Environmental Discourses in Science Education

Michael P. Mueller
Deborah J. Tippins
Arthur J. Stewart *Editors*

# Animals and Science Education

## Ethics, Curriculum and Pedagogy

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# Environmental Discourses in Science Education

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# Wild Awakedness and Animalistic Inquiry: Introducing a Book on the Role of Animals with/in Science Education

Welcome to the one of the few books in science education that addresses the roles of animals with/in science education! We hope you will enjoy the character of the conversations led by diverse authors as they guide topical explorations with faculty, students, and colleagues across multiple disciplines in science education. Animals have interesting yet tenable positions in science that have yet to be explored. Fish, insects, amphibians, and small mammals are often kept in K-6 classrooms as pets for their calming effects or for teaching young children about personal responsibility. Some teachers do animal-rescue projects with their students and keep foster cats and dogs in the classroom. Service animals, too, may accompany teachers or children to school. Animals such as daphnids, earthworms, sow bugs, midge larvae, fish, or turtles often are studied in the classroom. Animals also may be discussed in the classroom to help analyze relationships between animals and infectious diseases, animals used in entertainment, effects of climate change, or topics such as genetic modification, cloning, invasive species, extinction, environmental conservation, stocking wildlife, farming, animal slaughter, antibiotic use, the Endangered Species Act of 1973, and organizations that make statements about animals, such as People for the Ethical Treatment of Animals (PETA) or the American Society for the Prevention of Cruelty to Animals (ASPCA). Animals also are dissected in biology or anatomy courses, and specimen collections have long served education focused on Earth's natural history. Many large metropolitan areas have museums, zoos, aquariums, conservation centers, and wildlife rehabilitation centers. In short, animals play a large role in the sciences and science education, and yet they remain one of the least visible topics in educational literature.

## Animals and the Ancient Greeks

To understand why animals are de-emphasized, we need to go back about 2000 years to the ancient Greeks. The Greek legacy largely shapes the ways in which animals have been thought about and intimately associated with in academic disciplines. Socrates and his student, Plato, had little to do with animals other than to consider their subservience to humans, assigning them largely to the servitude and welfare of their masters' hand. This subjugation is not unlike what is found in the Bible, where many Biblical stories use analogies or metaphors describing animals in largely anthropomorphic ways in relation to human strengths, weaknesses, desires, and passions. The worth of animals was described in terms of the ways in which they served humans. Ancient Greeks placed animals and nature at the lowest level in the hierarchy of how society might be organized, and humans were considered apart from animals in every way. More specifically, the ancient Greeks organized their societal hierarchy in this way:

Man
Woman
Slaves
Children
Nature

| Man | Woman |
|---|---|
| Culture (Human) (human) | Nature (animal) |
| Rational (categorized) | Irrational (wild) |
| Productive (work) | Reproductive (home) |
| Mind (intellect) | Body (emotion) |

Men were considered the brokers of culture, rationality, intellect, and productive work, whereas women were considered the brokers of the home, body, and reproductive processes of society. The characteristics traditionally associated with women over time have historically limited their participation in the sciences and constrained what they could do as teachers. Carolyn Merchant, Karen Warren, and other ecofeminists provide outstanding studies of this history and show how it was exacerbated by the scientific revolution, industrialization, and capitalism – forces that further separated humans from nature and animals as they began urbanizing. Indeed, Francis Bacon used female metaphors to discuss the exploitation and domination of nature in his accounts of science. These ideas have very strong residuals in science even today.

It is worth talking a bit more about the ancient Greek philosopher, Aristotle. Aristotle was largely associated with reinforcing the hierarchy that still subjugates animals and the earth beneath human concerns and issues (or anthropocentrism). He was also responsible for the current trajectory of the more animal-centered ethics stemming from those who are concerned with the well-being and livelihoods of animals, for Aristotle's biology emerged not only through careful naturalistic studies of organisms in the environment but also through considering the intimate relationships of humans with animals in industries such as fishing, beekeeping, and animal husbandry. Some of his observations about animals in biology are still relevant.

## Animals and Indigenous Epistemology: Lost Dialogues

For many indigenous societies, both far before and far later than the ancient Greeks, the relation of animals and their role with/in education is paramount for understanding our place in the world. There are always exceptions. However, much has been written about native peoples' relations with animals and their embodied epistemologies around the significance of animal ethics – so much, in fact, that we do not need to rehash that literature here. Even with this vast literature and understanding of indigenous ways of knowing, native epistemologies have had very little influence on the topic of animal well-being in relation to science. This marginalization of indigenous epistemology points to the lack of their voice in the conversation around animals with/in science education. Native epistemologies have been largely discounted in relation to more popular notions of science, which emphasize exploitation and domination of the natural world and the animals and plants in it. Rather, extreme forces of anthropocentrism and capitalism reinforce economic models that are based on animal exploitation for food, agriculture, pharmaceuticals, cosmetics, pets, exotic animal trade, and fashion.

## Neoliberalism and the Economic Rationalization of Animals

Neoliberalism, the twentieth-century perspective driving economic rationalization, stemmed largely from the philosophy of the ancient Greek society. The irrationalities or imperfections of "wild" nature, including animals (and women), were refined through scientific inquiry and technologies designed to take advantage of animals and manipulate their lives for ours. This hegemonic mindset firmly established animals as subjects of the humans, and their animalistic natures were thus "approved" for a more desirable future. Yet even as corporations are now genetically modifying organisms to withstand the harsh realities of the farm, other scientists are engineering methods for growing meat and other foods in the laboratory. Interestingly, with education and growing acknowledgment of the pain and suffering of animals involved in conventional agriculture, society is turning toward organic and responsibly nurtured foods and better ways to protect wild game and fisheries. However, very few people know how to grow their own food, and even fewer know how to hunt and fish. So even with a transition from conventional agriculture, there is still a heightened dependence on the market to meet the food needs of humans on Earth. In short, we may need to shift to an education for and with animals, rather than against them. Such shift will involve engaging students in experiences centered on gathering, hunting, and fishing wild foods. We will describe this trend as cultivating *wild awakedness* and *animalistic inquiry* in the next section.

## Toward Wild Awakedness and Animalistic Inquiry

How might we bring into greater attention the significance of animals with/in science education? Reclaiming the conversations of native peoples and women is one way to start. We've done that above by noting the vast literature on the importance of indigenous epistemology and the acknowledgment of the ecofeminists and others who have helped catalyze wild awakedness and the animalistic inquiry of the human species in relation to more than human. The chapters in this book go further to heighten our attention for animals in science education. Hopefully, these chapters will stimulate ways to prepare teachers, or work with teachers in schools, or talk with faculty colleagues, or discuss the importance of animals with community members. For the ideas of wild awakedness and animalistic inquiry to mature, they will need to be used with youth, as well. These conversations are the beginnings of much-needed dialogue in environmental discourse. They should help us to see our relationships as animals with animals in more nuanced ways.

## Wildly Awaked Vision of Animalistic Inquiry

Is it wild to think that we might embrace our animalistic nature rather than treat "her" as an object to be exploited and manipulated? We are critically dependent on the natural world for our survival. But have we deeply experienced and thought about the ways in which we are absolutely inseparable? Humans have interacted with animals for millions of years, primarily by harvesting them for food. But through evolutionary time, our relationships with some animals have evolved. Consider, for example, the evolution of our relationships with dogs: unlike some animals, domesticated dogs will sometimes stare "longingly" at their human owners, and through this extended gaze, they can induce serotonin production in the human who stares back. By this means, through gaze alone, dog-human interactions trigger a chemically mediated sense of well-being and trust (Grimm 2015). Dogs, in this case, seem to have hijacked the human hormone system, and some dogs, at least, can use it to better their lot in life. How wonderful is that?

Other examples of fine-tuned adjustments in human-animal interactions have also been discovered. In Africa, wild honeyguide birds will come to human calls and willingly lead their human caller to an active bee tree. The birds are then rewarded for their help by being allowed to eat the honeycomb wax as their portion of the prize. How wonderful is that?

Further, through science, the line between humans and animals is likely to become increasingly blurrier, adding to ethical dilemmas. The National Institutes of Health, for example, is opening the door now for developing chimeras (animals containing human genes) (Stein 2016). We have difficulties now – or at least, plenty of variation – in the ways in which we think about interacting with animals. Difficulties in determining the appropriate ethical standards seem to be greater, somehow, for larger so-called charismatic megafauna than for smaller, out-of-site, out-of-mind invertebrates. When we have chimeras to contend with – or only slightly more futuristically, when we have companion animals that are genetically modified to contain some of our own genes – then, our current framework for thinking about ethics and how we engage animals in an ethical context may fly right out the window. To adjust an old Chinese saying, we may yet live in an ethically interesting time!

With the broad array of topics covered in this book, even more surprising is how many topics simply could not be covered due to limitations of space. Not directly addressed, for example, is how much our understanding of evolution has been fueled by thousands of scientific studies involving literally thousands of kinds of animals, starting, most notably, with measurements of beak length, beak width, and body size of finches on the Galapagos Islands. Birds, bats, and butterflies, fossilized remains of *Archaeopteryx*, wooly mammoths (Mayell 2001), pigs (Giuffra, Kijas, Amarger, Carlborg et al. 2000), whales (http://evolution.berkeley.edu/evolibrary/article/evograms_03), turtles (Rieppel and Reisz 1999), and the social evolution of ants (Bourke and Franks 1995) – we know a lot now about how animals came about, compared to what we knew just a few hundred years ago. And in so doing, *we've learned a lot about ourselves as well* – physiologically, socially, morphologically, and behaviorally, by studying animals, ethically or not. In our various considerations of how we can or do or should interact with animals, we must not forget that we, too, can be considered as animals – just naked apes (Morris 1967).

In this book, several chapters provide clear guidance as to how some kinds of animals can be used in the science classroom to help students learn about animals. Missing are several tens of thousands of other chapters focusing similarly on this topic. Much K-12 science teaching is constrained largely to classroom environments, where teachers can find it very difficult to expose students to meaningful encounters with animals in any kind of systematic or rigorous manner due to constraints imposed by resources, time, testing schedule, and syllabus. In this context, we risk missing even simple opportunities to encourage students to experience, firsthand, many kinds of animals they might be vaguely aware of but know next to nothing about. We have strong and storied relationships with charismatic mesofauna and megafauna, such as wolves, salmon, and bears, and students need to understand such relationships because they are important. But we have strong and non-storied relationships with tens of thousands of "little species," too, and students need to understand these relationships, because these relationships, too, are important.

Teachers and their students can justifiably celebrate when a water flea, housed in a gallon jar of pond water in a classroom, sheds her exoskeleton and releases, into her little environment, a dozen babies. In the world of little, there's opportunity aplenty to consider what the water flea babies will require for food, how they eat, and where, outside the jar, they might survive and why.

Teachers and their students can justifiably mourn the death of a single member of a roly-poly community, set up in a shoebox-sized plastic container in the back of a classroom. In that world of little, there's opportunity aplenty to consider what that small loss can mean, to larger-scale processes such as decomposition and to the other roly-polys that survive. Freshwater aquatic snails are much smaller than salmon, but snails and salmon both have fascinating life histories, unique features, and important ecological roles. In short, life's magic does not scale as a simple function of animal size. Rather, every living thing is important, and every living thing has a deep and wonderful story it can tell. Teachers and their students can respectfully gather around, settle, observe, and listen. It is in these nuances for teachers and their students that a wild awakedness will emerge and then catalyze a vision for their animalistic inquiry of the future. It is through this metaphorical way of thinking about science and the role of animals that serves ecojustice and, in turn, influences behaviors around a more enhanced vision of science work.

## The Nuances of This Book

Not surprisingly, there has been very little attention for the role of animals with/in science education beyond the ethical treatment of specimens used for scientific research.

The most visible organization has been the National Science Teachers Association (NSTA). Most universities and corporate institutions have an ethical board of review for studies that involve animals in scientific research. However, the NSTA and these university and institutional ethical review boards are often limited in scope to vertebrate animals, and rarely consider ethics around the use of invertebrates or plant specimens used in the classroom or laboratory. The closer that animals appear as specimens related to humans (such as chimpanzees or dolphins), the more scrutiny they receive, to the point where some organizations, such as PETA, protest any role for animals with/in science. Yet, from a contradictory perspective, without the lives of animals that contributed to the well-being of the very mindset underpinning our scientific society, there would be a conflict for values, which inhibits too particular a cementing of roles for animals. If there is one thing that children learn about animals in school, it is the ways in which they provide countless contributions to the health, beauty, and lifestyles comprising the status quo.

The topic of animals with/in science education is at best a compromised conversation. The mere mention of ethics pushes the boundaries of traditional scientific work that has fed our human population and cured its diseases. The human dimensions of scientific inquiry dominate the landscape of science education at the expense of a richly dynamic and polysemic animalistic inquiry and wild awakedness. Now, more than ever, we need this enlarged conversation to pave the way for thinking about the unthinkable – animals with human genes or culturally desired human traits. A surprisingly broad array of topics are explored in this book. There are straightforward talks about the use of animals as devices for teaching in the classroom, to complex considerations of ethical and moral relationships between humans and animals, those wild, and those for food.

In this book, we take on the logic of domination and symbolic violence embodied within the scientific enterprise that has systematically subjugated women and nature and emboldened the thrusting androcentric tendencies and exploitative expressions for the future role of animals. We share part of the responsibility for setting these things right in light of the changes for our climate and planet that are the result of the very same influences that sidelined animals. With a wild awakedness and thriving animalistic inquiry, we might:

1. Better understand the ways of the invertebrate worm (Chap. 1 on silkworm) or honeybee (Chap. 2 on honeybees)
2. Foster new engineering solutions that contribute to ecosystems (Chap. 3 on managing fish waste)
3. Relate with the experiences of animals under our care (Chap. 4 on the deployment of animals, and Chaps. 5 and 6 on the pedagogical opportunities within the context of farming)
4. Integrate aesthetic and contemplative practices alongside science (Chap. 7 on poetic inquiry)
5. Provoke ethical dialogue among youth (Chap. 8 on the ethics of biomedical research in school)
6. Reorient nature study for promoting inquiry around sustainability (Chap. 9 on live specimens)
7. Challenge the perspective that nonhuman animals need to be used for science whatsoever (Chap. 10), and
8. Reconceptualize the study of dead animal specimens (Chaps. 11 and 12)

   Becoming more wide awakened to the wild and animalistic inquiry requires a shift toward forms of science education that better cultivate epistemic practice (Chap. 13 on socioscientific issues) grounded in cultural integrity and connected habitats (Chap. 14 on Hawaiian citizen science). Science education for animals and the role of animals with/in science education becomes more enlivened with interspecies interweavings of curricular wild awakedness and animalistic inquiry, which reclaims the care and nurturance of gender-balanced curriculum choices for science education (see Chap. 15). The final chapters focus on the theoretical conversations around cultivating critical thinking skills (Chap. 16) and the ethical role of animals (Chap. 17).

   We are not advocating for neologisms around wild awakedness and animalistic inquiry, but rather suggest that such conversations should begin with imagined possibilities and heightened consideration of perspectives encased in this book. We hope, too, that this book will additionally create diversions from more traditional scientific concepts that place us at the center of things.

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# Animals and Science Education

## Ethics, Curriculum, and Pedagogy


**Full Book Abstract**

Animals have an interesting relationship in science education that has yet to be explored in a meaningful and significant way. This book will explore the vital role of animals in science education, specimens, protected species, and other associated issues with regard to the role of animals in science. The most visible issue of course is the ethical treatment of specimens used for scientific research, and this category of animals is so important that it is an essential standard for science teacher preparation for the National Science Teachers Association. Most universities employ an ethical board of review for projects that involve animals in scientific research. However, these reviews are often limited to vertebrate animals rather than invertebrates, and there are numerous other issues that come up with specimens. The closer that animals as specimens are related to humans (such as chimpanzees), the more scrutiny they receive to the point where some organizations such as PETA protest animals used in science work. Yet we know animals have provided innumerous contributions to the health and lifestyles we all enjoy.

The authors of this book hope to elicite conversations around the relationship between animals and infectious disease, animals used in entertainment (e.g., circus), analysis of the Endangered Species Act of 1973, and analysis of PETA, ASPCA, and others that make statements about the use of animals in science. We explore the topic of keeping animals as pets, particularly issues around "dangerous" animals in the classroom, care for animals in the classroom, and the release of animal pets into the wild. We examine high-profile issues in the media such as climate change, bees and pollinators, colony collapse, and pollinator education. Likewise, the topic of collecting and studying organisms from nature, the role of natural history museums and specimen collections, the use of genetically modified organisms in school science, invasive species, cloning, genetics, antibiotic use, and toxic chemicals are explorations that stem from this book. Still other chapters may stimulate conversations around science connected with habitat restoration, extirpation, rare species conservation, stocking wildlife, farming, animal slaughter, and raising and harvesting animals in school. Some cultural perspectives on animals and

specimens will surely play a role in this book, including views on dissection, animal housing, zoos, aquariums, wildlife conservation centers, rehabilitation, and so on.

This book emphasizes theory, research, and practice around animals and specimens in school science. In particular, we are interested in theory and pedagogy associated with ecojustice philosophy, socioscientific frameworks, citizen science, school programs, and education policy orbiting the role of animals in science education. Finally, authors hope to catalyze conversations around specific animals – snails, daphnids, earthworms, sow bugs, midge larvae, fish, and turtles often found in the classroom, for example – or animal therapy programs used specifically in science education.

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# About the Editors

**Michael P. Mueller** is a professor of secondary education with expertise in environmental and science education in the College of Education at the University of Alaska Anchorage. His philosophy focuses on how privileged cultural thinking frames our relationships with others, including nonhuman species and physical environments. He works with teachers to understand the significance of cultural diversity, biodiversity, and nature's harmony.

He is the coeditor in chief of *Cultural Studies of Science Education*.

**Arthur J. Stewart** of Lenoir City, Tennessee, is a scientist, science educator, and poet. He earned his Ph.D. at Michigan State University in aquatic ecology and worked at the Department of Energy's Oak Ridge National Laboratory for 17 years as an ecologist and ecotoxicologist before becoming a science education project manager for Oak Ridge Associated Universities. In addition to publishing over a hundred scientific articles, book chapters, and technical reports, his poetry has been published in numerous literary magazines and in more than a dozen anthologies.

**Deborah J. Tippins** is currently a professor in the Department of Mathematics and Science Education at the University of Georgia. Her scholarly work focuses on encouraging meaningful discourses around environmental justice and sociocultural issues in science education.

# Chapter 1
# Worm Spit: Integrating Curriculum Through a Study of Silk and the Amazing Silk Worm

**Michael L. Bentley and Teresa Auldridge**

Among the characteristics of science widely taught in school is that scientific claims are both tentative *and* durable. One reason that results in science are considered tentative because the *modus operandi* of scientific investigations is primarily inductive rather than deductive reasoning. Inductive reasoning involves having conclusions based upon analyzing some number of collected data, whereas in deductive reasoning, one argues from known premises to a certain end. In the inductive type of work, one can never account for all cases, so there is always the chance of having overlooked one or more significant cases contrary to one's conclusion. Nevertheless, scientific claims based upon inductive reasoning are durable if the research they are based upon has been well designed, adequate supportive data has been collected, and appropriate research protocols have been followed.

