legitimize the displacement and disenfranchisement of the poor to save the Earth's forests, air, water and soil for the wealthy. Shiva (op. cit.) notes that the impoverished are now seen as "villains in these ecological plans—and women, who have struggled most to protect their children in the face of ecological threats, become the elements who have to be policed to protect the planet" (p. 301). She proposes that the affluent must share what they have.

Marginalizing "Non-Scientific" Perspectives

At many universities and corporations, the natural sciences employ many highly paid scientists who receive financial support for scientific research. Other disciplines, in contrast, such as schools of teacher education and public K-12 schools, lack the financial support that occurs in the natural sciences. Ironically, the field of education is increasingly more relevant to countering the inherent tensions of the commons. Now, most NSF-funded grants require the collaboration of science and education (NRC, 2003). The environmental sciences and education are beginning to see the benefits of working together, particularly as the global stakes change (Brewer & Gross, 2003; NRC, 2003). Education provides a way for environmental findings to reach the largest audience, which in turn, impacts the ability of people to effectively work with scientists to make decisions.

Unfortunately, there are significant incentives for aligning scientific research programs with whatever is deemed worthy by private and government funding agencies. Addressing this issue in the 2001 IPCC report on climate change, the NRC (2001) warns:

> It is critical that the IPCC process remains truly representative of the scientific community. The committee's concerns focus primarily on whether the process is likely to become less representative in the future because of the growing voluntary time commitment required to participate as a lead or coordinating author and the potential that the scientific process will be viewed as being too heavily influenced by governments which have specific postures with regard to treaties, emission controls, and other policy instruments. The United States

> should promote actions that improve the IPCC process while also ensuring that its strengths are maintained (p. 5).

Considering the political and corporate influences that scientists must contend with, the crisis supposition may be oppressive for researchers who do not follow certain methods. Research approaches such as those embodied by traditional ecological wisdom may be dismissed as pre-scientific myths, astrology, witchcraft, quackery and the occult.

Diverse perspectives of multiple stakeholders have been called for in recent ecology reforms (Brewer & Gross, 2003; Clark, 2003). However, the government and private funding agencies may be slow to realize the benefits of such diverse perspectives (NSF, 2003). A problem with thinking crisis is that it favors scientists over science teachers, parents, children and other community members in ecological decision-making. An implicit danger of the certainty thinking reinforced by the myth of ecological crisis is that people who are impacted in the most ways will be the least likely to be consulted. This limitation does not allow for the full effective range of science teachers and their students. Science teachers and students may be viewed as “pretend scientists” or “scientist helpers,” which is demeaning and asks too little when they are community stakeholders. Aslaksen and Myhr (2007) remind us of the seriousness of the societal infrastructure that promotes “scientist as the expert” is when the potential consequences of genetically modified organisms (GMOs) are considered. Who is favored to decide “what counts” as genetically beautiful, strong, or otherwise naturally selected? It might be argued that in our agricultural and industrial society, GMOs provide more profits for farmers and more success when grown in gardens, which means we select these choices.

Capitalist structured societies are prone to inevitable supports. My point is that the crisis positions certain people and science methods over others to tackle environmental issues.

TEKs may be undervalued to do scientific work. Most Indigenous cultures emphasize living well with the land, and yet living well with the land may be considered an out-of-reach proposal for dealing with the urgency implicit in the crisis supposition. The urgency projected by the cultural myth of ecological crisis may favor any scientific perspective that hastens the certainty of progress and growth. Thus, integrating Indigenous ways of knowing and living well with the natural environment may be perceived at odds with more "advanced" methods (NSF, 2003). Moreover, the urgency of ecological declines may legitimize the need to patent the flora and fauna of the natural world (and TEKs) before they are lost. It may seem perfectly acceptable to disenfranchise cultural groups of their TEKs, especially when the chemical compositions of plants can be put together in the scientific lab once the knowledge has been obtained, by means illegitimate or legal.

The acts of patenting flora and fauna are defined as *biopiracy* by Vandana Shiva (1997). She describes how patents enclose the life spaces of women, ancient peoples, plants and animals through private intellectual property rights. She questions the legitimacy of a science community that deemphasizes or ignores the contributions of Indigenous peoples. She maintains that TEKs are legitimate scientific knowledge, evidenced by the fact that TEKs are now being patented. Shiva (op. cit.) explains that patents for "new" life forms have been justified based on the circular argument that scientific corporations are the constructors of nature, so it must be their property.

Ironically, the same corporations turn around and claim that the GMO *is* nature, which enables GM products to be placed on the shelves of supermarkets.

According to Shiva (1997), the patenting of nature and traditional ecological wisdom elicits two forms of violence: (a) "life forms are treated as if they are mere machines, thus denying their self-organizing capacity" and, (b) "by allowing the patenting of future generations of plants and animals, the self-reproducing capacity of living organisms is denied" (p. 23). In the process of genetically modifying flora and fauna, life is essentially colonized. But, it might be argued, that "natural biopiracy" (e.g., mitochondria in human cells pirated from bacteria, and photosynthetic bacteria, put into servitude as chloroplasts by plants) is the Earth's evolutionary process eclipsed by ethics. Indeed, the point is that ethics narratives may undermine the Earth's narrative, and Shiva (op. cit.) explains that the biopiracy associated with the ethics of genetic engineering, for example, where the impetus of the cultural myth of ecological crisis may legitimize the knowledges of scientists who work on GMOs over more informed TEKs, is unethical. Thus, she is claiming that TEKs are more aligned with the Earth's evolutionary process.

I have shown there are dangers associated with the cultural myth of ecological crisis that marginalize particular people's experiences, beliefs and values, and narratives. In the next chapter, I will show how the early naturalists wrestled diligently with wanting to think with absolute certainty while encountering the ecologically unknown world. Modern day positivists may continue to wrestle with absolute and decontextualized certainty to obtain funding and influence policymakers. Because of my limitations, some important perspectives are missed, and I hope other scholars will continue to break down the ecological crisis further to even the stakes. Educators might rethink using the phrase "ecological crisis." Perhaps *ecological uncertainty* will supplant or some form thereof that better represents human-nature. Preparing science teachers and students to become comfortable with ecological uncertainty now points to the need for a theory in ecojustice and science education that acknowledges the high value of multiple perspectives, beliefs and values, and personal expectations and experiences. I now work to develop a theory of uncertainty thinking for ecojustice and science education without taking forward the meta-narrative of ecological crisis. Uncertainty thinking is a natural fit for ecojustice and science education because of the many ways that it is place-situated and contextualized.

Summary

The meaningful purpose and aim of ecojustice is to strengthen and renew the commons. Scholars such as Prakash (1995), Gruenewald (2003a, 2003b), McLaren and Houston (2004), and Brickhouse and Kittleson (2006), outline concerns that hopefully have been alleviated. In turn, I raised concerns with the certainty assumptions of TEKs, science, and the Earth-in-crisis. Moreover, I noted that ecojustice education will be enacted differently depending on the community, intergenerational knowledges and skills, narratives, the arts, and the bioregion (the goal of revitalizing the commons remains the same). Yet I followed Brickhouse and Kittleson (op. cit.) to discuss the essential role of science in ecojustice education, and the importance of competencies (in the sense of an understanding, not necessarily aligned with the priority of test taking) of topics such as Darwinian evolution and natural selection, Earth's wild ecosystems, and the causes and consequences of biodiversity. Thereafter, I extended Bowers' (2001,

2006) ecojustice education by discussing how aspects of evolutionary ecology (e.g., geographic mosaics and coevolutionary tales) can inform ecological philosophy. Likewise, I used several of Wilson's (2002, 2006) works to show that he too is interested in working to revitalize the environmental commons. Wilson's (op. cit.) inclusion of science teachers and students will be further discussed in chapter four.

The ecological crisis has been taken-for-granted in many environmental works, and so this ideal is not just a problem for ecojustice scholars, but for the vast majority of environmentalists. I hope that my analysis of the cultural myth of ecological crisis started to break down several harmful assumptions, which may marginalize people and methods. These assumptions may privilege thinking with certainty, who gets to participate, and which views are taken seriously, to reduce humankind's devastating impacts. Moreover, I am not convinced that the phrase "ecological crisis" has external coherence beyond environmentalists, particularly in the ecology science community. My expectation is that in troubling the ideas associated with the cultural myth of ecological crisis, there will be fewer concerns with ecojustice education in science education, and perhaps a better understanding of ecological work, which is highly uncertain. In the next chapter, I will argue that uncertainty thinking is a much better fit for ecojustice and science education. Moreover, I will discuss how thinking with uncertainty in mind will help science teachers and students evaluate ecological vulnerability, projections and scenarios, and work with multiple stakeholders to conserve cultural pluralism and sustain the Earth's ecosystems.

Chapter 4: Thinking with Uncertainty in Mind

My intention, in chapter three, was to provide some groundwork for ecojustice, and to begin breaking down the certainty myths of Earth-in-crisis, science and scientists, and traditional ecological knowledges. In particular, the cultural myth of ecological crisis may inadvertently perpetuate thinking with generalized and decontextualized certainty. It may privilege people who are assumed to think with more certainty than others, which privilege whose views are taken seriously and who gets to participate in local decisions. The myth of ecological crisis also may privilege certain methodologies and criteria, especially those methods and criteria upheld by people within the scientific community. Ironically, the "ecological crisis" has little relevance outside of ecological philosophy, and is seldom, if ever, mentioned in the scholarly publications of ecological scientists. It simply does not pertain to whether humans should renew and revitalize the commons, which I will further support throughout this chapter. Ecologically influenced perspectives in philosophy and science are accompanied by change, complexity, and high uncertainty. A better understanding of these conditions in ecological philosophy and science will alleviate concerns with people- and places-, or ecojustice-centered science education. Now, I will discuss how thinking with uncertainty in mind will help science teachers and students evaluate ecological vulnerability, projections and scenarios, and work with multiple stakeholders to conserve cultural pluralism and sustain the Earth's ecosystems.

My work is not focused on developing a framework for how environmental scientists think with uncertainty, nor do I work to develop a theory of certainty thinking. *On Certainty* (1969/1975) by Ludwig Wittgenstein, for example, provides an anti-foundationalist argument that claims all knowledge is subject to skepticism and doubt. Anti-foundationalism is when philosophers reject any form of fundamental belief or principle (i.e., metaphysical Truth), which is the foundation of inquiry and knowledge. Enlightenment epistemology, stemming from Rene Descartes (1596-1650), strives for knowledge with absolute certainty that is immune from sources of skepticism and doubt. Wittgenstein's (op. cit.) work shows that certainty propositions are the common grounds that function to provide an agreed upon context for empirical investigations of the world. He argues that some things must be taken for granted in order to communicate and make sense of the world, for example, "*here is one hand*," which provides contextual certainty (p. 7, emphasis in original). For Wittgenstein (op. cit.), the proof of certainty relies on whatever taken-for-granted propositions are adopted, which are always subject to doubt.

Where I differ from Wittgenstein (1969/1975) is that I argue that some human knowledges-experiences of Earth's ecosystems are not subject to skepticism and doubt. More similar to Charles Sanders Peirce (1958), I argue that we cannot separate thoughts from experiences, which provide some necessary foundations for making decisions to act. For example, almost all traditional ecological knowledges are reflective of thousands of years of intergenerational experiences of living well within the limits of local ecosystems. Experiences with Earth's changing, complex, and uncertain ecosystems are dependent on places, and the particularities of places are essential for life on the Earth as we know it. My work is focused on developing an educational framework for ecojustice and science education that acknowledges the high uncertainty valued in the environmental sciences. My expectation is that a theory of uncertainty thinking will help science teachers and students effectively evaluate ecological risks, projections and scenarios, and work with multiple stakeholders to conserve cultural diversity and the biodiversity of the Earth. My position is that uncertainty thinking allows people in places in relation to others to define what it means to renew and revitalize the commons and whether it is right to do so. In other words, I am arguing for a place-centered and contextualized part certainty in inherently uncertain and relational places, inspired by Barbara Thayer-Bacon's (2003) qualified relativism (i.e., relational epistemologies), which is grounded in the classical American pragmatist theory of John Dewey—something I call "ecological pragmatism."

Today's presumed "ecological crisis" meta-narrative (i.e., story told to justify another story—the Earth's natural narrative) was anticipated long ago. It began with the need to be certain in the face of the unknown. The drive to think certainty is in our genes, says Reg Morrison (1999): it is a matter of species reproduction and the laws of nature—an ecological tale more than 2.5 million years in the making. Other scholars, such as David Abram (1996), Jonathan Barnes (1982), Peter Bowler (1992), and Barbara Thayer-Bacon (2000, 2003) claim that the superiority of reason and absolute certainty are part of a meta-narrative that can be traced from the ancient Greeks, to the early naturalists, to the mid-19th century positivists. Richard Feynman (1998) argues that science has always been uncertain knowledge, and correspondingly, Henry Pollack (2003/2005) argues that learning to work with high uncertainty is essential to the environmental sciences.

Here, I should clarify that the term "certainty" differs from the term "rationality" in that someone can be certain in notions that may not seem rational (e.g., spiritual faith). I use the term "certainty thinking" to refer to cultural narratives or meta-narratives that are adopted to think of the Earth in generalized and decontextualized, universalized ways. For example, many environmental scientists concede that the Earth's climate is warming

(IPCC, 2001). However, the presumptiveness that is associated with the statement that the Earth is in “crisis” is a generalized and decontextualized belief of applied certainty. Thus, certainty can take the form of imposing particular ways of knowing on the natural environment (e.g., categorizing species), which may justify particular cultural attitudes and behaviors, as if they were universals. Certainty may take the form of root metaphors (e.g., anthropocentrism, individualism, patriarchy, scientism…), which are reinforced by the residue of cultural memories. Thinking with certainty in mind may inadvertently perpetuate the idea that Earth is stable, fixed, limitless, unchanging and noncomplex. And yet, the Earth is constantly evolving in highly uncertain and irreducibly complex ways, which cannot be reduced to certainty. Certainty applies to beliefs, and because no two people share the *exact* same thoughts and experiences, fundamental beliefs and values are limited, fallible and corrigible. However, I am not arguing for *incommensurability*, or the perspective that no two or more people can agree to come to terms on common grounds.

My claim is that people are partly certain in places in relation to the whole Earth, which refers to thinking with uncertainty that is contextual, intersubjective and relational. This epistemological perspective of part certainty is developed by Thayer-Bacon (2003):

> Given that the universe is unfinished and pluralistic, rather than evolving to one necessary conclusion, then we can only hope for temporary alliances and agreements, and truths that satisfy our corrigible standards. This is quite all right, for in the disagreements and disharmony come the stimulation of more awareness and growth, and the chances of improving our understanding of our own unquestioned background assumptions as well as expanding our selected interests. Inclusion of others’ perspectives in our conversations allows us the

means for adjusting for our own limitations, correcting our standards and improving the warrants for our assertions, and recognizing the role of power and privilege in epistemological theories (p. 71).

Beyond Thayer-Bacon (2003), my theory of uncertainty thinking is grounded by scholars such as E.O. Wilson (2006), Wolff-Michael Roth and Angela Calabrese Barton (2004), Richard Feynman (1998), and Henry Pollack (2003/2005). These theorists argue for the ideology of a citizen-centered science. *Citizen-science* is essentially an argument for scientific literacy, which typically refers to empowering people to use science to make choices in their everyday lives (National Research Council [NRC], 1996). My theory is that uncertainty thinking repositions (i.e., *re*places) science teachers and students as legitimate members of the scientific community, who should share some of the responsibility for becoming informed and effectively participating as stakeholders (i.e., people who share particular interests or advocate for affected others, including humans, nonhumans, and the Earth's natural systems).

My use of the term *uncertainty thinking* is inspired by Carol Brewer and Louis Gross (2003), who provide a conversation on the importance of multiple stakeholders in the ecological decision-making of local communities, and the collaboration of ecologists and educators. These scholars argue that as ecologists and policymakers work together, they have discovered the benefits of including multiple perspectives and criteria to evaluate ecological vulnerabilities, scenarios, and projections with highly uncertain outcomes. Further, my definition of uncertainty thinking is aligned with post-normal science (Ravetz and Funtowicz, 1999) and current ecological theory (Aslaksen and Myhr, 2007), which notes the importance of subjecting ecological work to the extended peer review community consisting of many diverse stakeholders and advocates with differing place-centered knowledges, beliefs and values, personal expectations and testimonies.

To substantiate my theory of uncertainty thinking for ecojustice and science education, I will develop four connected arguments A-B-C-D. Argument A is based on the ecojustice principle to reduce thinking patterns that contribute to ecological declines. Reducing thinking patterns and behaviors that negatively impact Earth's ecosystems is a significant goal. But, it is naïve to think that such conditions will be eliminated entirely. In the pragmatist and postmodern traditions, I will provide snapshots of historical context to show that humans developed generalized and decontextualized certainty thinking to reduce the Earth's uncertainties, to survive and reproduce (even at the expense of others). While I argue that all human narratives and meta-narratives of the world have commensurate environmental costs, meta-narratives of certainty disguise Earth's history.

Argument B shows that meta-narratives of the environmental sciences, which underpin an understanding of ecological declines, now recognize the high value of thinking with uncertainty in mind. Uncertainty thinking is most aligned with post-normal science, which is subject to the extended peer review community. As part of the extended peer review, teachers and students are stakeholders in the local community and ecosystems. Argument C posits that teachers and students are also citizen-scientists, who must become informed to share some of the responsibility for participating more fully in local decisions, to democratize science. Finally, argument D analyzes a theory of uncertainty thinking in environmental science, which is then used to argue that uncertainty thinking is democratizing place-centered science, which involves situated, relational thinking and ethical, political, and social evaluations. These arguments all work to establish a theoretical framework of place-centeredness in science education for ecojustice.

Argument A: Meta-narratives of Certainty Disguise Earth's Natural History

The philosopher Reg Morrison (1999), author of *The Spirit in the Gene: Humanities Proud Illusion and the Laws of Nature*, notes that the origins of rationality can be traced from *Homo habilis* (i.e., "handy man") to the emergence of agriculture-based settlements, when the need to be more certain emerged as a way to ensure human survival and reproduction. Keeping cattle and farming food helped humans to become the most populated species of mammals on the Earth—only second to the cattle now kept for food. Morrison (op. cit.) argues that humans have now entered "plague status" or severe overpopulation and are headed towards anticipated population collapse by mid-21st century. He explains that humans have, up to this point, followed all the characteristics of species that are on the verge of collapse and that our science and technology can do little to bail us out of this predicament. He argues that humans use cultural mysticism (i.e., meta-narratives) to disguise the Earth's natural evolutionary process and as a way to ensure genetic survival. In other words, Morrison (op. cit.) claims that humans will think of Earth in certainty to protect the genetic imperative to reproduce.

Morrison (1999) builds his case by pointing out how humans and chimps are 99.6% similar, and yet minor differences such as the Broca's and Wernicke's areas in the human brain have allowed for specialized language development. Recent environmental declines can be attributed to our DNA or genetic wiring differences: the ability to spread out, to develop culture and language, and to rationalize the Earth. The problem is that humans tax the natural systems much more than other species do, on a per capita basis, and we view consumerism as acceptable and admirable. We devastate biodiversity and, consequently, strengthen the numbers of pathogenic species that prey upon other species and us. We rationalize humankind's devastating impacts: land degradation, exhausted soils, intensive erosion, dryland salinization, overzealous land clearing, overfertilization, transgenically altered crops, declining fisheries harvests, destruction of freshwater and oceanic habitats by aquaculture, freshwater shortages, highly toxic pollutants, ozone destruction and acidic rain. We legitimize this destruction with the culture myths of "growth" and "progress" and, consequently, the worst may be yet to come from the rapidly thawing tundra, which releases methane, a potent greenhouse gas having the potential to dramatically increase the Earth's temperature in just a few decades.

With increasing rates of population growth and a lack of sufficient food, the abundance of methane in the atmosphere may reach levels that would inevitably result in abrupt population collapse. There may be very little that humans can do to counter Earth's natural stabilization process, evidenced by five mass extinctions in the last 600 million years. Even seemingly "environmentally friendly" practices such as biotechnology and aquaculture have implicit impacts. More than a billion people are without sufficient food to eat because of the protein-rich diets of Euro-Westerners: "we currently feed between a quarter and a half of our annual grain harvest to livestock, even though it would be far more energy-efficient to eat the vegetable biomass ourselves" (Morrison, 1999, p. 44). Likewise, two-thirds of the world's freshwater supply is already being depleted for agriculture. By the year 2025, 70% of the Earth's freshwater will be required by the increasing human population. Morrison (op. cit.) notes that "even when humans are reduced to eating nothing but white rice, mere subsistence costs about 2 metric tons (almost 530 U.S. gallons) of water a day per adult" (p. 46). His key point is that there is no scientific or technological solution to our ecological problems; every illusionary solution exacts a commensurate environmental fee. Morrison (op. cit.) notes that the impact of humans on the natural systems is based on three criteria: "the size of the population, its per capita level of activity, and the level of technology it employs" (p. 52). He warns that any amount of population growth with unchanged levels of activity and technology will result in devastating consequences.

Morrison (1999) argues, "the remedy for such imbalance is as simple and effective as it is inevitable: the [human] plague brings about its own collapse, the biota rebuilds itself, and life goes on" (p. 129). Although his thesis may shock the senses, the scientific evidence he uses to warrant his claim is coherent. The distinguished biologist Lynn Margulis notes in the forward of Morrison's (op. cit.) book that his work may be met with some initial resistance, and yet his work "cannot even be deeply criticized without well-developed counterevidence" (p. viii). Margulis' (Margulis & Sagan, 1995) symbiosis work strengthens Morrison's (op. cit.) arguments, and he follows James Lovelock's (1979/1987) Gaia Theory closely, which helps him to claim that humans are not exempt from the Earth's natural evolutionary process that dictates self-destruction for other plague-prone mammals (e.g., lemmings, mice, rats, prairie dogs).

While Morrison (1999) emphasizes genetics, he should not be misinterpreted as suggesting that genes work independently of cultural feedback. He explains the interplay: "our final decisions still represent the inevitable reactions of our particular genetic makeup to the peculiar patterns of perceived information investing us at the time" (p. 173). He further notes that every scrap of pollution we generate and add to the Earth's biosphere is the byproduct of our pursuit to send forth our genes—all species produce wastes. Humans, however, have the ability to "habitually attach some degree of mystical significance to anything that has a bearing on the survival of our genes, now or in the future, and this extends to the very edge of our perceptions and the limits of rationality" (p. 184). A million years ago, too much culture would have been detrimental for humans who needed to rely on their instincts (i.e., genetically informed) to survive Earth's many uncertainties. Today, cultural mysticism succeeds because it allows humans to bend the rules of the evolutionary process—however, "all species must fail eventually, especially the very successful ones, or the whole system would grind to a halt" (p. 191). It is cultural mysticism that humans now attach to everything, which serves as the X-factor for Morrison (op. cit.) to conclude that "Gaia is running like a Swiss watch"—in other words, extraordinarily well.

The notion that we will continue to populate the Earth at existing levels and make it unscathed requires a great deal of spiritual faith or cultural meta-narratives. Unfortunately, our species is not exempt from the Gaia mechanism that has effectively dealt with many species plagues during the course of Earth's four billion year natural history. It takes a great deal of faith in the human spirit, science and technology to think it any differently. Morrison (1999) notes:

> . . . technology merely lures us deeper into the environmental trap. Meanwhile our myth-based technoculture keeps us thoroughly bedazzled, entertained, and unable to comprehend the magnitude of our blunder until all the exits are blocked

> and the consequences are unavoidable. The denouement of our 2-million-year play will not dawn on us until very late, however. We will have to wait until climatic disorder, rising sea level, rampant famine, social disintegration, and a growing list of pandemics finally bring the human plague to a halt for the full gravity of our predicament to sink in. Nevertheless the truth is creeping up on us even now in a million microscopic forms (p. 250).

Beyond the fact that humans are now spreading diseases more efficiently around the world (e.g., jetliners, cars, rail…), we are now contributing to the Earth's climate change. The massive reserves of methane that will be released if the Earth continues to warm may not be taken seriously. The cultural ability to think of the Earth in certainty is what may eventually lead to the anticipated human population collapse. Certainty goes against the evolutionary process of incremental change, irreducible complexity and high uncertainty.

Discussed in chapter three, Jared Diamond's (2005) work resonates with Morrison's (1999) thesis and provides examples of why ancient civilizations collapsed. Civilizations collapsed because they privileged particular ways of knowing, the cultural narratives that led to their ultimate demise. Unfortunately, the scientific evidence that supports Morrison's (op. cit.) work makes for a scary situation in which the "right" thing to do might be to continue what we're doing to Earth. While it might be argued that Morrison (op. cit.) argues for genetic determinism, he contends that the devastating overload on the world's ecosystems was triggered concurrently with the development of cultural narratives, which diverged into diverse cultural memories, which impose rationality and certainty on the Earth. These memories all have something in common:

the capacity (and perhaps NEED!) to consume and pollute, some in more effective ways than others, and yet they are essentially the same for almost all cultures.

For the sake of argument, if humans did not privilege survival and reproduction, there would be no need for cultural myths. It might be argued, that Morrison's (1999) argument is essentially ethnocentric and anthropocentric, and yet cultural mysticism is used to justify human progress and growth, which legitimize some narratives over others. The cultural narrative of renewing and revitalizing the commons, which is based on the certainty of ecological crisis (i.e., meta-narrative), is aligned with the cultural imperative to protect the survival and reproduction of the species. It does not matter how the story is told (i.e., genetic or cultural), the ending is plausible, and yet remains highly uncertain.

Because ecojustice philosophy does not support cultural thinking patterns and behaviors that accelerate ecological declines, the focus should be on the meta-narratives that legitimize human rights to survive and reproduce at the expense of others in the Earth's ecosystems. The certainty myth of ecological crisis is the thinking that drives accelerated ecological injustice for Gaia because it legitimizes the human-centered imperative to survive and reproduce. That Bowers (2001, 2006) fails to recognize the certainty thinking of these meta-narratives in his own work may support the notion that cultural myths disguise anthropocentrism (i.e., human survival and reproduction). For Bowers (op. cit.), the cultural meta-narratives that perpetuate accelerated ecological impacts developed concurrently with the Enlightenment and Industrial Revolution, but the roots of these meta-narratives also have been traced to the ancient Greeks (Abram, 1996; Barnes, 1982; Bowler, 1992; Thayer-Bacon, 2000, 2003). The ancient Greek meta-narrative that led to the decaying relationship between humans and the natural world has now been firmly established by many philosophers. Interestingly, it may be too easy to blame the ancient Greek dichotomy between humans and nature for the cultural roots of today's "ecological crisis." The ancient Greeks did not make the connection that humans could negatively impact their natural surroundings. They could not know that the Earth's resources were finite when so few people lived on the Earth and their standards of living were insignificant compared with today's.

Nevertheless, the desire to think with certainty for the ancient Greeks led to the creation of a cultural meta-narrative that later developed into the sciences. In particular, Aristotle privileged rationalizing a world "out there;" he privileged the construction of cultural meta-narratives that inadvertently disguised the Earth's uncertain natural history (Barnes, 1982; Kaufman, 1998). These things were thought to make the Earth more predicable, precise, and certain. Adversely, the process of rationalizing the Earth's history is the very contemplation trap that is inclined to be absolutely certain in the face of the ecological unknown. Perhaps this contemplation trap is the imperative to protect anthropocentric tendencies. The cultural residue of the ancient Greek meta-narrative of thinking the Earth in certainty still permeates today's environmental sciences.

The Emergence of the Environmental Sciences

Now, I will provide historical examples to further support the notion that today's cultural mysticism, or thinking the Earth in certainty, contributes to ecological declines. My historical examples are taken from Peter Bowler (1992), a professor in the history and philosophy of science at Queen's University Belfast. He has written extensively on the history of the environmental sciences (e.g., biology, ecology, geology, meteorology). Bowler (op. cit.) explains that when the environmental sciences first emerged in the 18th and 19th centuries, they were considered less responsive to the rigors applied in the labs of the physicist and chemist. He notes that “one of the most important developments within the cultural framework of modern science is the emergence of this awareness that Nature has a history that determines its present structure” (p. 6, capitalization in original).

The beginnings of the environmental sciences can be traced to *natural theology*, the view that the natural world was divinely created by God. Bowler (1992) notes that the natural theologists viewed God as an intimate part of nature and they took for granted that the Earth remained perfect or stable after humankind’s fall into sin. Initially, the natural theologists did not want to see that the Earth has an “imperfect” or uncertain history. As natural theologists wrestled with trying to find certainty and stability in the natural world, they encountered a constantly changing and irreducibly complex Earth.

The early naturalists were caught in the flux between their desire for certainty thinking and what they actually observed and experienced. The naturalists’ efforts to reduce the natural world into certain categories resulted in the compartmentalization of the disciplines. Naturalists would now favor science as *the* way of knowing the Earth. Robert Hooke (1635-1703; *Discourse of Earthquakes*, 1705 as cited in Bowler, 1992) was an early scholar to propose that the Earth had an uncertain, complex past—lacking stability and divinity. Hooke pointed out that the fossils in the rocks were once living organisms, uplifted by earthquakes, and revealed by erosion. He was irritated by the naturalists’ spiritual views of God’s divinity in the natural environments. Hooke thoroughly challenged the religious sentiments, arguing that some of the fossils in the rocks were once living and now extinct. This scientific narrative went against the spiritual grain of the naturalists who were trying to make sense of a perfectly created Earth that could not have extinct species.

Another scholar, James Hutton (1726-1797; *Theory of the Earth with Proofs and Illustrations*, 1795 as cited in Bowler, 1992) proposed that volcanism was the primary mechanism of change for the Earth's landscape. But unlike Hooke, Hutton wrestled mightily with certainty: he was unable to accept an idea of a decaying Earth that did not have the hope of balanced renewal, the "perfect workmanship of God," (Bowler, 1992, p. 133). Thus, Hutton postulated a new theory of the Earth: the idea of perpetual balance between constant erosion and mountain building or uplift. While the naturalists were starting to come to terms with Earth's changes and complexity, they still needed to resolve their ideas with certainty in mind, which stirred more conflicts. The beginning of thinking with uncertainty was there, but it was still out of reach for those who desired to think of Earth in certainty.

The cultural myth that "order in nature" was imposed by God lingered on in the minds of naturalists. This historical period is often referred to as the beginnings of the Age of Enlightenment, which also inspired Romanticism with thinkers such as Jean-Jacques Rousseau (1712-1778). Romanticism was characterized by a heightened interest in the natural world and it began to dissolve the certainty thinking with imagination and emotion. However, thinking with certainty in mind was still privileged as scientists tried "to reimpose divine order upon a world that had degenerated into chaos" (Bowler, 1992, p. 111). But, Bowler (op. cit.) can be criticized for not emphasizing that "chaos" also is a human constructed meta-narrative for the uncertainty of Earth's changes and irreducible complexity. Gradually, the early naturalists began to accept the biodiversity and changing and complex Earth as beautiful.

Bowler (1992) notes: "paradoxical that an age that was becoming increasingly conscious of the earth as a source of minerals to be exploited for industrial development should develop an enhanced awareness of natural beauty" (p. 111). The earlier ideology of separating spirituality, philosophy and the arts from science made it easier for industrial thinkers to exploit the natural systems and for scientists to exact physical laws. In other words, while artists were off painting beautiful mountains and landscapes, industrial leaders were exploiting nature and scientists were imposing order on it. One example is the Swedish naturalist Linnaeus (1707-1778) who envisioned a *natural economy* "in which each species depended on others for its food, and in turn was depended upon by its own natural predators" (p. 144). Linnaeus was strongly influenced by the religious views of a stable Earth, and yet was able to position the Earth as the property of humans to be categorized. Religion and science did not have to be "at war" if they could be logically separated to accomplish different goals. The science meta-narrative would remain at the foreground when needed.

Earth's natural history became one of the most contested areas of the sciences in the 18th century. Bowler (1992) explains that the "challenge faced by eighteenth-century naturalists was that of balancing the human passion for imposing order upon the world against growing evidence that the world was so complex that its true order would forever remain unknowable" (p. 159). The notion of a stable Earth continued to break down when Thomas Malthus published a book in 1797 called *Essay on the Principle of Population* (Bowler, op. cit.). In this book, Malthus "proclaimed that the human race's capacity to breed ensured that the population would constantly tend to outstrip the food supply" (p. 172). This book challenged the very foundations of natural theology, and it became more difficult for naturalists to reconcile their static views of nature with the anticipation of a rapidly growing population, changing standards of living and environmental changes.

The Enlightenment and Industrial Revolution ushered in Darwin's theory of natural evolution, more geologic evidence for natural history in the fossil record, and new conflicts (Bowler, 1992). Despite increasing specialization in what is now known as the natural sciences, the role of certainty for the "scientist" becomes recognized in 1840:

> Governments were forced, some of them reluctantly, to support scientific research and education. The scientists argued that, in an increasingly industrialized world, they alone held the key to progress and hence to national development. In order to make this case, however, they had to stress the practical value of scientific knowledge rather than its theoretical content, often concealing their own real interests from their paymasters (p. 195).

The ideological conflicts between science and other cultural ways of knowing might be seen as the consequence of how society thought it should be governed. Bowler (op. cit.) notes that theory was deemphasized and many scientists "abandoned" theoretical work. He notes that scientists who persisted with theoretical projects received very little funding. Theory would be seen as "secretly" informing scientifically-based decisions. The generalized certainty of science was exciting for Euro-Westerners, which led to accepting it prima facie as the highest form of knowing: it was believed to provide the rigor and reason needed for making government decisions. Science would help expand the frontiers of industrialization. But, a limitation of using Bowler's (op. cit.) description is that he does not name specific scientists who deemphasized or ignored theory work. Yet, Bowler's (op. cit.) description is highly plausible, and I will eventually show that the cultural residue of deemphasizing or ignoring the Earth's high uncertainty continues to linger in the scientific reports produced by groups of environmental scientists worldwide.

In the early 20th century, with the acceptance of natural history, the need for an interdisciplinary know-how led to the field of ecology. The term "ecology" was actually coined in 1866 by Ernst Haeckel to describe the relationships and interactions of organisms within the natural world (Bowler, 1992). Ecology emerged quickly for scientists from diverse fields because they could access research funding for many different kinds of projects. For most scientists, ecology became a way to better inform the management and sustainability of the exploitation of natural resources (this goal garnered the most research funding from private institutions and the government).

Environmentalism developed concurrently with the emergence of ecology. Bowler (1992) defines *environmentalism* as the emergence of a "green" movement "with its emphasis on the use of science to pinpoint the problems of the modern world . . . a two-edged sword . . . to support either an exploitative or conservationist view of the environment" (pp. 4-5). The "Green movement has appropriated the term 'ecology' for its own purposes by pretending that anyone aware of the complexity of the interactions between species must be concerned to preserve the natural balance" (p. 362). In more recent years, the environmental movement has gained considerably more attention.

Environmentalism and the Cultural Myth of Ecological Crisis

Environmentalism has been growing in the U.S. and abroad: research institutes, citizen-based organizations, corporations, spiritual groups and non-profit foundations—all have had a hand in its growth. Despite the prevailing cultural view, environmentalism does not adhere to certain virtues. For example, in Germany the environmental movement was adopted by the rise of the Nazi party to warrant genocide (Bowler, 1992). Bowler (op. cit.) explains that environmentalism fit "into the Nazi's ideology because they encouraged a suspicion of urban values and saw a renewed peasantry as the foundation of their social order" (p. 513). The Nazi party "established nature reserves – on land cleared of Jews and Poles sent to the death camps" (p. 513). Not surprisingly, the American public developed a disdain for environmentalism in the post-war years, and yet it caught on as an important endeavor linked with the preservation of the natural world with early scholars such as John Wesley Powell (1834-1902), famous explorer of the Colorado River, who "warned that it would be impossible to irrigate large areas of the arid lands of the west and protested against the destruction of forests" (p. 203). Another scholar, William James (1901) wrote about the destructive clear-cutting practices of the colonial settlers in the Smoky Mountains of North Carolina. In turn, Aldo Leopold (1949/1968) and Rachel Carson (1962/1994) began writing about conservationism and land ethics. A theme of "respect for nature" emerged during the 1960s and in 1972, the Club of Rome report on the status of the environment improved cultural attitudes towards environmentalists. And finally, in the late 1970's and early 80's there was a reemergence of holistic theory with scholars such as James Lovelock (1979/1987). Bowler (op. cit.)

explains that for scientists, Lovelock's Gaia Hypothesis sounded too much like cultural mysticism to take seriously.

Cultural mysticism is now recognized as intimately woven into the social threads of scientific works. Science may be used to legitimize particular modes of reality construed by humans, conceptualizations which reflect and endorse beliefs and values, as well as the expectations and interests of the constructors. Bowler (1992) warns:

> Whether you support the free-enterprise system, or see industry as a curse that must be removed, you should do so because that is how you feel about the situation in which you live, not because you think science offers unequivocal support for your position (p. 548).

Science does not "speak for itself" and cannot be used to support an exclusive-objective or reality position—not even for the ecological crisis. Rather, the significance of multiple perspectives, including agendas on both sides of an issue ought to be upheld. When faced with high uncertainty, there is always more than one right or certain way of knowing, which may conflict with the *status quo*.

A study of the history of the environmental sciences and environmentalism helps us to witness the emergence of the "ecological crisis," whether anticipated *or* real. The meta-narrative came to be, as humans started to learn from, and apply knowledge to, the changing and complex Earth. These explorations have been traced to the ancient Greeks and through the emergence of the environmental sciences. However, humans have been creating meta-narratives to think of Earth in certainty since the beginnings. These meta-narratives share common grounds when the taken for granted assumption is that humans have been granted the essential anthropocentric rights to survive and reproduce on Earth.

The notion of “where people put their faith” is what makes the presumption of ecological crisis so dangerous, particularly, when thinking with certainty in mind is privileged. The environmental sciences are now less concerned with thinking of Earth in certainty, and more concerned with how to reduce uncertainty. In the environmental sciences, however, the shift to thinking with uncertainty in mind is subject to criticism when the methods and criterion used to evaluate possible ecological outcomes inadvertently perpetuate the human constructed meta-narratives and hierarchies that certainty thinking implicitly privilege, such as mathematical modeling. Unfortunately, mathematical proof may be taken more seriously than peoples’ local knowledges, beliefs and values, expectations, and personal testimonies. But, it might be argued, that reducing Earth’s uncertainty through whatever means provides the most certainty for making qualified ecological decisions is justified for human survival and reproduction. To that, I cannot argue. However, I turn to argument B to discuss how we might minimize humankind’s impacts.

Argument B: Thinking with Uncertainty in Mind

Most environmental scientists now recognize that the Earth’s systems are complex, constantly changing and highly uncertain (Grimm, 2006; Pollack, 2003/2005). Many unforeseen cultural and environmental consequences may now be linked with the anthropogenic (i.e., caused by humans) contributions to Earth’s climate changes (International Panel on Climate Change [IPCC], 2001; NRC, 2001, 2002). While ecological philosophy developed concurrently with ecology science at the turn of the 20th century, many well-intentioned ecological philosophies have been written in largely decontextualized ways that deemphasize or ignore the environmental sciences (Bowler, 1992). Because Chet Bowers' (2001, 2006) ecojustice theory supports the certainty of *the* ecological crisis, his ecojustice theory deemphasizes the environmental sciences. If ecojustice philosophy is to be taken seriously as a guide for what should be renewed and revitalized, philosophers cannot deemphasize the work of ecologists, evolutionists, wildlife biologists and other environmental scientists. Because the Earth's changes now strongly support the need to conserve and revitalize the commons, ecojustice philosophy and criteria for educational reforms will help philosophers to critique the root metaphors that accelerate ecological denigration. Already, philosophical considerations are an essential part of doing scientific work where the uncertainty of Earth's changes is expected. My expectation is that when integrated, ecological philosophy and science will help prepare science teachers and their students to become informed and share some of the responsibility for local ecological decisions.

Grounded Philosophy and Scientific Literacy

The early pragmatists, such as Charles Sanders Peirce (1958), John Dewey (1910/1997), and William James (1901) were excited about how science might work with philosophy to deal with societal issues. They emphasized the practical consequences of meaning and truth, and yet the early pragmatists tended to deemphasize or ignore the harmful assumptions of science. However, pragmatism has come a long ways since the turn of the 20th century (Seigfried, 1996; Thayer-Bacon, 2000, 2003). Now, thoughtful pragmatists are addressing many of the cultural views still privileged by today's rapidly changing science and technology (e.g., patriarchy, scientism, consumerism).

Unfortunately, science educators who have used pragmatism to develop pedagogy still run the risk of taking-for-granted the root metaphors of inherent progress, which continue to linger in the natural sciences, much influenced by Charles Darwin.

For example, science education scholars (Pugh & Girod, 2007) have used John Dewey's (1934) *Art as Experience* to construct science pedagogy that emphasizes transformative, aesthetic experiences and metaphorical thinking in science classrooms. This science pedagogy takes-for-granted the assumption that students' cultural lives are devoid of transformative, aesthetic experiences that might be analyzed and reinforces the linear presumption that transformative, aesthetic experiences are inherently progressive. Thayer-Bacon (2003) notes that late in his life, John Dewey explained that by "experience" he meant "culture." It follows that transformative, aesthetic experiences (i.e., cultural narratives and meta-narratives) are already a significant aspect of the students' cultural lives, which are not always progressive (e.g., ecological degradation). These experiences may frame the students' relationships with the natural environment. While enrichment experiences are typically beneficial in the sense that they expand the students' horizon, the assumption that these experiences always leads to educational progress limits how effective this pedagogy will be at confronting ecological declines. Examples include all of the ways that transformative, aesthetic experiences contribute to accelerated ecological declines (e.g., interest in science used to exploit Earth's resources).

Ecojustice philosophy should make a concerted effort to bridge the grounded pragmatic experiences of commons renewal and revitalization that help educators make the connection between ecojustice thought and activism, which better positions educators to critique the cultural views of science and engage in neighborhood and environmental revitalization projects. I use the term *ecological pragmatism* to heal the split between ecological philosophy and ecology science, and to refer to grounded ecological pursuits. For example, if evolutionary ecology is acknowledged, emerging scientific theories such as "geographic mosaics" will do much to inform ecological philosophy (Pennisi, 2007). Likewise, ecological philosophy provides a "checks and balances" approach for preparing new scientists, and science teachers and students to thoughtfully consider root metaphors that may privilege particular thinking patterns and human-nature relationships.

But, it might be argued, that the "golden objective" of science education is to teach science and not necessarily teach how to reduce humankind's ecological footprint. Without the cultural myth of ecological crisis, why should confronting ecological declines become the aim of engaging teachers and students in the competency of science? If the meaningful purpose of science education is to empower citizens to make choices in their everyday lives, then the ecological context of their everyday lives must be included. The National Research Council (1996) identifies teaching students to use science in their everyday life as the goal of science education, which is also defined as scientific literacy. Other scholars (Hurd, 1998; Mueller & Bentley, 2007; Roth & Calabrese Barton, 2004) agree with this definition of scientific literacy, albeit with differing conceptualizations. Because science teachers and students are situated in the local community and natural environment, an important part of scientific literacy cannot be deemphasized or ignored. If science educators value the moral imperative to leave our children an inhabitable planet, the movement to make ecological concerns the aim of science education should not be considered "fool's gold." Thus, science literacy must focus on how to empower science teachers and students to make decisions that affect local communities and Earth.

A shift towards a scientific literacy that embraces and values the Earth's changes, complexity and high uncertainty is now unavoidable. Since there is no monopoly on "uncertainty thinking" (to create one is counterintuitive), part of my strategy has been to provide a historical context for what has been deemed its opposite—"certainty thinking." However, my intention was not to create a dichotomy between certainty and uncertainty. Readers will discover that pragmatically grounded certainty comes back into view as I develop a theory of uncertainty thinking for ecojustice and science education. My expectation is that scholars will not reduce their conceptions of uncertainty to my theoretical framework, but continue the conversation of how uncertainty thinking helps empower science teachers and students to participate more fully in ecological decisions. It might be argued, that uncertainty thinking can lead to no action. However, no action is impossible, since no action is a decision not to act. The point of thinking with uncertainty in mind is that we need to make decisions with humility rather than arrogance. We need to gather as much evidence from past experiences as we can, eliminate harmful choices, along with the things we are not going to do, and make decisions based on part certainty.

Because ecojustice activities cannot be founded on the presumed ecological crisis, we might seek opportunities to reduce ecological impacts for other reasons. The symbols that make up the Chinese word for crisis are "danger and opportunity," says Henry Pollack (2003/2005, p. 237). He suggests that while many people are now familiar with the perils linked with global warming (i.e., the first part of the Chinese word for crisis), very few people share an appreciation for the second part of the Chinese word for crisis—*opportunity*. Pollack (op. cit.) identifies opportunities for corporations interested in migrating to an environmentally friendly mode of operation. For cities, there are economic gains when converting to energy efficient modes of transportation. For average people, there are savings linked with home energy reductions and fuel efficient automobiles. These actions are considered *precautionary measures* when prompted by the opportunity to think through the uncertainty of the ecological world. Uncertainty thinking includes an element of precaution because there are always double binds with regards to opportunity, such as the venture capitalists now vying for shipping rights through polar areas that are expected to become ice-free year round, and planning for oil explorations in areas that will be "opened up" for the first time by melting polar ice.

The *precautionary principle* has been used to guide thinking about the potential of harm to the Earth's ecosystems with deep-rooted uncertainty (Aslaksen & Myhr, 2007). Aslaksen and Myhr (op. cit.) note that the precautionary principle can be used to recognize "the multidimensional nature of environmental qualities and risks, such as irreplaceability, irreversibility, uncertainty and complexity" (p. 489). A strong version of the precautionary principle is described in the *Bergen Declaration*:

> In order to achieve sustainable development, policies must be based on the Precautionary Principle, environmental measures must anticipate, prevent, and attack the causes of environmental degradation. Where there are threats of serious or irreversible damage, lack of scientific uncertainty should not be used as a reason for postponing measures to prevent environmental degradation (Cameron & Abouchar, 1991 as cited in Aslaksen & Myhr, 2007, p. 492).

Precautionary perspectives elicit the values of people connected to places, which must be represented by many different stakeholders. Aslaksen & Myhr (op. cit.) highlight the importance of extending the scientific peer review community to include multiple methods and criteria, interdisciplinary scholars and the people most affected by the environmental issues. A social and environmental responsibility to future peoples, which may be excluded in the scientific process, is included in the precautionary principle to guide important decisions that affect the bioregion. The precautionary principle provides equal opportunity for scientists, policy makers, and other stakeholders to address the high uncertainty of Earth's changes and complexity. Moreover, when multiple perspectives encourage creativity in the spirit of uncertainty, they may not be reduced to certainty.