And yet it is always exciting when a new finding overturns what was once presumed to be an established fact. Consider how we can no longer say that spider silk is the strongest known biological material. A study by researchers Barber, Lu, and Pugno in the United Kingdom, published in 2015 in *Interface*, a journal of the Royal Society, found that the strongest material made by an organism is that composing the teeth of limpets, a group of mostly marine gastropods. These teeth are composed of reinforcing goethite nanofibers and are three to six (or more!) times stronger than spider silk, the long-time record holder for strong stuff in nature. Kudos to the limpet!

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The Gastropoda, formerly called univalves, is a vast class of animals that includes slugs and snails, and is second only to the insects in terms of the total of named species. There are 611 families of gastropods, of which 202 are extinct in a fossil record that goes back to the Late Cambrian time (541 million years ago). Limpets 'hang out' on the surface of rocks in shallow water, but they aren't barnacles. When the tide is in, marine limpets feed on algae by moving along rock surfaces with their tongue-like appendage, called the radula. The bottom parts of the radula have a set of teeth that are exposed to great forces as the small animal rasps algae from the hard surfaces. Perhaps, as the researchers speculate in their paper, this material can be simulated in the lab and used in high-performance engineering applications such as in automobiles, the hulls of boats and aircraft structures.

Whatever might be made from artificial goethite nanofibers, spider silk is still impressive, and very strong, comparable to that of high-grade alloy steel and about half as strong as Kevlar. And spiders aren't the only animals that make strong silk, either. Silk made by silkworms, the larvae of the moth *Bombyx mori*, has been used for centuries to make all kinds of fabrics, and silkworm silk is still one of the strongest natural fibers. In fact, silk was stretched ~~of~~ on the wings of some of the earliest airplanes because of its strength-to-weight ratio (Sobol 2012). A recent edition of "Science Friday" broadcast on National Public Radio featured innovative uses of silk in biomedical engineering (Groskin 2015). This newscast captured listener attention by calling this silk "worm spit" – because in the case of the silkworm moth, the silk is an extrusion from its caterpillar's mouth while the more familiar spider silk is extruded from two to eight sets of glands called spinnerets, located near the animal's anus.

Both spider silk and silkworm silk are complex proteins. In the "Science Friday" broadcast, Tufts University's Dr. David Kaplan explained how bioengineers are constructing its adaptable protein, *fibroin*, into a multitude of medical materials. Helpful characteristics of silk for applications in medical and veterinary practice include these: it has a low inflammatory response, so it doesn't initiate an immune reaction, plus it biodegrades over time inside the body. One new application is to use silk nanoparticles for drug delivery; another is that of making dissolvable plates and screws for orthopedic repair devices, and still another is providing the scaffolding for growing tissues and organs. Kaplan is now working on implantable silk biosensors. The outstanding mechanical properties of silk have been further enhanced by Chinese chemists who fed larval silkworms mulberry leaves sprayed with single-walled carbon nanotubes and graphene (Patel 2016). Parts of the fed carbon nanomaterials were incorporated into the spun silk fibers and, compared to regular silk, the carbon-enhanced silks were found to be twice as tough and could withstand half again higher stress before breaking. Researchers have also fed titanium dioxide nanoparticles to silkworms to create ultra-strong silk that resists ultraviolet degradation and conducts electricity, making it usable for sensors embedded in textiles and possibly useful in medical applications related to reading nerve signals.

## 1.1 Silk and the Silkworm in an Integrated Curriculum

The study of silk and *Bombyx mori*, its creator organism, can be the focus of an integrated inquiry in the intermediate elementary grade classroom. Such an inquiry could easily be designed as a "STEM" (science-technology-engineering-math) unit, and such integrated studies are prominently encouraged in the Next Generation Science Standards (NGSS Lead States 2013). Consider how this study might facilitate a healthier relationship between young children and animals often perceived as "yucky". Youngsters at this level are often apprehensive, even averse to study unfamiliar living organisms (Gullone 2000). But there are several benefits to having live, non-traditional animals in the classroom (or at home), and they include providing children the opportunity to explore behavioral and structural adaptations to acquire respect for living things, as well as to practice the scientific skills of observing; inferring; predicting; measuring; communicating; gathering, organizing and interpreting data, and theorizing. Further, with the study we suggest here, children would be able to experience first-hand the phenomenon of metamorphosis. In our experience, after several weeks of slowly acclimating students to silkworms, most children become comfortable with observing them closely, if not holding them and letting them crawl on their hands or arms.

Overall, *Bombyx mori* is simply a wonderful classroom animal for student investigations and learning. This chapter makes concrete suggestions about obtaining living organisms, setting up habitats, and learning to care for them. We also suggest ideas for studying their environmental preferences and behavior and integrating the social studies connection by including their long history and social significance.

## 1.2 Back in Time in a Faraway Land

Silkworms have a rich history, having been cultivated by humans for about 5000 years. There are many legends about the earliest cultivation of silkworms in China. Many versions of the story say that a queen accidently dropped a cocoon into a cup of hot tea. As she turned it over and over in the water, a thread began unraveling. When she put several threads together they were strong enough to be used to weave cloth, and silk had been discovered. The Chinese were able to keep the origin of their beautiful cloth a secret for about 3000 years. Beginning around 200 BCE, traders from ancient Persia (now Iran) traveled to and from China across barren deserts and mountains creating trade routes that came to be known as the Silk Road. They sold their unique cloth to the Romans and others in the west at fabulously high prices, and traded other goods valuable in the West, such as jade, horses, spices, gunpowder and paper.

Silkworms were bred in China at least as early as the Longshan period (3500–2000 BCE), and possibly earlier (Vainker 2010). The evidence for this comes from a few textile fragments, artistic depictions of apparel, and documentary evidence in the *Shi Ji*, a history of China's dynasties, written between the end of the second century and the beginning of the first century BCE by Han Dynasty scholars (Beckwith 2011). The value of silk led to the creation of an extensive network, dividing and converging and forming the earth's greatest road, extending some 6000 kilometers (4000 miles), starting in China and running into the high mountains of Central Asia, across Afghanistan and present-day Iran and into Turkey. It was not simply a trade route: rather, it hosted the passage of armies as well as the communication of ideas and inventions (Thubron 2007). The history of silk also includes the many ways in which it has been used other than for making cloth. For instance, the Romans used it to tie up blood vessels and it was used in making objects ranging from telescopes (for the crosshairs and to hold magnets) to clock pendulums (Feltwell 1990).

Part of the intriguing story of silkworms is that they will eat *only* leaves from the mulberry tree. When eggs of the insect were finally smuggled out of China around 550 CE, it is said that mulberry tree seeds had to come with them. Thus, the Chinese monopoly on silk production finally ended. But that pairing of the silkworm to the mulberry was limiting to industry. In the mid-nineteenth century, in an effort to find an insect that would produce silk but not be such a picky eater, E. Leopold Trouvelot, an American naturalist, brought another insect to America to set up his own silk-producing industry. The larvae of this moth also spun cocoons but they were inclined to eat a wider variety of vegetation. A few of those moths were accidentally released from Trouvelot's cages around 1869 near Boston, Massachusetts, and quickly began to reproduce and expand their territory. We know this moth today as the gypsy moth (*Lymantria dispar*) – and its story is another lesson humans have learned about introducing exotic plants and animals to a non-native habitat.

Since the time of its release in Boston, gypsy moths have spread and are currently established throughout the Northeast, as far south as Virginia and west to Michigan and Wisconsin. It has become a pest that periodically defoliates, and sometimes kills, trees and entire forests. Becoming an invasive pest is not a worry when it comes to the silkworm: they are so thoroughly domesticated that they have been selectively bred to make their wings useless for flying. If they are accidently introduced into a neighborhood environment, they are assuredly not going to create a future problem.

The story of the silkworm in human history is long and interesting. Children can investigate the history of the domestication of silkworms, the impact of the Silk Road trade route to the east, and the economic value of silk over thousands of years, as well as how the silk industry today is a source of income in developing nations. And, of course, the potential future applications of silk in medicine and other areas can demonstrate that we are not done with seeing the value and uses of this fascinating organism.

## 1.3 *Bombyx mori* in the Classroom

Raising *Bombyx mori* in the classroom is relatively easy. It is an ideal creature to provide children with a first-hand experience of the remarkable process of *metamorphosis*, a feature of the life cycle of many insects. This process begins with eggs that are about the size of the period at the end of this sentence. Silkworm eggs are readily available for purchase from several biological supply companies (see sources listed in the Appendix). The eggs will generally hatch within a week after they arrive if kept between 78 and 85 degrees, but may take up to 2 weeks at cooler temperatures.

Silkworm larvae are only 2–3 millimeters long when they hatch from their eggs. They must have a supply of young, tender mulberry leaves from the day they hatch. Alternatively, if mulberry leaves are not available, they can be fed a nutrient that is made of mulberry leaves, which can be purchased from the suppliers who sell the eggs. If silkworms are started on the *substitute nutrient* instead of natural mulberry leaves (which we learned the hard way by experiencing a high mortality rate in one batch of larvae), they need to continue on the nutrient until they spin cocoons, and if they eat genuine mulberry leaves as young larvae, that must be their food up to the pupa stage. Apparently picky eaters don't like change.

Silkworms are such voracious eaters that around week three of their larval stage, you can put your ear close to a container with 20–30 silkworms and actually *hear* them munching on their mulberry leaves. Over a period of approximately four weeks they will continue to eat and grow, and eat and grow, increasing their mass about 10,000 times! Not a worry, though, they still are only about 6 centimeters long and about a centimeter in diameter when they begin the task of spinning their cocoon. This fairly quick, dramatic growth makes them ideal for study by children. They are so tiny at first that they are not intimidating, and they need to be fed twice a day so children almost see them grow before their eyes. We have seen students become so comfortable with them during the 6–8 week total life cycle that they even put the full-grown larvae on their noses.

Like mealworms, pet owners often raise silkworms as a nutritious food for fish and reptiles, so there are many websites describing their cultivation. One, which is very comprehensive, is wormspit.com. The larvae need to be in a room-temperature environment (no need for lights or incubators), with fresh mulberry leaves that stay moist enough for the larvae to munch on but not so moist as to promote the growth of mold. A shoebox covered loosely with a plastic bag that is open for good ventilation is a good environment in which to get them started. Carolina Biological suggests washing the mulberry leaves before feeding them to silkworms, but we have found it isn't necessary to do that and have had many successful generations without doing so. Mulberry trees are widespread – just collect the leaves in an area where they will be free of pesticides.

A frequent question is how to give them water to drink. They do not need any extra water. They get what they need from the mulberry leaves or the nutrient. Your job as the silkworm caretaker is to be sure their food is moist but not wet, and that there is definitely no mold in their habitat.

Like newborn babies, brand-new larvae are very delicate and need soft, tender food. While they are really tiny, they can be moved onto their mulberry leaves or food using a small dry artist's paintbrush. If you are not using the *substitute nutrient* as food, gather brand new, small leaf shoots that are pale green, and transfer the larva to fresh leaves twice a day. Later, when they are larger, they can be handled safely with fingers and you will find that they are exceptionally soft to the touch. They can begin eating any size leaf once they are large enough for you to pick them up with your fingers.

After thousands of years of cultivation, silkworms are so completely dependent on humans that they will starve if you don't put them on their food, or very close to it. You might want to move them to a larger container after a week or so, depending on how many larva you are raising. Put a layer of newspaper on the bottom, then put in the larvae, and finally put on a layer of leaves still attached to their twigs and branches. Within minutes, the larvae will climb upward to get to the food and start devouring it with relish. Add a second layer of leaves toward the end of the day. Eventually each larva will eat a whole leaf or more each day. It is a good idea to clear away the old newspaper, stems and twigs, and the *frass* (poop) once a day. You can recycle the paper, and compost the vegetation and frass together in a compost bin, a vermicomposter, or you can just throw it out on your lawn or garden to add a little fertilizer.

If you aren't familiar with mulberry trees (family Moraceae, *Morus* spp.), call a local horticulturalist or look up your Cooperative State Research, Education, and Extension Service to ask where to find them (any species of mulberry will be fine). The CSREES is an agency within the U.S. Department of Agriculture (USDA) associated with the land-grant university in every state and they will have agents who specialize in trees. *Morus rubra* is widespread in states east of the Mississippi River and south of Wisconsin through Pennsylvania while *Morus microphylla* is found in places in the southwest. You will become a botanical detective as you drive around your town looking for mulberry trees – just don't drive off the road as you search for sustenance for your silkworms! Since the female mulberry trees tend to create a mess when their fruits drop to the ground, they are not a highly desirable landscape species. We find them most often in older neighborhoods, around parking lots, and along streams and riverbanks. It is helpful to carry a pair of shears in your car along with a large zip bag so you can cut branches off without damaging the trees. A batch of leaves in a plastic bag can be stored in the refrigerator for several days.

As silkworms grow and you handle them more, you will discover that they have "sticky pads" on their *prolegs* that allow them to hold onto the leaves or onto fingers – or noses! These "prolegs" are not actual legs. Look toward the head to see the official six legs that classify them as insects.

When fully grown, a silkworm larva weighs about 10,000 times more than it did when first hatched (Sobel 2012). Silkworms eat 24 h a day except during four brief periods of their life span when they are shedding their exoskeletons to transform to their next instar stage. They go through five instars all together, and the old skins look like either tiny flat snakeskins or sometimes like scrunched up paper from a soda straw. ~~In~~ Chinese medicine values these shed skins to make medicine, so they are worth way more than their weight in gold if you can find a buyer.

The larvae eventually develop a protrusion that looks like a “horn” on their tail end. The horn is *not* a stinger and they don’t bite anything but mulberry leaves (another reason they are an ideal organism for classroom or home observation). For some reason, we have become somewhat “germophobic” in our society. We have had students reach for hand sanitizer immediately after handling silkworm larvae. One reason this organism is so good for home or classroom study is that they do not carry any disease or harmful bacteria that can be passed on to humans. However, the alcohol in hand sanitizers can kill the larvae so ask children not to use a sanitizer before handling silkworms, and perhaps use this opportunity to discuss the evolution of antibiotic resistant bacteria due to overuse of unnecessary antibiotics.

Over the thousands of years of human cultivation of silkworms, artificial selection has produced significant changes in the original organism. Because the Chinese who first domesticated them decided they didn’t want such valuable insects to fly off when they emerged as adult moths, they bred them until the moths were unable to fly. And so the species *Bombyx mori* is not currently known to exist in the wild. Their original defense mechanisms have been lost and they are totally dependent upon humans to survive. Nevertheless, studying this animal still provides an opportunity to discuss with one’s children or students about why “exotic” plants and animals should not be flushed down the toilet, released in the wild, or otherwise placed outdoors.

When the larval stage of the silkworm is complete in 3–4 weeks, they begin to spin their cocoon. You can provide a paper egg carton or several sections of a tube from a paper towel roll in their habitat for them to use as an incubator cubbyhole and watch them spin silk continuously for 2–3 days, or just let them spin on the side of their container or on a leaf. Their cocoon ends up being a single thread of silk that is from 0.5 to 1.5 km (1 mile) long (Sobol 2012). Think about the fact that just 7 to 10 unraveled cocoon threads could be fastened end to end and reach from sea level to the height of Mt. Everest!

During the two weeks they are inside the cocoon, they transform first into a pupa, a stage that looks totally different from the caterpillar or larval stage, and then into an adult moth. Be sure to gently use scissors to cut open at least one of the cocoons a week or so after it is spun so that the students can see the pupa inside. It will twitch and wiggle frequently but the pupa will not be harmed. You can also see that last shed skin inside the cocoon, scrunched up inside the cocoon like an old sock.

When the pupa transforms to the next stage of metamorphosis and is ready to emerge, the adult moth secretes a liquid that dissolves the “glue,” called *sericin*, that makes the cocoon hard, and it will then squeeze out through one end of its temporary home. The female moths have much larger abdomens and males have larger antennae. Their only purpose as adult moths is to mate, lay eggs and die. They have no mouthparts and do not need any care at all at that point, but they are still

**Table 1.1** Life cycle of silkworms *(Bombyx Mori)*

| Stage | Approximate number of days |
|---|---|
| Eggs | 7–14 |
| Larva | 21–30 |
| Pupa | 7–14 |
| Adult moth | 3–5 |

Note: This table represents approximate times for the various stages for batches of organisms that were raised in the spring in the mid-Atlantic region. There may be some variation in different climates

fascinating to watch. The males will flap their wings vigorously to attract a female who will lay up to 200 eggs after mating.

The total adult stage only lasts 3–5 days, a fact of life that is just almost incomprehensible for young children. Students always ask many questions to try to understand the end of the silkworm life cycle. The eggs should be stored in a plastic bag in a refrigerator (not the freezer) for a few weeks to a year until you and the mulberry trees are ready for another batch of larvae. The eggs seem to need that cold period in order to be viable and actually hatch into larvae again. Table 1.1 summarizes the stages of silkworm development.

The production of raw silk by raising silkworms is called *sericulture*. Sericulture farmers who want to use the silk usually don't allow the adult moth to hatch out of the cocoon, because the emerging adult breaks the long, single strand of silk. They either bake the cocoons or drop them into boiling water to kill the pupa and dissolve the "glue". Then they find the end of the filament, unwind the cocoon onto a spool, spin it into thread and then weave it into silk cloth – a skill that has been refined over thousands of years. It takes some forty hours of spinning by hand to make a pound of silk thread and a week of hand weaving to make just three feet of silk cloth. Altogether, it takes some 110 cocoons to make enough silk for a necktie, 630 cocoons for a blouse, and 5000 cocoons for a long dress (Sobol 2012).

## 1.4 Silk Is Big, Even Today

Creating silk from the "worm spit" of *Bombyx mori* remains an important industry to this day. Silk is still considered "chic" as a fabric and is always in great demand by clothiers and designers, and now by engineers for its unique properties. Over thirty countries now produce silk but the global leader, as it always has been, is China (Feltwell 1990). Currently, according to the International Sericultural

Commission (2015), the world produces 178,039 metric tonnes (196,000 tons) of raw silk annually, with China contributing 82% of the total. Other countries with sizeable silk-producing industries include India, Uzbekistan, Brazil, Japan, Republic of Korea, Thailand, Vietnam, DPR Korea, and Iran. Sericulture is labor-intensive. More than ten million farmers in China raise silk and nearly half a million people are employed in silk-fabric production (Hays 2010). More than 8 million more are employed in the silk industry in India (Central Silk Board 2016) and tens of thousands in other countries.

Older children (and their parents) can research the history of the silk trade in ancient times and learn about the opportunity the silk industry presents for families even today to become self-supporting in developing countries. Knowing that a silkworm life cycle is about 6–8 weeks, teachers and parents can plan ahead to prepare for an exciting multi-disciplinary learning opportunity for children. Pay attention to the time your mulberry leaves begin to sprout in the spring, and an adventure studying this unique creature can begin.

## Appendix

### *Books and Resources for Children*

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Johnson, Sylvia A (1982). *Silkworms*. Minneapolis, MN: Lerner Publications Company.