Uncertainty thinking is highly valued because it acknowledges that science evidence alone cannot be used to effectively deal with the plurality of ecological issues. Ecological decisions now require researchers to embrace and value multidisciplinary approaches to thinking with uncertainty in mind (i.e., philosophy, spirituality, the arts…). Because there are ecological trade offs that must be considered in the decision-making process, Aslaksen and Myhr (2007) provide the example of the multiple factors that come into play when thinking about the worth of a wildflower versus a genetically modified organism (GMO). They note:

> The challenge for environmental risk management is to include the value of a wildflower, with its qualities that are not easily expressed in terms of market value. The failure of market prices to reflect potential health and environmental risk can give GM crops an unjustifiable advantage in the market place (p. 493).

Aslaksen and Myhr (op. cit.) ask "who are the stakeholders representing the wildflower?" (p. 494). They point out that multiple stakeholders are required as contextualized advocates for the worth of the flora and fauna of local places. Knowledges of places are essential to the decision-making process represented best by the people who live in those places. When affected parties come together to deal with environmental issues, the "evaluation methods could include multicriteria analysis and deliberate processes for assessing uncertainty, for accommodation of scientific disagreements, and for integration of stakeholder perspectives" (p. 495). In the process of making ecological decisions, the stakeholders' beliefs and values, attitudes, and assumptions must be made explicit. The expectation is that stakeholders bring different "beliefs, values, attitudes, and assumptions creating a frame through which they see themselves and the world, in their identification of which values are important to protect" (p. 495). The participation of all affected parties, policy makers, scientists, and other community stakeholders, marks a well-designed process for community and environmental policymaking.

Consequently, the process of decision-making is complicated by predicting the various outcomes of particular decisions for the community and the local ecosystems. Ranking the significance of particular ecological decisions over others requires the acknowledgement that "contemporary social, economic, and political issues complicate the management of natural resources," and depend on a diversity of stakeholders with conflicting agendas and priorities (Fuller, Gross, Duke-Sylvester, & Palmer, in press, n.p.). Fuller et al. (op. cit.) explain that ecological decisions must be balanced with the different needs of species and habitats and the practical reality of a variety of stakeholders' interests. In their work, Fuller et al. (op. cit.) use computer models to simulate the complexity of ecosystems and project how different policy decisions will impact the south Florida wetlands. They note how uncertainty inputs (e.g., lack of knowledge, weather patterns, mortality rates…) entered into the computer to construct models may result in significantly different outcomes. The robustness in ranking different scenarios increases with the relative assessment of diverse methods, multiple criteria and different stakeholders' interests. The encompassing challenge is helping various stakeholders to think with uncertainty and understand various environmental inputs, so they can participate fully in policy decisions that will affect the future of ecosystems.

Programs now are being developed allowing stakeholders to construct different ecological scenarios and visualize the consequences of alternatives of future environmental outcomes. The Environmental Protection Agency's (EPA's) Regional Vulnerability Assessment Program (ReVA; see http://www.epa.gov/reva/) is an example of this approach. Environmental data layers such as land use, land cover, water quality, air quality, geophysical data, economic, urban growth, and other trade-offs are incorporated into the model so that users can construct different ecological scenarios and forecast the implications of ecological decisions explicitly chosen by stakeholders. Some of these data layers are strongly influenced by personal experiences, ecological systems knowledge, scientific evidence and stakeholders' beliefs and values. Helping potential stakeholders to appreciate and understand the ways in which scientists work with uncertainty is not an easy task and will require increasing collaborations between scientists and educational scholars; for teaching is the expertise of educationalists.

The difficulty of the public linked with understanding uncertainty thinking with regards to ecological decision-making is evidenced by the fact that today's environmental scientists produce different types of summary documents for policymakers, that reflect "less emphasis on communicating the basis for uncertainty and a stronger emphasis on areas of major concern associated with human-induced climate change" (NRC, 2002, p. 4). The reason for deemphasizing uncertainty thinking for policymakers is that content of scientific report sometimes is taken out of context or selectively referred to by policymakers, in a way that serves a particular agenda (Pollack, 2003/2005). Because of the cultural views reinforcing certainty and precision linked with scientific work, an expression of uncertainty can provide enough "wiggle room" to stir controversy in the public mind or advance a political platform. This outcome can frustrate scientists and supporting organizations, causing them to counter with simplified documents that stress the key points needed for potential ecological outcomes.

The lack of understanding of uncertainty thinking by policymakers and U.S. citizens is a direct reflection on the quality and cultural views linked with today's science education. If the vast majority of science teachers and students do not understand what the term uncertainty means to scientists, they (i.e., science teachers and students) are not being educated such that they will feel empowered to participate fully as bioregional stakeholders, even if they are given the opportunity to make decisions that affect their local communities and ecosystems. Ironically, the meaningful purpose of science education is to empower people to use science to make decisions that impact their uncertain everyday lives, even as standardized certainty thinking (e.g., facts/concepts, drilling, testing…) as found in today's schools continues to fuel the Earth-in-crisis viewpoint, as well as accelerated ecological declines.

As educators focused on scientific literacy, how can we better empower science teachers and students to participate more fully in the decisions that affect their local communities and natural environments? A major hurdle will be preparing teachers and students to think with uncertainty in mind. Moreover, science teachers and students will need to be prepared as advocates for what can be conserved and sustained in the near future—linking the worth of particular flora and fauna in the local places that they know best. As I've discussed elsewhere (Mueller & Bentley, 2007), science teachers and students will become indispensable by learning to embrace and value cultural and ecological pluralism—to be reflective, reliant, and reciprocal of local peoples and places. Scientific literacy can be reshaped by the pluralistic goals and competencies of science (e.g., knowledge of systems and how they operate), and by the ways in which teachers and students participate more fully in ecological decision-making. The first challenge should be shifting towards developing a more robust understanding of how scientists think with uncertainty in mind. Thus, the ecological crisis view must be scrutinized carefully if we wish for our science teachers and students to meet on equal grounds with working scientists and other stakeholders. As environmentalists, we might seize the opportunity side of the "crisis" to get on with the essential ecojustice work ahead of us, which includes grounded philosophy to further explore notions of scientific literacy.

Post-Normal Science

The philosophical stance most aligned with uncertainty thinking which acknowledges the aforementioned is *post-normal science* (Ravetz & Funtowicz, 1999). Ravetz and Funtowicz (op. cit.) define post-normal science as a developing insight, rather than a theory, refined through thought and experience, which highlights "why it is necessary, not merely for political justice, but also for the quality of the decisions themselves," that science explicitly acknowledge the "problems of uncertainty and value-conflict" (p. 641). These authors note that the message of post-normal science was radical from the start because it emphasized "the uncertainties and value loading of policy-related science, it implicitly contradicted centuries of conventional wisdom for science, in which uncertainty was tamed, ignorance suppressed, and the supposedly value-free character of science proclaimed as a great value" (pp. 641-642). Post-normal science calls for an extended peer community and multiple methods and criteria, which legitimizes the plurality of knowledge. It lays bare the political dimensions of the scientific process and posits the advantages of a "post-normal style of adaptive management, where the scientists provide *narratives* rather than predictions, and participate as equals with the others" (p. 644, emphasis added). Keep in mind that science *is* human meta-narratives. For this reason, post-normal science is not a "normal" paradigm shift.

Post-normal science counters Thomas Kuhn's (1962/1970/1996) *normal science*, which emphasizes scientific progress as characterized by revolutionary paradigm shifts, or transformations of theoretical thought within the scientific community. Alan Chalmers (1976/1982/1999) notes that Thomas Kuhn theorized normal science works as follows: "*pre-science – normal science – crisis – revolution – new normal science – new crisis*" (p. 108, emphasis in original). Kuhn's (op. cit.) theory is that multiple perspectives will inevitably precede the formation of a single structured and directed science paradigm that is adhered to by large majority of scientists, who are considered "normal" scientists. The normal science paradigm is recognized until a crisis occurs which attracts more and more attention to a new normal science or paradigm shift (i.e., scientific revolution). Chalmers (1972/1982/1999) argues that sociological perspectives outside of science do not qualify as part of Kuhn's normal science (i.e., Kuhn rejects relativism). Thus, "normal scientists must presuppose that a paradigm provides the means for the solution of the puzzles posed within it" and "normal scientists must be uncritical of the paradigm in which they work," (p. 110). In other words, the scientist must privilege resolutions to conflicts from within the normal science paradigm until a new normal science paradigm begins to take shape. Chalmers (op. cit.) argues that Kuhn's normal science takes for granted the cultural assumption that paradigmatic shifts continue to occur and are inherently progressive. Kuhn's normal science also deemphasizes or ignores the extended peer review community (i.e., people not historically thought of as scientists). In contrast, post-normal science acknowledges that multiple perspectives are needed to deal with high uncertainty. Post-normal science has been viewed with disdain by some scientists, primarily because it does not uphold the rigors and rationality of Kuhn's (op. cit.) normal-science paradigm.

Post-normal science places a high value on pluralistic perspectives, local knowledges, beliefs and values, personal experiences, and the bioregional narratives where people live and work. Because science is one way to understand the natural world that does not purport to provide definitive solutions for every problem, there is usually the need for an extended peer review community, including those outside of science. Consequently, post-normal science could be interpreted to mean that scientists no longer uphold the "rigors" of normal science. Rather, post-normal science allows researchers to think with fluid categories constantly in flux (e.g., genes that play multiple roles, species that do not fit into neat categories…). If ecological philosophy aligns itself with the sciences through post-normal perspectives, scholars have to remain open-minded as new variables arise and others change, which warrants an epistemic approach that values the excitement of learning when facing the ecological unknown.

Most interestingly, post-normal science suggests that philosophical considerations may supersede what is scientifically quantifiable to make local ecological decisions. Mathematical modeling (i.e., ecological forecasting), for example, is just a tool to help with local ecological decisions, but may not take priority over social and ethical values. Thus, a perspective that integrates philosophical and scientific considerations (and others) provides an enlarged forum for wrestling with what should be conserved and sustained when confronted with ecological tradeoffs (i.e., a GM crop versus a wildflower). An educational philosophy approach aligned with post-normal science brings together the projects of ecological philosophy and the natural sciences for science teacher education.

Post-normal science is about inclusion, where local knowledges and languages, personal expectations, beliefs and values, and place-centered narratives are highly valued. Local stakeholders are generally more sensitive and susceptible to the intricacies of the local ecosystems (Aslaksen & Myhr, 2007). Given that usually there will be ecological tradeoffs which will need to be considered in the face of a rapidly advancing society and changing Earth, citizens most aligned with the local ecosystems are the best advocates for the worth of particular flora and fauna. But, it might be argued, that when stakeholders fundamental needs are not met, for example, in Appalachian regions where coal mining provides the means to raise a family, desperately poor local stakeholders may not vote to protect a stream if it means that coal-mining jobs are at risk. Thus, the local authority called for by ecojustice philosophy and post-normal science must include outsider's perspectives, such as stakeholders who may be otherwise excluded from local decisions (see chapter three for a discussion of qualified relativism; Thayer-Bacon, 2003).

Outsiders can offer “enlarged thinking,” or macro perspectives, in relation to particular micro perspectives that are often too limited to perceive the larger part of the picture.

Because many young people are naturally drawn to explore the outdoors, their advocacy as stakeholders should not be undermined. Science teachers prepared to work both with ecological philosophy and science may serve as local advocacy guides and help students to participate fully with other stakeholders. Although my next point may receive some criticism, it is worth the effort, anyway, because youth will outlive the adults in the community and thus have a longer-term investment in the local ecosystems. As a result, they may take a more precautionary approach with nature’s uncertainty. But, it might be argued, that this point sets up teachers to deliberately bias the inputs of young people towards the longer-term sustainable practices and agendas, which might not resonate with the immediate interests of policymakers or their constituents. However, if youth in the community are not afforded opportunities to participate more fully in local policymaking, then will the longer-term perspectives be represented by youth advocates? The current voting age in the U.S. may limit who gets to participate in local decisions and whether a longer-term movement towards sustainable practices and agendas is represented at all. My suspicion is that if teachers help guide students’ thinking and activism, together they will represent both short- and longer-term insights for the local community and Earth’s ecosystems. Post-normal science and ecojustice align with a movement in this direction.

Replacing Citizens

Now, I will argue that science first needs to be democratized by repositioning it as something to which all citizens can contribute. In the best of current worlds, teachers teach students what they need to know to navigate the dominant cultural milieu, get into college, obtain financial support, and enter the workforce. Yet, as Chet Bowers (1993, 2001, 2006) points out, teachers also pass on what society deems necessary for students to become effective consumerists. Schools may implicitly prepare students to rely on the market, to rely on science as the highest form of knowing, and to rely on technology as inherently progressive. The market is a powerful force in students' lives, and it may lead to nihilism and skepticism. Cornel West (2004) notes, "the oppressive effect of the prevailing market moralities leads to a form of sleepwalking from womb to tomb, with the majority of citizens content to focus on private careers and be distracted with stimulating amusements" (p. 27). West (op. cit.) explains that the market economy may make democratic matters seem out of reach for the vast majority of today's youth. Thus, youth can come to believe that they do not have the power to make a difference.

If not careful, teachers may implicitly teach students that their local knowledges, face-to-face conversations, oral narratives, ceremonies, and the arts, are not as important as the standardized curricula that reinforces prescribed facts and concepts. Unfortunately, many teachers have no other choice than to haphazardly reinforce the certainty of science facts and concepts and "recipe experiments" with certainty outcomes (Kozol, 2005). In turn, students may be taught to think of the Earth in certainty—to name it, opine it, categorize it, and reconstruct it. Students may be taught that environmental problems will be proved and solved with the advancements of science, technology and the market.

In contrast to all the certainty thinking going on in schools, today's ecologists (Brewer & Gross, 2003; Clark, 2003) and other scientists emphasize thinking with uncertainty in mind. Uncertainty thinking is privileged because it helps bring stakeholders together on equal grounds to make important ecological decisions that affect the community. However, K-12 students' perspectives may not be valued as highly as the adults in the community. Students may be considered too immature to make such important decisions as what aspects of the local bioregion should be conserved and sustained. Yet, as I pointed out, youth are very attracted to exploring the natural world and may be more sensitive to the changes occurring within natural places. In fact, young people may serve as the only advocates of particular plants and animals, especially when species lack economic worth. I maintain that today's youth will provide essential viewpoints that must be considered during these times of uncertainty. Young people need to be recognized for the legitimacy of their knowledges, observations, and narratives.

Throughout his career, Jonathan Kozol (2005) explains that he has been criticized for relying too heavily on students' narratives in his works. He notes:

> . . . I have always found that children are a great deal more reliable in telling us what actually goes on in public school than many of the adult experts who develop policies that shape their destinies. Unlike these powerful grown-ups, children have no ideologies to reinforce, no superstructure of political opinion to promote, no civic equanimity or image to defend, no personal reputation to secure. They may err sometimes about the minuscule particulars but on the big things children rarely have much reason to mislead us. They are, in this respect, pure witnesses . . . (p. 12).

Kozol (op. cit.) has been an educator and researcher for more than forty years and continues to trust the powerful narratives of children. If all citizens have an equal shake at participating more fully in the decisions where they live, then today's youth might be valued for their less-than-tainted ways of knowing and observing. Now, the potential of including students as legitimate citizens of the local bioregion begins to take shape. Yet even as students are viewed as equal citizens, science teachers will need to foster place knowledges where they live so that today's young people will not lose sight of places. Without place knowledges, students may not have the collateral needed to be included.

In "Beyond the 'Decorated Landscapes' of Educational Reform" (Mueller & Bentley, 2007), the metaphor of "decorated landscapes" is used to make the case that preparing students for economic interests is short-sighted when compared with the goal of preparing students to live as reflective, reliant, and reciprocal citizens with each other and within the limits of the local ecosystems. If students are considered legitimate citizens of the ecological world, science teachers will focus on their landscapes of pluralism—gender, class, race, ethnicity, and natural environments. The landscapes of pluralism (i.e., peoples and places) are what contextualize uncertainty thinking for legitimized peoples. When science education is reconceived as reflective, reliant, and reciprocal of citizens and places, it empowers citizens to conserve and sustain their local place knowledges. The incentive in preserving environmental spaces is the empowerment gained from being recognized as authorities on a place. For science teachers and students, this power will help position them as indispensable in the local decisions of the community. Adversely, when educational reforms (i.e., standardized curricula) are focused primarily on preparing students for financial incentives, young people are *dis*placed as citizens. The educational priority of *dis*placing citizens, by privileging the same concepts everywhere, takes power away from students and denigrates the natural environments where they live; for it is not possible for citizens to be inhabitants nowhere. Decontextualized education displaces citizens so efficiently that when students' cultural and environmental spaces are enclosed, they must rely on the market for their survival. Measures of displacement are immediately apparent when the marketplace is no longer accessible, for example, when Hurricane Katrina hit the city of New Orleans in 2005.

Another example will help drive this point home. Corporate scientists are now seeking alternate fuel sources such as corn-based ethanol in an attempt to respond to environmental troubles. The problem with corn-based ethanol is that it is a high water-use crop and requires fertilizers and pesticides to ensure sufficient growth rates (Brower, 2001). Even switchgrass, which is being considered as an alternative to corn for biocellulosic ethanol, has problems: it needs inputs of nutrients to be productive enough to warrant economic consideration. However, the latter can be solved with genetically modified corn (or *Bt corn*), which temporarily resists damage from economically destructive insects; and corn can be modified genetically to withstand herbicides used to kill the surrounding weeds. But *Bt corn* also can kill other important pollinators, such as the monarch butterfly caterpillars and can affect the natural systems in other significant ways. As Lincoln Brower (op. cit.) explains, *Bt corn* is highly valued by industrial agriculture and companies such as Monsanto, Novartis A.G., and Pioneer Hi-Bred of DuPont, and so they took every available measure to protect themselves from an adverse scientific consensus in recent environmental scrimmages. Again, the argument is valid, that farmers favor *Bt corn* because it is less expensive to plant it and not spray later for insects, than to plant conventional corn, then have to spray it with insecticides two or more times during the growing season. Because we, the customers, want cheaper corn and renewable fuels, a capitalist structure supports the high value of *Bt corn*. In the end, Brower (op. cit.) notes that the scientific findings were compromised by the interests of the agriculture industry, as well as by the U.S. federal regulatory system that evaluates the safety of all GMOs when peer reviews were minimized in the efforts to resolve the matter quickly. *Bt corn* entered the market too quickly to be investigated adequately for potential adverse effects.

The economic self-interests of large corporations (i.e., Monsanto, Novartis A.G. and Pioneer Hi-Bred of DuPont) were privileged in the rash decisions to trade the immediate economic benefits of *Bt corn* for monarch caterpillar declines. While the declines of one pollinator species such as the monarch might not seem a big deal at first glance, a scientific report on the declines of many pollinators such as North American honeybees may suggest otherwise (NRC, 2007). With the lack of place knowledges (i.e., long term ecological data needed), the majority of pollinators remain unprotected by the Endangered Species Act of 1973 (ESA)—*they cannot be listed as threatened or endangered because the ESA exempts any insect that can cause economic damages.* However, these pollinators are essential to about three-quarters of the more than 240,000 species of the world's flowering plants and enable the cultivation of over ninety different agricultural crops. Moving forward into the uncertain future, there may continue to be instances where tradeoffs linked with GMOs and environmental toxins will carry the far reaching consequences of abrupt plant extinctions, economic hardships for farmers, and declines in the food supply, medicines, wood and fibers. Without cultivating citizens with place knowledges, *how* will stakeholders know when to take appropriate actions on important ecological issues?

Today's greatest barriers to cultivating citizens with place-centered knowledges are the national and state testing priorities linked with yesterday's national science education (NRC, 1996). The priorities in the No Child Left Behind (NCLB) program have reduced teachers to robotized test administrators in some schools (Kozol, 2005). Kozol (op. cit.) provides a powerful account of how high-stakes testing has devastated or demoralized teachers, students, schools and natural places. Decontextualized high stakes tests *dis*place the context-dependent subjects such as history, geography, and science. Moving forward into the uncertain future without place-centered knowledges is dangerous—*especially for the least-advantaged children in society*. Kozol (op. cit.) explains, "most Americans whose children aren't in public school have little sense of the inordinate authority that now is granted to these standardized exams and, especially within the inner-city schools, the time the tests subtract from actual instruction" (p. 112). Ironically, when most Americans want to see the "achievement gap" closed, between the students-that-have and the students-that-have-not, the citizens more likely to be *dis*placed are the intercity youth, according to Kozol (op. cit.). If place-centered science education that comes from thinking in places in relation to other places is not made the priority in schools, the ultimate sacrifice will be more *dis*placement of more people and places.

Replacing "Citizen Science"

Another roadblock to cultivating citizens in the places where they live is the current view of scientific literacy, which emphasizes science teachers and students as the *consumers* of science and scientists as the *producers* of science (Hurd, 1998). Paul deHart Hurd (op. cit.) argues that students who wish to become scientifically literate need to recognize "scientific researchers as *producers* of knowledge and citizens as *users* of science knowledge" (p. 413). The role of citizens as the "*users* of science knowledge" is too restrictive and privileges what scientists do, as opposed to what citizens might do. It undermines the scientific contributions of science teachers and students who wish to be acknowledged as legitimate members of the science community. Science is something that people do, not just the people with the professional hats. The scientific literacy proposed by Hurd (op. cit.) does not go far enough to enable science teachers and their students to be viewed as authoritative sources of knowledge, which means that they may not be taken seriously when it comes time to make important ecological decisions.

Scientific literacy proposed by Hurd may be *re*placed through "citizen science"—a growing interest for science educators (Roth & Calabrese Barton, 2004; Wilson, 2006). Roth and Calabrese Barton (op. cit.) explain that "when students begin to participate in 'citizen science,' they enter multiple relations, situations through which science is enacted in the community" (p. 177). They differ from Hurd in that they propose a scientific literacy with a postmodern taint which positions the science institution within the socio-cultural situations between individuals at work in the community and the natural environment. This cultural approach to scientific literacy acknowledges that science teachers and students represent the culture of science in many different ways and takes seriously the multifarious relationships when science is enacted. It also prepares science teachers and students to value the importance of contributing to the welfare of the place. This kind of community and environmental agency helps to cultivate place-centered knowledges from within the localities where science teachers and students live. Because local knowledges may not be represented elsewhere, Roth and Calabrese Barton (op. cit.) empower science teachers and their students and help them to be taken more seriously by decision-makers.

In a similar way, E.O. Wilson (2006) defines "citizen science" as the science knowledge that any person interested in understanding the ecological world can partake. He points to an example of citizen science in the success of the All Taxa Biodiversity Inventory (ATBI) of the Great Smoky Mountains where scientists, science teachers, students and other citizens work together to investigate species distributions, habitat interactions, population sizes and the life cycles of organisms. The ATBI is the kind of project where the science knowledge produced by citizens is taken seriously by ecologists, biogeographers, conservationists and others. Essentially, it is place-centered knowledge that makes science teachers and students indispensable in local decisions. Wilson (op. cit.) is working to develop an online and worldwide *Encyclopedia of Life*, where science teachers and students will be able to contribute their studies to a databank. This databank will then be used to track the impact of Earth's abrupt changes and other ecological trends, place-centered knowledges in relation to other places.

For my purposes, the "citizen science" proposed by Roth and Calabrese Barton (2004) and Wilson (2006) is a step in the right direction for science education. When science teachers and students are considered legitimate contributors to scientific work, they will be better positioned to participate in the decision-making of the community. Currently, much scientific data are now available on the web, from sea turtle and bird migrations, to real-time earthquake monitoring and volcano activity logs. These datasets can be analyzed by science teachers and students and compared with the scientific work occurring around the world: it is not limited to Earth-place knowledge.

During my first year as an Earth science teacher, I was introduced to the Mars Student Imaging Project (MSIP) facilitated by Arizona State University and Phil Christensen—a Regents professor of geology and NASA scientist (Mueller & Valderrama, 2006). Christensen advocated that science teachers and students should be able to use his Thermal Emission Imaging System (THEMIS) on board the NASA Mars *Odyssey* orbiter, to engage students in authentic scientific research. The THEMIS camera captures visible and infrared images to decipher mineral distributions and geological structures (i.e., analyze the natural history of Mars). THEMIS images are available on the internet as soon as they are downloaded from the Mars *Odyssey* (http://themis.asu.edu/). My students designed and submitted a proposal to NASA/Arizona State University (ASU), which was accepted, to use the THEMIS camera to image a rampart crater near the Elysium Mons. My students worked on analyzing the image for the entire semester: they looked at depth, width, height, sun angles, and geological features such as gullies, ripples, landslides, sand dunes, lava flows, crevasses and stratification. They compared their crater to other craters on Mars and Earth (e.g., Barringer Meteor Crater). They discussed whether the Mars crater location would be a good place to establish a space habitat, and what it might take to sustain it. Likewise, they located potential exploration spots and places where specific kinds of life might exist. A full report was submitted to the NASA/ASU Mars Space Flight Research Facility and uploaded to the MSIP website to share worldwide with other research teams. Each semester thereafter, new students built their investigations on the work of the previous semesters' students. As the Mars projects continued to build, collaborations with other science teachers led to the development of a science computer lab and greenhouse to analyze more Mars images, weather data, hydroponics, rovers and other student initiated investigations. There are now thousands of THEMIS images available for science teachers and students who are recognized as legitimate members of the NASA/ASU Mars science community (far too many images for scientists to work). The result is that science teachers and students are now being viewed as indispensable to the scientific project to understand Mars-place natural history.

A "citizen science" where science teachers and students are recognized for the legitimate contributions they can bring to the scientific community was addressed in the recent report on North American pollinator declines by the National Research Council (NRC, 2007). The NRC (op. cit.) calls for high-intensity biodiversity surveys, and notes, "the assessment should include monitoring of pollinator status and function that integrates the work of professional scientists and citizen-scientists to maximize the depth and breadth of effort" (p. 10). Moreover, the NRC (op. cit.) calls for the conservation and restoration of pollinator friendly habitats, such as wildflower gardens, as well as the public outreach and education needed "to raise awareness of pollinator's ecological and economic contributions and to encourage public participation in conservation" (p. 11). The NRC (op. cit.) notes "as part of their outreach, federal granting agencies should make an effort to enhance pollinator awareness in the broader community through citizen-scientist monitoring programs, teacher education, and K-12 and general public education that center on pollination" (p. 11). However, the "citizen science" proposed is still subject to the criticism that it does not go far enough to ensure that the science produced by science teachers and students will be taken seriously when important decisions are made.

Most "citizen science" admirably recognizes that science teachers and students (and other community members) are legitimate members of the scientific community. When teachers and their students become aware of what data are needed and supply these data, at any appropriate level of quality, they are taken seriously. Any decision-making process is constrained to answer one or more particular questions, and particular data are needed for this purpose. If the question has to do with Monarch butterflies and GMO corn, then data on salamanders or hummingbirds may be irrelevant and thus "useless" for the intended purpose. The matter of data-acquisition (i.e., more or less equivalent to experimental design) needs to be explained by the decision-makers such that teachers and their students can gain meaningful involvement. When their scientific work compliments the needs of the local community and ecosystems, they will be recognized as legitimate.

However, Roth and Calabrese Barton's (2004) interpretations of "citizen science" take too much away from individuality. They note: "because interaction and participation cannot be understood as the sum total of an individual acting toward a stable environment, learning cannot be understood in terms of what happens to individuals" (p. 178). The problem with this universal assumption is that it marginalizes individual experiences and expectations, fundamental beliefs and values, and private interactions with the natural world (i.e., human-nature). Moreover, the pervasive cultural residual that reinforces normal science may still dominate the thinking of science teachers and students who approach science through the collective praxis, where the normal institution remains the basis for relative comparison. Because a certain way of doing science is taken more seriously by policymakers, science teachers and students may still favor certainty thinking as an influence on local decisions. "Citizen science" that is other-than-normal science may be perceived as token science (Aikenhead, 2006), which penalizes any science that deviates from the *status quo*. If the relevant scientific knowledge produced by science teachers and students is to be taken seriously, the cultural narratives of science will need to be repositioned as post-normal and essentially uncertain.

Unfortunately, "citizen science" does not prepare science teachers and students to proactively deal with the thinking patterns of a population that grows without recognizing that its consumer-dependent activities must be reduced. As the population increases and natural resources begin to run thin, citizens may discover that property values become increasingly connected to the conservation of natural capital (Daly, 2002). In turn, citizens who are prepared to think in places will benefit from the high value of relying on each other and the land (rather than the market) and conserving species and habitats that are beneficial for both survival and economic worth. Unfortunately, in places such as Phoenix, Arizona, and Las Vegas, Nevada, where high property values are maintained by the transportation of natural resources, food and freshwater from miles away, the mirage of economic growth may be a tragedy-in-the-making. Since ecojustice education supports community and environmentally-centered revitalization projects, "citizen science" is already a major aspect of the overarching goal of ecojustice activism. However, ecojustice education deemphasizes the vital role of scientists in working with science teachers and students to build the science knowledge needed to protect natural capital. It can now be argued that post-normal science is uncertain, better served by *citizen-science*.

Argument C: *Citizen-Science*, Post-Normal Science and the Value of Uncertainty

Thinking with uncertainty in mind is highly valued by the environmental sciences, which is consonant with post-normal science described in argument B. In contrast to Kuhn's (1962/1970/1996) normal science that is regulated by the certainty of normal scientists, post-normal science recognizes that high uncertainty requires the extended peer review, to whom science teachers and their students are an important and relevant part. Now, I turn to argument C to argue that ecojustice is reciprocally supported by uncertain science, which is democratized by *citizen-scientists.* Citizen-scientists think with uncertainty in mind. Thus, it makes no difference whether a person assumes the role of a scientist or philosopher or any other citizen for that matter, to participate fully in local decisions. This point takes the responsibility for what scientists do and how science is applied and places it firmly where it belongs—on everyone's shoulders, to construct and democratize.

The phrase *citizen-science* emphasizes that citizens should not be separated from science, and that science should not be separated from citizens: citizen-scientists must work with uncertainty thinking in their everyday lives. To develop this point, I turn to *The Meaning of It All: Thoughts of a Citizen-Scientist* (1998)—a book on Richard Feynman's 1963 lectures at the University of Washington. Beyond being recognized as a *citizen-scientist*, Feynman (op. cit.) was considered a remarkable educator, public man, radio repairer, lock pick, artist, dancer, bongo player, and decipherer of Mayan hieroglyphics, according to his biography. Science, for Feynman (op. cit.) has the power to do great things and should not be avoided just because it lacks instructions for how to use it wisely. He notes that the struggle to think of how best to use science is a worthwhile endeavor. When science is a citizen-scientist pursuit, the notions of being a citizen and being a scientist are complementary. All people have the ability to use science in their everyday lives—it is simply a matter of finding things out (i.e., scientific inquiry).

For Feynman (1998), citizen-science is multifarious. The citizen-scientist does not try to prove they are right, they try to find the exceptions to rules, as many as possible. He notes that there are no absolutes and points out that the scientific process cannot be universally applied to all human situations (i.e., scientism). The citizen-scientist relies on all aspects of thinking, including philosophy and other multidisciplinary perspectives and methods. Feynman (op. cit.) elaborates: "in any decision for action, when you have to make up your mind what to do, there is always a "should" involved" (p. 17). Without *citizen*-science, the scientist would be very limited by the cultural illusions of neutrality and unbiased outcomes that come with the emphasis of exclusive rationality. Because of the complexity and uncertainty inherent in finding things out, "there is no authority who decides what is a good idea" (p. 21). Feynman (op. cit.) continues by saying that "most people find it surprising that in science there is no interest in the background of the author of an idea of in his [or her] motive in expounding it" (p. 22). If ideas originate with all people, then citizen-scientists need equal opportunities to contribute new ideas and to be taken seriously in science; citizen-scientists may find new exceptions to scientific ideas, which is the exciting part of doing scientific work (i.e., subject to being wrong).

According to Feynman (1998), the search for universality stimulates the *scientific imagination*, which he defines as thinking of something that is completely consistent with what is already seen and yet completely different from what has been thought of. Making guesses is not unscientific—it is just an example of uncertainty thinking. Science is "universal" to the extent that it is constantly subject to exceptions, which is the necessary contradiction of thinking with uncertainty in mind. Because nobody knows for certain, there are always great departure points within every perspective and subsequently, the real value of uncertainty thinking is being open to knowing even when you think you know. Uncertain science is essentially always in process.

Feynman (1998) argues, "it is necessary and true that all of the things we say in science, all of the conclusions, are uncertain, because they are only conclusions" (p. 26). As uncertainty thinkers, we might never stop looking in all sorts of directions for ideas. Feynman (op. cit.) explains that "the rate of the development of science is not the rate at which you make observations alone but, much more important, the rate at which you create new things to test" (p. 27). The key point is that authentic, real-world science can not be any certain way. Accordingly, there is freedom to doubt linked with the responsibility to thinking with uncertainty. Feynman (op. cit.) puts it this way:

> I feel a responsibility as a scientist who knows the great value of a satisfactory philosophy of ignorance, and the progress made possible by such as philosophy, progress which is the fruit of freedom of thought. I feel a responsibility to proclaim the value of this freedom and to teach that doubt is not to be feared, but that it is to be welcomed as the possibility of a new potential for human beings (p. 28).

Feynman (op. cit.) recognizes that science provides the freedom to doubt what is constantly uncertain and irreducibly complex; the citizen-scientist is recognized for their creativity and creation of new and exciting investigations into the ecological unknown.

Uncertainty thinking justifies the need for many diverse perspectives, which enhances the democratic decision-making processes. Uncertainty and doubt are intimately linked with democracy and open-minded and open-ended conversations. Feynman (op. cit.) further explains that “no government has the right to decide the truth of scientific principles, nor to prescribe in any way the character of the questions investigated” (p. 57). Rather, he continues, government “has a duty to its citizens to maintain the freedom, to let those citizens contribute to the further adventure and the development of the human race” (p. 57). It might be argued, that the National Science Foundation (NSF), which is a major scientific research funding institution and an arm of the U.S. government, has a great deal of control over which projects are selected. Yet, NSF grants are decided by the peer review of people independent of the institution, and many different people share responsibility for democratizing science and education. Grant reviewers also do not work at the institution that employs proposing researchers, and more than 50,000 people typically participate each year (http://www.nsf.gov/). Promising frontiers of science are often highly uncertain. Previous NSF grants have been awarded to fund scientific research projects that demonstrate a commitment to increase the health and well being of people and the Earth. For example, NSF funding supported scientific research projects that led to the development of *nanotechnology* (i.e., science and technology on the scale of a nanometer), which has environmental benefits such as water purification, artificial photosynthesis of clean energy and pollution control systems.

If science teachers and their students are embraced and valued as pluralistic members of society, or citizen-scientists, they also should be included in these decisions. As citizen-scientists, science teachers and students should be afforded the freedom and professional autonomy to think with the uncertainty of the natural world, which is now constrained by public school districts. Since local people are the school district, we have a responsibility to afford science teachers and students the freedoms and professional autonomy to think with uncertainty in mind. Thinking with uncertainty provides an equal opportunity to work with other community professionals to find out new things, which cultivates people and places knowledges. Place-centered knowledges help science teachers and students to participate more fully in local decision-making. In turn, science teachers and their students will be empowered to share in the responsibility of society to democratize science and the uses thereof.

Although Bowers' (2001, 2006) ecojustice philosophy supports the democratizing of science and technology, uncertainty thinking is a better fit for ecojustice and provides opportunities for science teachers and students to confront the enclosure of the commons: enclosure takes the form of certainty thinking when it limits pedagogy. Without uncertainty thinking, science teachers and students could easily dismiss the value of including multiple perspectives, methods and criteria, personal expectations, beliefs and values, and place-centered narratives. Citizen-science invokes a full spectrum of thought: mystery, spirituality, creativity, initiative, open-mindedness, conviction, the freedom of doubt and democracy. According to Feynman (1998), the meaning of it all is that science is inherently uncertain, and thus, science is more aligned with a post-normal paradigm that highly values uncertainty, which is subject to the extended peer review community.

Argument D: Analyzing Choices and Making Evidence-based Decisions

Now that I have established that uncertainty thinking is an essential aspect of how *citizen-scientists* deal with the ecological unknown, I will analyze the underlying theory of how uncertainty thinking works for environmental scientists—argument D. Uncertainty thinking is equated with democratizing place-centered science, which involves situated thinking and ethical evaluation. Argument D is the last component of my theory of uncertainty thinking in place-centered science education for ecojustice. At this point, I connect with Henry Pollack (2003/2005), who is a geologist at the University of Michigan. His book *Uncertain Science…Uncertain World* (op. cit.) helps me to demystify the uncertainty of science. He notes that uncertainty thinking puzzles many people, mainly because the answers to scientific issues are never straight forward and almost always contain possible contradictions. Pollack (op. cit.) provides a conceptualization for how science thinkers work with the Earth's high uncertainty and complexity. I will explore his work to discuss how science teachers and students can be prepared to think with uncertainty and to effectively impact local choices.

Choices are often made in the absence of certainty or choices simply endorse the *status quo*, which is consonant with precautionary and post-normal perspectives. Pollack (2003/2005) notes that predictions of the future, in science, are seldom accurate and mid-course corrections are invoked continuously to realign aims. Despite the challenges, uncertainty thinking in science is the stimulus of creativity and ingenuity and "science is an important, accessible, and empowering part of everyone's world" (p. 4). Great scientific successes in the environmental sciences are the result of learning to deal with nature's uncertainty.

Unfortunately, there is a tendency to assume that science leads to certainty. Pollack (2003/2005) notes that people have been "conditioned by the highly precise and accurate predictions of eclipses, of the daily progression of ocean tides, of the exact times of the local sunrise and sunset, of the clockwork precision of a spacecraft landing on a distant planet" (p. 6). When things do not happen with certainty, the underlying science may be written off completely (e.g., evolution and global warming). Because uncertainty and unreliability are accompanied by discomfort and unease, the high uncertainty of the environmental sciences may lead people to discredit science to advance their agendas. In turn, uncertainty thinking might evoke controversy, conspiracy theories, skepticism, and legitimize other sources of "certainty" (e.g., telepathy and clairvoyance).

Because science is an uncertain-creative process of finding out new things, science often elicits an agreed-upon process acknowledging uncertainty and falsification, coherent peer review, peer-reviewed journals and conferences where debates occur. However, uncertain science is always in-process, open to changes, and never guarantees certainty or soundness. Pollack (2003/2005) explains that "*uncertain* science, *unsettled* science, is hardly the same as unsound science. The normal state of affairs in science is unsettled and uncertain, and no amount of new research will completely eliminate uncertainty" (p. 16). A major part of the scientific process is being open to learning new things about the uncertainty of the process. In this regard, Pollack (op. cit.) notes that young children start out naturally curious in the uncertain world only to be stifled when they get to schools where the certainty of science facts and concepts eclipse the creative and uncertain process of finding things out. He places the blame on the "testing, testing…" priorities of educating youth (pp. 18-22) which deemphasizes or ignores the importance of developing process skills in science education: “how to observe carefully, how to think critically, how to deal with conflict, how to develop teamwork” (p. 19).

My suspicion is that because science education has not historically prepared young people to democratize science and education (i.e., which is not considered *the* priority in schools), the dilemma of today’s educational situation is inadvertently perpetuated. Ironically, science teacher educators and science teachers will often ask students what contexts of scientific knowledge matter most in their everyday lives, and work to contextualize the decontextualized national and state priorities that prescribe what students should know. Next, teachers and students return to the decontextualized knowledge to measure the success of their educational efforts. It follows, that the disjunctive process of making science education relevant to the lives of people in the community (NRC, 1996), and then having to privilege the decontextualized exams as the measure of success in schools is not altogether commonsensical. If youth were prepared as *citizen-scientists*, where community-centered knowledges are considered a priority, then perhaps the high priorities of “testing, testing…” would be less favored by policymakers and property owners (i.e., property values based on schools’ test scores).

Science knowledge is sometimes abstract and not easily accessible when people think in terms of their everyday life experiences. Thus, science also requires that people think beyond their own situations. For example, scientific issues such as global warming may be too difficult to comprehend without an understanding of how incremental things in our everyday lives can affect the larger picture. Pollack (op. cit.) notes: “in a modern context, when humans are asked to consider the concept of global climate change, a phenomenon that is planetary in scope and which operates on a time scale that exceeds political term limits, generations and life spans, there is a hesitation, even skepticism, that arises because it is outside the realm of ordinary experiences derived from day-to-day living" (p. 44). Global climate change evokes a precautionary approach because it is difficult to discern from the limited views of places that experience fluctuations in the weather. Because weather is what happens on a daily basis and climate is "the long-term characterization of the 'average' weather" (p. 46), climate is linked with regions of the world (e.g., Mediterranean) and is described in terms of seasonal temperature variability, kinds of precipitation, and the annual number of rainy, snowy and sunny days. Moreover, global climate change is linked with high uncertainty because of the slow incremental temperature changes (i.e., seasons, day-and-night, regions). The danger of being able to control the climate in houses (i.e., heating and air conditioning) is that people lose touch with the incremental climate changes of the natural world and make the assumption that the weather occurring in their neighborhood is likely to happen everywhere else.

If, to make well-informed choices, science teachers and students need preparation in knowing how to interpret the incremental changes of the Earth's wild ecosystems, then deciphering how best to prepare science teachers and students to make choices in the face of uncertainty is an appropriate and significant aim. When faced with uncertainty, some confidence can be established by being open to knowing even when you think you know, and thinking with confidence can be accomplished by reducing observation noise, increasing measurement sensitivity and using multiple measures (Pollack, 2003/2005). However, Pollack (op. cit.) explains that the precision and accuracy of measurement, calibration and repeatability emphasized in students' textbooks may not adequately address the encompassing issue of how to put the parts of a puzzle together or interpret the larger picture.

Analyzing the larger picture is a significant aspect of thinking with uncertainty. Pollack (op. cit.) uses the following analogy to clarify this claim:

> The pointillist style of painting, so well developed by the French artist George Seurat (1859-1891) is at close range just a collection of paint daubs. From a distance, these dots merge to become a representational picture and work of art (p. 78).

This analogy illustrates how comparing some grounded certainty at one point with many diverse points, as well as gaps and errors, can help to interpret a larger picture. However, it is important to remember that uncertainty is ever present in the larger picture because the aggregated data hides specific data points that are not accessible, limited in some way, or consciously excluded. And yet, the large representation of different data points helps with deciphering how much uncertainty to account for (i.e., margin of error), which (back to the ecological perspective) builds into the cumulative experiences of carrying out local ecological decisions.

There are many possible paths to follow for collecting and analyzing specific data. Statistics and probabilities may be used to establish probabilities or estimates of likelihoods or to help rank decisions, and yet they should not be used exclusively to make generalizations or decisions across contexts. Pollack (2003/2005) explains that "in much of probability theory, every event is considered an independent event, and not conditional on another event" (p. 92). To reduce uncertainty, Pollack (op. cit.) notes that science conceptualizations and investigations are the ebb and flow of undertstanding the conflicting, incomplete, inaccurate and highly uncertain aspects of natural systems. The process of dealing with uncertainties associated with the complex behavior of ecosystems is a fluid, back-and-forth motion: it includes observing the complex behavior of ecosystems, developing models/concepts, observing them again, and further developing the models/concepts. Pollack (op. cit.) notes that "when this fluidity is lost, for example when a scientist promotes or adheres to a concept in the face of considerable evidence to the contrary, or places too great a reliance on observations that are inaccurate or irrelevant, then progress stalls" (p. 105). The vast majority of science thinkers work with a few parts of the whole: recognizing the difficulty of dealing with the entire system, they work to develop a model/concept that is representative of a few interactions. In the process of working with parts, more uncertainty is revealed, because even significant parts are less than the whole. Uncertainty arises as diverse thinkers perceive differently, weigh evidence differently, and develop different conceptualizations and investigations.

Flawed conceptualizations may impede understanding, and therefore, cause greater uncertainty. Flawed conceptualizations include Ptolemy's geocentrism, the notion that humans evolved from monkeys and the flat-Earth hypothesis. Another example of a flawed concept is, as Bowers noted in chapter two, that science is inherently progressive. When addressing the cultural assumptions of science, new uncertainties are likely to arise and new pathways are subject to changes and complexity. However, conventional wisdom also may impede new ideas because "rejecting or challenging the conventional wisdom is an act that replaces apparent certainty with disconcerting uncertainty" (Pollack, 2003/2005, p. 119). Thus, consensus viewpoints hold the danger of blocking scientific achievements and may be simply based on “wishful thinking”—or allegiance to particular ideologies such as the cultural myth of ecological crisis.

Wishful thinking (which is consonant with certainty) is a well-known danger in science. It is seldom an effective long-term strategy, especially when it deemphasizes or ignores the science that supports alternate views. For example, Pollack (2003/2005) explains that the fossil fuel age may be over well before fossil fuels are ever depleted:

> In the long sweep of human history, both past and future, the era of fossil fuel reliance will be seen as a temporary crutch during the interval when humans learned how to harness and concentrate the virtually endless radiative energy delivered directly to Earth by the Sun. Fossil fuels such as coal and petroleum are, in fact, nature’s somewhat clumsy and inefficient products in which is stored the solar energy of the past, in the form of fossilized vegetation and microorganisms, appropriately decomposed and recomposed through cooking while buried in the Earth’s crust (p. 121).

Pollack’s (op. cit.) open-mindedness and explanation of conceptual frameworks reminds us to welcome the uncertainty thinking of knowing that what you know is always open to change. As new science knowledge develops, new uncertainty emerges and will require citizen-scientists to become informed to democratize it. The process of becoming informed must be an increasingly shared responsibility if the democratization of science and technology is to occur, which is the aim of ecojustice education.

When the outcome of investigations sometimes conflicts with the investigator’s preconceived notions, it can be difficult to abandon the preconceived notions. Pollack (2003/2005) explains that “there is a tenacity with which some experimenters hold on to their initial ideas, even in the face of experimental evidence that suggests, or even shouts, for a new conception of the way the system works" (p. 130). Several historical examples include Giordano Bruno (1548-1600) and Galileo Galilei (1564-1642), who were instrumental in advancing Copernicus' theory of heliocentrism, and Alfred Wegener (1880-1930) who put forth a theory of continental drift (Gribbin, 2002).

Despite these challenges, science investigations help with high uncertainty by narrowing the range of reasonable choices. For example, Pollack (2003/2005) notes how the inside of the Earth is uncertain, and yet the possible structure can be deciphered by analyzing earthquake waves that travel through materials with different pressures and temperatures. Because researchers cannot travel to the Earth's center to personally observe the rocks and minerals along the way, they must rely on science investigations of the way that rocks behave under pressure and heat by testing rocks in giant presses and then heating them to different temperatures to simulate the Earth's interior. Moreover, these investigations are always uncertain because they cannot represent the ways in which rocks are actually squeezed in parts of the Earth's interior. However, these investigations help with inferences about what the interior of Earth is *not* made of. Although the Earth's interior remains highly uncertain, scientific researchers can use seismic and laboratory data to make confident and well-informed statements about the Earth's interior, and well-informed decisions.