Park, Linda Sue (2005). *Project Mulberry.* New York, NY: Random House, Inc. Reprinted by Houghton Mifflin Company.

www.eurekalert.org – The Eurekalert search tool offers quick-N-easy access to all kinds of scientifically sound current information

### *Biological Supply Companies: Sources for Silkworm Eggs*

Carolina Biological Supply Company, Burlington, NC, Phone (800) 334–5551, http://www.carolina.com

Niles Biological, Sacramento, CA, Phone: (916) 386–2665, http://www.nilesbio.com

Mulberry Farms, Fallbrook, CA, Phone: (760) 731–6088, http://www.mulberryfarms.com

The Silkworm Shop, San Diego, CA, http://www.silkwormshop.com

Lady Silkworm, Long Island, Flushing, NY, http://www.ladysilkworm.com

Silkworm.ca, Canada, Phone: (905) 864–5898, http://www.silkworms.ca

## *Photos*

Leaves of the mulberry tree (Moraceae)

Cocoon of *Bombyx mori*

Silkworms (*Bombyx mori*) with mulberry leaves

Eggs of *Bombyx mori* with mulberry leaf and dime for scale

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## Additional Resources for Further Study

Dandolo V. (2015). *The Art of Rearing Silk-Worms* (1825 translation, Cambridge Library Collection – Zoology). London: Cambridge University Press.

Edge, D. (2016). *The silk roads: A new history of the world.* New York: Knopf.

Hazzi, J. (2012, orig. 1923). *Silk-worms: Letter from James Mease, transmitting a treatise on the rearing of silk-worms.* Ulan Press (location unknown).

Nebenzahl, K. (2011). *Mapping the Silk Road and beyond: 2,000 years of exploring the East.* London: Phaidon Press.

Norell, M. (2011). *Traveling the silk road: Ancient pathway to the modern world.* Asheville: Sterling Signature.

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# Chapter 2
# You Can Give a Bee Some Water, But You Can't Make Her Drink: A Socioscientific Approach to Honey Bees in Science Education

**Jonathan Snow and Maria S. Rivera Maulucci**

Humans have long been fascinated by the European honey bee (*Apis mellifera*). First, feared for their sting but treasured for their honey, honey bees have evolved from a source of gathered food into an integral part of our current agricultural system through their pollination services. Second, honey has a long history of use for medicinal purposes. Third, honey bees also produce beeswax, an important commercial product used in cosmetics and pharmaceuticals (Bogdanov 2004). Fourth, like humans, honey bees are highly social. As global demand for honey and pollination services increases, some regions of the world are experiencing perplexing declines in managed honey bee populations attributed to land-use changes, weather, pests and diseases, climate change, and pesticide use (Carreck 2016). How would the extinction of honey bees affect humans and other species on the planet? How are honey bee management practices contributing to the declines? What are the ethical dimensions of honey bee management and research? These questions situate honey bees and their health, management, and research as a significant socioscientific issue for investigation in science classrooms or other educational settings. In this chapter, we briefly review the benefits of a socioscientific issues (SSI) approach to science education, provide vignettes about honey bees that illustrate their unique ecological contributions and significance to human welfare, and propose ideas for structuring an SSI unit on honey bees.

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## 2.1 What Is a Socioscientific Issues Approach to Science Education?

SSI and science education seek to place scientific content in controversial, real-world, social contexts as a way to engage students in moral reasoning and ethical decision-making alongside developing a deeper understanding of scientific information (Zeidler and Nicols 2009; Sadler et al. 2006). The SSI framework involves more emphasis on open-ended questions that provide opportunities for multiple perspectives, discussing and debating science concepts in the context of personal and social issues, cooperative group work that simulates work in scientific communities or advocacy groups, the use of scientific evidence for argumentation and ethical decision-making, and the use of authentic assessments (Wilmes and Howarth 2009). SSI facilitates the types of critical thinking, evaluation of evidence, and moral reasoning that may equip students to address the issues they will face in their lives outside of school (Sadler and Zeidler 2004). In the following sections, we will show why honey bees provide an ideal topic for an SSI approach.

## 2.2 What Are Honey Bees?

Honey bees are insects of the Order Hymenoptera that live in large eusocial colonies of about forty thousand individuals. Eusociality, derived from a Greek word meaning "true social," describes the highest level of organization of animal societies defined by cooperative brood care, overlapping generations within a colony of adults, and a division of labor into reproductive and non-reproductive groups (Holldobler and Wilson 2008). Eusocial insects include bees, ants, termites and others, representing only 2% of insect species while making up two-thirds of the insect biomass. The division of labor in eusocial insects creates specialized behavioral groups within their society, which are sometimes called 'castes'. Three types of individuals exist in honey bee colonies (Fig. 2.1). First, the sterile female worker bee constitutes the vast majority of individuals within the colony and performs all non-reproductive tasks. In contrast, the queen bee serves as the sole reproductive female in the colony. Male drones make up 1-5% of the members and mate with the queens derived from their own colony. Honey bees feed on the nectar and pollen of flowers to make honey and pollinate crops, and it is this characteristic of their life history that has made them part of the human story.

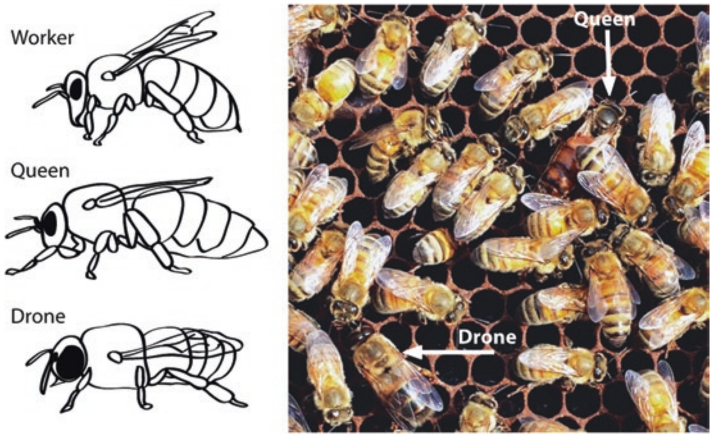


**Fig. 2.1** Honey bee castes (*left*) and examples on a typical comb (*right*) with drone and queen examples denoted by *arrows*

## 2.3 How Did Humans Start Keeping Bees?

The role of honey bees has transformed from a source of honey and beeswax in our pre-history to an integral role in an industrial, agricultural system that requires honey bee pollination services. Eva Crane's (1999), *The World History of Beekeeping and Honey Hunting*, conveys much of the detail of the history of human use of bees that we use to write this chapter. Honey, a concentrate of nectar, is the oldest sweetener and gathering honey from bees may have been a human activity since before we earned the name, *Homo sapiens*, with the earliest evidence found in Neolithic cave paintings. In addition to honey, beeswax is a valuable and useful commodity, widely used in food, cosmetics, pharmaceuticals, and even some industrial processes as a lubricant. More recently, chemical analysis of Neolithic archeological sites reveals chemical traces of beeswax, dating back 9000 years (Roffet-Salque et al. 2015).

The first gathering of bee's honey and wax was from wild honey bees living in naturally occurring nests. During ancient times, honeycomb, wax cells filled with honey, would be recovered from a wild nest using smoke to pacify the bees but also with significant damage to the nest. Little, if any, management of the bee colonies (i.e., beekeeping) occurred to increase survivorship of the bees or to increase the yields of harvested products. Eventually, beekeepers took on the responsibility of caring for nests of bees which moved them from the wild to apiculture. The techniques for gathering wax and honey remained the same during this transition. A significant change in beekeeping occurred with the invention, perhaps accidental, of moveable fixed comb hives. Although varied in the materials that were originally used and shaped, these hives were typically open tubular vessels, kept horizontally or vertically, which allowed for bees to build a strong comb. The first evidence of this comes from a bas-relief from 2400 B.C.E. in Egypt, with the first real example of a hive also from Egypt around 1900 B.C.E.

This new form of hive led to the proliferation of traditional beekeeping across the globe, which initially became widespread throughout the Mediterranean and the Middle East, with the first archaeological evidence of an apiary or group of managed hives being found at a site dating to 3,000 years ago in northern Israel (Bloch et al. 2010). By the time of the Roman writer, Publius Vergilius Maro, known as "Virgil," beekeeping in this managed form had acquired some sophistication, as described by him and other later Roman writers. He spends the entire Book IV of *Georgics* discussing honey and the bees that produce it: "Of air-born honey, gift of heaven, I now / Take up the tale" (Georgics Book IV, Ln 1-2). In addition to being able to move the colonies easily, the honeycomb in these hives was more readily accessible to beekeepers and easier to harvest. Superficial extensions could be added to allow for an increased comb space and for honey storage during the times of high production, and new colonies could be started from captured swarms or by placing comb from an existing hive containing brood into a newly manufactured hive structure.

Beekeeping changed very little through the middle ages. However, from the beginning of the scientific revolution in the late 1500s, new hive designs with various improvements proliferated rapidly. In Massachusetts in the mid-1800s, L.L. Langstroth, building his knowledge extensively on the work of many others, developed the hive design that is most commonly used today by beekeepers – the Langstroth Hive (Langstroth 1853). Key features of his design included a moveable comb stabilized in frames loaded from the top of the hive, an inexpensive and potentially modular, rectangular, wooden, outer shell for the frames, and a precise spacing called "beespace" of hive components to prevent bees from building unwanted comb. The design allowed for the easy inspection and manipulation of individual sections of comb in the frames, and although these hives were more expensive than traditional types of the past, it quickly became the norm for beekeepers throughout most of the world. The Langstroth system enhanced opportunities for hive movement, expansion, and management.

## 2.4 What Can Honey Bees Teach Us About Our Agricultural System?

The first intentional use of honey bees for pollination did not occur until the late 1800s when advances in beekeeping allowed the honey bee colony to convert into a pollination machine (Fig. 2.2). Today, honey bees provide critical pollination services to humans and their agricultural endeavors (vanEnglesdorp and Meixner 2010). For example, almond trees, which cannot self-pollinate, require insects to bring pollen from other trees, and honey bees are used extensively for this service. As our agricultural system has become more homogeneous, and monocultures such as almond groves have become the norm, honey bees have emerged as the the only

**Fig. 2.2** Honey bee pollinating white clover in Central Park

pollinator with the ability to pollinate these vast orchards and fields in the industrial agriculture model. The bee hives are easy to move on large semi-trucks, provide a high number of pollinating individuals per colony, and they are generalists in the plants they will pollinate. California, the primary almond growing state, imports as many as one million bee hives during the February almond pollination season (Cavgli et al. 2015). In addition to the crops like the almond that require honey bee pollination, for many plants, honey bee pollination, while not required, increases production dramatically. Experts estimate that one of every three bites of food we eat results from animal pollination, including honey bees, and there could be significant health consequences should we lose this service (Smith et al. 2015). Although many other animal pollinators, including other species of solitary bees, are more important for pollination than honey bees in some contexts (Garibaldi et al. 2013), we certainly rely on honey bee pollination more than we ever have in the past for today's agricultural system. It is because of this that beekeepers have a constant struggle to keep up with the increasing agricultural demand, especially in the face of recent colony losses, now referred to as Colony Collapse Disorder (vanEngelsdorp and Meixner 2010) and new management practices put intense pressures on honey bees. The bees are often driven by truck thousands of miles to reach crops in need of pollination, and they are fed the empty calories of sugar syrup to make up for gaps in their diet from this travel and the low species diversity of the agricultural landscapes that they will encounter when they are released to do their job. High colony density also provides the ideal conditions for the spread infectious disease, and in response, beekeepers treat them with increasing levels of toxic pesticides and antibiotics. Quoted in the San Francisco Chronicle, Marla Spivak, bee expert and entomologist from the University of Minnesota says in his article that, "we're transporting them like they were a machine...and expecting them to get off the truck and be fine" (Agnew 2007).

Jon's research focuses specifically on understanding some of the stresses that may be contributing to bee disease and also to discovering how bees respond to these stresses at the cellular level. For example, honey bees can be infected by a variety of insect parasites and pathogenic microbes, which can spread rapidly among individuals from colonies maintained at high densities in modern agriculture. To elaborate on this notion, a unicellular fungus called *Nosema ceranae* infects the digestive tract of bees causing a reduced lifespan in individual bees and perhaps contributes to colony collapse. Although *N. ceranae* infection can be controlled by treatment with the drug Fumagillin, high doses of this drug are toxic to bee cells. Moreover, since we have no easy, cheap, and reliable field test for *Nosema* infection, Fumagillin is often administered regardless of the presence or absence of infection. This drug overuse likely causes sub-lethal health issues in treated colonies, reduces the flexibility of honey production for human consumption, and may inadvertently lead to resistance against the drug with continued use. In light of this, Jon established a novel diagnostic assay that allows for detection of *Nosema* infection in honey bee tissues (Snow 2016) that is currently being developed into a tool to help beekeepers detect actual *Nosema* infections. This assay may reduce the rate of unnecessary antibiotic treatments. To provide another example, the recent discovery of RNA interference (RNAi) and characterization of its mechanisms and possible applications have assured that the next generation of genetically engineered (GE), or genetically modified (GM), organisms will make use of this technology to improve desired crop plant characteristics. RNA are strings of nucleotides that perform many functions in cells. The RNAi technology works through the expression of small, specially designed RNA molecules in plants of interest. The insertion of specially designed RNA molecules into plants can then modify the expression of genes within the plant to confer new properties on it, such as drought resistance. The small RNA molecules can also be designed to affect the survival of ingesting organisms, such as insect pests, thereby providing a potent pesticide. On one hand, the use of RNAi through genetic engineering has the potential to transform agriculture. This technology offers the potential for much greater specificity in its effects on other organisms compared to many small molecule pesticides and the current generation of GM organisms. On the other hand, this technology requires rigorous research to assess the safety of these small RNA molecules and the plants expressing them. Understanding the effects of these RNA molecules on off-target organisms, such as honey bees, which may ingest them when foraging, is of particular importance as this technology moves forward. Jon's research has contributed significantly to solving this problem by establishing a methodology for detecting small RNA from the environment in honey bee tissues (Masood et al. 2015) and measuring the uptake of small RNA in feeding assays. These tools can be used in the future to assess the safety of RNAi technology for bees.

The transition that honey bees have encountered in their agricultural role and management over the last 50-70 years mirrors the evolution of the place of animals in our agricultural system as a whole. The modern system, referred to as modern Industrial Agriculture, consists of vast single-crop farms and animal-production facilities. While this system has allowed for increased productivity to meet the demands of a growing world population, concerns abound regarding the sustainability of a system that has many environmental, animal welfare, human health, and community costs. The application of industrial manufacturing practices to living organisms and their ecological connections may be both unethical and impractical. Some key questions that are being asked in agriculture right now include 1) How far is too far to push the organisms that are part of our agricultural system? 2) Do such extreme practices even provide a sustainable framework for food production? The case of bees in agriculture provides a useful microcosm of both the development of industrial farming and a tool for illustrating the positives and negatives of such a system, even though it is highly unlikely that our agricultural system would abandon honey bees either as a source of products or as a source of pollination services.

## 2.5 Are Honey Bees Domesticated?

When we think of animals involved in agriculture, we usually think of domesticates, such as cows or chickens. However, despite the inclusion of honey bees in this category, the domesticated status of honey bees is anything but clear. As E.O. Price, an expert on domestication theory, suggests, "one can debate whether the western honey bee (*Apis mellifera*) is a true captive domesticate" (Price 2002). Whether we define them as a domesticated species has real implications for their future in light of the beekeeping practices of industrial agriculture. Further domestication, such as artificial insemination to control reproduction or constant supplementary feeding, is likely to integrate them more efficiently into the current agricultural system, but may come with costs and could result in loss of some of their unique features. Definitions of domestication as reviewed in, The Domestication of Animals, by Melinda Zeder (2012), vary in their emphasis on the balance of power within the partnership, the degree of control, and intentionality. On one extreme, definitions suggest a human-driven process through which "humans deliberately and with forethought assume control over the domesticates' movement, feeding, protection, and above all its breeding" with the goal of achieving a particular purpose (p. 162). On the other extreme, domestication is akin to other mutualistic relationships in nature; wherein two organisms have coevolved toward a codependent and symmetrically beneficial relationship. As a key tenet of relationships of this type, natural selection operates on both partners.

In her work on domestication theory, Zeder (2012) offers a theory of domestication that lies somewhere between these two extremes, suggesting, "domestication qualifies as a form of biological mutualism with clear benefits for each partner in the relationship" (p. 162). However, she also notes that the extraordinary human "capacity for the invention and transmission of learned behavior shifts the balance of power" (p. 163) towards humans. Her modified definition includes,

> *a sustained, multigenerational, mutualistic relationship in which humans assume some significant level of control over the reproduction and careof a plant/animal in order to secure a more predictable supply of a resource of interest, and whereby the plant/animal is able to*

> *increase its reproductive success over individuals not participating in this relationship, thereby enhancing the fitness of both humans and target domesticates.* [original emphasis] (p. 163–4)

During the initial domestication process, artificial selection is applied to the species in question through control of breeding and for animals, "the primary focus of selection under domestication tends to be on genes that control behavior" (p. 164). Nevertheless, insect domestication is less well understood than that of vertebrates, in part because the examples are fewer, understudied, and less similar to other domesticated animals that are typically larger, more obvious, or more charismatic. Significant control of reproduction and diet are key elements to most definitions of domestication and examining these can provide an interesting discussion of the domestication theory and status of honey bees.

## 2.6 How Do Humans Control the Reproduction of Honey Bees?

Breeding of the colony requires the queen to take a 'mating flight' and mate with one to ~25 drones. Our understanding of the science during this process is limited, but it certainly requires open space for her mating flight and a sufficient number of drones to inseminate the queen. In *Honeybee Ecology: A Study of Adaptation in Social Life*, Tom Seeley writes that "the honey bee has not been strongly modified by artificial selection" (Seeley 1985, p. 15). This fact has been shown again and again, with a recent study finding an increase in the genetic diversity of managed colonies in comparison to those of their wild ancestors (Harpur et al. 2012). Seeley explains that humans did not control breeding to any extent until the mid-1900s, and even today, bees derived from breeding programs have not been widely available until recently.

Once a queen has mated, she and the 'colony superorganism' to which she belongs may multiply itself through a swarm event: when the original queen and some portion of the workers fly to find a new nest site. The ability of the colony to multiply through swarming in the wild is in fact rather limited, with a natural swarm rate of 3.6 daughter colonies per originating colony (Winston 1987), a reproductive range similar to other domesticated livestock such as cows. However, because of the focus on maximizing honey production or meeting pollination contracts as the primary goals for honey bees, swarms are heavily discouraged by management techniques that favor buying new hives in the form of packages (literally a box of 10,000 bees!) or nucleus colonies from commercial operations. One of the reasons swarms are discouraged is that it is notoriously hard to choose the exact timing and the intermediate and final resting points of a swarm of bees. Although beekeeping management techniques allow colonies to be divided to avoid the more uncontrolled swarming behavior, swarming still occurs. In fact, for many years, part of the job of New York Police Department Detective, Anthony "Tony Bees" Planakis was to capture wayward swarms for the public good (Taste 2015). Thus, evidence suggests that we control the reproduction of bees, especially with regards to the selection of traits that make them more useful to humans, only to a limited extent.

## 2.7 How Do Humans Control Honey Bee Diet?

Humans can supply honey bees with the nutrition they need. As Randy Oliver, a beekeeper and biologist explains, all they need is "a dry box and plenty of flowers" (Oliver 2010). By thoughtfully placing bees in an environment with a variety of plant species that together produce a constant source of blooming flowers, their diet is managed. In fact, in the early days, after people understood their role in pollination, beekeepers paid to give their bees access to flowering acreage. However, the diet is not easily controlled by humans, as it is almost impossible to decide which flowers the bees visit. The collection of infinitesimal quantities of nectar from untold numbers of flowers by thousands of bees and the concentration of this substance into honey is the very process that interested early humans in the first place. This reality has interesting consequences for honey production and introduces quandaries, such as where we can have 'organic' honey? While beekeepers may raise the bees according to organic standards, it is almost impossible to ensure that the bees eat according to those rules (U.S Department of Agriculture, National Organic Program [NOP] 2010). Studies show the presence of insecticides in honey, pollen, and the bees themselves in populations of samples from wild and managed honey bee colonies and the expansion of industrial agriculture has exacerbated this problem (Mullin et al. 2010). For example, a study of agricultural practices showed that tractor movement and the wind from fields of newly planted corn treated with pesticides generated large quantities of dust. Scientists then found pesticides in samples of the soil, nearby flowers, honey and pollen stored in local hives, and in the bodies of dead bees outside the hives (Krupke et al. 2012). Since the vast majority of corn planted in North America receives this pretreatment with pesticides, we must recognize that the spread of these chemical products goes beyond the margins of the cornfields and into the neighboring ecosystem with impacts on local species and our broader food supply.

Jon, the first author of this chapter, recently ran into a problem with diet control for his bees that live in hives atop Barnard Hall on campus. In addition to pollen and nectar, the female honey bees forage for other resources, including water. In the middle of Manhattan, the last thing you want is bees showing up unexpectedly to gather water, so city beekeepers always provide a water source near the hives. But Jon's bees did not like the water he provided. Instead, they preferred the moisture available to them on the damp moss covering the steps by Lehman Library (Fig. 2.3). No matter how he tried to entice them to his water, the honey bees congregated in twos, tens, and on hot days, even hundreds, on steps in the middle of a vibrant college campus. Apparently, humans exert a limited influence on the diet of honey bees.

**Fig. 2.3** Honey bee foraging for water on Lehman steps

In summary, honey bees only partially satisfy the criteria for domestication. First, the nature of the products and services they provide specifically involves visiting many flowers, which cannot all be controlled by humans. Second, the mating of the females “on the wing” has made their reproduction, and breeding for specific traits difficult except in specialized environments. However, many scholars conclude that the process of domestication is a continuum, which implies that although honey bees may not yet fit the criteria for domestication, we may be pushing them more towards this state, especially in the context of the current agricultural system. However, if we interfere too much with their ‘beeness’ by providing the majority of their food or by confining them to control their reproduction, not only may they become of little use to us, but they could very well cease to be the source of wonder first described millennia ago.

## 2.8 Are Honey Bees Invasive Species?

Honey bees, previously only native to the Old World, were spread significantly by humans during the Age of Exploration, first reaching North America with hives shipped to the Virginia and Massachusetts colonies between 1622 and 1639. Thus, honey bees are not native to the New World, and some people debate whether we should worry about the decline of a non-native species. The concern about native versus non-native species stems from the ways in which some introduced species wreak havoc on natural ecosystems by contributing to the loss of biological diversity, damaging commercial crops, or by carrying infectious diseases that can harm humans and other species (Schlaepfer et al. 2011). These species are typically called invasive because of their deleterious effects on the ecosystem. However, the authors make the argument that some non-native species such as European honey bees, deserve conservation as a result of their desirable effects on an ecosystem, or for their recreational, agricultural, or aesthetic value. Conservations biologists are by no means in agreement on this issue, with some researchers strongly endorsing their view and others vehemently protesting.

## 2.9 What Might an SSI Approach to Studying Bees Entail?

In the standard science curriculum, students might learn about honey bees as part of learning about pollination. They might read nonfiction texts about bees and learn about hive structure and the division of labor in the hive. They might plant pollinator gardens and observe bees, or even go on a bee hunt (Mueller and Pickering 2010) to investigate bees and other pollinators. Some schools even have a beekeeping class students can take. Yet given the current situation with honeybees, an SSI approach provides a unique opportunity to connect the science of honey bees to pressing social and environmental issues. An SSI unit could focus on the overarching questions: How would the extinction of honey bees affect humans and other species on the planet? How might current honey bee management practices be contributing to the declines? What are the ethical dimensions of honey bee management and research? How should honey bees be managed to ensure their health and our own? Under these overarching questions, a number of learning outcomes could be pursued. First, students could describe the history of honey bee domestication and their introduction to other ecosystems and explore their behavior and roles in the ecosystems. Students could then debate the ethics of introducing new species and whether the benefits outweigh the harms. Are the honey bees displacing native pollinators? How might this displacement affect other plant species that rely on native pollinators for reproduction? Second, students could examine the relationship of honey bees to industrial agriculture and explore the possible causes of honey bee declines and instances of colony collapse disorder. They could also investigate how honey bees are managed, the ethical dimensions of their management, and generate solutions to ensure better, or more humane honey bee management practices. For example, would plantings of other wildflowers among almond monocultures provide more variety in honey bee diets and improve their health? How might we reduce the unnecessary use of drugs to keep honey bees healthy? Third, students could calculate cost estimates of the contributions of honey bees to agriculture and to the economy and debate whether the lack of diversity among the introduced honey bees might put our food and economic systems at risk as we increasingly involve them in industrial agricultural operations.

The design of the unit draws on two excellent resources, Jurgen Tautz's (2009) book, *The Buzz about Bees: Biology of a Superorganism*, which deals with aspects of their fascinating biology, and Eva Crane's (1999) book, *The World History of Beekeeping and Honey Hunting*. Among the many fascinating personal accounts of beekeeping, we recommend two sources from different eras, one from 1903 by C. C. Miller (1903) and another from 1988 by Sue Hubbell (1988). Finally, an excellent chronicle of migratory beekeeping can be found in Douglas Whynott's "Following the Bloom" (1991). State and local beekeeping associations around the country provide incredible resources. A quick search of the list at http://www.apiaryinspectors.org/index.html will help locate the most local beekeeping organization, often organized by county, sub-state region, or municipality. These groups of beekeepers and bee enthusiasts are committed to educating the public about honey bees. Members are glad to come to go the classroom and talk about bees (often bringing an observation hive for direct observation) or to host an apiary tour. In New York, Jon regularly gives talks about honey bees.

Beekeeping is a rewarding experience. Obviously, school safety and liability are central concerns, but with responsible behavior, appropriate protective measures, and meticulous attention to the management of one's colonies, these issues can be reduced. Honey bees have minimal requirements to keep them safe and happy while producing great side benefits. For learning about the theory and practice of beekeeping, there is no substitute for the resources offered by the local beekeeping organizations. The class Jon took at the Topsfield Fairground, given by the Essex County Beekeepers' Association in Massachusetts, served as a key source of information, provided a community for support, and gave him the confidence to get started with his own box of 10,000 bees. Also, many excellent books provide instruction and advice for beginners, one of which is, *The Beekeepers Handbook*, by Diana Sammataro and Alphonse Avitabile (2011). One of the most exciting new roles for honey bees is in urban agriculture (life in the city), where their small area footprint and wide foraging range allows honey bees to take advantage of otherwise untapped floral resources to produce delicious honey. As a Manhattan beekeeper, people always ask Jon if honey from the middle of New York City tastes good. After consuming about four gallons this past year, he promises that it is quite tasty.

## 2.10 Conclusion

Honey bees are an ideal species to use in an educational setting for helping students learn about our agricultural systems, our relationships with domesticated animal species, and ethical dimensions of animal care and management. You can give a bee some water, but you can't make her drink. And really, who would want to exert any more control over such a fascinating and inspiring animal?

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# Chapter 3
# Engineering a Solution for Managing Fish Waste

**Alexandra West Jefferies**

Fish and humans have a long-standing predator-prey relationship. Fish have been, and remain, an important component of human diet, and fisheries are central to many coastal communities' economies. According to Serge Garcia (2005), globally about 17% of animal protein is derived from fisheries, with greater percentages in coastal communities. Garcia states, "The most considerable and substantial contribution of fisheries worldwide is the supply of highly nutritious animal protein for human consumption and the employment and income generation in often-remote coastal areas" (n.p.). Well-managed sports fisheries also can contribute appreciably to an economy through recreation and tourism.

The unusual life cycle of migrating from freshwater to saltwater and back again is called anadromy, and fish that exhibit this pattern are anadromous (Montgomery 2003). Both in transit to spawning waters and in death, anadromous fish contribute important marine-derived nutrients to freshwater ecosystems. American Rivers notes: "Food resources for almost all kinds of animals are variable in space and time, but the anadromous fish system is an extreme case in which prey is temporarily very abundant, spatially constrained, relatively easy to capture, and more or less predictable" (n.p.). Mary Wilson and Karl Halupka (1995) also note: "… Wildlife species capitalize on available concentrations of anadromous fish and may change their distribution and even breeding biology in response to the abundance of these fish" (p. 493).

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When Alaskans think of anadromous fish, a salmon steak or a fillet sitting on our dinner plate probably come to mind. Those of us who live near an abundant wild salmon population know the effort it takes to get these fish from the ocean or stream to the dining room table, and we know also how much of each fish goes unused in the process. Once cleaned and the nutritious flesh removed, the unused remains must be disposed of. There are various methods for doing so, but some of these methods can be considered polluting, while others can cause unintended consequences, as discussed below.

## 3.1 Fish Waste Issues

Salmon anglers typically retain fillets from their catch, which leaves the carcass as something that an angler needs to dispose of. While Alaska Natives conventionally use the entire fish, most anglers consider the carcass to be "waste". Moreover, the salmon carcass is either disposed of onsite, such as in the stream or ocean, or the fish is packed out whole and the carcass is disposed of later with other waste, such as one's home garbage. For anadromous fish, the volume of fish waste produced over a period of time is much larger than a non-anadromous species. This is primarily because many Alaskans catch enough salmon to sustain them through the year, and anadromous species have a defined run period, during which large quantities are present in a river over a short, finite period of time.

This fish waste, if not disposed of properly, can create a myriad of issues. According to Oasis Environmental in the 2012 ADEC Fish Waste Management Plan: Kenai Personal Use Dipnet Fishery:

> A large volume of fish waste disposed of in a particular location can create accumulations of waste sludge and whole fish parts, cause the generation of toxic hydrogen sulfide gas, if discharged to surface water could cause dissolved oxygen concentration to decrease below state water quality standards (WQS), increase the concentrations of scavengers, and create noxious conditions caused by odors, bacteria and waste decomposition (p. 1).

Not only can fish waste create water quality issues, smell, and attract pests, but it also can create an aesthetic concern for visitors to Alaska. This is important, due to the increasing emphasis on ecotourism for the state: ecotourists are a significant part of the economic future in Alaska.

Whether fish are caught commercially or recreationally, waste results. Commercially caught fish waste is the responsibility of the business producing it, but recreationally caught fish waste often ends up as the responsibility of the fishing area's land management entity (more specific to freshwater fisheries), and fish waste management is imperative.

## 3.2 Fish Waste Management

In coastal and riverine environments where fishing is popular clutter, the most common annoyances associated with fish waste are aesthetics and odor. However, in southcentral Alaska on the Kenai Peninsula, specifically the Russian River recreational fishery, how fish waste looks and smells to them may be the least of anglers' worries. Most fish carcasses are disposed of in shallow waters or slow-moving areas and end up on river banks. These carcasses attract scavenging wildlife such as gulls and bald eagles, but also resident brown bears.

Various fish waste disposal and management options for different sites have been considered in the past. Let's explore these next.

### *3.2.1 Ocean Disposal*

Most fisheries are based on salmon that are caught commercially in the ocean. Commercial fishing vessels catch the fish and either process them onboard or transport them to a cannery facility on land. Once the parts of the fish deemed useful have been processed, the remainder of the carcass must be disposed of. Canneries often grind the fish waste into small pieces of a mandated size, then transport and dump the sludge at a location offshore where most of it sinks and collects on the ocean floor.

As this sludge decays, the bacteria facilitating the decay consume oxygen. These offshore sludge dumps often result in a locally significant oxygen sink: the dissolved oxygen concentrations in the water become too low for some ocean life to survive. Canneries and others using this disposal method are required by the Environmental Protection Agency (EPA) and other permitting agencies to monitor these areas closely.

River-based fisheries also can use ocean disposal; however, this method involves greater transportation costs and can still contribute to environmental problems.

### *3.2.2 Landfill*

For smaller quantities, fish remains can be deposited with the rest of human-generated trash in municipal landfills. Larger quantities of fish waste create problems. "In many countries, solid waste is recycled into fish meal plants or treated along with the municipal waste, whereas liquid waste is disposed of through the municipal sewage system or directly into a waterbody" (FAO Fisheries and Aquatics n.d.). On the Kenai Peninsula of Alaska, the local landfill limits the amount of fish waste accepted, and requires notification and approval of larger quantities for dumping, so when the waste arrives, it can be covered immediately.

### *3.2.3 Composting and Fertilizer*

A green, productive garden can result from beneficial use of fish waste. In 1989, a New York state law was passed that restricted the disposal of fish waste, with a few exceptions. These restrictions helped lead to the discovery, by researchers at Cornell University and the New York Grant Extension Program, that a mixture of fish parts and peat moss could create an effective compost for gardening (Environmental Protection Agency [EPA] 2012).

### *3.2.4 In-River Disposal*

For riverine fisheries, a common method for disposing of fish waste is to return the carcasses to the river from where they came. This method resembles what happens naturally: as fish die, their marine-derived nutrients are left near the site of death for the surrounding vegetation and animals to use. This disposal method can include tossing the entire carcass into the water, or chopping/grinding the waste before disposal. The success of this disposal method depends greatly on several factors: the amount of fish waste being generated, the popularity of the fishery, the size of the waterbody (i.e., flow rate), the water velocity, and the size of the fish-waste particles.

I want to focus more specifically on the Russian River near Cooper Landing on the Kenai Peninsula of Alaska (Fig. 3.1), and the sockeye salmon runs that occur twice each summer. Despite this focus, however, there are other streams that have similar issues throughout the Pacific Northwest, and what I will discuss has greater implications nationally.

The fish-waste issues on the Russian River are fairly unique in the fact that many of the issues manifest at one specific location. The Russian River is smaller than the Kenai River, and has slower velocities; the sockeye salmon runs in the Russian River are abundant, and the fishery attracts as many as 150,000 anglers (Fig. 3.2) annually (United States Forest Service [USFS], United States Fish and Wildlife Service [USFWS] and Alaska Department of Fish and Game [ADF&G] 2013). In the past, ADF&G has stated that the first run, occurring sometime before June 15, averages about 27,000 fish, whereas the later run, which occurs near mid-July, averages around 61,000 fish (ADF&G 2006). The small size of the stream, relative to the size of the fishery, creates an overwhelming large amount of fish waste. As with other riverine fisheries, the quantity of fish waste attracts wildlife. However,


**Fig. 3.1** Kenai and Russian River Confluence Area (GoogleEarth 2011)

**Fig. 3.2** Anglers in the Kenai River near the Russian River Confluence (© Alexandra West)

the Russian River also happens to be in an area that is home to a large population of brown bears that visit the location for the same reason anglers do—to catch salmon.

During the summer of 2008, nine brown bears were killed on the Russian River (Campbell 2009). These bears either became aggressive towards humans or threatened people or their property along the river. This is unfortunate, for the Russian River two sockeye salmon runs benefit both humans and bears. While bears and humans share the food source, humans leave the remains of their catch—and this, in turn, attracts unwanted attention from the bears.

Anglers have been asked to dispose of their waste properly. With any fish management procedure, public education is imperative. The area's management organizations, including the U.S. Fish and Wildlife Service (USWFS), the U.S. Forest Service (USFS), and the ADF&G have tried various methods of fish waste disposal. These agencies have suggested refraining from in-river disposal by educating anglers to either pack the fish out whole and clean it elsewhere (disposal of the fish waste likely using landfill disposal), or chop the carcass into many small pieces and throw them into fast-moving water. Over the years, these agencies have placed fillet tables in strategic locations to encourage anglers to dispose the fish waste in the faster-moving water; they have also placed hand grinders here and there to encourage anglers to grind the fish carcasses into small pieces before disposal. Unfortunately, area management has reported that these methods have not been successful: users do not want to exert the extra effort to grind the carcasses, and they do not usually chop the carcass into small enough pieces. As a result, the pieces can concentrate in eddies or areas where the water flows slowly, and thus, still collect on the riverbanks.

## 3.3 Hydro-powered Fish Carcass Disposal System

To retain the marine nutrients in the riverine ecosystem and to prevent large, odorous pieces of fish from collecting on the riverbanks and attracting wildlife, small pieces of the fish carcass must be dispersed into fast-moving water. For this method to be effective, the disposal process must be near effortless for the anglers: history has shown that anglers are unlikely to grind their waste up themselves. A grinder still seems to be the solution—but a power source other than human muscle may need to be considered.

I can’t say when I first became intrigued with fish and engineering, but growing up in a wildlife- and science-minded family helped. Furthermore, in elementary school, my 5th and 6th grade classes participated in an “Adopt a Stream” program. We would often walk, as a class, down to Slikok Creek, near our school, and spend time with a biologist collecting aquatic insects, setting fish traps to catch and identify juvenile salmon, and taking water quality measurements—all of which were used to collect ongoing information on the health of the stream. Additionally, I was lucky enough to help care for our ADF&G-sponsored “Salmon in the Classroom”, which involved raising baby salmon from eggs to fry, in our school, before releasing them. Learning about the importance of our salmon, watersheds, and ecosystem at a young age helped me later pair my growing passion with my higher-level STEM education in engineering to invent the hydro-powered fish-carcass disposal system.

As an undergraduate civil engineering student at the University of Alaska Anchorage (UAA), I was tasked with selecting a project I was passionate about that pertained to engineering. I had been aware of the issues along the Russian River for years because it was near where I had grown up and my father was involved with managing the area. As a civil engineer, I did not go into detail designing a grinding system—that task could be left to a commercial grinding company or a mechanical engineer! But I could investigate methods for powering the device. I focused on hydrology and hydraulics at UAA, and thought, how might one power something in or near a river? With a problem identified and a question asked, I began designing a conceptual hydro-powered fish-carcass disposal system. UAA patented the device in 2014 under U.S. Patent 8,833,682 B2. In 2015, three senior undergraduate civil engineering students (Jennifer Baker, Nathan Harris, and Brandi Opsahl) contributed to a more complete design for their capstone course at UAA.

### *3.3.1 Design*

The designed hydro-powered fish-carcass disposal system harnesses the energy of flowing water using an undershot paddlewheel. The paddlewheel rotates, and these rotations either directly turn the grinder through a gearing system, or the paddlewheel connects to a generator that would then power a commercial-style electric grinder. The entire system is mounted on pontoons in the river, connected by cables and a slide from the bank. The slide allows anglers to fillet their catch on a cleaning table, and toss the waste on the slide, which feeds into the grinder. Figure 3.3 shows the 2015 plan drawing of the system.