While the sciences typically privilege choices that are evaluated on what is considered "evidence-based," there is nothing magical about evidence-based decisions other than they are another avenue to making decisions with more mystical confidence. Because evidence is an extrapolation of what is either learned in the science laboratory or in the field, it is limited by caveats because what is learned never reflects universally what is happening in the real world (i.e., the millions of years that Earth takes to do what it does). Pollack (2003/2005) notes, the "obvious fact that the Earth does not fit easily into a laboratory and that humans do not have the luxury of time to conduct experiments at the pace of natural processes" reminds us about how difficult it is to work with the changes and complexities of the ecological world (p. 132). In 1907, for example, Albert Einstein posited a theory of general relativity (i.e., gravitation ascribed to space-time curvature), which supersedes Sir Isaac Newton's laws of universal gravitation (i.e., gravitation ascribed to force). Thinking about almost every theory requires investigators to adopt metaphysical assumptions (i.e., the underlying principles of theoretical work), and yet metaphysical assumptions are inherently uncertain. But, it might be argued, that adopting metaphysical assumptions is necessary from a scientific standpoint, but not from a philosophical standpoint because some philosophers seek *the* Truth. An epistemological perspective that values uncertainty and continues to heal the split between ecological philosophy and science recognizes that humans can only be partly certain in relation to others (Code, 2006; Thayer-Bacon, 2003). Ironically, Newton's laws of gravity continue to be represented in a large number of public school textbooks in the U.S., which suggests that Newton's theorem is still embraced as if it were a certainty. If theory did not have to be tested against the world, it could be absolutely certain. But since it does, even Einstein's theorem is subject to being superseded in the future (as was Newton's).

The responsibility of becoming informed means becoming comfortable with making decisions in lieu of high uncertainty, constant changes and irreducible complexity—the goal of science education for everyday life. Science conceptualizations and investigations, such as thought experiments and laboratory investigations, and the Earth's natural unfolding processes and events, are reprieve with uncertainties. The paradox is that the more conceptualizations and investigations represent what is occurring in the natural world, the more uncertainty that is likely to be experienced. In other words, the closer citizen-scientists get to what they are trying to investigate, the more their understanding will be influenced by the uncertainty of Earth's changes and complexity. Environmental scholars such as Rachel Carson (1955/1983, 1962/1994), Aldo Leopold (1949/1968), Henry David Thoreau (1962), and John Muir (1987/1997) are pertinent examples of how thinking in Earth places in relation to others heightens ecological consciousness when faced with the high uncertainty of nature.

In the face of the ecological unknown, Pollack (2003/2005) notes that keeping an open mind is better than succumbing to an ideological perspective. He compares thinking with uncertainty to playing video games. When people play video games, they encounter differing circumstances or terrains, which strengthen thinking patterns and behaviors over time. Better players will assimilate the lessons of these multiple experiences and develop "patterns of play that respond successfully to broad categories of circumstances" (p. 196). Pollack (op. cit.) notes that the game of "what if" science investigations is similar and seeks to understand the particular vulnerabilities of environmental situations. He explains that by analyzing different environmental scenarios and potential risks, we become more sensitive to new challenges, changes and complexities. In turn, we use what we know to make better and better decisions by learning to think with uncertainty in mind.

There might be an explanation for how uncertainty thinking differs from keeping an open mind, and yet Pollack (2003/2005) does not offer it. Although Pollack (op. cit.)

mentions that social, political, and ethical evaluations are part of the process of science, he deemphasizes why we should advocate and care for particular agendas and not others. An essential element of uncertainty thinking has been missed. To resolve local issues, such as which local flora and fauna should be legitimately conserved and sustained, science teachers and students as citizen-scientists/stakeholders, must work with social, political, and ethical judgments and learn to advocate and care for others and the Earth. Environmental science, however, deemphasizes the importance of being an advocate and caring for unrepresented others, who may not be able to participate in local decisions. The final component of my argument D for uncertainty thinking is to demonstrate that ethical evaluation, which will be aligned with Thayer-Bacon's (2003) *caring reasoning*, helps position citizen-scientists as essential advocates for the local community and ecosystems, which extends democratic decisions to legitimized others and the Earth.

Caring Reasoning and Ecological Advocacy

Here, I argue for the shared responsibility of science teachers and students as citizen-scientists, or local stakeholders and advocates for the places where they live. Thinking with uncertainty involves ethical considerations as a large part of the process of science. In *Relational (e)pistemologies* (2003), Barbara Thayer-Bacon argues for the plurality and relationality of knowledges, without working towards the universal notion of certainty. Thayer-Bacon's (op. cit.) epistemologies are situated somewhere. Her work is multidisciplinary and moves in the direction of developing an integrated, holistic *ecological pragmatism* (i.e., my term of description). Her work has helped me to position teachers and students as grounded and transactional individuals in relation to others and in relation to the Earth. Qualified relativism (as noted in chapter three) helps the local authority of the commons make decisions about what is right for particular places, which requires caring for others. Thayer-Bacon (op. cit.) notes that *caring reasoning* means making decisions "that we value the other enough to notice it and try to understand it" (p. 120). By "other," she means the cultural plurality of people and ecological plurality of the natural environment.

Thayer-Bacon (2003) notes that caring reasoning "not only plays a vital role in moral orientation . . . but it also is vital to a nontranscendent (e)pistemology" (p. 119). She explains how caring reasoning functions to help people to pay serious attention to others. Because we intuitively care for and pay attention to certain things and not others, thinking with uncertainty requires that we pay attention to the uncertainty and complexity we might not value. For example, I care for the wild habitat in my backyard, whereas a neighbor might perceive it as a messy yard that needs mowing to protect property values. Thus, we are reminded that others are rejected in our effects to selectively attend. At first, we commit to others by suspending judgment, and yet caring reasoning helps us to focus on the qualitative aspects of our experiences which become the basis of evidence for deciding how involved we want to become. Caring reasoning is inherently uncertain, and what we pay attention to is strongly situational. Because we are embedded in many different cultural and environmental situations and may belong to multiple communities, caring reasoning helps us to sort out what, when, how and why to pay attention. Since we think in places, we care for what we are surrounded by and compare other places to what we know and what we come to know in the future. Place-centered and contextualized experiences help to ground our lives and adapt to changes, complexity and uncertainty.

Caring reasoning helps us to attend to our limitations, personal expectations, intergenerational knowledges, beliefs and values, and local place-centered narratives. While Bowers' (2001) ecojustice recognizes the local authority of peoples and places, it may not resolve oppression because it does not argue for places in relation but rather for *the* same crisis everywhere. Whereas, caring reasoning emphasizes the process of dealing with oppression in places in relation to other places working with the local authority of the commons, including but not limited to ecologists, wildlife biologists, and other scientists. Not mentioned in ecojustice reforms are the scientists' perspectives, which are needed to help science teachers and students address what can be conserved and what may be detrimental to the community and local ecosystems. Because species distributions are abruptly changing and uncertain, a places-in-relation-to-other-places approach is much better for making ecological decisions that affect the community and the viability of the local ecosystems. Caring reasoning is a natural fit for ecojustice because it provides someplace for the consideration of cultural thinking patterns and behaviors.

It is only because we are embedded in someplace(s) that we can legitimately argue that the places where we live are becoming more denigrated in relation to others. How would we ever know to protect North American pollinators (NRC, 2007), for example, if we did not know that they are healthier in ecosystems elsewhere or had been healthier in our past (i.e., history of the same location gives us a way to compare too)? Thus, caring reasoning helps us to understand that disparities need to be addressed in the world. It helps us to evaluate those disparities and critique and imagine what is right for someplace and perhaps what may not be right for other places. But, it might be argued, that there are many disparities in the world with differing hierarchies or priorities. How will we know which disparities to attend to, for example, “what counts” for some and not others? Because these choices are subject to the situations and democratic practices of local people, caring reasoning recognizes the similarities and differences of perspectives. Most importantly, what is advocated and cared for between places almost always differs, which warrants a perspective focused on how we live together. While caring reasoning, or local ecological advocacy, is devoted to the particularities of people who live somewhere, it does not deemphasize the interests of others by acknowledging that human beings are both partly certain in places in relation to others and in relation to the Earth.

While caring reasoning now aligns with the local authority called for by ecojustice, it goes a step further with the idea of communities-in-relation advocacy. Thayer-Bacon (2003) notes: “caring reasoning highlights our commonalities and our interconnectedness with each other. Caring reasoning allows us to use our hearts and our minds, to openly embrace others as well as critique others. We cannot fairly critique until we have lovingly perceived the other” (p. 211). Thus, caring reasoning differs from other forms of evaluation in that it extends the democratic decision-making of the community to other affected parties, which includes the Earth’s ecosystems, which may be excluded.

Ethical reasoning can be found in the scientific community. For example, the preparation of environmental scientists now includes courses in environmental ethics, and philosophy is being taken much more seriously than in the past. Moreover, scientific institutions are now using ethical evaluation to engage in the environmental sciences. For example, the *Manual for Addressing the Ecological and Human Health Effects of Genetically Modified Organisms* (1998) by the Scientists Working Group on Biosafety at the Edmonds Institute (Seattle, Washington) notes that the genetically engineered organisms (GEO's) will improve agricultural crops and crop yields, plant susceptibility to insects and diseases, and cultivate microbes for bioremediation that can be used for projects such as environmental cleanups, and yet genetic engineering may also lead to environmental hazards to human health and hazards. The Scientists Working Group (op. cit.) explains that there are high uncertainties with GEO's: changes may include but are not limited to growth rates, reproductive outputs, tolerances to physical and chemical variables, hybrid organisms, and the allergenicity, toxicity, and nutritional composition of foods. The risks linked with these changes may include new evolutionary competitions, gene transfers, human well-being, and unforeseen ecological surprises. Because of the potential dangers involved with GEO's, the Scientists Working Group (op. cit.) advocates careful scrutiny, or biosafety assessment, which "systematically examines the potential consequences of the deliberate or accidental release of a GEO and does so with sufficient thoroughness to enable a reasonably confident determination of whether the particular GEO can be used safely" (p. 5). Working with GEO's requires something not always acknowledged as scientific work—the anticipation of the effects of research on the cultural and environmental milieu (i.e., the preponderance of care, concern, and commitment).

Beyond the environmental sciences, in epidemiological work, for example, scientists evaluate ethical, political, and social issues associated with attempts to eliminate diseases, improve patient care, and use resources more effectively (de Melo-Martin & Intemann, 2007). There is a broad agreement to eliminate racial disparities to improve healthcare for racial/ethnic minorities. Scientists evaluate genetic differences across racial/ethnic populations to understand why particular races/ethnic minorities are susceptible to particular diseases or respond differently to medicines and other treatments. Defending racial/ethnic categories in research to reduce racial disparities "requires scientists to evaluate political and social factors that bear on the efficacy of genetic knowledge" (p. 217). de Melo-Martin and Intemann (op. cit.) provide several examples of why "the extent to which genetic research can help reduce health inequalities depends in part on the context in which these strategies are employed" (p. 217). If racial/ethnic populations do not have access to genetically tailored drugs, for instance, then these drugs do little to remedy health inequalities stemming from racial/ethical genetic differences. Epidemiologists must make ethical evaluations with respect to the research programs that will generate greater future outcomes and diminished health disparities in the long term, which is consonant with caring reasoning because epidemiologists are advocating for affected people who may otherwise be excluded.

de Melo-Martin and Intemann (op. cit.) point out that they are subject to the criticism that scientists should not be involved in the political aims of scientific research. However, they reject that assumption based on the notion that scientists are not involved so much in the policymaking, as they are involved in reducing health disparities. They note that the "aim of research on health disparities is not just to accurately describe health differences or determine their cause, but to do so in a way that will be useful to making predictions, preventing greater disparities, and improving human health" (p. 218). Scientists will make value judgments about what kinds of data to collect, how that data should be measured (regardless of whether race is socially constructed or biological), and how to compare data to monitor and track improvements or reductions in health disparities. While race/ethnicity provides a useful category for epidemiology work, other categories may include “genetic markers, drug metabolism, disease incidence, socioeconomic status, education, or exposure to environmental hazards” (p. 219). However, without the socio-cultural contexts of racial/ethnic injustices, then the value judgments do not accurately represent the aim of trying to reduce health disparities.

Science education for ecojustice will need to prepare scientists, science teachers and students to think with uncertainty, which involves social, political, and ethical views. de Melo-Martin and Intemann (2007) explain that “epidemiologists often must consider and endorse certain social or political aims of the research and determine how their research can best help promote those aims” (p. 219). They propose that scientists make explicit the ethical decisions involved to engage in better scientific research and explain: “we are not arguing that training in ethical reasoning is good for epidemiologists because this would make them more conscientious human beings. Our point is that it will make them better scientists” (pp. 219-220). Moreover, scientists will be better positioned to evaluate whether the value judgments result in reducing health disparities and whether resources are being allocated appropriately. de Melo-Martin and Intemann (op. cit.) conclude that “scientists should not present their results as if they were value-neutral, when in fact, they are not” (p. 220).

Relying on value judgments to engage in the complexity and uncertainty of scientific work is not new to scientists who recognize scientific work is highly uncertain. In the practical world of scientific work, ethical evaluation has always been a part of making convictions to this or that research agenda. As noted, the early 20th century scientists had to decide whether funding mattered to them when they picked research goals, resulting in less theory work in science. I face the same dilemma today, as an ecological philosopher in science education where philosophical work is less funded and less acknowledged as research than empirical work (i.e., quantitative and qualitative). The Association for Science Teacher Education, for example, lists "philosophical essay" as a separate category from "research study" for submitting conference paper proposals. Separating philosophical work from "research study" perpetuates the cultural myth that "scientifically-based" educational research somehow does not include theory work, which is oppressive for educational philosophers and other scholars who analyze ideas. This false dichotomy creates a hierarchy that legitimizes the high-status of "what counts" in science education, which reinforces certainty not found in the environmental sciences. Science education that fails to recognize philosophical work does not advocate or care for the work of philosophers and fails to recognize that science education is highly uncertain. This disregard for theory has been found within hundreds of reviewed science education studies that do not support their theory frameworks (Abd-El-Khalick & Ackerson, 2006).

Moreover, notwithstanding the philosophy of science and education, value judgments have long been deemphasized or ignored in science education research studies. To advocate and care for something or someplace, a person must become contextually exposed, however, the more contextualized and place-dependent science/science education becomes, the more it may result in devaluation, less funding and less prestige. The more science education invokes certainty claims that were used to obtain funding in the early 20th century, the more science education must be like the "high-status" sciences. Thus, physics and chemistry are still viewed with higher-status than the environmental fields (biology, ecology, geology, ecological philosophy, the environmental arts…), which is perpetuated by the hierarchies still reinforced in public high schools across the nation that determine if particular courses are taken by students and during which years.

Ethical considerations are now being viewed as an essential part of the scientific process by the scientific community, as environmental scientists rely on the explicit endorsement of particular value judgments to decipher new directions for science. However, in science education, where the wheels are slow to turn, science teachers and students are seldom prepared to engage in a scientific process that acknowledges the importance of ethical considerations when confronting the high uncertainty of the Earth. Because uncertainty thinking is now highly valued in post-normal science and aligns well with the overarching goal of helping people to use science to make decisions, it aligns well with the importance of ecological pluralism in ecojustice philosophy and education, which values renewing and revitalizing the cultural commons. My suspicion is that ecojustice studies will continue to decipher how philosophy informs the work of environmental scientists, science teachers and students. In addition to evoking powerful science questions and investigations, further efforts to heal the split between ecological philosophy and the natural sciences may prove to be an interesting way to investigate ethical, political, and social values as part of scientific and science education work.

To define uncertainty thinking, definitely, would undermine other concurrently developing ideas that may enlarge, enhance, and expand a theory of uncertainty thinking. Uncertainty thinking values other peoples' voices (i.e., past, present, and future), multiple criteria and methods, beliefs and values, and place-centered narratives. Uncertainty thinking is both situated and democratic: there is no limit to what can legitimately support uncertainty thinking and that is the real beauty of using a theory of uncertainty to amend and extend ecojustice. However, to narrow the choices and to make confident, well-informed statements, or grounded truths, uncertainty thinking should be focused on people thinking in places in relation to others, which pragmatically justifies and qualifies thinking with uncertainty in place-centered science education for ecojustice. Perhaps the emphasis should be on what uncertainty thinking is *not* (e.g., generalized and decontextualized, universal notions of certainty in science and science education). These claims are argued with the hopes that other scholars will pick up my work and continue the conversation, perhaps disagree entirely, but continue the conversation nevertheless. Moreover, the prize for the ecojustice thinker-activist is the continued development of how the commons might be protected from uncertain enclosures. Now that uncertainty thinking in science plays a vital role in ecojustice, protecting the democratic process of uncertainty thinking is the essence of ecojustice-centered philosophy and education.

Summary

Thinking with uncertainty allows people in places in relation to others to decipher the meaning of renewing and revitalizing the commons and whether it is right to do so. Yet, the common grounds for ecojustice are pragmatically-centered on preventing enclosures. It is irrelevant to discuss whether ecojustice has essential anthropocentric tendencies—almost all species will strive to survive and reproduce. Earth's natural history indicates that survival and reproduction is a part of the evolutionary process spanning millennia. I have shown that reducing uncertainty is something humans do to survive and reproduce. Consequently, cultural narratives and meta-narratives emerged that generalized and decontextualized the uncertainty of Earth's constant changes and irreducible complexity. Aristotle linked thinking with certainty to mankind. The certainty thinking associated with science was firmly established in the time leading up to the term "scientist" in 1840. Thinking with certainty inadvertently perpetuates the notion that the Earth is stable, fixed, limitless, unchanging and noncomplex. And yet, the natural world is constantly evolving in highly uncertain and irreducibly complex ways, which cannot be reduced to certainty. My first argument A, established that the development of narratives and meta-narratives have commensurate environmental costs, and that certainty thinking is a meta-narrative that has contributed significantly to accelerated ecological declines.

My next argument B showed that the environmental science underpinning ecological declines is highly uncertain, which is most aligned with post-normal science. Post-normal science is subject to the extended peer review community, which includes citizen-scientists. Part of this argument was intended to show that ecological philosophy and ecology science cannot continue to be dichotomized by ecojustice-centered activities. I connected with other scholars to demonstrate that a precautionary approach is necessary for helping community and environmental stakeholders think with uncertainty. Adversely, uncertainty thinking is deemphasized or ignored in science reports produced for policymakers and the general public, which is a direct reflection on science education. Science literacy that empowers people to become informed and participate fully in local decisions is the meaningful purpose of science education, which necessitates uncertainty. Post-normal science is the perspective most aligned with uncertainty thinking, and post-normal science is taking hold in science education shifting towards citizen science. However, citizen science must embrace and value individuals-in-relation-to-others, without minimizing peoples' differences in relation to similarities (i.e., human-nature). Uncertainty thinking repositions *citizen-science* as something that involves all people.

Thus, I showed that science teachers and students have legitimate knowledges, observations and place-centered narratives, and should be included in local decisions. Students' place-centered knowledges, in particular, cannot be displaced or students will not be empowered to participate more fully in thinking in places in relation to others. As citizen-scientists, I showed through argument C that science teachers and students should share some of the responsibility for democratizing uncertain science. The uncertainty of science-in-process is multifarious and subject to being wrong, which is the exciting part. What fun would it be to engage in a science and science education that is already certain? The necessary paradox of thinking with uncertainty is that it both incrementally reduces uncertainty and fosters more uncertainty, accompanied by creativity and imagination. The freedom to doubt uncertain science extends the democratic process to science teachers and students, who are valued as legitimate pluralistic members of the science community.

Finally, argument D analyzed a theory of uncertainty thinking in the environmental sciences and posited that thinking with uncertainty is democratizing place-centered science and science education, which is situated and includes value judgments. I showed that the uncertainty thinking of the environmental sciences is stifled by schools. There is nothing special about "evidence-based" science, with the exception that it may be provided more legitimacy than other types of cultural mysticism (i.e., meta-narratives). Metaphysical assumptions underpin human constructed narratives and meta-narratives, which are always subject to being amended or extended at some point in the future. The goal of becoming informed is becoming comfortable with the Earth's high uncertainties. Keeping an open mind is a large part of interpreting the larger picture, but caring reasoning is also necessary if citizen-scientists will advocate and care for local places. Expanding the current notions of science and science education with uncertainty thinking will most likely ensure that every child will be preceded by ecojustice-centered ethics.

Chapter five will provide a summary of my work in the previous four chapters, and I will focus on recommendations for shifting towards uncertainty thinking in science education and ecojustice-centered projects and reforms. I will put forth an educational framework that values ecojustice and place-centered science education focused on relational foundations, which embodies thinking in places in relation to other places. I will use this framework to discuss more recent place-based versus place-centered reform. Moreover, I will provide pragmatically grounded examples of how uncertainty thinking helps science teachers and students, as citizen-scientists, to effectively evaluate ecological risks, projections and scenarios, and work with multiple stakeholders to legitimately conserve cultural diversity and the biodiversity of the geographic locations where they live. I also will discuss whether the Earth Charter Initiative should serve as a guide for shifting towards uncertainty thinking in science education for ecojustice. Finally, I will conclude this philosophical project with an imagined ecological problem, in which science teachers and students become informed and participate as stakeholders.

Chapter 5: Educational Implications

The previous chapter provided a theoretical framework to support uncertainty thinking that helps people think with some certainty in places in relation to the Earth. I made the case that epistemologies are narratives and meta-narratives of human-nature. These stories are subject to more or less certainty, depending on the particularities of local people and natural environments. However, generalized and decontextualized, universal notions of certainty thinking are not supported by ecojustice-centered projects (this chapter will provide some additional groundwork for this argument). Concomitantly, while certainty thinking may influence local decisions, it cannot be used to determine how to renew and revitalize the cultural and environmental commons, or even help in deciding whether it is right to do so. These decisions are subject to the democratic practices of local people who think with uncertainty in mind (i.e., place-centeredness, ecological valuations and advocacy), in relation to others and the needs of the Earth.

I will now return to answer the questions I sought to investigate in this philosophical project and then move on to establishing educational implications. This chapter first focuses on discussing a relational foundation for ecojustice and science education (i.e., place-centered education), which acknowledges the nature of uncertainty. I will align my educational implications with grounded examples to demonstrate that uncertainty thinking helps citizen-scientists (e.g., teachers and students) effectively evaluate ecological vulnerabilities and work with community professionals and other stakeholders to legitimately conserve cultural diversity and Earth's biodiversity, both in the U.S. and abroad. Then, an ecological issue will serve as the context for an imagined situation where science teachers and students become informed and share some of the responsibility for local decisions. Finally, I will point to several emerging ideas that run counter to an ecological philosophy of education warranted by uncertainty thinking. And, I will explore whether the Earth Charter Initiative (ECI) should serve as a guide for science education and ecojustice and I will highlight new directions for research.

A Relational Foundation for EcoJustice and Science Education

The moment one gives close attention to anything, even a blade of grass, it becomes a mysterious, awesome, indescribably magnificent world in itself. –Henry Miller

I began this dissertation with a discussion of a culture and community project that is used to help prospective teachers recognize and foster interrelationships in their local community, appreciate differences and similarities, and conserve and sustain cultural and ecological pluralism. These considerations collectively invoke ecojustice activism, or a movement to revitalize the commons, which is evident when students describe how working on their projects foster long-term relationships within their local community. One student, for example, explains how she spent hours working with her father on a part of her project, revitalizing a broken relationship from previous years. Another explains how she was recently married, leaving friends behind in another state, and developed a remarkable friendship with her mother-in-law while learning about a family tradition. Other students talk about exploring a “haunted” church in their community, and how they were scared out of their wits and laughed all the way home. Still other students took a hike in the woods and discovered “slave graves” that prompted further investigations. These activities demonstrate how students are sharing some of the responsibility for becoming informed about the interrelationships in their local community and ecosystems.