### *3.3.2 Location*

As previously mentioned, the Russian River is the location of concern. Part of this popular fishing spot includes the confluence of the Kenai River with the Russian River. The sockeye salmon fight upstream from the ocean, approximately 74 river miles from the Kenai River's mouth at Cook Inlet to the Russian River confluence,

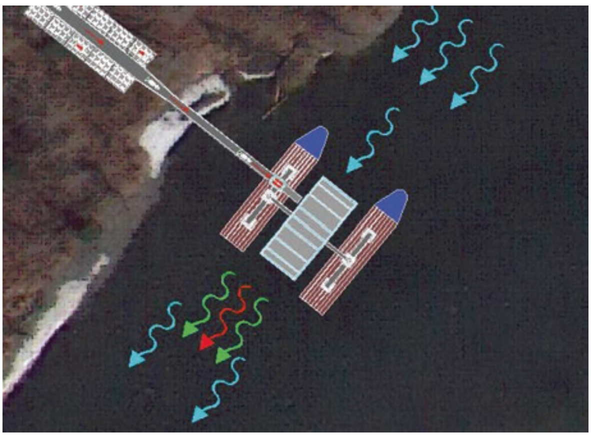

**Fig. 3.3** Conceptual layout of fish cleaning tables and the paddlewheel grinding system (Baker et al. 2015)

**Fig. 3.4** Potential location of the hydro-powered grinding device on the Kenai River (©Alexandra West)

and then into and up the Russian River to spawn. Anglers fish along the confluence as well, but the Kenai River is much wider and deeper, which reduces anglers' ability to wade in the water, but also makes it easier to dispose of fish waste into faster currents.

The Russian River itself does not have water velocities great enough to power a hydrokinetic device capable of powering a grinder large enough to handle fish waste, but the Kenai River does. The fish-table/grinding device (or devices) could be deployed in the Kenai River, at a location accessible to anglers leaving the Russian River area. The proposed location is adjacent to parking lots, a boat launch, and the renowned Russian River Ferry. The Russian River Ferry is a privately owned business that charters anglers across the Kenai River, from the highway side to the Russian River and the confluence.

The preferred location for a grinder device is across the Kenai River from where most of the fishing occurs (Fig. 3.4). At that location, water depths are greater, there is less of a navigability hazard to rafters and drift boaters, and the area is still accessible to anglers after they leave their fishing site. The location also affords a significant educational aspect: area management would probably need to encourage anglers to either pack out their catch, or get the fish waste to the grinder area.

### 3.3.3 Size

The size of the device will depend on the stream's water velocity. Undershot paddlewheels are not very efficient, but they work well in lower-velocity conditions. They are also relatively cheap and fairly straightforward to construct. The device's paddles are sized proportionally to the average speed of the river during the period of use, and they float off the bank at a specific distance where velocity is maximized (without being in the main part of the channel and causing a hazard to boaters). Once the paddles have been sized, the rest of the device (frame and pontoons) can be sized to ensure it stays erect and afloat.

### *3.3.4 Grinder*

Due to environmental concerns and permitting regulations, the device must be able to grind fish waste to particles that are about 0.5 inches in any direction. A non-motorized grinder could be designed to do this task, or a commercial grinder, such as those used at canneries, would be hooked up to a generator. Our research indicates that a grinder capable of grinding fish bones (specifically skulls) into small enough pieces would need approximately 5 horsepower. The JWC Environmental 3-SHRED grinder is an example of a commercial grinder that has been used in canneries and that has met permitting discharge regulations.

### *3.3.5 Environmental Concerns*

Although the "Stop, Chop, and Throw" process has been suggested and used by professionals for many years, discharging organic material can raise some important environmental questions. Oxygen is needed to decompose organic materials, so discharging a large quantity of fish waste in one location, even if the particles are small, could accelerate oxygen consumption. This could create a significant dissolved oxygen sag downstream of the device, which in turn could harm salmon, other fish, and macroinvertebrates in the river.

Another concern is particle transport. Small pieces of fish waste might flocculate, fall to the streambed, and create a massive "slime" downstream of the device. Initial calculations based on a conservative assumed use of the device during the peak fishing season have shown that the small fish waste particles should easily be transported and dispersed downstream, so dissolved oxygen probably would not become an issue (Baker et al. 2015).

### 3.3.6 Health and Safety

As with any highly used area, public health and safety must be considered. The device would need to be monitored to ensure it is not misused or abused, and examined daily (according to the Alaska Department of Environmental Conservation) to ensure that it is functioning properly and that discharges meet the aforementioned regulations. The grinder itself would be positioned out on the device, encased in a hopper so that no sharp components would be exposed. The grinder also would be kept clean by pumping water frequently down the slide and through the blades. Pumps could be attached to the device and powered through a generator, or water could be obtained through a water retrieval system connected to the paddlewheel, similar to waterwheels, or norias, used throughout history for water retrieval and irrigation.

## 3.4 A Solution to Fish Waste Management

Whatever mess results from fish waste—odor, aesthetics, or pests such as gulls, or bears—it must be managed appropriately. Not all locations will be able to benefit from a hydro-powered disposal system, but other waste-handling methods, such as composting and those discussed earlier, need to be considered holistically. Ultimately this chapter provides a powerful idea for the ingenuity of STEM students as they explore the role of animals in relation to science education and the ways that engineering is now inseparable from it.

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# Chapter 4
# Learning Science in Aquariums and on Whalewatching Boats: The Hidden Curriculum of the Deployment of Other Animals

**Teresa Lloro-Bidart and Constance Russell**

Many people living in suburban and urban spaces appear to crave experiences with "nature" as evidenced by the 181 million people visiting Association of Zoos and Aquariums (2015) accredited facilities in 2014, the 282 million people flocking to U.S. National Parks in 2012 (Errick 2013), and the 13 million people visiting national parks in Canada in 2014 (Parks Canada 2014). Whether this "nature" manifests itself in an urban zoological garden, aquarium, or a national park designated as a site of significant ecological value, it is a complex amalgam of tourist destination, sacred retreat, educational facility, something worthy of preservation, and home to those living within its boundaries. Human-constructed zoos and aquariums house captive animals from all over the globe and national parks are mostly wild spaces where animals generally roam free; these spaces are thus quite different in some respects, but they nonetheless share similar aims as evinced in their mission statements. Their goals include promoting conservation and stewardship of the natural world, often through educational means, while also providing a leisurely, recreational, or restorative experience for visitors. In most of these spaces humans enroll other animals in a variety of educational endeavors, such as the interactive touch exhibits at aquariums and whalewatching excursions that we will describe here.

The informal science education literature generally takes for granted that any experience with the natural world is beneficial. We wish to trouble this assumption by analyzing the hidden curriculum often unwittingly communicated to visitors at

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these sites. We begin by briefly sketching the history of the use of animals in zoos, aquariums, and wildlife-focused tourism in national parks in North America, describing typical interpretations in those spaces, and identifying some of the anthropocentric gaps in the informal science education research literature on this topic. Drawing on ethnographic research conducted at two sites, a public aquarium in southern California and a national marine park in Quebec, Canada, we then describe how the animals who live there are politically deployed in educational processes and the hidden curriculum issuing from such deployment.

## 4.1 Interpretation in Zoos, Aquariums, and Parks

Zoos, aquariums, and national parks grew out of a desire in the mid to late nineteenth century to escape the confines of urban life and replenish one's mind, body, and soul with contact with nature (e.g., Hanson 2002). Elizabeth Hanson's (2002) environmental history demonstrates how early zoological gardens emphasized a White middle class ethos that constructed what constituted a "proper" balance of nature and culture. For wildness to be part of the city, it needed to be confined to zoological gardens and aquariums in what Irus Braverman (2013) describes as an act of power guised as care. Spaces like national parks, in contrast, embody late nineteenth century notions of "wilderness" mostly devoid of human presence (e.g., Cronon 1996), thereby justifying the forced removal of Indigenous peoples from these areas as part of the larger colonial project (e.g., Sandlos 2008). Parks and protected areas today are seen to offer an "in-situ" experience where people can embrace "realism" through the "fiction of our nonintrusive intrusion" into "nature" (Desmond 1999, p. 189).

Early zoological parks generally aimed to leverage captive wildlife to entertain, educate, advance science, and conserve animal species, although the emphases on these various commitments has significantly changed over time (see Braverman 2013). Current AZA standards require its member institutions to prioritize both conservation and education in their missions, although in some cases entertainment retains a predominant role in actual practice (e.g., Lloro-Bidart 2014). Parks and protected areas have a long history of encouraging nature-based tourism within their boundaries. Typically, ecotourism is justified on both economic and educational grounds; the International Ecotourism Society (2015), for example, asserts, "ecotourism provides effective economic incentives for conserving and enhancing biocultural diversity" and "promotes greater understanding and appreciation for nature, local society, and culture" (¶ 1). Whalewatching is no different in that regard. The tension between economic and educational mandates can be keenly felt in "edutainment" ventures like aquariums and whalewatching, which may influence interpretation in particular ways.

Compared to schooling, which experiences strong pressure to reproduce the status quo (e.g., Kincheloe 2008), informal learning sites such as zoos, aquariums, and parks face far less control when it comes to pedagogical content or approach; no one is calling for standardized testing in these sites, for example. Yet, ironically, educational endeavors in these spaces often remain highly conservative in terms of both pedagogy and content; many interpreters adopt a transmission mode of pedagogy, *telling* visitors what is important, and content tends to emphasize scientific facts, rarely venturing into advocacy territory (e.g., Russell and Hodson 2002). Further, zoos, aquariums, and parks tend to work from the assumption that experience with nature or other animals automatically leads to knowledge acquisition which then leads to caring and then to advocacy; such a simplistic linear model of experiential environmental learning has long been demonstrated to be without warrant, yet it persists (e.g., Russell 1999).

In the informal science education literature, scholars tend to focus on human learning experiences through impact studies (e.g., Dierking et al. 2001) and research on conservation or science attitudes (e.g., Clayton et al. 2014). The literature also invokes sociocultural and identity theories (e.g., Falk et al. 2008) and social theories of kinesthetic or interactive learning (e.g., Rowe and Kiesil 2012) to make sense of what and how people learn in these institutions. While this scholarship certainly has value, the general lack of engagement with more critical, politicized work in science and environmental education and zoo, aquarium, and ecotourism studies in the social sciences and humanities has resulted in a subfield of informal science education that largely fails to consider how these institutions serve as conduits of an anthropocentric hidden curriculum. Indeed, we assert that insufficient attention has been paid to anthropocentrism generally and the "animal question" specifically.

## 4.2 The Political Deployment of Other Animals

In this section, we provide context to help situate our discussion of how other animals are deployed in these settings. In both cases, the animals involved have little choice but to participate in these teaching and learning processes. This is particularly obvious for the captive animals in the aquarium, but is also the case for the wild whales who need to make the most of the short summer season.

The Aquarium of the Pacific's Shark Lagoon exhibit features both large and small sharks in two separate sections. This analysis focuses on the small sharks, whose bodies are available for touching by any human passerby. Consisting of three shallow and oval-shaped pools, two of which are connected so they make a giant U-shape, this portion of the Lagoon is home to bamboo, epaulette, and juvenile bonnethead sharks and other sea creatures like mangrove rays, horseshoe crabs, and tropical fish. As visitors approach the pools, staff on the microphone discuss the crucial role sharks play in their ecosystems as apex predators and share facts about basic shark physiology. (For example, their teeth are embedded in cartilage instead of bone like ours; they have teeth-like structures on their skin called dermal denticles, which make them feel rough to the touch; they lay eggs colloquially referred to as "mermaid purses"). Some staff infuse these narratives with bits of information to directly counter negative perceptions of sharks, such as informing visitors that most sharks are small like the ones in the pools and not large like "Jaws," or by explaining that sharks only bite humans in cases of mistaken identity. Staff also repeatedly instruct visitors how to touch the sharks: two fingers only because one finger feels like a "poke" and a whole hand feels like a "grab."

The juvenile bonnethead sharks resided in the single pool and were sometimes described by staff as "wind up toys" due to their swift movements. As obligate ram ventilators (i.e., they have to swim to breathe), bonnetheads are typically difficult for visitors to touch because they constantly swim about the exhibit. This physiological necessity in some ways shields them from visitor touch, especially since the oval pool they live in provides little space for them to avoid contact with people. In the conjoined oval pools, the exhibit design also provides minimal refuge for the bamboo and epaulette sharks, who swim more infrequently and gather together in what staff describe as "cuddling," "huddling," or "piling up" as sharks "nap" or work to "appear larger to a predator." On busy days, a staff member dons rubber boots and wades in one of the conjoined pools to hoist sharks to the surface. This facilitates the touch experience for small children or other people who have difficulty reaching inside. On a busy summer day more than 7000 visitors typically walk through the Aquarium's doors, many flocking to the Lagoon during the average 2.5 hour visit. This means an individual shark in the Lagoon might be touched by hundreds of different people over the course of a day. The vast majority of staff believe that the touch experience is crucial because, in their words, it helps people "learn to love the ocean, protect it, to enjoy it," enables them to "teach guests about animals in the water," and "restore[s] the image of the shark."

The St. Lawrence-Saguenay Marine Park (SSLMP) in Quebec, Canada is approximately 1245 $km^2$ , covers "the water column and sea bed, and extends to the normal high-tide line," and its mandate includes ecosystem protection as well as encouraging "educational, recreational and scientific uses" of the Park (SSLMP 2010, p. 2). Prior to the advent of whalewatching in the 1970s, the area relied on forestry, shipbuilding, fishing, hunting (including of beluga whales), and some tourism; this is not the typical "pristine" wilderness that many people associate with parks. Whalewatching is arguably the most popular activity in the Park, generally occurring between mid-May and mid-October, peaking in July and August. Since 2002, limits have been placed on the number of whalewatching boats plying the waters, but not on the number of excursions each boat can make (Ménard et al. 2014). Approximately 53 boats operate in the area, ranging from motorized rubber boats carrying as few as 8 passengers to large, multi-deck boats that are capable of carrying almost 500. In 2005, it was estimated that over 274,000 people took part in sea-based whalewatching (SSLMP 2010); there is no reason to believe that these numbers have changed much since then (Ménard et al. 2014).

Focal species for whalewatching are fin and minke whales who migrate to the area each summer for food. Both are baleen whales who feed by using their baleen plates like sieves, filtering out water and retaining creatures like krill and capelin. Fin whales are the second-largest whales in the world, usually around 60–70 feet long, weighing up to 50 tons, and can often be seen feeding in groups. Minke whales are considerably smaller, 20–35 feet long, weighing up to 10 tons, and can regularly be seen lunging out of the water as they chase krill or capelin to the surface. There is also a resident population of beluga whales in the Park; these white, toothed whales are "only" 15 feet long. Designated as threatened, this population of belugas has been particularly hard hit by pollution. There thus is strict regulation on how close boats can approach them, although there continue to be infractions (Ménard et al. 2014).

Whalewatching expeditions generally last between 2–3 hours. The larger boats employ naturalists who deliver interpretation through a sound system. The smaller boats often rely on the captain to not only drive, but also provide interpretation. The Park requires compulsory training of captains and naturalists, which includes knowledge of Park regulations, the natural and cultural history of the area, whale biology, and threats to whales (SSLMP 2014). As is common in much park interpretation, the transmission of scientific facts tends to be emphasized, even though some whalewatchers have expressed a desire for more politicized discussions of whale conservation (see Russell and Hodson 2002). Over a third of the whalewatchers interviewed stated that they had not learned anything at all on their trips, emphasizing that interpretation was either "minimal" or an "endless stream of blather." Such seemingly contradictory reports may reflect varied skills of interpreters, but also illustrates how little interpreters usually know about what visitors already know or desire, which is not surprising given how little time they have with them.

In both of these cases, individual animals find themselves part of educational processes designed to contribute to conservation of the wider population of animals and/or the ecosystems to which they belong. These sites can thus be seen to politically deploy animals in educational processes (see Ogden et al. 2013). Little attention, however, appears to be paid to the hidden curriculum of this deployment. When seemingly objective scientific facts and depoliticized discourses of care are emphasized in such edutainment ventures, what other messages might visitors be receiving? Is the hidden curriculum communicating particular values related to human/animal relationships that contradict the intended curriculum? These are the questions we turn to next.

## 4.3 The Hidden Curriculum

At the Shark Lagoon, two aspects of the hidden curriculum emerge as particularly contentious: the touching of small sharks residing in exhibits where they have little refuge and the lack of discursive focus on the lives of the animals as individuals. Animal touch exhibits at aquariums, marine parks, and related facilities have grown in popularity, with some research indicating that they may provide important developmental activities for children and even promote scientific reasoning (e.g., Rowe and Kisiel 2012). Yet this research focuses strictly on human experience and sensemaking, categorizing live animals as "tools of organizing behavior, communicating, and, ultimately, thinking" (Rowe and Kiseil 2012, p. 64). It also assumes that *any* experience with "nature" is incontrovertibly beneficial for people and ultimately animals, which counters the findings of critical research in environmental education (e.g., Lloro-Bidart 2015b). Not surprisingly, this anthropocentric research perspective largely supports the idea that zoos and aquariums contribute to conservation through educational means. Yet only three of the 28 visitors in this study reported learning a new fact about sharks; none indicated caring more about sharks or discussed plans to take concrete actions to benefit sharks. Interviewed visitors mostly reported enjoying the exhibit as part of their family outing, birthday celebration, or weekend getaway.

These findings, coupled with extensive observations and analysis of the exhibit, suggest the institution implicitly communicates to visitors that the exhibits, and by extension the animals, exist primarily for people's entertainment. Although the Aquarium emphasizes actions that seemingly account for the small sharks' needs and wants, such as the two-finger touch rule and the provision of restaurant-quality "sustainable seafood" for their daily meals, the encounter is ultimately created for human visitors. The exhibit design, which provides little refuge for sharks who may not desire interaction, coupled with staff who wade in the pools and lift sharks to the surface, communicates to visitors that confined wild animal bodies are essentially objects available for viewing, touching, and interacting. These sharks are not hunters (they are fed through controlled means), lovers (the sharks in the tank are all females who do not appear to interact sexually with one another), or parents (their eggs are removed), nor can they be seen as truly wild animals; rather, they are docile bodies who seemingly enjoy regular human interaction. These sharks are safe, touchable, and controllable, domesticated yet wild enough that they get discursively lumped together with the Aquarium's large sharks as "remarkable predators" of *non*human animals. This careful balance of domestic and wild is designed to provide direct contact with the sanitized wildness that visitors to these facilities have come to expect and to convince visitors that the small sharks' wild counterparts (of all shapes and sizes) are worthy of saving precisely because they, too, are unlike the vicious beast in the film "Jaws."

Whales have a much better reputation than sharks. Metta Bryld and Nina Lykke (2000) chart the general transformation of whales from feared to revered creatures. Arne Kalland (1993) described this as the "superwhale" phenomenon, wherein characteristics of various species are lumped together into an image of a generic whale who is very large and highly intelligent, as well as an amazing singer who engages in co-parenting. He argues that the superwhale has eroded support for whaling, so this particular social construction likely has been very good overall for whales. Still, there is something problematic about failing to attend to specific species and to individual whales, as Anne Bell (1997) argued in her discussion of the important role the practice of natural history can play in environmental education. Some of the more experienced interpreters were able to disrupt this construction by naming individual whales they recognized and sharing their own stories of encounters with specific whales. In general, though, the interpreters more often focused on the whales' spectacular behaviors. This is not surprising since it is hard not to be impressed when belugas fluke, minkes lunge feed, and fin whales move through the water in groups. There is nothing wrong with being amazed by whales, as all the whalewatchers in this study were, but when promotional materials and media representations of whales raise expectations that whales will "perform" in spectacular ways, disappointment can follow. Some whalewatchers indeed confided that they were somewhat underwhelmed by the whales, including a group of high school students who expressed dismay at not seeing a whale give birth on their 3-hour tour! The whalewatchers, then, stepped on the boats with particular expectations of the whales (see Russell 1999). In this way, the whales can be understood as prepackaged and marketed commodities that are an integral part of a big business. The dangers inherent to the commodification of nature have been extensively discussed in the critical tourism literature, particularly in discussions of the "tourist gaze" (e.g., Fletcher 2015).