Ecojustice activism is also accompanied by uncertainty thinking. Students think with uncertainty when participating in decisions to protect the commons from enclosures. For example, one student was asked by her church to put her culture and community project on the bulletin board to share with other members, and another student was asked to display her project in the local historical museum. Other students discuss golfing with neighbors they now know, or passing on their newly learned knowledge to their children. One student notes he will continue to bake the “famous family recipe” that only three people now know, and another student notes how she became involved in efforts to preserve a local cave and increase a population of bats. Culture and community projects help my students to meet their neighbors, cultivate networks of community and self-reliance, appreciate their cultural heritage and traditions, and situate themselves within local communities and ecosystems. As prospective teachers, my students recognize their roles as learners, participants, and thoughtful uncertainty thinkers. The key point of my research was to further explore an emerging epistemology and ontology of uncertainty, an ecological philosophy of education that embodies the uncertainty of the Earth.

To work towards a theory of uncertainty thinking, I first established the need to analyze Chet Bowers’ (2001, 2006) ethical theory of ecojustice and recommendations. An underlying assumption of Bowers’ (op. cit.) philosophy was identified as cultural memories, or how language encodes and reproduces cultural knowledges over thousands of years of intergenerational experiences. The residual of these cultural memories is often taken for granted in vernacular languages, for example, when root metaphors of language reinforce dominant patterns of thinking that amplify certain structures and reduce others (i.e., individualism, anthropocentrism, scientism…). These notions have helped me to think of how the thinking patterns of communities reflect some narratives and meta-narratives of human-nature, even if these things are deemphasized or ignored in schools. Youth in today's schools are relevant extensions of the Earth's ecosystems, and therefore, no field of education can eclipse a shared responsibility to the encompassing ecosystems. The key point of chapter one was to provide a large part of the picture, Bowers' (1993, 1995, 1996) insights that have influenced my work with prospective teachers, and to defend a philosophical style used to evaluate Bowers' (op. cit.) ecojustice philosophy.

Since Bowers (2001, 2002, 2003, 2004b) is a prolific scholar, I narrowed my interests to his critiques of the cultural root metaphors (i.e., ideologies) of science, and analyzed his proposals for how ecojustice education may be used in science education. These ideologies are interesting because of my work with beginning science teachers. Science teachers and their students need opportunities to think carefully about ideologies that may be encoded and reproduced in languages that reinforce certain thinking patterns. In chapter two, I provided an interpretation of Bowers (op. cit.) ethical theory of ecojustice and provided his critiques of educational extrapolations of Darwin's evolution. Bowers' (op. cit.) central claim is that ecojustice-centered criteria should be used to strengthen the commons by renewing and revitalizing what was once available to all people and places. These criteria (Bowers, 2006) include: (a) understanding of ecosystems as essential to human life and identification of cultural assumptions that undermine ecosystems; (b) identifying and eliminating "environmental racism;" (c) identifying how hyper-consumerism exploits particular people and places for human and natural resources; (d) renewing the commons and revitalization and protecting them from cultural and environmental enclosures; (e) advocating Earth democracy as defined by Vandana Shiva (2005); and (f) sharing responsibility to the prospects of future people and the inhabitants of Earth's ecosystems. I will come back to and apply uncertainty thinking to Bowers' (op. cit.) educational implications throughout the remainder of this chapter.

My philosophical style acknowledges the above notions of cultural memory and its effects on the ways in which people interpret their relationships with the natural world. I maintain that philosophical research is appropriate and significant in science education, and defend my philosophical style which is grounded by classical American pragmatism (Dewey, 1916/1966; James, 1901; Peirce, 1958). My philosophical research style is built of contemporary pragmatism and postmodernism (Thayer-Bacon, 2000, 2003, 2006). Pragmatism helped me to find the disconnections between thought and action in Bowers (2001, 2006) ecojustice and critiques of science. Subsequently, I found that notions of the local authority of the commons, "Western" science and scientists, and the "ecological crisis" are based on certainties of thought, which is inseparable from the inherent uncertainty of experiences in the natural world. And, postmodernism helped me to find the direct links between power and knowledge in Bowers (op. cit.) presumptions of a deepening ecological crisis. I found that notions of ecological crisis disguise inescapable anthropocentric and anthropomorphic tendencies, and favor more accepted versions of science that carry forward the cultural residual of generalized and decontextualized, universal notions of thinking with certainty in mind.

Universalized certainty assumptions of Earth-in-crisis, science/ scientists, and traditional ecological knowledges (TEKs) were amended and extended in chapter three. Generally, I argued that Bowers (2001, 2006) privileges TEKs as the metaphor of local authority of the commons, and his metaphor lacks much needed pragmatic groundwork. Likewise, I highlighted political and economic concerns for Bowers' (op. cit.) ecojustice, and I emphasized that current efforts to bridge ecojustice education and Gruenewald's (2003a, 2003b) critical pedagogy of place is a move in the right direction, but remains convoluted in science education. Underlying assumptions in Gruenewald's (op. cit.) critical pedagogy remain unresolved (i.e., that critical is an inclusive-oriented direction). Equally, if not more importantly, critical pedagogy has yet to adequately address how the general public will resist capitalism and how resistance connects with environmentalism. For environmentalists, actions speak louder than words. Environmentalism is focused on locations and relationality, and is a significant part of the grounds for ecojustice projects.

Chapter three also addressed the problem of TEKs as the metaphor for the local authority of the commons in major metropolitan areas, where TEKs may no longer exist. I noted examples of ecologically influenced construction codes and other projects in New York and other cities to show that people in the U.S. are taking the initiative to move society in more ecologically informed directions, which should not be deemphasized. These pragmatic justifications serve to stimulate local ecojustice activism in urban communities, because people can better identify with the places where they actually live. Pragmatic justifications may help people to confront sources of conflict and oppression in both metropolitan and non-metropolitan locations. Because today's youth are embedded in what is considered *status quo*, they also need guidance from teachers and other adults to mediate the implicit cultural assumptions underpinning accelerated ecological declines.

Science education for ecojustice will be most aligned with students' lives and the kinds of ecosystems that can be found within surrounding areas. Bowers (2001) proposes that teachers be viewed as "significant others," or cultural mediators, who make explicit the root metaphors of language when appropriate. But, in my work with secondary and post-secondary students, I have found that intergenerational knowledges are relational. Thus, I do not interpret *significant other* as a "top-down" approach: instead, it can best be interpreted as uncertainty prompting interpretations that are subject to people and places (e.g., school in St. Paul, Minnesota or school on a Sioux reservation in North Dakota). Thus, science teacher as significant other must be defined according to particular peoples' relational perspectives, situations, and geographic places. Uncertainty thinking warrants that students also are conceived as significant others because of their embodied, relational experiences, beliefs and values, and place-centered narratives of human-nature. It is a reciprocal relationship, as evidenced by my work with students who both learned and taught intergenerational knowledges and skills in Arizona and Eastern Tennessee.

Uncertainty thinking aligns with Bowers' (2001) proposals for teachers to include local resources, community surveys, and comparative cultural studies in their classrooms. Finding out what students know and eliciting their everyday experiences provides a frame of reference for analyzing thinking patterns that affect local communities and ecosystems. Other elements of Bowers' (op. cit.) ecojustice-centered curriculum worth maintaining include an emphasis on the significance of appreciating and understanding traditions; understanding the ways in which people renew marginalized skills; and determining which cultural practices have the least impacts on the Earth's natural systems. Likewise, a balanced view of science and technology will provide an adequate appreciation and understanding of the philosophy, sociology, and history underpinning scientific thought, as well as recognizing the social and environmental consequences of scientific work. This pedagogy will help teachers and students explore their local authority of the commons.

Because there is high uncertainty when dealing with oppressive conditions in urban places, I showed that oppressive conditions are now being taken seriously by ecojustice scholars in Detroit, Michigan (Martusewicz, 2005b; Edmundson, 2001, 2004). Scholars are now encouraged to write about local projects as groundwork for ecojustice and there are forums to discuss these projects in journals and at education conferences. My work showed that local communities need some forms of "cultural relativism" to make decisions about what should be renewed and revitalized in their local commons. We now know that *qualified relativism* (Thayer-Bacon, 2003) is better aligned with the ways in which people think with uncertainty in mind when enacting ecojustice projects. Qualified relativism privileges the inclusion of multiple perspectives to determine what is right for particular people and situations in relation, while conserving social diversity. Generalized and decontextualized, universal standards may influence the local authorities of the cultural commons, but it is highly unlikely that such standards will satisfactorily meet the particular needs of people and places. Generally, for example, environmentalism does not hold virtues that apply everywhere (e.g., Nazi environmentalism; Bowler, 1992). The key point is that qualified relativism helps people come together on what is right for somewhere in relation to other somewhere's, and yet the goal of renewing and revitalizing the commons is a substantial and congruent aim for many different places.

I also critiqued Bowers' (2001, 2006) reductions of "Western" science and scientists to certainty thinking. My critique showed that science is better qualified as the plurality of ways that humans come to know and express themselves in relation to others and in relation to the Earth's ecosystems. Likewise, I pointed out that a significant role of science in science education and ecojustice necessitates an adequate understanding of the conceptualizations of Darwinian evolution and natural selection. Scientific fields of evolutionary ecology are now moving in place-centered directions, and science education has little or no choice than to follow. Adversely, the national and state policies that mandate standardized testing run the risk of leaving every child behind because such reforms sluggishly trail the place-centered work of science and science education researchers. Today's youth will eventually have little in common with the place-centered science taught at the university if K-12 science education does not deliberately shift towards emphasizing the importance of local people and places, in relation to others. Research in evolutionary ecology, such as geographic mosaics and coevolutionary tales indicates that educational policymakers are slow to recognize the significance of places.

Unfortunately, the cultural myth of ecological crisis has been taken for granted in the vast majority of ecological and environmental philosophy. The last part of chapter three showed that thinking the Earth-in-crisis is irrelevant to renewing and revitalizing the cultural and environmental commons and protecting them from becoming enclosed. The cultural myth of ecological crisis inadvertently privileges thinking with certainty, and privileges who participates and which methods and criterion reduce ecological impacts. The Earth-in-crisis conclusion regarding environmental issues such as global warming is not coherent with the environmental scientists and reports that advocate high uncertainty

(IPCC, 2001, NRC 2001, 2002, 2007). That does not mean that phenomena such as global warming are not occurring: it means that there is no need for absolute certainty. My suspicion is that in troubling the certainty notions associated with the cultural myth of ecological crisis, there will be fewer concerns with ecojustice and science education that provides a better understanding of ecological works. I have argued that uncertainty thinking is a much better fit for ecojustice and science education and helps science teachers and their students to evaluate ecological risks, projections and scenarios, and work with multiple stakeholders to conserve and sustain the pluralistic landscapes of people and places. My key point is that anthropocentric and anthropomorphic tendencies may be privileged in Bowers' (2001, 2006) ecojustice philosophy that deemphasize or ignore that the presumed "ecological crisis" is essentially a human constructed myth.

My uncertainty thinking theory for ecojustice and science education is a relevant extension of Bowers' (2001) proposal for teachers to understand the *ecological of the classroom* or meta-communication (what I describe as narratives and meta-narratives). Thinking with uncertainty helps teachers to understand how human narratives and meta-narratives of generalized and decontextualized, universal certainty disguise Earth's story. In chapter four, I argued that human meta-narratives were developed to disguise the uncertainty of the Earth's complex ecosystems, and to help humans to survive and reproduce (oftentimes at the expense of the Earth's other biota). Science teachers will find that these meta-narratives continue to be taken for granted in today's science education. While it is naïve to think that these meta-narratives could be entirely eliminated, science teachers should work with their students to explicate root metaphors of certainty thinking, which makes uncertainty thinking different from Bowers' (op. cit.)

ecojustice philosophy. Since all human stories have commensurate environmental costs, uncertainty thinking is aimed at reducing the most ecologically taxing meta-narratives of thinking with certainty.

My foundational argument in chapter four is that the Earth's natural systems are not subject to skepticism and doubt; Earth's ecosystems are fundamentally significant. Humans must adapt and survive dependent on Earth's natural changes and complexity, and the uncertainty of Earth's changing and complex ecosystems is inseparable from the experiential basis of an emerging epistemology and ontology of uncertainty thinking. Uncertainty thinking is inseparable from the cultural residue of thousands of years of intergenerational experiences of living with the local ecosystems embodied by all people.

During these times of uncertainty, we need to work with uncertainty to make important decisions that will affect the community and the Earth's ecosystems for many years to come. Thus, we ought to acknowledge the advantage of perspectives that incorporate uncertainty into our thinking. Such perspectives must allow for ambiguity and complexity, and must be able to survive the peer review of diverse stakeholders. Uncertainty thinking is a better fit for ecojustice and science education. It will allow science teachers and students to participate more fully in the local decisions of communities and better serve as advocates for affected parties and the natural systems. Thus, I argued for an *ecological pragmatism* to guide the projects of educationalists interested in exploring the inseparable thought and action in human-nature relationships.

Ecological pragmatism provides a grounded philosophy and scientific literacy. If the meaningful purpose of science education is to empower citizens to make choices in their everyday lives (National Research Council [NRC], 1996), then ecological pragmatism should be used to support the inclusion of students' lived ecological contexts. Ecological pragmatism is a shift in thinking about scientific literacy that embraces and values the unavoidable uncertainty of the Earth's natural systems. Although my intention was not to define uncertainty thinking definitely, I argued that science teachers and students should be empowered to work with uncertainty and share some of the responsibility for local decisions. They should consider all the evidence they can muster, including past experiences, beliefs and values, expectations and cultural narratives. Science teachers and students must become informed in place knowledges to be viewed as indispensable authorities of places and to be taken seriously in decisions of trade-offs. A well-designed ecological decision-making process includes multiple stakeholders and other affected parties, who consider precautionary measures, ecological vulnerabilities, projections and scenarios, and advocates for Earth's biodiversity lacking economic worth.

Thinking with uncertainty in mind is highly valued in the environmental sciences, and most congruent with a post-normal science movement (Ravetz & Funtowicz, 1999). Post-normal science is different from Thomas Kuhn's (1962/1970/1996) normal science: it is subject to the extended peer review community. Thus, I argued for a science in which all citizens can contribute. Young people should be included and recognized for their knowledges, observations and narratives. Young people may offer additional longer-term perspectives, not always considered by adults. Science teachers can help young people develop the place knowledges they need to rely on each other and the land. When science education is reconceived as reflective, reliant, and reciprocal of citizens and geographic places, science education will empower citizens to conserve and sustain their local places.

I argued for a *citizen-science* that repositions science teachers and students as legitimate members of the peer review community of post-normal, ecological sciences. The phrase *citizen-science* emphasizes that citizens should not be separated from science, and that science should not be separated from citizens: citizen-scientists must work with uncertainty in their everyday lives. Citizen-science is multifarious and stimulates the scientific imagination, which is scientific inquiry that is essentially always in process. Uncertain science justifies multiple perspectives and enhances the democratic process. As citizen-scientists, science teachers and students should be afforded the freedom, professional autonomy, and empowerment to think with the uncertainty of the world. Uncertainty thinking helps science teachers and students to democratize science. It provides more informed opportunities for teachers and students to confront enclosures, such as mandated enclosures (e.g., high-stakes testing) that limit professional practice.

Young children begin their lives as citizen-scientists intrigued by the uncertainty of the natural world. Unfortunately, schools miseducate them by emphasizing certainty. Today's disjunctive way of preparing science teachers asks them to make science relevant to their students' lives and then mandates decontextualized measures of success. How sensible is a science education that asks science teachers to teach uncertain science and then asks science teachers to measure achievement with *certain* facts and concepts? To make well-informed choices as stakeholders of places, science teachers and students need preparation in knowing how to interpret the incremental changes of the ecosystems. Deciphering how best to prepare science teachers and students to make these choices in the face of uncertainty, is an appropriate and significant goal for school policymakers.

My final argument analyzed how environmental scientists think with uncertainty. In science, no amount of evidence can completely eliminate uncertainties, but science investigations and conceptualizations help people narrow the range of reasonable choices. Our responsibility of becoming informed is reprieve with uncertainties, and yet uncertainty does not justify deemphasizing or ignoring science as a way to make choices. Science education, unfortunately, has failed to prepare citizens to think with uncertainty, which is reflected by the controversies surrounding phenomena such as climate changes. Uncertainty thinking is deemphasized in scientific documents prepared for policymakers such that they do not understand what uncertainty means for environmental scientists. This lack of uncertainty understanding in science education negates the National Research Council's (1996) emphasis on empowering citizens to use science in their everyday lives. Science education that seeks to empower people to use science in their everyday lives will be stymied by certainty thinking until the high value of uncertainty is acknowledged.

Thinking with uncertainty necessitates caring reasoning (Thayer-Bacon, 2003). As citizen-scientists and ecological advocates, science teachers and students should be prepared to care for local affected parties and the biodiversity of Earth's ecosystems. Ethical, social, and political judgments are part of the process of doing uncertain science. Caring reasoning helps us to understand that disparities are always selected in the world. It helps us to evaluate those disparities and critique and imagine what is right for someplace(s) and perhaps what may not be right for other places. My work showed that environmental scientists and epidemiologists use caring reasoning to advocate for others and the Earth's biodiversity, which may be otherwise excluded. Although, for a long time now, scientists have used forms of ethical evaluation to decipher which research agendas are privileged, evidenced by Peter Bowler's (1992) history of the environmental sciences, caring reasoning provides enlarged perspectives for scientists who recognize uncertainty.

Finally, in science education, there is a high priority for empirical research. Empirical research is perceived as more influential in terms of impacting the classroom (Eisenhart, 2005; Eisenhart & DeHaan, 2005). Hopefully, I have shown that a separation between ecological philosophy and science is unwarranted by those who think with uncertainty in mind. The grounds for thinking with absolute certainty that reinforce empirical research as more influential than philosophy are now shattered by uncertainty. Likewise, empiricists in the environmental sciences have been shown to embrace and value thinking with uncertainty in mind as inseparable from philosophical considerations. Philosophy of science education will no longer be deemphasized or ignored by science educators who embrace and value thinking with uncertainty in mind. Thinking that delegitimizes philosophical research is the same ignorance that leads to discrimination. Thinking with uncertainty is an ecological philosophy of education that provides the grounds for different ways of thinking with part certainty in places in relation to other places and the Earth, and a relational way of being in science education for ecojustice.

Place-*centered* Science Education for EcoJustice

If I had influence with the good fairy who is supposed to preside over the christening of all children, I should ask that her gift to each child in the world be a sense of wonder so indestructible that it would last throughout life. –Rachel Carson

We need a pertinent philosophy, or ecological pragmatism, in place-centered, science education for ecojustice if we wish to renew and revitalize the commons. Grounded philosophy helps define what it means to invoke local authority and prevent enclosures, which provides the common grounds for thinking with uncertainty in mind. Ecological pragmatism is congruent with Terry Tempest Williams' (2004) notions of *ground truthing*, which is when we confirm findings to calibrate observations: it is the process of using validation and verification techniques by situating ourselves in places. Ecological pragmatism invokes thinking with uncertainty in mind when it encourages educators and their students to "listen" to what the ground has to say. Williams (op. cit.) notes that "democracy depends on engagement, a firsthand accounting of what one sees, what one feels, and what one thinks, followed by the artful practice of expressing truth of our times through our own talents, gifts, and vocations" (p. 85). Thus, thinking with uncertainty is calibrated by the ground truthing of ecological pragmatism, emphasizing particular relationships between people and the Earth. Ecological pragmatism, as a place-centered mode of philosophico-scientific inquiry, provides opportunities for science teachers and their students to engage in research that contributes to the success of places.

For example, I recently met a beginning science teacher who is fascinated by the Earth's diversity of life and the complexity of ecosystems. He currently collaborates with field herpetologists (i.e., experts in reptiles and amphibians in the wild) across the state of Georgia to find and photograph native snakes, lizards and salamanders. He epitomizes the work of a citizen-scientist in that he collects records on sightings of more uncommon species for the state herpetologist and these contributions are used to understand species distributions and forecast species movements due to the Earth's regional climate changes.

This beginning science teacher embraces and values an educational philosophy of ecological pragmatism: he shares a responsibility for becoming informed and makes decisions to participate in conserving and sustaining wild reptiles and amphibians. Because ecological pragmatism acknowledges the multidimensionality of Earth's complex places, science teachers and their teachers are especially suited to become locally informed authorities on places, participate fully in decisions, and act as advocates.

Deliberately shifting towards ecological pragmatism and thinking with uncertainty offers new directions for ecojustice and place-centered science education: (a) ecojustice projects and community immersion requirements for science teachers; (b) synthesized ecological philosophy and science courses for science teachers, which involve place-centered research components and work with environmental scientists; (c) deemphasized national testing priorities, which allows professional science teachers to work with local people to interpret science standards to use as appropriate in curriculum; (d) citizen-science networks (i.e., *ecojustice mosaics*) and ecojustice-centered schools to share some of the responsibility for ecological advocacy and local ecological decisions. These educational implications work to acknowledge and emphasize the significance of place-centered science education theory, research, and practice for ecojustice. Now, I will provide grounded examples of what I mean by each of the proposed implications above.

Starting Closer, Not Farther: EcoJustice Projects and Community Immersion

The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively: the land. –Aldo Leopold

An article in *Educational Studies* that addressed education and globalization, aligned with the goals of ecojustice, was provided by Madhu Suri Prakash and Dana Stuchul (2004). The world-wide fast food industry was used as a metaphor to explore the assumptions linked with globalized education, as well as the grassroots efforts emerging world wide. Prakash and Stuchul (op. cit.) explain the significance of perceiving education as a way to break the Euro-Western mold: learning and living that marginalizes globalization and industrialization and regenerates the commons. They point out that the notion of "one world" is a Euro-Western fantasy that privileges the presumption that humans will become homogenous, which legitimizes the ideal of colonization. Unfortunately, the West has tried to "remake the world in its image" since before WWII, and today's Euro-Western global economy is associated with globalized education.

In particular, there are superficial linkages between large corporate food companies and globalized education, according to Prakash and Stuchul (2004). They explain that "it is no secret that college campuses, just like grade schools, are increasingly subsidized by corporations, educating the young and old alike in the art of drinking Pepsi, Coke, and other addictive substitutes for 'real food'" (p. 61). They note that the global education advocated in homogenous textbooks and curricula aligns well with the fast food industries' credo of moving things along quickly, efficiently, in a well packaged and standardized manner. Yet they explain that "in the global race toward 'education for life,' the mobility guaranteed by McEducation and McDonalds is grieved by those who cherish rootedness; who celebrate the virtues and ideals of staying home, connected to commons; of caring for the places we belong to and those that belong to us" (p. 62). Prakash and Stuchul (op. cit.) argue that McDonalds and McEducation are two sides of the same economic “coin” that legitimizes colonization, the exploitation and destruction of Indigenous peoples, and the decontextualization of more and more places. What comes next is significant: they remind us how Indigenous peoples in Mexico, Canada and the United States were nearly educated to extinction by the early Euro-Western schools.

Prakash and Stuchul (2004) note the ways in which grassroots efforts in Mexico, and elsewhere, are reclaiming their cultural rootedness and commons today. They explain how teachers and students are now celebrating the commons, local traditions and cultural roots, by questioning the structures of globalization at the Universidad de la Tierra in Oaxaca, Mexico. They describe how professors and students are engaged in political and economic questions, case studies, classroom debates, publications, workshops, reading circles, community apprenticeships, and the study of the language traditions of Indigenous groups, as part of the grassroots movements in Mexico to bring back to life, the commons beyond the classroom walls. They point to the importance of learning “*from* the world rather than *about* the world” (p. 65, emphasis in original).

Finally, Prakash and Stuchul (2004) explain how local people banded together to ensure that McDonalds would not be able to put a store in the main plaza of Oaxaca. The teachers and students worked together to prepare local foods to serve free to people in the main plaza. They also discussed position papers, handed out leaflets, and distributed videos, in a peaceful movement to keep McDonalds (and this aspect of globalization), from destroying their commons. They note the importance of the grassroots efforts in Mexico to regenerate the traditional, cultural rootedness and place-centeredness that ties people together, and prepares students for life and work in the community. Prakash and Stuchul (op. cit.) remark that the human activities that regenerate the commons, recover the local knowledges, and provide alternate ways of teaching, learning, and living, are aligned with the reality of many diverse worlds, yet not compatible with the globalized mold. Now, I will connect with other scholars who emphasize commons-strengthening.

Commons-strengthening activities are very important for beginning science teachers who seek opportunities to express themselves in relation to others and Earth. Emphasizing science teachers and their students' cultural narratives in relation to the meta-narratives of scientific work helps cultivate community-centered foci in science. One possibility is what Lynn Bryan and Deborah Tippins (2005) call *impressionist tales*, or a tool that gives a voice and authority to the experiences of beginning science teachers:

> Impressionist tales portray highly personal perspectives of a special instant or moment in time. They are written with the intention of drawing the reader into the image—to make the reader feel, hear, see, smell, and taste what the storyteller describes. The evocative language that reveals and represents the writer's deepest feeling about the topic is a central characteristic of impressionist tales (p. 230).

Impressionist tales advocate and care for the conversations that begin with the teacher and move outward to connect with others and with the natural world. Acknowledging science teachers and their students' legitimate tales helps to foster a frame of reference for authentic and meaningful discussions of the nature of science and scientific inquiry. When perspectives are treated with respect, teachers and students are more likely to want to engage in conversations that are controversial or conflict their interpretations of reality. Bryan and Tippins (op. cit.) offer several techniques for achieving this condition:

- asking questions for clarification and critique, thus modeling skills of questioning and critique for students to engage in with their peers;

- encouraging elaboration of incidences in the stories and explanations;
- juxtaposing concrete experiences with abstract concepts, thus helping prospective teachers relate their stories to beliefs, tensions, and insights about science teaching and learning; and
- encouraging and supporting multiple perspectives (frames) on and interpretations of experiences (p. 231).

Most importantly, science teachers and students will co-construct impressionist tales by deciphering what it means to be a large part of the science that happens in local contexts, which ultimately helps *re*place science teachers and students who have been displaced.

Trends now are shifting to *re*place science education in many parts of the world. Science educators (Aikenhead, 2006; Entsua-Mensah, 2004; Glasson et al., 2006; Jegede, 1995, 1997; Kroma, 1995; Nichols et al., 2006; Tippins, Handa, Bilbao, & Lourdes, 2006) are working in parts of Canada, Ghana, Kenya, Malawi and the Philippines to replace generalized and decontextualized science curriculum with traditional knowledges that embrace and value the long-term perspectives and local authority of the commons. The community-centered knowledges of local people in relation to places are emphasized as the contexts for learning and co-constructing science education curricula in almost all of the above works. Immersing science teachers in the local community, so they can have community-centered discussions with local people about their livelihoods invites local people to share some of the responsibility for what occurs in their schools.

In particular, Nichols et al. (2006) and Deborah Tippins et al. (2006) provide descriptions of *community immersion* in the Philippines or "a vision of science teacher learning and professionalism which emphasizes relational learning, collaboration connectedness, and commitment to self, to others and to the community" (p. 1). Nichols et al. (op. cit.) and Tippins et al. (op. cit.) advocate that science education is a community-mediated activity that involves working with people in contextualized places. An anthropological tool called "memory banking" is used to help science teachers and students to "generate accounts that represent sociohistorical referents they deemed important to life in their community" (Nichols et al., 2006, p. 349). Elements of community immersion include action research; cultural immersion; service with the community; co-planning and co-teaching; community surveys; trust-building activities; demonstration teaching; and portfolio assessments and exhibits. Community interviews, cultural events, journals, photoessays, and historical artifacts are emphasized to explore intergenerational knowledges and skills, personal and shared experiences, expectations, beliefs and values—with a central focus on local people's oral narratives.

Tippins et al. (2006) describe how beginning science teachers work with the community to develop a soap-making livelihood project, a de-worming campaign, coconut and mahogany re-forestation projects, dental care, composting, herbal gardens, erosion control projects, waste segregation, and community history projects. Subsequently, Tippins et al. (op. cit.) explain that the evidence gathered from their research in the Philippines strongly suggests that beginning science teachers immersed in the community "rethink their ideas of relevance in terms of a more community-centered, rather than community-based approach," which is focused on "co-constructing curriculum with community members rather than abstracting it from their input" (p. 2). In other words, teachers immersed do not import their criterion as the basis for interrogating any human experience or inquiry. The science education curriculum that emerges is subject to the responsibility of locals.

Tippins et al. (2006) present a careful dialogue dubbed as “a dialogue of life” that occurs when teachers respect the local knowledges as part of the project of schooling. Through community immersion, science teachers become responsible to the place, and work to conserve and sustain cultural diversity and Earth’s natural environments. Science teachers engage in ecojustice-centered projects to protect the commons from enclosures. There is no need to “reinhabit” places when the multiple perspectives of all stakeholders are considered relevant to the conversations of what should be the case in local schools. Recognizing that cultural and ecological pluralism already exist in most places will help prepare science teachers in ways that are subject to the shared responsibility of locations. Community-centered science education that values immersion acknowledges that Earth’s people and places are constantly changing, irreducibly complex and highly uncertain. Nichols et al. (2006) notes that even when the shared Catholic identities of community people are identified as promoting a faithful sense of place that deemphasizes or ignores environmental conservation, this local knowledge is legitimately upheld nonetheless.

Back in the U.S., Nichols and Goldston (2006) provide opportunities for their students to engage in community immersion, where science teachers go into the community to meet with people who live there and discuss the co-creation of curriculum. Digital storytelling and community mapping provides an opportunity for the teachers to understand where they are located and how their teaching is responsive to a place. Science teachers use digital storytelling to document cultural diversity and environments, and they do not deconstruct or transform places, but rather work to strengthen places.

Community mapping provides an opportunity for teachers to develop networks and explore local organizations, resources, housing, parks, churches, green spaces, trash spaces, employment, and other ways of knowing and living within the local ecosystems. Teachers obtain artifacts, photos, stories, maps, and present a collage of the community. Perhaps they might work with other professionals to measure the quality of the air, water, and soil as well, to extend community immersion to include the environmental commons.

Science teachers need opportunities to work in the local community and ecosystems as part of their graduation or degree-granting requirements at universities. The National Council for Accreditation of Teacher Education (NCATE) and the National Science Teacher Association (NSTA, 2003) could take the lead and adopt revised policies that advocate strengthened requirements for preparing new teachers to share some of the responsibility for participating in evaluating ecological risks, projections, and deciphering what they need to find out to be informed and involved in local decisions. The NSTA's (op. cit.) Standard 7 notes:

> To show that they are prepared to relate science to the community, teachers of science must demonstrate that they: (a) identify ways to relate science to the community, involve stakeholders, and use community resources to promote the learning of science, (b) involve students successfully in activities that relate science to resources and stakeholders in the community or to the resolution of issues important to the community (p. 25).

The NSTA further notes that teachers of science must find ways to integrate students' belief systems into the curriculum: "through study and analysis, to accommodate these deeply held beliefs; for example, by discussing beliefs at a different level, i.e., by examining the role of belief in all human thought" (p. 25). Essentially, teaching students how to think with uncertainty in mind is an increasing priority for preparing science teachers. Analyzing narratives and meta-narratives of human-nature, and opportunities to use uncertainty thinking to evaluate local ecological vulnerabilities and projections will effectively contribute to how seriously science teachers and their students are taken as citizen-scientists, community stakeholders and ecological advocates.

As noted in chapter four, the Environmental Protection Agency's (EPA's) Regional Vulnerability Assessment Program (ReVA; see http://www.epa.gov/reva/) allows stakeholders to construct different ecological projections and visualize the results of alternatives of future environmental outcomes. It would be interesting to include science teachers and their students as place-centered liaisons to monitor local ecosystems as part of a national EPA citizen-science network group. But to do this effectively, science teachers will need training, and they would need to be included in place-centered projects in their bioregions. Ecologists (Brewer & Gross, 2003; Clark, 2003) have already noted the possibilities of collaborations between ecological scientists and science educators. The focus of potential connections between ecologists and educators will be to help community stakeholders appreciate and understand the ways in which citizen-scientists and stakeholders work with uncertainty such that they will be taken seriously when participating in local ecological decisions. The ReVA program might be broadened to encourage local access, so that science teachers and their students can contribute to a scientific database.

The 13-state Appalachian Regional Commission (ARC), in conjunction with the Department of Energy's Oak Ridge National Laboratory (ORNL) and Oak Ridge

Associated Universities (ORAU), conducts a summer institute that has provided opportunities for science teachers and high school students to work with ecologists and other environmental scientists to investigate local stream ecosystems, assess ecological risks, and participate in decisions, for a number of years. This program offers the kinds of experiences with ecologists and local ecosystems that are needed for science teachers and high school students to eventually contribute to a national EPA citizen-science network (http://www.orau.gov/arc2006/aquatic_eco.shtml). In 2005, for example, one ARC project involved high school students in an investigation of the impacts of urban development on a stream in eastern Tennessee. Several aquatic ecologists worked elbow-to-elbow with students as they surveyed an area of land near the stream, which had been stripped of its vegetation to hard clay. There, students found improperly installed silt curtains and bails of hay did not prevent the clay from eroding into the creek. In other areas, students found large trees that provided root structures that protected the stream bank shade for several varieties of fish, crawdad, snails, and other aquatic organisms. Invasive plant species were identified along the stream bank, and the ecologists worked with students to help them investigate "how invasive plants can out-compete native vegetation, reducing biodiversity and lowering the quality of food and habitat available for wildlife" (Stewart, 2005, pp. 3-4). The structures of a healthy stream (e.g., pools, runs and riffles) also were identified, and students worked with the ecologists to record snails, crawdads, and fish species: hogsuckers, white suckers, stoneroller minnows, striped shiners, bluegill sunfish, blacknose dace, snubnose darters, creek chubs, and banded sculpins. One of the ecologists, Arthur Stewart (op. cit.), notes that student-scientists learned how different fish do things differently as part of a community of organisms that work together to form a stream ecosystem. He notes: “five years from now, or ten years perhaps, after they’ve settled down and become productive individual members of society, they may remember how to take care of a stream” (p. 5). More federal-state programs are now needed to prepare science teachers and students to think with uncertainty, evaluate ecological vulnerabilities, and make projections and decisions. Science teachers and students who have these types of experiences will be better situated to participate more fully in the local ecological decisions of their respective communities.

The Synthesis of Ecological Philosophy and Science in Science Teacher Preparation

Teachers, I believe, are the most responsible and important members of society because their professional efforts affect the fate of the Earth. –Helen Caldicott

In colleges of teacher education, new courses with fluid borders between ecological philosophy and the natural sciences should be developed to prepare science teachers how to navigate emerging scientific theories, such as geographic mosaics and coevolutionary tales. These courses also could prepare teachers on how to make value judgments as part of scientific work. These twin projects have historically provided “checks and balances” for each other: it will be increasingly important for science teachers to have ecojustice experiences analyzing root metaphors and participating with scientists to construct scientific stories. Moreover, the integration of ecological philosophy and science will stir new scientific research questions and investigations invoked by teachers and their students.

Ethnobiology, for example, is a field of study involving how humans interact with bacteria, fungi, plants and animals that integrates characteristics of ecojustice education and the ecological sciences. Carol Brandt (2004) provides a three-year description of her work at the University of New Mexico. She notes that ethnobiology is the combination of biology and anthropology, with an awareness of intergenerational knowledges and the "cultural and the environmental context of knowing, art, narrative, and traditions" (p. 96). For Brandt (op. cit.), ethnobiology is educating for sustainability, where nature's ability to sustain life is not interrupted by the community infrastructure, and forms the basis for an exploration of science as a human endeavor. Ethnobiology is a way to teach for ecojustice, which ensures the inclusion of local knowledges, interdisciplinary analyses of science, student agency, and the importance of making moral and social decisions. Ecojustice topics remain at the forefront of instruction as Brandt's (op. cit.) students explore "the sociocultural, political, economic, and environmental relations enmeshed in a specific locale and the knowledge generated at a geographic location" (p. 101). She asserts that public schools and universities have a responsibility to restore and renew communities rather than disintegrate them. She recommends that science teachers, students, researchers and community members come together and study local environmental contexts and Indigenous knowledge systems.

In Brandt's (2004) ethnobiology courses, members from Indigenous communities, along with university students, share the responsibility of co-instruction. Water and water rights are the central focus of conversations over the local government's management of water resources, which in some cases deprives the local Indigenous communities of the activities linked with their cultural identity. Students design field trips, discuss reflective journals, invite guest speakers, review ethnobotanical works and other scientific literature, and explore a multitude of available topics connected with local ecosystems. Likewise, students write ethnobotanical autobiographies as a way to make connections between the local ecological wisdom and their everyday lives. Brandt (op. cit.) notes that students eventually realize that their personal experiences "using traditional medicine, in practicing farming or gardening, and in collecting plants for basketry or other material uses" are an essential part of what it means to be scientifically literate. Brandt (op. cit.) advocates a form of place-centered thinking, or local epistemology, which helps students understand their role in developing sustainable community and engaged citizens. Brandt (op. cit.) believes that Bowers' ecojustice education, as a form of place-centered thinking, has the potential to evoke the natural sciences in its most democratic form.

Other cultural communities may not have a word for "science," yet the cultural phenomenon of synthesized ecological philosophy and science is alive and well. At Sinte Gleska University, located on the Rosebud Reservation in South Dakota, Peggy Tilgner (2005) describes a science education methods course and the challenges of teaching "science in a culture that has no word for science" (p. 2). She explains the value of a culturally relevant science education that originates with family and place-centered individuals, intergenerational knowledges, oral narratives, ceremonies and the arts. Tilgner's (op. cit.) course aligns well with ecojustice-centered education. She describes the Rosebud Sioux views of science that place an emphasis on "identifying relationships and changes, observing and evaluating context and using a circular view of time" (p. 3). She points out that Rosebud Sioux emphasize survival, coexistence, and relationships, with each other and with the animate and inanimate natural world. Tilgner's (op. cit.)

students view knowledge as something that is earned when one becomes responsible to the Earth. Therefore, the ecological wisdom of the community is not accessible until the student has demonstrated that they are prepared to learn and will be responsible with the learned knowledge, which involves advocacy and care for others.

Tilgner (2005) notes that even though her students have many of the modern media conveniences found in major cities, they begin with the intergenerational knowledges of their family members and community to learn ecology and astronomy. Elders teach students to be careful observers of the natural world, and they explain the traditional uses of plants found on the reservation. Students are asked to find a plant, observe it, draw it, and discuss it, using oral narratives. Only after students have learned the ecological wisdom from the community and the Earth, do they compare their TEKs with the Euro-Western views. Interestingly, students find that their ancestors were not the primitive people so often described in textbooks. Tilgner (op. cit.) notes a deep sense of cultural pride that emerges as students learn to rely on the Elders as science authorities. Tilgner's (op. cit.) Rosebud Sioux students are learning in ways that synthesize ethnobiology, ecojustice-centered education and the authority of local people and places.

The main theme of synthesized ecological philosophy-science is responsibility. Teacher education should take the lead in preparing new teachers to share some of the responsibility for participating in place-centered decisions. Jeff Edmundson (2001, 2004) provides a view of his work with teachers at Portland State University. He begins his teacher education courses by analyzing how language encodes particular cultural ideas that are found in textbooks, curricula, and the language used by students in the local schools. He encourages teachers to think about culture as "a socially constructed web of meanings within which humans suspend themselves" (2001, p. 50). Edmundson (op. cit.) points out that ecojustice-centered education provides many opportunities for his beginning teachers to rely on their perspectives to analyze cultural traditions, the myth of cultural neutral scientific narratives, technology, constructivism and critical pedagogy.

Edmundson (2004) notes how similar ecojustice work is with what social justice advocates have encouraged. He elaborates:

> By way of comparison, social-justice teaching uses critical pedagogy to encourage individuals to think critically about their own lives, ecojustice teaching helps students look at their own lives to develop a thoughtful awareness of culture and the traditions that sustain them as well as those that oppress them (p. 122).

Edmundson (op. cit.) engages with his teachers in a thoughtful comparison of the non-commodified traditions and consumeristic habits in their everyday lives. He explains that when teachers discuss the "emotional power of human connections that emerge from personal traditions, there are few dry eyes, and students are a little less willing to jettison those traditions" (p. 122). Similar to my work with teachers in Appalachia, Edmundson (op. cit.) asks his teachers to learn a new skill from someone else in the community. He explains that students "turn to their mothers, aunts, uncles, and friends to learn everything from canning to belly dancing to guitar to horseback riding" (p. 122). He finds great enjoyment in these place-centered projects with teachers and encourages other scholars to engage with teachers in ecojustice education and activism.

In the Detroit "commons" in Eastern Michigan, Rebecca Martusewicz and Jeff Edmundson (2005a, 2005b; Edmundson & Martusewicz, 2004; Martusewicz & Edmundson, 2004a, 2004b) note the "collaborative intelligence" of people that have faced over fifty years of economic, political, and cultural enclosures. Martusewicz (op. cit.), in particular, describes the grassroots efforts, and community relationships, that develop as local citizens work to revitalize old neighborhoods, empty lots, play areas, community gardens, and church buildings. She points out the embodied connections of the people and their love of the landscape: the spirituality required to reclaim neighborhoods, the re-invigoration of the city in local artists' large mural projects, and the aspirations of people and dreams of a better place for their kids. Local people engage in grassroots environmentalism, ranging from high school girls testing soil and teaching residents how to determine if their soil is safe for planting; to the self-sufficiency and moral reciprocity of people teaching each other how to build and maintain compost bins; to exchanging seeds and seedlings; and to cultivating over 150 city-wide gardens. These ecojustice-centered projects provide the groundwork to work toward Earth democracy and foster relationships needed to strengthen bioregions.

According to Edmundson and Martusewicz (Edmundson & Martusewicz, 2004; Martusewicz & Edmundson, 2004a, 2004b), ecojustice-centered education emphasizes a responsibility to particular people and places, or a *pedagogy of responsibility*, which cultivates the cultural relationships that nurture a spirit of care and community reciprocity with the nonhuman world. Although not stated in their work, Edmundson and Martusewicz's (op. cit.) pedagogy of responsibility models synthesized ecological philosophy and science, and their perspectives provide conceptualizations for other scholars who want to engage their community in ecojustice-centered reforms. Ecojustice scholars must continue to conduct their work locally when considering ecojustice themes, such as responsibility, care, and connection to the community and to the Earth's wild ecosystems. In this regard, ecological location has been responsible for cultivating a love for the Earth. Most of today's environmentalists will say that, as children, they were provided opportunities to explore and care for the natural world, according to the most recent environmental literacy report (Coyle, 2005). Our beginning science teachers and their students need similar opportunities today in terms of community service, environmental restoration and conservation, and collaborations with working scientists and other community professionals. Increasingly, science teachers and students will need to be seen as partners or producers, rather than consumers of scientific work, which may require another look at the current national science education standards for teacher preparation.

The National Science Education Standards

Teachers teach because they care. Teaching young people is what they do best. It requires long hours, patience, and care. –Horace Mann

The national science education standards (National Research Council, 1996) were not originally intended to be used for the No Child Left Behind (NCLB) testing priorities. They were designed to guide science teacher preparation and to initiate conversations of what teachers should teach and students should know to become scientifically literate. The standards are generalized and decontextualized guidelines that lack place-centered aims for engaging science teachers and students in the competency of local ecosystems. My concern is that national and state priorities have reduced the standards to a set of facts/concepts to be regurgitated on end-of-course exams that do not prepare citizen-scientists to use science in their everyday lives or democratize science and technology. As advocates and stakeholders in the local community and ecosystems, science educators must be afforded the professional autonomy as plural citizen-scientists to work with local people to decide how the standards guide efforts to renew and revitalize the commons.

One barrier that needs to be overcome is that the textbooks and science curricula of many public schools do not start with the peoples and places where students live. Imagine a *text*book designed specifically to feature the community, native species and habitats, and geological structures—a field guide to use *in* the field. For students living in the Great Smoky Mountain region, there may be an emphasis on the TEKs and other local knowledges, reflective of the flora and fauna, and rocks and fossils of Appalachia. Photos and descriptions of plant varieties such as the hemlock, mountain laurel, papaw, wild geranium, yellow wake-robin, common blue violet, and the resurrection and rattlesnake fern, with room for students to write and to sketch their own investigations, which may revise the original interpretations and add flavor to the ecological narratives. In turn, teachers and students could study the harsh winters and realities of living in the Appalachian woods, high birth rates and death rates, and the weather lore that helped the early settlers anticipate the seasons—all relevant to a science class focused on ecojustice.

In the summer of 2006, several science educators including myself (Dollar et al., 2006) met with staff of the *Knoxville News Sentinel* to create a community-centered publication for teachers and students in grades four through eight. We prepared a book that could be used to learn about the community and the natural environment, without neglecting the Tennessee State Science Education Standards. In each of seven lessons, we included topics on how plants survive and reproduce; biodiversity; invasive species; healthy trees and healthy communities; the plants we eat; healthy foods; and where solid wastes and stormwaters end up. We also included an Eastern Tennessee guide to native plant species as a resource for students' investigations. The book was packed with local statistics, resources, community contacts and newspaper activities that would help students expand from their classrooms and into the community and natural environment. Local artwork and photographs of local people and places were featured throughout the book. We also included ways for teachers and students to get involved in the local decision-making process of the community (e.g., develop and present a public service announcement skit to educate the public on dominant pollutants). This example is just one way that science educators can work together to counter the nationwide distribution of decontextualized textbooks. The books are being provided for free to over 14,000 science teachers in Eastern Tennessee when they attend a free workshop on how to successfully integrate local knowledges into their curriculum (thanks to partnerships with several local companies, which is an example of how local businesses get involved).

The potential for using ecojustice education to prepare teachers and students to work in the community and environment as *the* con*text* of their learning stems from previous work to reconceptualize science education and scientific literacy as "preparing students to make informed choices and fully participate in society in ways that are reflective, reliant, and reciprocal of Earth's many natural environments that sustain life itself" (Mueller & Bentley, 2007, p. 3). If school science was structured around people and places, it might better achieve the aims of mindfully conserving the landscapes of pluralism: gender, race, ethnicity, religious background, class, socioeconomic status, and the diversity of ways humans come to know and express themselves: collectively, these things provide some foundation for places, or part certainty of places in relation to others. Science education for ecojustice is intended to be people and place-centered: it can help foster place-knowledges for teachers and students, and repositions them as indispensable.

EcoJustice-Centered Schools

A small group of thoughtful people could change the world. Indeed, it's the only thing that ever has. –Margaret Mead.