The majority of whalewatchers also arrived with concern for whales. A number of them, in fact, shared their worries about the possible impacts of whalewatching on the whales prior to embarking on their trip. When asked post-expedition about whether whalewatching was negatively impacting the whales, less than a third of them were able to confidently say "no," with some stating that they would never go whalewatching again. For those whalewatchers, the pleasure of encountering whales was tinged with guilt. Still, all the whalewatchers expressed delight in seeing whales in their natural environment. An oft-mentioned source of pleasure was the opportunity to experience the whales through senses other than vision. The sound of a whale's blow, the feel of the breeze and the sea underfoot, and for those close enough, the fishy smell of the whale's breath contributed to a wondrous encounter. Such fully embodied attention to other life and the more-than-human world is a commonly overlooked yet essential element of interspecies education that seeks to disrupt anthropocentrism (see Fawcett 2013). Nonetheless, there remains a shadow side to such encounters if there is a lack of reciprocity; for example, if whales are being negatively impacted by whalewatching, of which there is some evidence (e.g., Higham and Lusseau 2007), one must ask what the whales are getting out of the encounter.

## 4.4 Re-thinking Animal-Focused Informal Science Education

As we hope we have illustrated, the informal science education offered in animal-focused edutainment ventures such as these need to be critically examined. While there are obvious time constraints in place that limit interpreters' opportunities to get a sense of what visitors already know and want to know, pedagogies that rely on the one-way transmission of depoliticized facts are problematic. Critical environmental education research demonstrates, for example, that when teachers or interpreters explicitly engage the political aspects of environmental learning (such as policies guiding animal treatment), learners emerge with greater sense of responsibility for caring for other animals (e.g., Gannon 2015). Further, the hidden curriculum in both cases contains anthropocentric elements that undermine stated conservation goals. As commodities packaged for our viewing pleasure, the sharks and whales are transformed into docile creatures who do not seem to be bothered by our intrusions into their lives. There is very little attention to them as individual subjects of their own lives; rather, they act as representatives of their kin or their ecosystems, martyred in the name of conservation.

There is a growing body of educational literature that we argue informal science education would benefit from engaging. Critical animal pedagogy (e.g., Corman and Vandrovcová 2014), ecopedagogy (e.g., Kahn 2010), environmental education that engages the "animal question" (e.g., Oakley et al. 2010) and "naturecultures" (e.g., Fawcett 2013), humane education (e.g., Oakley 2009), interspecies education (e.g., Andrzejewski et al. 2009), and posthumanist education (e.g., Lloro-Bidart 2015a) have much to offer given their troubling of anthropocentrism, their attention to other animals as both members of ecological communities and as individuals, and their calls for building sustained and more reciprocal relationships with other life. Informal science education would do well, then, to ponder how a more "politicized ethic of care" (i.e., Russell and Bell 1996) could be fostered in places like aquariums and whalewatching boats. Only in doing so might we be better able to bring the explicit and hidden curriculum into congruence to tackle the root problems underlying our destructive relationships with other animals and the planet.

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# Chapter 5
# Tracing the Anthrozoological Landscape of Central Iowa: Place and Pedagogical Possibilities

**Cori Jakubiak**

> The study of rural communities informs us about aspects of modern life in a predominantly urban world. (Thomas et al. 2011, p. 175)

When I (a city-dweller) accepted an academic position at a small, liberal arts college in central Iowa, I imagined that I would rent and move into an old Midwestern farmhouse. Along the lines of something out of the movie, *Field of Dreams*, starring Kevin Costner, perhaps: I pictured a clothesline, lace curtains, and ample land on which my two dogs could roam. From the very beginning, then, animals (and my relations to them) provided a defining, albeit perhaps romanticized, framework for making sense of life in rural Iowa. Little did I know or understand the extent to which human-animal relations do, indeed, shape the economic activity, sociopolitical concerns, and physical contours of the region. However, the reality of the dominant form of human-animal relations in central Iowa—industrial meat production—bears scant resemblance to the images I had conjured in my mind.

Historian Charles Fruehling Springwood (1996) would note that my early, bucolic assumptions about rural Iowa reflect the *Pastoral Ideal*: a nostalgic motif of agricultural innocence and wistful simplicity. Dairy product packaging, meat advertisements, and children's toys with a "farming" theme often evoke the Pastoral Ideal: they feature architecturally interesting red barns, human-scale windmills, and smiling pigs. The ever-popular Fisher Price farm set, for example, contains a bevy of diverse farm animals, doors that "moo" when opened, and movable fencing for children to create outdoor pastures. Yet this contrasts with the reality of confined animal feeding operations (CAFOs), which are prevalent on the Iowa landscape. CAFOs are windowless production facilities that contain literally thousands of hogs or chickens. Raised solely for their meat or egg products, industrially produced animals' day-to-day existences are grim. Denied access to sunlight and natural

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behaviors such as rooting or nesting, these animals are forced to stand in their own manure, have their tails or beaks docked to prevent mutilation by self or others, and literally cannot turn around in breeding pens or cages (Kimbrell 2010). As geographer Alice Dawson (1999) observes, “Modern agricultural production of pigs [and other industrially raised animals] creates an environment based on human convenience and economic profitability that is quite different from the image of Old MacDonald’s farm” (p. 202). As a place-based teacher educator with a strong interest in ecojustice, it was humbling to learn, upon moving to Iowa, that my preconceptions of the state and the dominant human-animal relations in it were simply *wrong*. However, by attending more carefully to human-animal relations in central Iowa over the past several years—what Hal Herzog (2009) would call its anthrozoological landscape—my politics and pedagogy have changed.

## 5.1 Why Educators Should Attend to Human-Animal Relations

This chapter follows feminist geographer Jody Wolch’s (1998) call to “bring the animals back in” (p. 123) to any project with social justice ends. Given that classroom teaching can be a powerful and radically political act (Gruenewald 2002; hooks 2003), I argue that educators should pay much more attention to the anthrozoological landscape of the context(s) in which they teach. Doing so provides a deeper understanding of the politics of local place-making. Although place-based educators have long asserted that the “local” should play a key role in educational curricula, their arguments about the centrality of place to schooling have generally centered on the natural world and community economic development (e.g., Sobel 2005). The ways in which human-animal relations actually *construct* places and the social relations therein are much more rarely part of place-based or environmental education movements (see Kahn and Humes 2009 for a related critique). The low-wage, high-risk labor demanded by meat processing plants near CAFOs, for example, brings economically vulnerable, often undocumented, transmigrant families to U.S. rural towns. These demographic changes, in turn, place new demands on local schools and other social service providers (Hamann et al. 2015). They also can alter rural communities in creative and unforeseen ways (Grey et al. 2009).

Because places are constructed in part through the human-animal relations that occur in them, investigating these relations is also critical for helping students develop place-based identities. Rural theorists Alexander R. Thomas, Brian Lowe, Greg Fulkerson, and Polly Smith (2011), drawing upon Barbara Ching and Gerald Creed’s (1997) work, note that despite the “exploding” literature on identity politics, “there is a gross neglect of how place (rural and urban identities) intersects with the other dimensions of identity such as race, ethnicity, class, and gender” (p. 7). Children who grow up downwind or downstream from a CAFO, for example, face unique forms of place-based marginalization. They are greater risk than other populations for developing antibiotic resistance (Horrigan et al. 2010), and their outdoor activities are restricted when CAFOs inject foul-smelling, antibiotic-laden sewage waste into nearby crop fields (Imhoff 2010). Ecojustice oriented, place-based education needs to attend to these forms of environmental *placism*.

Finally, supporting anthropologist Ivan Sandoval-Cervantes' (2015) perspective, I suggest that "problematizing our ideas about non-human animals can help us better understand our place as humans" (p. 30). Interrogating the human-animal relations of particular locales provides insight into ourselves. When two Iowa teenagers recreationally shot a bald eagle in my county a few years ago, the event made regional news. Yet, literally thousands of hogs and chickens are killed weekly in the same county with nary a word from the media. Why does the death of one bald eagle promote public outrage while CAFOs receive public money through federal subsidies (Imhoff 2010)? Human geographers Chris Philo and Chris Wilbert (2000), noting the deep inconsistencies within human-animal relations, observe that

> Human-animal relations [are] filled with power, commonly the wielding of an oppressive, dominating power by humans over animals, and only in relatively small measure have animals been able to evade this domination or to become themselves dominant over local humans. Examples can be adduced of the latter, such as plagues of locusts, rampaging elephants, or perhaps the ramifications of BSE or 'mad cow disease' [or, I might add, the contemporary bald eagle conservation movement]. Yet, usually animals have been the relatively powerless and marginalized 'other' partner in human-animal relations. What surely cannot be denied is the historical and global significance of such human-animal relations for both parties to the relationship—to be sure, they commonly entail matters of life and death for both parties, the animals in particular—and any social science which fails to pay at least some attention to these relations, to their differential constitutions and implications, is arguably deficient. (pp. 3–4)

Politically engaged social science, then—and by extension, politically engaged classroom teaching—must pay heed to human-animal relations. Doing so not only provides insight on how power works in society, but also draws our attention to potential vectors for change.

This chapter proceeds as follows: first, I propose that more attention to the human-animal relations of particular locales provides a richer understanding of how places are socially constructed. Without explicit attention to the anthrozoological landscape(s) of a town or region, opportunities to name (let alone remedy!) particular problems are foreclosed.

Second, I suggest that attending to human-animal relations helps us to more clearly "place" ourselves (Urbanik 2012). The ways in which industrial meat production strips human-animal relations of any fellow-feeling, for example, mimics neoliberal modes of governance that privilege formal rationality across domains and discourage collective responsibility for vulnerable others (Squire 2009). Investigating human-animal relations sheds light on our complicity in these forms of governance and the ways in which they (re)produce inequality. To be unable to open one's lace-curtained windows on the first, beautiful spring day in April (for a CAFO's noxious fumes) may seem like a small inconvenience to some. Yet, rural Iowans must live this way as a matter of course, so that the rest of the U.S. can have cheap bacon and be protected from the "cold evils" (Kimbrell 2010) of factory farming.

Finally, I draw attention to the inconsistencies of human-animal relations, which point to potential openings for sociopolitical and personal change. As Chris Philo (1998) observes (following Tuan), whether "animals are conceptualized by humans on scales oscillating between reverence and revulsion, compassion and control, utilitarianism and disinterest … will obviously shape their socio-spatial practices toward these beings on an everyday basis" (p. 51). Examining the various, historically fluid, socio-spatial practices of human-animal relations reveals that these relations are temporally contingent and always subject to transformation. The popular "farm-to-table" dining movement, for example, has returned small-scale chicken farming to U.S. backyards in ways not seen in decades (Squire 2009). Similarly, recent concerns about the loss of monarch butterfly populations have more North Americans gardening with an eye to flight and food corridors (Monarch Joint Venture 2015). These changes offer hope for new kinds of human-animal relations and, with any luck, an altered Iowa.

## 5.2 Human-Animal Relations in the Making of Place

Environmental historians have long noted the ways in which human-animal relations construct place. Historian William Cronin (1995) points out that so-called "wild" places in the U.S. such as national parks, wildlife preservations, and game reserves—places in which neither people nor agricultural animals actually live—are "entirely cultural intervention[s]" (p. 70). These places were established in response to the closing of the American frontier and the rise of industrialization. In the decades following the Civil War, for example, big-game hunting in "wilderness" areas allowed new capitalists to temporarily enact the myth of pioneer individualism. Similarly, hiking and camping in "unspoiled" terrains allowed affluent city dwellers short-term escape from increasingly polluted urban centers (Cronin 1995).

Human geographer Alec Brownlow (2000) concurs that the designation of certain places as "wild" or "tame," among other monikers, depends on the human-animal relations that are sanctioned in those places. When settler colonialists moved into upstate New York's Adirondack region, for example, they viewed the land there as primarily agricultural and shaped the landscape's meaning accordingly. Although grey wolves had long lived in the Adirondacks, they were rapidly eradicated in response to settler colonialists' financial and other interests. Brownlow explains:

> With the settling of New York, wolves and other 'loathesome animals' were quickly replaced in the socio-physical landscape by animals more culturally suitable, more economically viable. The introduction of domestic livestock was among the first and most significant steps taken by early settlers to 'tame' the New York landscape. … Wolves, cougars, and other 'vermin' were constructed as fundamentally 'out of place' in this 'new' landscape, physically and symbolically displaced then re-placed by a regionally novel group of domesticated animals. … Livestock symbolized and signified a new ideological landscape within which wolves had no place. As such, they had to go. (p. 147)

Eliminating the grey wolf from the Adirondacks brought what was perceived as wild landscape under civilized control. Ironically, late twentieth-century efforts to recast the Adirondacks as a "natural" recreational site have again shifted the discourse on the place of wolves in the region. Although many local residents firmly oppose the reintroduction of wolves into the Adirondacks, contemporary, urban-based conservation ideology is highly inclusive of the animals. Consequently, wolf restoration projects in upstate New York have been gaining ground (Brownlow 2000).

Alongside environmental historians, animal geographers also "shed light on animals as central agents in the constitution of space and place" (Wolch and Emel 1998, p. xiii). As Philo and Wilbert (2000) explain, the nascent field of animal geography focuses "squarely on the complex entanglings of human-animal relations with space, place, location, environment, and landscape … Spaces and places involved make a difference to the very constitution of the relations in play" (pp. 4–5). Animal geography is thus particularly useful for making sense of CAFOs in Iowa. Commonly dubbed "flyover country," the state of Iowa has little presence in the average U.S. resident's consciousness. Its population has declined since the 1980s farm crisis, when hundreds of family farms collapsed and were replaced by corporate mono-cropping ventures (Iowa State University Extension and Outreach 2015). This shift in agricultural production from small, diverse family farm crops (sold locally or regionally) to federally subsidized commodities (sold internationally) relied on automation and thus decimated Iowa's small towns. Rural schools have consolidated rapidly over the past thirty years, and main street, local businesses have mostly shuttered (Iowa State University Extension and Outreach 2015). Most young people now raised in rural Iowa leave their hometowns, if not the state, if they are college educated (Carr and Kefalas 2009).

Because so few people actually live in rural Iowa relative to U.S. population centers, the reality of what occurs in, around, and because of Iowa-based CAFOs also escapes the consideration of most people. This physical distancing of CAFOs from the majority of U.S. residents is buttressed by numerous, state-sponsored "Ag-Gag" laws, which prohibit journalistic exposure of CAFOs' practices (The Humane Society of the United States 2016). As Dawson (1999) observes, "We are uncomfortable with these places where pigs are rendered into neatly packaged pork products from live creatures.… So pig farms and processing plants are located out of sight (and smell), actually hidden from the landscape" (p. 200). Strategic, place-based and ideological distancing, then, restrict widespread interrogation of CAFOs and (attempt to) absolve consumers of moral complicity in them. "How can so many blithely tolerate the unspeakable cruelties visited upon these countless sentient creatures [animals in CAFOs]?" Andrew Kimbrell (2010) asks. "Part of the answer lies in the physical distance between the buyer of these animal commodities and the factories that produce them" (p. 30).

The framing of Iowa as "flyover country," then, is more than a simple travel metaphor. It speaks directly to the ways in which the dominant human-animal relations of rural Iowa—CAFOs—are those that people would rather not see, smell, or confront. As geographer Owen Jones (2000, citing Weston) points out, "[T]here are no worked-out ethical defenses of factory farming; it is hard to escape the conclusion that it is a practice sustained by silent collusion, by the wish to not know" (p. 269). Like the upstate New York's Adirondack region, where the presence (or absence) of grey wolves has determined the landscape's meaning over time, the presence of CAFOs in Iowa renders it a "flyover" region of the country: unworthy of broad consideration, cloaked in shame.

The power and durability of discourse framing Iowa as "flyover country," in fact, recently led to an interesting controversy on my own college campus. For a time, a popular T-shirt sold in the campus bookstore read "Where the hell is Grinnell?" on the front and "Who the hell cares?" on the back. Protesting this lack of critical attention to place (and the ignorance it fosters), student members of the college's Center for Prairie Studies Advisory Board created an alternative T-shirt. It read "Grinnell: Rooted in place, en route to everywhere" and featured an illustration of prairie plant root systems. This new, place-sensitive T-shirt was also a wry call to sociopolitical awareness, as many industrial livestock facilities are Chinese-owned (e.g., Smithfield Farms) and, in Iowa, the meat is processed by Latino transmigrants (Iowa State University Extension and Outreach 2015). Far from being "flyover country," rural Iowa is actually a significant node in the global economic grid.

Scientists have also linked rural Iowa to broad-scale environmental problems. CAFO sewage waste applied to industrial row-crop fields results in high concentrations of nitrates downstream by way of the Mississippi River. As a result, the Gulf of Mexico's hypoxic, or dead, zone is growing (Mutel 2008). In the summer of 2015, for example, the Gulf's dead zone was measured at 6474 square miles—larger than predicted by scientists—and it was attributed to nutrients leached from the Mississippi River watershed (National Oceanic and Atmospheric Administration n.d.). Relatedly, the Des Moines [Iowa] Water Works—home of the largest water denitrification plant in the world—has initiated a federal lawsuit against the state for inadequately attending to public water quality (Eller 2016). The myth that Iowa is "flyover country" thus belies the far-reaching, ethically questionable, practices that occur with regularity in the state. As Jones (2000) writes, "far from being spaces where nothing of concern is happening, [the locations of CAFOs] are the spaces where the ethics of the encounter are not being told" (p. 281).

Oscillating between the Pastoral Ideal (Springwood 1996) and "flyover country," then, popular, discursive constructions of Iowa obscure (and even make possible) human-animal relations like CAFOs. Among those who live in rural Iowa, however, CAFOs and the political economy in which they are embedded have clear, identity-related effects.

## 5.3 Human-Animal Relations in the Construction of Place-Based Identity

How little most U.S. residents know about or understand contemporary rurality and the human-animal relations that undergird it was eerily captured on a recent season of *The Bachelor*. A nationally televised show that features numerous young women competing for a single man's affections, the fall 2015 "bachelor," Chris Soules, identified as a rural Iowa farmer. Throughout the season's episodes, misconceptions about modern-day rurality were routine. Many female contestants asked Chris, for example, about the animals' names on "his farm" (*a lá* the children's book, *Charlotte's Web*), and they seemed genuinely surprised that he raised corn and soy alone. Some contestants asked Chris (a commodity crop farmer) whether he farmed organically. Then, when Chris took four female finalists home to meet his family, the women's reactions to rural Iowa ranged from disappointment to shock. A young woman from California, for example, "started to crack after seeing Chris' hometown, Arlington, which has a population of 416 and a main street that looks more like a collection of abandoned warehouses than a hub of economic activity" (Crowder 2015). Another finalist, Jade, "a twinge of fear creeping into her half-hearted smile," expressed astonishment that "[T]here's not an open bar, coffee shop, movie theater or restaurant" in downtown Arlington (Crowder 2015).