Another promising avenue for developing a sense of responsibility, care and respect for biodiversity and the natural systems, is the movement toward environmental schools. Gregory Smith (2004) connects with ecojustice by providing a view into the curriculum of the *Environmental Middle School* in Portland, Oregon (renamed *Sunnyside Environmental School*; http://www.pps.k12.or.us/). He describes how ecological sustainability serves as the overarching theme at Sunnyside, to cultivate care for, and connection with, the community and the natural world. He wants ecological education to be centered on preparing students to care for, and to contribute to society, with community service and environmental responsibility in mind. Smith (op. cit.) explores the possibilities, which aim at fostering care and connection, without sacrificing test scores: ". . . in spring 2000, Sunnyside was the only secondary school in the state of Oregon to receive an exemplary designation by the state's Department of Education" (p. 74). Moreover, Smith (op. cit.) points to the values and commitments of the Sunnyside faculty: teachers choose to work there because they don't have to "check" their ideals at the door: "they bring what they care about to their classrooms and draw their students into a circle of care predicated on their desire for loving interactions among people, social justice in the broader community, and connectedness to the place where they live" (p. 75). Discussing Nel Noddings' (1984, 1992, 2002 as cited in Smith, 2004) works, Smith (op. cit.) notes how Sunnyside fosters care relationships through social interactions and both formal and informal experiences. At Sunnyside, students are placed in a mixed-grade classroom and stay with the same teacher through a three-year revolving thematic curriculum consisting of "rivers, forests, and mountains" (p. 78). This type of looping schedule allows teachers to integrate at least one day a week for environmental fieldwork or community service, which serve as sources for ecojustice-centered teaching and learning at Sunnyside.

Further, Smith (2004) notes how teachers and students work together to define the nature of care for, and connection with, the community and the natural world. Teachers and students alike have many opportunities to practice caring relations and connection. These opportunities are available in the forms of service learning projects, field investigations and other academic experiences. Teachers and students are encouraged to participate in activities that embody social and ecological justice. Projects include:

> . . . tree planting, the construction of raised vegetable beds at a camp for homeless people, the development of a pocket park in a low-income neighborhood close to the school, serving lunch at a local soup kitchen, the removal of downspouts from homes and public buildings, student organized canned food drives, Operation Shoebox (a project that collects and then distributes school supplies and toiletries

> to children in Honduras), and the collection of blankets and towels for animals at a local shelter (p. 83).

Smith (op. cit.) explains how students at Sunnyside enjoy getting to know other people better and learning in real-world situations. Teachers notice how students develop a "deep regard for the land" by practicing care for, and connecting with, the nonhuman world. Smith (op. cit.) explains that Sunnyside provides a trusting atmosphere for students rather than one that tries to constantly manage them. He says that Sunnyside is "predicated on the willingness to believe that, at base, young people are capable of care and choose to act in this way when encouraged to do so" (p. 88). Sunnyside emphasizes each student's ability to contribute to the well-being of the learning community.

At the end of each year, the eighth graders compile a portfolio of their three-year accomplishments (Smith, 2004). They present what they are taking away from Sunnyside during the final weeks of school. Smith (op. cit.) explains that eighth graders show their understanding and commitment to caring about the world through these final projects. He elaborates:

> . . . children are affectionate to one another and their teachers. They speak their minds. They stand in front of the entire school and read poems or make announcements about service-learning projects that are important to them. They share their thoughts about what they are grateful for and what they value (p. 90).

Smith (op. cit.) proposes that ecological scholars embrace and value the metaphors linked with the organic farmer who thoughtfully cultivates his/her field, who strives "to create the conditions under which seeds will grow into healthy and bountiful plants" (p. 90). He believes that schools like Sunnyside "prepare the soil" for a cultural shift towards social and ecological justice, sustainability, and rootedness. Most likely, Sunnyside's students are becoming informed such that they could advocate and care for affected others in the local community and ecosystems by participating more fully in the local policymaking. After all, Sunnyside's students are being afforded opportunities to think with uncertainty, which plants the seeds to be taken seriously as part of the local authority of the commons.

There should be more of an overarching agenda in the schools to emphasize local people and places, community-centered knowledges and skills, and science education. The middle school students at Sunnyside develop long-lasting relationships with other students and adults, and benefit the community and natural environments through service learning projects and field studies. In turn, this school's ecological contributions will have significant economic implications for the long term. For instance, as students learn to test water/air/soil quality, they may be employed by the city to conduct studies of biodiversity, invasive species, and the denigration of habitats. They may be engaged in urban development projects, and environmental clean up, conservation, and restoration. They may be consulted by the public to provide information on the pH levels of soil, organic fertilizers, pest controls and native plants. Students may serve as weekend guides in natural environments for busy adults who no longer have connections with the Earth. A cost-benefit analysis may show that ecojustice-centered schools economic benefits to the community and natural environment outweigh the real estate values gained from high test scores.

Shifting Towards Uncertainty Thinking in Science Education

Everything that is done in the world is done by hope. –Martin Luther

A recent news article brought to my attention that hundreds of genetically engineered trout (triploid chromosomes, to preclude the likelihood of reproducing), are being released into a lake near Seattle, Washington, where I learned how to fish as a child. The story explains that, as more of these fish are added, the lake is expected to become a real "hot spot" for sport fishers seeking enhanced trophy trout. While trophy trout may be great for sport fishers, I'm nervous that the long-term consequences of these fish to the ecology of the lake may not have been adequately considered (including the interrelationships with local people who have traditionally relied on the trout for food). As a young child, I was naturally curious by the rainbow trout (*Oncorhynchus mykiss*) living in this lake. These strikingly brilliant red-banded trout are unusual for salmonids because they can live their entire lives in freshwater. Almost everyday, I would ride my bike to the end of the long narrow fishing pier and chat with the Indigenous Pacific Northwesterners while they tied knots, baited hooks, and cast their lines among the lilies. I always insisted that they pull up their metal stringers to show me their catch for the day. These locals eventually taught me how to tie knots, set up a line with a sinker and two leads, bait the hooks with marshmallows and salmon eggs, cast my line and clean the trout. Although I released most of the trout that I caught, I sometimes kept a few to eat for breakfast or lunch. There is nothing like eating a fresh, tasty trout right from the source. I learned much about fishing for rainbow trout because I took the time to listen and learn from my mentors. One day I was even told that if I spit on both hooks before casting, I would catch two fish on the same line. So, I spit on my hooks, cast into the lilies, and reeled in two rainbows on the same line! I was the happiest kid alive.

This ecological issue of genetically modified (GM) trout might serve as the context for an imagined situation where science teachers and their students, as part of a network of citizen-scientists in Seattle, become informed and share some of the responsibility for participating as stakeholders. Thinking with uncertainty involves working with scientists to evaluate ecological risks, and constructing possible scenarios and analyzing the outcomes of particular decisions. While GM trout offer human-centered benefits (e.g., increased food production, or be designed to produce pharmaceuticals, or test water contamination), environmental concerns include whether sufficient regulatory safeguards are being used to protect human-nature relationships and the ecological sustainability of the local lake. Becoming informed on this issue could involve working with local ecologists and other scientists, or talking with Native peoples and other local residents, or researching pertinent regulations. Ideas that pertain to the local situation should be acknowledged and included. For example, advocates for sport fishing may argue that enhanced trophy trout will increase the kinds of family and community relationships needed to reduce local consumerism, which is a consequence of people doing things together that does not require spending. Reducing local market dependence and the potential lessons learned from stocked triploid trout may outweigh the benefits of not stocking the lake. However, caution is defensible, depending on the particular circumstances of affected stakeholders, all things considered. Uncertainty thinking helps science teachers and students to decipher which environmental outcomes are most likely to have the least harmful consequences, because almost every human activity has commensurate environmental costs. With uncertainty in mind, science teachers and students will work with others to effectively make ecological decisions, while advocating and caring for affected others and the needs of natural systems.

Nationally and internationally, there is much inherent uncertainty about the production and release of GM fish. Critics and scientists speculate that transgenic fish could harm wild populations due to competition and predation, and that they may become invasive and difficult to eradicate (Borgatti & Buck, 2004). Also, triploid fish with increased levels of sex hormones may overcome sterilization methods and potentially spread undesirable genes. Fish that are already endangered or threatened may become more susceptible to declines if GM fish are introduced, which justifies the consideration of precautionary measures. According to Borgatti and Buck (2004), many environmental and consumer groups are advocating that GM fish be specifically labeled for consumers. However, industry groups have been concerned that consumers will think their products are unsafe for consumption.

Unfortunately, in the U.S., there may be even greater roadblocks than uncertainty that limit how involved and proactive science teachers and students might become. The Food and Drug Administration (FDA) is responsible for regulating the release of GM fish and many other products. To assess the severity of negative ecological impacts, the FDA consults the Fish and Wildlife Service and National Marine Fisheries Service (NOAA Fisheries). However, as Borgatti and Buck (2004) explain:

> Under the FFDCA's provisions on new animal drugs (21 U.S.C. 321), the FDA must keep all information about a pending drug application confidential, with the exception of information publicly disclosed by the manufacturer. This approach

> limits the opportunity for public comment before approval. Consumer advocates are calling for more transparency in this process and for more authority to be given to environmental and wildlife agencies (p. 3).

Citizen-scientists and other community stakeholders are essentially excluded from the decision-making process that allows for the eventual release of GM fish into the wild. Without subjecting decisions about GM fish to the extended peer review community, or to general public, legitimate concerns may not be addressed over product safety, environmental impacts, ecological ethics, and whether specific labels are used to distinguish GM fish from non-GM fish. Moreover, ecojustice issues, such as the impacts on human-nature and other relationships may be considered irrelevant to the privileged decision-making groups. Consequently, science teachers and their students and other affected stakeholders may have their hands tied. And there are other situations, including the thousands of new chemicals developed annually that are not safety-reviewed (e.g., only 10% of cosmetic ingredients have been screened for safety; see http://www.safecosmetics.org/index.cfm). Authentic and relevant ecojustice issues are available in every school across the nation when we stop to think.

Targets of Scrutiny for Ecological Pragmatism: Place-based versus Place-centered

It might be argued that ecological pragmatism, or uncertainty thinking theory, is subject to a criticism of failing to reconcile a dualism of foundationalism and fallibilism. Humans are fallible, and yet that does not necessitate a globalized anti-foundationalist position. John Dewey (1938/1963) affirms that perspectives must be situated somewhere, which is consonant with other pragmatists (Seigfried, 1996; Thayer-Bacon, 2000, 2003). A "critical pragmatist" (c.f., Gruenewald, 2004, p. 284) scholar, David Gruenewald (2003a) argues that educators begin "interrogating the power of place as a construct for analysis," which can be "applied to any realm of human experience or inquiry" (p. 636). He wants teachers and students to challenge the national standards and engage in place-conscious education, such as explorations of Earth's natural history, cultural journalism and action research projects. In response to ecological pragmatism, he might argue that thinking with uncertainty is congruent with his *critical pedagogy of place* (2003b), where he claims that all people and places are subject to interrogation (i.e., questioning).

Gruenewald's (2003a) notions of interrogation suggest that what is most likely to be learned from local people and ecosystems is suspect, which is a position of certainty (i.e., God's-eye view). Moreover, he privileges exclusive anthropocentric knowledges, beliefs and values, expectations, and narratives (i.e., "outsiders" to Earth's natural story). In other words, he embraces *realism* (c.f., Gruenewald, 2004, p. 284), which is an age-old meta-narrative that positions a natural world "outside" of human experiences or inquiry. He does not provide a strong argument for his multicultural *foundations of place* (2003a): interrogation cannot be "applied to any realm of human experience or inquiry" (p. 636). Suspect equates with disrespect when peoples' narratives (i.e., situated in places) and the narratives of the natural world are not cared for, prior to being critical of people or places (i.e., caring reasoning). Gruenewald (op. cit.) is obligated to show that it is possible for people to use interrogation as the mode of analysis for any human experience or inquiry, and yet people do not interrogate any human experience or inquiry. This notion is evidenced by many peoples' cultural meta-narratives that privilege eating ecologically destructive cattle, or that favor human survival and reproduction at the expense of other species. Moreover, Gruenewald (op. cit.) argues that all of the national standards for education should be challenged, which differs from my perspective that there will always be standards and that policymakers should reevaluate standards that enclose commons. Other standards, such as those that ensure students' safety and welfare when engaging in the science laboratory are sometimes open to interrogation, but certainly not universally.

I maintain that thinking with uncertainty provides some partly certain foundational grounds for ways of thinking and acting in some places in relation to others. If humans are inseparable from the Earth's changing, complex and uncertain ecosystems, then human experiences are definitely part of the Earth's complex ecological foundations. Not all knowledge is suspect if human experiences are partially derived from ecosystems. The universal anti-foundationalist claim that all knowledge is suspect and subject to interrogation is the same contemplation trap as thinking with generalized and decontextualized certainty, which has historically led to accelerated ecological declines. The world is inherently uncertain, and humans since the beginning of time have been justified in creating some partial certainty in places to survive. In part, certainty in places (i.e., in relation to others) is not universalized and decontextualized certainty thinking, but rather an epistemological and ontological stance that acknowledges Earth's changes. But, it might be argued, that perhaps all knowledge is suspect, until, by interrogation, we arrive at a place approximating consensus. It is impossible to interrogate from nowhere, interrogation always starts from within a particular context, situation, or interpretation. "Outsiders" favor what they know unless the local authority of the commons is valued; for caring reasoning teaches us that we cannot know others if we are not first centered on their perspectives, expectations, beliefs and values, narratives, methodologies and criterion that developed concurrently, which includes the Earth (Thayer-Bacon, 2003).

Gruenewald's (2003a, 2003b) critical pedagogy of place is subject to undermining diverse peoples' voices (and Earth's story), if our own perspectives (i.e., as outsiders) are privileged (i.e., why it was necessary for me to argue that meta-narratives may disguise Earth's history). Elizabeth Ellsworth (1989), for example, provides a case when critical pedagogy was used in her classes, but led to the silencing of her students' voices. Ellsworth (op. cit.) cautions that diversity is silenced in the name of decontextualized liberal pedagogy. Further, she notes "there have been no sustained research attempts to explore whether or how the practices it [i.e., decontextualized liberal pedagogy] provides actually alter specific power relations outside or inside schools" (p. 303). She reminds us that it is not reasonable to presume that humans can ever know the foundations of people and places for certain. Pedagogy of place fails to recognize that any human experiences or inquiry must be approached by thinking with uncertainty in mind, simply because the intellectual world is partly certain. Uncertainty thinking helps to move those interested in pedagogy of place in an inclusive direction, where *some* things may be interrogated.

Thus, I differ from Gruenewald (2003a, 2003b) in that uncertainty thinking is inclusive and relational, which better serves to strengthen communities and ecosystems. Uncertainty thinking also acknowledges that some foundation is necessary to cultivate the conservation of inhabitable places (i.e., changing, complex and uncertainty places), and seeks the partial certainty of the local authority of the commons and the needs of Earth's ecosystems (chapter three argues how human thinkers reduce anthropocentrism). Educational frameworks that include dynamic, multidimensional perspectives that are particular to people and places recognize that the world's uncertainty calls for millions of small ideas, grounded in particular places, rather than one big context-abstract ideology. With so much cultural diversity working towards conservation and sustainability, the local authority of the local community and ecosystems must be considered without losing sight of other legitimized perspectives. There also are times when multiple communities and places will be consulted depending on the situation, which invokes thinking with uncertainty in mind. I do not want to minimize Gruenewald's (2003a, 2003b) important contributions to ecojustice that help scholars to think about oppressive conditions. While I do not want to be misinterpreted as saying that oppressive conditions should not be interrogated, I want to emphasize that the conditions for oppression involve uncertainties. People are situated in local contexts including the Earth's uncertain ecosystems, which provide some partial certainty for evaluating ecological scenarios and making decisions.

New Directions for Science Education Research

Perhaps the fundamental principles of the *Earth Charter Initiative* (ECI) (http://www.earthcharter.org/) should guide the national priorities of science education (Bowers, 2004c, Corcoran, 2004; Gruenewald, 2004). The ECI embodies a forward-thinking vision of social-, economic-, and eco- justice, and promotes human rights, world peace, and sustainability. Now available in many different languages, the Earth Charter is widely recognized as a statement on ethics and values for the teaching and learning of sustainability. Although *sustainability* can be defined differently depending on context, the Earth Charter notes that sustainable perspectives consider equally the needs of today's society while not depleting the needs of tomorrow's generations.

A nice summary of the ECI for ecojustice-minded scholars is provided by Peter Corcoran (2004). He notes:

> To the best of our knowledge, the Earth Charter Initiative has involved the most open and participatory consultation process ever conducted in connection with the drafting of an international document. Tens of thousands of individuals and hundreds of organizations from all regions of the world, different cultures, and diverse sectors of society have participated. The charter has been shaped by experts, government and civil society leaders, students, and representatives from indigenous groups and grassroots communities (p. 109).

Corcoran (op. cit.) notes that the Earth Charter is not the final word on a global ethical framework, but provides the common grounds for the beginnings of significant and appropriate conversations, which educational scholars should be involved in a large part. He remarks that notions of ecological crisis are so difficult to teach, however, "the Earth Charter is a source of inspiration and hope because of its value in teaching these topics" (p. 111). It heightens an awareness of the challenges and choices facing humankind and helps people learn to think globally and holistically. It fosters interconnectedness and cultivates cross-cultural and interfaith dialogues on fundamental beliefs and values, global ethics, and reflections on cultural assumptions that accelerate ecological declines.

The Earth Charter Initiative embodies the elements of uncertainty thinking theory. It implicitly advocates ecological philosophy and science synergy, which means working together to accomplish the similar goals of teaching human rights, social peacemaking, and ecological integrity. *Social peace* is defined as "a series of right relationships for oneself, with one's community, both past and future, and one's biosphere" and *ecological integrity* means that the social context of relationships on which ecology is constituted should remain just, participatory, nonviolent and peaceful (Corcoran, 2004, p. 112). Principles of the ECI may be used as a non-specific guide for making local decisions with respect to oppressive conditions for particular people and places. Perhaps, when coupled with ecojustice-centered science education, it will help to decipher what community and natural environmental revitalizations are right for particular people. An example of one general principle of the Earth Charter is affirming gender equality and equity as prerequisite to sustainability and universal access to education, health care, and financial means: the end of violence to women and girls, the full participation of women in the community, and strengthening the role of family and nurturing relations in society.

Both David Gruenewald (2004) and Chet Bowers (2004c) argue that the Earth Charter (op. cit.) should serve as "the basis of a transformative discourse" in ecojustice-centered reform, but these two scholars also identify several caveats. Both, for example, note that the most significant limitation is that the Earth Charter deemphasizes or ignores the assumptions implicit in the ecological science of "managing" and "restoring" the local ecosystems, and both agree that the cultural thinking patterns and behaviors implicit in ecological management and restoration contribute to accelerated ecological declines. As noted in chapter four, Gruenewald (op. cit.) and Bowers (op. cit.) are correct that ecological management and restoration thinking (similar to meta-narratives that disguise Earth's story) carry forward greater ecological impacts than other cultural narratives. Unfortunately, however, both scholars inadvertently perpetuate an unnatural dualism between ecological philosophy and ecology science, and the underlying metaphysical assumptions (i.e., to reduce negative ecological impacts) that support both philosophical critiques of the Earth Charter also can be found in the ecological sciences. Essentially, both ecological philosophy and science have anthropocentric tendencies, and yet these projects are two parts of the same efforts to reduce negative human impacts.

Thus, I differ from Gruenewald (op. cit.) and Bowers (op. cit.) in that I do not subscribe to deemphasizing or ignoring the need for science teachers and students to participate more fully in ecological management and wildlife restoration. As citizen-scientists, science teachers and students may not be taken seriously by policymakers without an adequate understanding of the appropriate knowledges needed to address particular scientific questions and investigations of local ecosystems. My suspicion is that uncertainty thinking of the environmental sciences will alleviate concerns with the ECI. For my purposes, the ECI is well-aligned with my proposed educational implications for place-centered science education and ecojustice. The essential role of science in the Earth Charter, and the aims of ecojustice education, will do much to help teachers and students navigate the ecological unknown. The Earth Charter should serve as an international guide for justice-centered science education. My next philosophical study will involve analyzing the ideologies of the ECI as a framework for science education and ecojustice.

Encountering a complex and changing Earth with the full spectrum of uncertainty thinking highlights the significant worth or intrinsic value of integrated ecological philosophy and science that inspires the renewal and revitalization of the commons. Encompassing ecojustice projects and community immersion, synthesized courses for teacher development, deemphasized national testing priorities, the establishment of citizen-scientist networks, ecojustice-centered schools, and the ECI, is a cultural narrative of faith and hope in more than the human spirit. This cultural narrative offers some new research directions for science educators and other scholars interested in ecojustice. For example, green-rooftop gardens on K-12 schools across the nation might serve to model ecosystems. Biodiversity surveys could be uploaded to a database that could be used to track and forecast species migrations and movements in response to climate changes. Many schools working in relation to each other might serve as an *ecojustice mosaic*, or a network of citizen-scientists who engage in becoming informed to participate more fully in local decisions and to advocate more fully for affected parties and local biodiversity.

By *spirituality*, I do not mean to revitalize the cultural myth of "war" between religion and science that has been largely perpetuated by historians of science (Bowler, 1992). The perpetuation of "war" is a meta-narrative of thinking with absolute certainty. The integration of science and spirituality served as a great source of inspiration for the early naturalists (Bowler, op. cit.) and for almost all ancient peoples (Aikenhead, 2006). As it is not possible to disprove the existence of the supernatural, the spirituality that I am advocating is not about promoting a particular generalized and decontextualized belief. Nor am I arguing for some type of implicit "intelligent design" theory for school science. Instead, I am proposing that uncertainty thinking in science education can allow for a diversity of ways of knowing that include spirituality; for human spirituality is the metaphysical foundation for almost every cultural narrative and meta-narrative known (i.e., ontology).

Science education that is honest to itself acknowledges that spiritual viewpoints are significant and appropriate for making decisions that include multiple stakeholders, which include Earth's advocates who care for the cultural and environmental commons. Spirituality involves faith and hope in more than the human spirit. This spirituality informs science teachers and students' uncertainty thinking in remarkable ways, as part of the foundation (i.e., experiences not separate from ecosystems) for engaging in the competency of ecojustice. Even though science and religion may seem at odds, these domains of thinking are also essentially consistent. Many people are able to think with science and spirituality in the same brain, without having to resolve false dichotomized contradictions. After all, these dichotomies are cultural narratives too, which are also supported by adopted and privileged sets of metaphysical assumptions. Science education research that recognizes the legitimacy of spirituality in the classroom may significantly reduce the anxiety and frustration that students have experienced for years when taking courses from teachers who discount "non-evidenced" epistemologies.

In sum, there are many advantages to having children in the world. One advantage is the hope and inspiration they provide others to engage in projects that protect the Earth. My experience of having a young child at home is this: when I ask what he means by something that he doesn't know how to explain in words, he enacts what cannot be said. His voice and actions work together to contextualize his thoughts. A significant part of being in a world that one wants to see is being the change one wants to see in the world. We learn this concept as young children and sometimes forget it as we become adults. Each of us has diverse and unique talents that can be used to renew and revitalize the cultural and environmental commons, which protects the commons from being enclosed. Simple things, such as turning off the lights can affect millions of people and places. Whatever choices we make in the face of high uncertainty, we should do so because we take the time to learn something and share a responsibility for participating more fully. We begin our lives by being the change we want to see. End with intentionality and hope.

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