Watching the show from my living room in Grinnell, Iowa, which is within smelling distance of numerous CAFOs and also lacks a late-night coffee shop (save the 24-hour truck stop near Interstate 80), it was hard to empathize with *The Bachelor's* dismayed finalists. Upon further reflection, however, the women's astonishment at being confronted with rural Iowa (where they would potentially live, should they "win" Chris' affections and thus the show), revealed an ignorance of contemporary rurality that was surprisingly familiar. My own preconceptions of Iowa had also been informed by the Pastoral Ideal: images of breezy lace curtains, charming farm animals on pastures, and checkered tablecloths. Like *The Bachelor's* female contestants, I had also been blissfully unaware of the "hollowing out" (Carr and Kefalas 2009) of contemporary rural America.

The Pastoral Ideal's remarkable durability, however—illustrated on *The Bachelor* as well as through my own, personal experience—raises numerous questions that merit exploration and analysis. Why, for example, in an age when "the global" is increasingly celebrated and anticipated in urban settings—in everything from fast fashion to K-12 school mission statements—are people surprised that globalization has changed the rural? Who benefits when the dominant perception of rurality remains tied to the Pastoral Ideal? Finally, who is marginalized, and how, by widespread ignorance of modern-day rurality? Thomas et al. (2011), engaging with similar lines of inquiry, note that

> as with other forms of identity, the images and ideas attached to rurality are constantly in flux since the world is always changing. It is a mistake to equate rural identity with the agricultural past. This static conception neglects the way rural areas have been re-defined under the capitalist global economy. (p. 11)

Akin to how perceptions of Iowa as "flyover country" mask the realities of CAFOs, the Pastoral Ideal is convenient cover for modern-day rural life. The capitalist global economy has dramatically altered what it means to be a "rural" person; in central Iowa, being rural now means living in proximity to CAFOs and accommodating their numerous effects.

CAFOs negatively impact the quality of life in rural places. Local economies benefit little from CAFOs, so the small towns in which they are embedded often lack people, family farms, and vitality (Poweshiek CARES 2012). Most industrial meat producers are contract workers rather than independent farmers; they are employed by large, vertically integrated corporations that set prices and "leak" profits elsewhere (Imhoff 2010). Additionally, those who work in processing plants near CAFOS are usually exploited and underpaid. They are often immigrant laborers who lack union protection despite doing dangerous work (Watts 2000). The rural communities that harbor CAFOs and related meat processors, then, are often economically and socially precarious. It is not surprising that Starbuck's and other chic businesses are unmotivated to locate in such places.

CAFOs also decrease property values and create hardships for the local community. Contra Joel Salatin's (2010) observation that "healing farms" (p. 356) "should be places where people like to congregate" (p. 357), CAFOs are repugnant to sight and smell and pose health risks to nearby residents. As human geographer Julie Urbanik (2012) notes,

> [L]ife next to a hog CAFO is not pleasant. Hog waste is kept in open-air lagoons that not only smell unpleasant but can rupture, sending waster into local water systems. While this push to industrialized animal production has reduced the price of pig meat, it has come at a cost to local landscapes, local livelihoods, and animal quality of life. (p. 116)

Other unsavory effects of CAFOs include flies, increased risk of asthma due to poor air quality, and overexposure to antibiotics, because confined animals generally receive an abundance of medications (Poweshiek CARES 2012). Having numerous CAFOs and meat processors nearby also makes rural life loud. 18-wheel trucks are in motion constantly, shipping cheap meat outside of the region (e.g., the Swift fleet), and commercial grain dryers, which provide food for confined animals, can run 24-hours a day.

Equating contemporary rurality with the Pastoral Ideal, moreover, allows U.S residents to support the values that undergird CAFOs and their practices. Said differently, perceptions of rural Iowa as a place where cute farmers lean on pitchforks and address animal menageries by name disavows "[t]he modernist insistence on cool rationality … that makes factory farms … possible" in the first place (Emel and Wolch 1998, p. 22). According to Kimbrell (2010), "The exploitation of animals for profit is enabled by a cold, calculating Trinity of Science, Technology, and the Market that has stripped our public life of empathy" (p. 29), and studies reveal that employment in the CAFO industry fosters attitudes of self-interest and fragmentation. Susan Squire's (2009) discussion of Linda Lord, a line worker at Penobscot Poultry in the rural U.S. Northeast town of Belfast, for example, demonstrates that industrial meat processing work encourages separation and efficiency over wholeness. One must accommodate oneself to rational systems to be successful as an industrial meat processor. Describing Linda Lord's orientation toward work, Squire explains:

> Linda Lord's relations with chickens are instrumental rather than emotional, and focused not on their generative capacities (the eggs they lay or the companionship they offer), but on their destruction. She attributes her skill as a chicken-sticker to a lack of fellow-feeling for the birds themselves, a trait that seems to have been nurtured by her employer. (p. 188)

Rural communities dominated by industrial meat production, then, contain a large number of people whose job is to kill with efficiency. In that sense, CAFOs and the industries it supports deny both animals' and humans' full subjectivities (Coetze 1999). The calculating values of the industrial meat industry, in turn, can influence local communities. Squire writes:

> Penobscot Poultry embodies the rationalization of life in the way it compartmentalizes its poultry production. … The industrialization, consolidation, and final deindustrialization of regional poultry production has not only reframed and narrowed the meaning of labor for agricultural workers, but has also arguably eviscerated the meaning of community to the town of Belfast. (p. 189).

Healthy, vibrant, democratic communities need people who are whole and spiritually developed. They need people who see the connections among issues and can empathize with others' concerns (Thoreau cited in Gruenewald 2002). Akin to how models of education based on "control, skill development, remediation, and job preparation … seriously restrict the possibilities for self-development (Gruenewald 2002, p. 536), employment in CAFOs and related processing industries encourages fractured individuals and thus communities.

To be sure, contemporary rurality under globalization is shaped by industrial values. It is centered on formal rationality in which the ends (i.e., cheap meat) justify the means (i.e., cruelty or pollution) (Thomas et al. 2011). Kimbrell (2010) terms this value system "cold evil" and cautions that *all* people—rural and urban alike—are implicated in it. Although rural Iowans must physically shoulder the stink and pollution of CAFOs, *all* U.S. residents are participants in cold evil when industrial logic goes unchallenged. Kimbrell explains:

> Quantitative science, efficiency, corruption and profit are the central dogmas underlying not just [CAFOs] but also the entire industrial enterprise. These dogmas have been the underpinning of the industrial system that has spawned much of the wealth and the stunning daily 'miracles' of modern technological society. The sufferings of billions in factory farms and other tragic results of applying these industrial ideologies to life have arisen not out of cruelty or passion, but rather from the impassive application of the 'laws' of science, efficiency, and the market to living beings. That is why factory farms and other evils of the system are 'cold' evils. They are not created by terrorists, religious fanatics, or psychopaths, persons acting out of uncontrolled 'hot' violence, anger, or lust. Rather it is the business people, scientists, policy makers, and consumers who are acting 'rationally' by comporting themselves with these 'laws' of science and economics on which our system is based. (p. 31)

Well-aware that McDonald's farm is gone, rural residents in places like Iowa at least realize they are participants in cold evil. In my community, locals' concerns have spawned activist groups such as Poweshiek CARES (Community Action to Restore Environmental Stewardship), a coalition of Poweshiek county, Iowa residents who work to oppose CAFOs and their expansion. By contrast, people whose ideas of contemporary rurality remain informed by the Pastoral Ideal—such as *The Bachelor's* contestants—participate in and foster cold evil without their awareness or consent. In this way, urban-dwellers are also exploited, as industrial values thrive on peoples' ignorance.

## 5.4 Inconsistencies in (Dominant) Human-Animal Relations as Potential Sites of Change

Despite the devastating effects of CAFOs on the land, animals, and social life, alternative models of human-animal relations exist—suggesting possibilities for change. For one, I am deeply inspired by Wolch's (1998) notion of *zoöpolis*: a "renaturalized, re-enchanted city" (p. 124) that would "allow for the emergence of an ethic, practice, and politics of caring for animals and nature" (p. 124). Zoöpolis, as Wolch defines it, is an urban space in which people and animals are reintegrated. Rather than living in binary opposition (e.g., per the culture/nature divide), humans and animals would live side by side as kin in a broader ecology. In the zoöpolis, "an interspecific ethic of caring replaces dominionism to create urban regions where animals are not incarcerated, killed, or sent off to live in wildlife prisons, but instead are valued neighbors and partners in survival" (p. 125). Zoöpolis envisions a new partnership between humans and animals that would form the basis for political action. As humans came to appreciate animal subjectivity on its own terms—by and through sharing living space with animals, as equals—urban worlds and political agendas would change dramatically. Wolch writes:

> The reintegration of people with animals and nature in zoöpolis can provide urban dwellers with the local, situated, everyday knowledge of animal life required to grasp animal standpoints or ways of being in the world, to interact with them accordingly in particular contexts, and to motivate political action necessary to protect their autonomy as subjects and their life spaces. Such knowledge would stimulate a thorough rethinking of a wide range of urban daily life practices: not only animal regulation and control practices, but landscaping, development rates and design, roadway and transportation decisions, use of energy, industrial toxics, and bioengineering—in short, all practices that impact animals and nature in its diverse forms (climate, plant life, landforms, and so on). (p. 124)

In other words, the zoöpolis model of urban life would honor animals' subjectivities. As a result, riparian corridors would trump those of commercial strip malls; coyotes in subdivision backyards would be viewed as natural predators rather than nuisances; and trees would be planted with an eye to avian nutrition rather than simply aesthetics, among other outcomes. As Wolch argues, "Zoöpolis invites a critique of contemporary urbanization from the standpoints of animals but also from the perspective of people, who together with animals suffer from urban pollution and habitat degradation" (p. 135).

Although Wolch's concept of zoöpolis focuses centrally on urban centers, zoöpolis is desperately needed, I argue, in places like rural Iowa. For one, the smelly, loud, depopulated, and unhealthy environment produced by industrial agriculture would be immediately and radically altered were animals' subjectivities taken seriously. To wit: currently confined hogs and chickens—their numbers far greater than that of humans in Iowa—would repopulate the physical landscape and dramatically change its physical topography, undoubtedly raising important questions about carrying capacity, etc. (Imhoff 2010). Second, granting animals subjectivity poses deep challenges to the industrial mindset. Viewed as social subjects, hogs and chickens could no longer be profit "units" to be efficiently housed, measured, altered, and executed. As scientist Barbara Smuts (1999) observes, "when a human being relates to an individual nonhuman being as an autonomous object, rather than as a being with its own subjectivity, it is the human, and not the other animal, who relinquishes personhood" (p. 118). Zoöpolis in rural Iowa, then, could make people there more humane.

Thinking of animals as *individuals* also challenges human-relations like CAFOs—relations that are ethically questionable and marked by cruelty. The concept of animals as masses (e.g., "poultry") disregards the individual subjectivity of each animal in the mass. Akin to how my own two companion dogs, Penny and Leroy, each have their own personalities, walking paces, and food preferences, individual hogs and chickens also have their own dispositions and quirks. These traits, however, go unnoticed and disregarded when animals are grouped as a whole. Jones (2000) explains:

> The ethical invisibility of the individual non-human other has been and remains extremely useful and probably essential to modern societies. This has generally enabled humans to manipulate, exploit, displace, consume, waste, and torture non-human individuals with impunity. … Individual non-human others are often ethically and politically invisible … and they become lost in the crowds of their own and other kinds. (p. 279)

Recent outrage over the shooting of Harambe, a 17-year old western lowland gorilla in a Cincinatti zoo, illustrates how attention to individual animals alters human-relations with that animal. Although western lowland gorilla habitats in the Democratic Republic of the Congo have been severely compromised due to coltan mining, few Americans have given up new cell phones out of concern for the species as a whole (Stanford 2012). Yet, despite zoo officials' insistence that Harambe might have killed the child who fell into his enclosure, emotions ran high after the shooting and many people protested that Harambe (one gorilla) deserved more protection (Grinberg 2016).

Suggested here is that individual animals are often granted personal subjectivity. A companion cat, the Kentucky Derby winner, and a visually-impaired person's seeing-eye dog are all assumed to have preferences, needs, and rights. It is in these moments of seeing animals as individuals that humans extend their humanity to them; new, more ethical, human-animal relations occur when a single animal comes out of the group. Jones (2000) observes:

> when animals do emerge into individual (ethical) focus in media reports of 'animal incidents,' this commonly results from some sort of spatial 'disruption' of usually unarticulated

> (un)ethical geographies. For example, consider whales being washed up on a beach, or trapped in ice, where incredible efforts are made to save them and to return them to the aquatic space where their fate again becomes unarticulated. (p. 282)

CAFOs in rural places like Iowa constitute an "unarticulated unethical geography." Hidden behind windowless factory walls in a region mystified by nostalgia, confined animals produced for human consumption have few opportunities to ever surface as individual subjects. Yet, as more people around the U.S. engage in practices such as backyard fowl-keeping, new possibilities emerge for understanding individual animals' subjectivities (Squire 2009). Akin to zoöpolis, here is where new kinds of human-animal relations might begin.

## 5.5 Human-Animal Relations, Situated Classrooms, and New Directions for Academic Inquiry

Philo and Wilbert (2000) note that "[h]umans are always, and always have been, enmeshed in social relations with animals to the extent that the latter, the animals, are undoubtedly constitutive of human societies in all sorts of ways" (p. 2). In this chapter, I have used the anthrozoological landscape of central Iowa to reveal some key facets of the present. Ethically unsettled by the human-animal relations that feed us—CAFOs—we enact these relations in rural places where few people actually live. Then, to comfort ourselves or excuse our complicity in rationalized, inhumane systems, we retain romantic, outdated images of rural farm life. These misunderstandings of contemporary rurality deny the ways in which globalization has changed the rural; moreover, they decrease the likelihood that activist alliances among *all* beings—people, urban and rural, and animals, as social subjects—can ever form.

Tracing a place's anthrozoological landscape offers deep insight into that place: its problems, its people, and the political economy in which it is embedded, among other issues. Living in rural Iowa, it is hard to deny the impact of CAFOs on nearly every facet of social life there. Consequently, any class I teach at Grinnell College—from Educational Principles in a Pluralistic Society to the Cultural Politics of Language Teaching—includes attention to CAFOs and their far-reaching effects. The increase of English Learners (ELs) in rural schools, for example, is often tied to their parents' employment in CAFOs or industrial meat processing (Hamann et al. 2015). I cannot prepare English as a Second Language (ESL) teachers without touching upon human-animal relations. Similarly, discussions of John Dewey in education courses also lead to CAFO-related lines of flight. It is difficult to talk about increasing one's modes of associated living (Dewey 1916) without referencing CAFOs and their impact on people in our community. I have also been surprised when my students take for granted the days when it really "smells" outside; I have thought seriously about wearing a rubber pig nose to class to mark the aberration and promote important conversations. (Plus—apologies to pigs here—I like the "greed" the nose would symbolize.)

I urge all teachers to seriously consider the anthropological landscape(s) of their regions. How are invasive lampreys affecting the Great Lakes and its communities, for example, and what are the consequent implications for emergent writers and readers in Port Huron, Michigan? What does the expansion of metro Atlanta mean for coyote and deer populations there, and how might schoolchildren in Canton, Georgia learn science in new ways as a result? Grinnell College's broader curriculum, for example, is drawing increasingly on local anthrozoology. The anthropology department offers a course called "Culture and Agriculture," which features field trips to a multinational seed corporation as well as nearby organic farms. The college's Policy Studies Concentration offers a course on food security; enrolled students analyze various iterations of the farm bill and the modes of food production it encourages. Students at Grinnell also have numerous opportunities to conduct CAFO-related research directly. In illustration, biology professor Shannon Hinsa-Leasure studies the microbial diversity and antibiotic resistance profiles of the soil and water near CAFOs (Leopold Center for Sustainable Agriculture n.d.). Her students collect and analyze these samples in biology courses as well as for advanced mentored projects.

The CAFO-dominated landscape of central Iowa has also inspired me to design a new course. A special-topic tutorial for incoming first-year students, "The Ethical Shopper" adopts a critical perspective on consumer-based citizenship, or the linking of political action to socially-conscious purchases. A primary response to CAFOs and their ills has been consumer-based citizenship. Widely regarded writers such as Barbara Kingsolver (2007) and Michael Pollan (2008), among others, have urged people to take a stand against industrially produced food (including meats) by shopping locally, researching where their food comes from, and connecting directly to farmers whenever possible. As a result, the number of farmer's markets, community supported agriculture projects, and other alternative food sources in the U.S. have grown substantially in the last decade (Runyon 2015). Indeed, the consumer-based citizenship movement vis-à-vis CAFO-raised meat has incurred such momentum that the sketch comedy show, *Portlandia*, even spoofed it. On one episode, stars Fred Armisen and Carrie Brownstein query a waitress about a chicken's origin to the extent that the waitress delivers them a dossier containing their about-to-be-dinner's former name, previous diet, and personal picture (Seitz 2011).

While this consumer-driven social movement against CAFO-raised meat has had innumerable positive effects, it is insufficient as a comprehensive response to CAFOs (see Jakubiak and Mueller 2013 for an extended discussion of consumer-based citizenship's limitations). For one, consumer-based citizenship restricts political participation to those who make individual purchasing choices. Free and reduced school lunch recipients, prison inmates, and government military personnel, among other groups, cannot chose between locally raised, grass-finished beef and industrially produced meat at mealtimes. Because institutions that purchase bulk quantities of food do their shopping with an eye primarily to price, there is little incentive for CAFOs to go away. Another limitation of consumer-based citizenship it that it restricts civic action to those who can afford to pay. For those on limited food budgets, the relatively high price of locally-grown, hormone-free, humanely-raised meats may prohibit their ability to "cast a vote" (Pollan 2008) against CAFOs and industrially produced food more generally.

"The Ethical Shopper" also interrogates a primary tenet of consumer-based citizenship: it uses the market as a way to address the very problems caused by (so-called) free, or re-regulated, markets (Lyon and Moberg 2010). CAFOs have flourished in an era of reduced environmental restrictions, the dismantling of unionized labor, and the convergence of corporate and state interests more generally through neoliberal policies (see Harvey 2005 for a thorough discussion of neoliberalism). Federal subsidies to commodity crop growers (who are represented by the powerful corporate lobby, the Farm Bureau) provide an indirect subsidy to CAFOs by keeping grain feed prices artificially low. CAFOs are thus incentivized in the marketplace, as alternative means of livestock production (e.g., pasture-raised livestock outfits) do not receive comparable subsidies (Gurain-Sherman 2008).

Extensive, direct federal subsidies to CAFOs also come by way of the Environmental Quality Incentives Program (EQIP), which originated in the 1985 farm bill as a way to support sound environmental practices among small farmers. CAFOs were specifically excluded from EQIP until a 2002 reauthorization of the farm bill, which declared that 60% of EQIP funding should go toward animal farming (Imhoff 2010). Because negotiating and arranging EQIP contracts requires the same amount of effort regardless of an animal producer's size, preference for EQIP contracts for CAFOs has risen dramatically in the last decade and a half (Gurain-Sherman 2008). Moreover, because CAFOs pose greater overall environmental risk, say, than do pasture-raised livestock farms (due to large sewage lagoons that can leak, etc.), EQIP money invested in CAFOs is seen as having greater return potential than that invested in small-scale operations. Doug Gurain-Sherman (2008) explains:

> The new EQIP regulation prioritizes activities that only CAFOs typically have the need to pursue, such as improvement of waste storage facilities, comprehensive nutrient management plans, and transportation of manure tied to environmentally and agronomically sound crop application rates. The explicit rationale provided for this ranking is that greater environmental improvement can be achieved by alleviating CAFO-related problems than pasture-related problems. (p. 38)

In other words, the logic of rational systems is clearly in operation vis-à-vis EQIP and CAFOs. Because CAFOs pose unique and potentially widespread risks to water, soil, and air systems, federal money flows toward them in the name of "environmental quality." At the same time, many small-scale, alternative livestock producers struggle to stay in the black without subsidies (Salatin 2007). The capitalist market's so-called invisible hand—while perhaps invisible to most consumers—operates in favor of CAFO meat as well as CAFO expansion.

A primary goal of "The Ethical Shopper," then, is to problematize consumer-based citizenship as a central response to CAFOs. I want my students to understand that addressing CAFOs' ills will require more than individual shopping trips to the local Whole Foods Market. Rather, it will take organized, direct social action and collective pressure on elected representatives at all levels. Jefferson County Farmers and Neighbors, Inc. of Fairfield, Iowa (2007) offers some insight on this point. The organization urges citizens living near existing or proposed CAFOs to engage in the following practices: (1) organize their communities and align with existing grassroots movements that oppose CAFOs; (2) hold frequent, visible community meetings to educate residents about CAFOs' effects; (3) review local CAFOs' manure management plans and discuss these with local CAFO operators; (4) assess how existent or proposed CAFOs will affect local and regional waterways; (5) ask nearby farmers not to accept "free" waste from CAFOs as manure fertilizer; and (6) send formal letters to CAFOs' financial investors. Note that none of these actions relies on socially-conscious purchases; rather, they involve groups of people working together as neighbors, citizen scientists, community stakeholders, and environmental stewards. Democracy, John Dewey observed, "must begin at home, and its home is the neighborly community" (cited in Orr 2004, p. 168). If my students learn only this in "The Ethical Shopper," then I will have taught them well.

Attending to local anthrozoology in central Iowa has brought me, in a way, full circle. No longer beholden to romanticized, outmoded images of rural life, I now know my neighbors as best I can, try to engage in civic action outside of the shops, and use my political sensibilities to create new courses and enrich existing ones. What is the nature of human-animal relations in *your* teaching context, and how might a closer examination of these relations change your pedagogy and engage your students? Environmental studies scholar David Orr (2004) reminds us that "all knowledge carries with it the responsibility to see that it is well used in the world" (p. 13). As teachers and teacher educators, helping our students understand this fact may be the most important work we can do.

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# Chapter 6
# Life After the Fact(ory): Pedagogy of Care at an Animal Sanctuary

**Christopher Bentley and Steve Alsop**

> I discovered… that once having given a pig an enema there is no turning back, no chance of resuming one of life's more stereotyped roles" –E.B. White (1948)

## 6.1 Where Species Meet

This is a story about stories – stories in which species meet and lives become entangled. It is a story of humans and nonhumans, in which they render one another more able, by learning with and caring for one another more fully. This is also a research project. It is the focus of doctoral work exploring pedagogy in a particular multispecies community, a farmed-animal sanctuary. As researchers, we have become more entangled with the animals of this community; with our experience in science education and animal studies, we wish to explore further how non-human others might be allowed to become ever more dynamic individuals within science education – non-human individuals, which if they had remained in a factory farm or traditional scientific experiment, might have gone unnoticed.

Let us begin with a story. One autumn day several years ago, a piglet barely three weeks old, destined for a nursery and eventual slaughter, miraculously freed himself from a transport truck in rural Quebec, Canada. Local authorities and animal welfare groups struggled to find the piglet a home, until he was taken in by a small farmed-animal sanctuary in Southern Ontario, Canada. Yoda, as he would later be known, made international news and became an Internet phenomenon, quickly amassing thousands of followers on his Twitter account (Cotroneo 2013). I (Bentley) first encountered Yoda on Twitter, as I scrolled through a list of recommended accounts, and began to see sanctuary life through the gaze of one of its most famous

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**Fig. 6.1** Trixie and Truffle (Credit: Jordan Bentley)

residents. Given my personal and professional interest in environmental and animal issues, I saw a compelling opportunity to make this community the focus of my future education doctorate research.

Shortly before Yoda's escape, a concerned individual contacted the Humane Society to report sub-standard conditions on a rural farm outside the Windsor-Essex area of Ontario. The group was hardly prepared for the scene they would find there. A dozen pigs were found dead after the farm's owner abandoned them to a fate of dehydration, starvation, and eventually cannibalization. In just a few short weeks, only three pigs remained (Wilhelm 2013). A local farmed animal sanctuary stepped forward to adopt two of them: Trixie and Truffle. I encountered and was warned about these pigs when I first arrived at the sanctuary as a volunteer and researcher (Fig. 6.1).

Yoda, Trixie, and Truffle live out their lives in peace at Wishing Well, a farmed animal sanctuary located in Bradford, Ontario. Established in 2012, this sanctuary houses and cares for dozens of neglected and abused rescues and escapees of various animal enterprises. Residents include pigs, ducks, horses, sheep, goats, and cattle. It is also a refuge for *humans* in need (or want) of humane education, spiritual rejuvenation, or a like-minded community of animal lovers.

For the purposes of our analysis, we conceive the sanctuary as a place where "species meet" (Haraway 2007) and renew their relationships and understandings with one another. It is a place where we like to think new, *multi*species relationships take shape and evolve as individuals learn-together.

Before proceeding, we should provide a note on terms: The first-person *I* refers to the first author, Bentley, while *we* refers to both authors. The term *animal* serves as a stand-in for the term *nonhuman/more-than-human,* or more specifically in our context, *formerly factory farmed animal*.

## 6.2 Storied Lives: 'Learning-with' Individual Animals

As a not-for-profit organization with numerous expenses pertaining to the care of its many animal residents, Wishing Well relies on the support of new volunteers to help provide this care and maintain the space. I applied as one such volunteer, for both research and personal interests, and soon found that providing education is one of Wishing Well's central concerns. As I have always sought ways to channel my activism into my professional pursuits in the education field, this was quite fortuitous. Wishing Well develops programs to inform others of and empower solutions to animal exploitation and cruelty, particularly within factory farm contexts. In spite of this position, their methods and ideology do not exactly mirror those of some animal rights/liberation thinkers, the most notable being Peter Singer (2001) and Tom Regan (1983). Rather, they pursue change through what might best be described as an expression of humane education, drawing on the work of educators such as Zoe Weil (2004).

While working at the sanctuary, I began incorporating the ideas proposed in Weil's book (2004) and online courses. She advocates learning with other animals to promote responsibility for these beings and our shared environments. Increasingly, I have monitored my ongoing relationships with the animals at Wishing Well, taking notice of how we *learn-with* and render capable one another to interact in new ways. This sometimes happens in simple, gradual ways such as negotiating acceptable exchanges of affection with a goat, or teaching a pot-bellied pig to willingly ingest his medication. Sometimes, it is more dramatic, as the following discussions reveal.

We began to wonder how our experiences at Wishing Well might apply to science and science education. After all, many ethology scholars have taken up projects that explore learning among and between humans and nonhuman animals. Following the early work of Herbert Friedmann (1955), who tracked the behaviour of honeyguide birds leading humans to bee hives, Claire N. Spottiswoode et al. (2016) explore communication between honeyguides and human honey hunters. They study signal patterns, which the humans and birds develop, learn, share, and exploit for mutual gain during the honey harvest. This is a rare case of humans and non-domesticated animals learning-with one another.

Our project here, is similarly unusual. We wondered if under certain conditions, and guided by humane ideologies, humans might learn-with formerly factory farmed animals, rather than simply learn *about* them (the dominant ethological stance), as we find ways to care for them.

Of course, there are a number of concerns sanctuary care providers must negotiate when developing care practices, not the least of which, are the residual effects on animals who have lived within a factory farm situation. For instance, different members of the same species enter the farm with varying degrees of sociality (fear of or affinity for humans, other animals) and physical ability (overweight, missing or damaged appendages). Barbara Noske (1997) identifies a process of "de-animalization" in factory farming which effectively deskills the animal in order to concentrate productive efforts on a single part of the animal being (p. 19). We try to account for such constraints and differences as we learn and formulate daily care routines, while working to maintain the animals' *long-term* social, emotional, and biological well-being, alongside our own, of course.

We openly acknowledge that the sanctuary is largely experimental and we still do not know much about these animals and their needs outside of what has been learned and practiced in the context of animal enterprise. We are also ever conscious of tradition: the ways that humans have often gone about understanding farmed animals often flattens our relationships with them. Lynda Birke and Jo Hockenhull (2012) are not alone, when they note that, "research has tended to focus on outcomes, or on only one side of the interaction" (p. 16). Instead, in this chapter, we encounter the sanctuary as an opportunity to think about and perform science education in a different way - as a form of ongoing multispecies learning and caregiving.

We hope to attend to our evolving relationships while remaining open and sensitive to new understandings. By blurring species lines and focusing on learning within evolving multispecies relationships, we argue that "humans and animals are more continuous than discrete and that non-human animals can teach humans as well as be taught by them" (Rice and Rud 2015, p. 2). With this stance, we stand alongside many environmental educators who advocate the central importance of education shaping and nurturing relationships with non-humans, within our shared organic world.

As we formulate our ideas surrounding a care-based science pedagogy, we see a useful analogy in the seminal work of geneticist Barbara McClintock and her observations of maize. We relate to how McClintock studied interactions between individual specimens and took time to "gain more than a cursory acquaintance with each plant and to follow its development within a generation" (Fox Keller 1984, p. 3). Her attempts to capture a "feeling for the organism" to understand them more fully resembles the careful attention and long-term relationships between species cultivated at the sanctuary. McClintock's work helps us in our reflections to find a place for the sanctuary's care-based pedagogy within science education.

## 6.3 Chapter Roadmap

Let us return once more to Wishing Well. After a number of visits, I began to accumulate a collection of stories about my encounters and relationships working with different animal residents. I quickly realized the importance of these stories for teaching and learning at a place like Wishing Well, wherein a sense of each animal's individual life is sought over any "objective" understanding of species. Through storytelling, not only do people learn from and with animals at the sanctuary, people learn from and teach one another about individual animals. Examples include: individual animals' positive responses to various stimuli, ways that different individuals play and interact, or odd and unusual behaviours (Fig. 6.2).

**Fig. 6.2** Lunchtime (Credit: Jordan Bentley)

Stories are central to science pedagogy. Further, we agree with Arthur Frank (2012) when he says that "human (and we would add nonhuman) life depends on the stories we tell: the sense of self that those stories impart, the relationships constructed around shared stories, and the sense of purpose that stories both propose and foreclose" (p. 3). In other words, we wish to tell stories about getting caught up in stories in order to show what stories at the sanctuary can *do*. What do we learn about these animals as we get caught up in their stories and our experiences, and what do we teach as we retell them? Out of this approach, we feel that a significant part of the sanctuary's pedagogy, and by extension the success of human-animal relationships therein, is built on storytelling.

Drawing on my experiences as a worker, a pedagogue and storyteller at the sanctuary, we now offer some stories recounting my earliest visits to the sanctuary, drawing out themes of shared pedagogical labour. We then turn to this narrative as an invitation to revisit science education. In response to Donna Haraway (2007), we ask what might (science education) become "when species meet"?

## 6.4 Initial Encounters: Preparing for Multispecies Science Education

I felt the densely packed snow crunch beneath my feet as I trudged the final stretch of road towards my destination. It was shortly before 8 in the morning and I had come to realize that, as an academician living in urban Toronto, I was ill-equipped for outdoor labour in January. I walked on, focusing on the quiet stillness engulfing me on this desolate country road, rather than the dizzying rush of morning commuters and buses that had only moments before.

Movement caught my eye as I made my way up the driveway. A brown, and visibly aging horse swished its tail, the only motion of an otherwise still creature curiously eying my approach. I opened my other senses, awakening them from the effects of winter transit. Barely 50 metres up the road, I heard a rooster's crow and the thud of a barn door while my nose was filled with the somewhat familiar scent of farm life; already I was being drawn into a new multispecies and multisensory experience.

Drawing on affect theory, Steve Alsop and Justin Dillon (forthcoming) talk about the importance of 'angles of arrival'; allowing oneself to learn, think, and feel in new ways. They claim that "how we encounter… affects our capacities to dispose, awaken, and orientate. In this manner, the promises of educational experiences are in their evolving capacities to direct us toward something different and generative" such as "new ways of being in science education" (p. 2).

This initial encounter compelled me to think through common understandings of what farmed and domesticated animals are and should be, as well as the traditional educational spaces in which we acquire this knowledge. Much literature shows that nonhuman animals are important in science education. We recall pedagogical activities such as the use of choice chambers to document insect behaviour (Yip 2000), or the practices of dissection and experimentation (Pedersen 2008), or even the use of live animals in schools, zoos and museums (Genovesi 2011). In much of this work, however, the focus of concern is placed upon pedagogical effectiveness (Hummel and Randler 2011), sometimes combined with ethical appropriateness of using real animals in educational contexts (Akbarsha et al. 2013). Others claim that students can get a better education through experiencing live animals (Edwards et al. 2014). In the presence of animals, some argue, children can learn how to act more ethically and humanely (Fraser et al. 2010); others advocate for the use of "animal stories" over interactions with real animals (Pedersen 2010).

Having already observed the sanctuary virtually through the lens of social media, I was aware of the potential for different encounters and story-worthy interactions between species. Every new day at the sanctuary means additional opportunities for "teachable moments" crystallized in narrative form. Thinking with Arthur Frank (2010) on the use of stories, I told myself to not only remember the events of the day, but be able to use them in relation to larger educational narratives concerning how we (might) learn and think with animals. Frank determines that stories are local and specific events, while narratives are collective resources used to help people "construct the stories they tell and the intelligibility of the stories they hear" (p. 14). We are interested in how the stories at the sanctuary fit into, but also challenge broader educational narratives of human-animal relations.

With snow to my ankles, I advanced towards the new, yet familiar, sounds and smells.

Glancing around the parking area, I realized I had arrived first, before the other volunteers and staff. The thudding barn door grew louder, intermittently interrupted by the crowing rooster, as I crossed the final bend and the whole of Wishing Well Sanctuary came into view. To my right were two adjoining barns, forming an L-shape, partially surrounding a set of four paddocks, each of which was separated with metal fencing and connected through several gates. I noticed warnings displayed on parts of the fence- "Staff Only" and "Caution: Electric". The setup made me think of the work of both animal studies scholars and animal activists in how they have begun to construct space, both material and theoretical, for reconsidering animals. Scholars such as Jennifer Wolch and Jody Emel (1998) might argue that these protected spaces effectively decenter the human and open up a space "to see animals… differently" (p. 18), namely as part of multispecies worlds rather than objects in anthropocentric ones.

But these constructed animal spaces seem to act as more than simply a means to "bring animals in." They give us space to think through entanglements with these creatures, and witness the implications of these entanglements brought to bear on individual animal lives and bodies. Our schematics for constructing a sanctuary in many ways resemble those of animal farms, as we use the same or similar materials to hold captive, in order to learn with and care for, the animals within. I considered that, perhaps, paying close attention to what happens in these spaces, while thinking through what happened before them, might allow us to do what animal geographers wish for their work: "draw attention to the lived experiences of the animal" (p. 6). These paddocks seem to act as reimagined and reconfigured learning spaces, with possibilities for science as well as countless other educations: spaces where species meet and render one another capable, to know and care for one another more fully.

I decided to investigate the spaces more closely.

In the far paddock, the barn door now rumbled and the whole building shook, as though an enormous creature was throwing itself against it. Eerily human-like squeals rang out from the other side. *Pigs,* I surmised, *gigantic pigs.* In the morning stillness and twilight, this sight was shocking to behold. My mind began to race: *what if they are injured, or are in pain?* I considered all that I knew – and reckoned – about factory-farmed pigs: they are bred to be large and with insatiable appetites. *Are they not also bred to be more docile?* I realized that I knew very little for certain about these imposing creatures.

A research project that seeks to "know more" about these animals might attend to students visiting Wishing Well in a particular way, perhaps studying their increasing understandings or empathy. But here we wanted to look more critically at the inherent anthropocentric and unidirectional assumptions built into the use of some animals. Scholars in fields including Science and Technology Studies and animal studies challenge systems of oppression and power hierarchies between species as they manifest in various contexts, including classrooms and research settings. By looking at the educational implications of animal cultures (Laland 2008), new and unexplored places and spaces of human-animal communities (Philo and Wilbert 2000), popular representations of animals (Boggs 2013), and systems of nonhuman rights (Mueller et al. 2011) we might help challenge anthropocentrism in education (Rowe 2015) and uncover new ways to understand and interact with animals for the purposes of teaching and learning (Rice and Rud 2015).

These new ways of thinking can shift our contemplations towards evolving relationships, rather than anthropocentric ways of maximizing value. We believe working with communities like farmed animal sanctuaries might serve to build upon a scholarly development, dubbed the ‘animal turn’. To help frame our project in a more concise way, we look to a recent workshop at UC Berkeley (Weaver 2012), in which attendees were asked to consider, in light of new scholarly genealogies, what it means to “teach science about and with animals” (para. 1). We consider it an important time for science education to take up this line of questioning, and thereby, perhaps, extend our stories. We ask, how might we tell a story of science education about and *with* animals?

## 6.5 Entangling Species: Sanctuary Stories as Pedagogy

I hurriedly found my way inside the paddocks, ran as close as I could to the barn door, and, using the comforting tone I use on my dog, began speaking to the pigs. Stopping only momentarily, they became more excited by the sound of my voice and intensified their efforts to break through the barn door. While I stood awkwardly and unsure what to do, a woman approached me dressed in heavy flannel and rubber boots; it was the sanctuary caretaker, Anne.

Reassuring me that the pigs were only anxious for breakfast, Anne led me to the barn to prepare their food. I mashed a warm slop of oats and pellets while she told me stories of Trixie, Truffle, and the other pigs. On one occasion, Trixie had run at Anne, who stood still and held her arms out. As if she had been trained to do so, Trixie had stood on her hind legs, rested her enormous head on Anne’s shoulder, and embraced her. The next day, Trixie began to do the same thing, only this time she pulled Anne to the ground and tore off her coat. I thought about how dangerous, but also complex and dynamic, these pigs, and our new relationships with them, can become (Fig. 6.3).

Arthur Frank (2010) tells us that “analysis begins in moments of interrupting” (p. 4) and we see interrupting as an important part of the process of storytelling

**Fig. 6.3** Charging Pig (Credit: Jordan Bentley)

itself. Our interruptions, like this one, break the narrative flow in order to attend to a particular moment, and analyze its significance. In the present, this story demonstrates the centrality of storytelling within the sanctuary's pedagogy. At the time, Anne used the story to inform me that much of her time at work involves learning and keeping track of individual animal's personalities and capacities.

I continued to think on Anne's story as I vigorously mashed and stirred wet grains in individualized bowls.

As I worked, I saw that I was surrounded by several bulletin boards, displaying medical, nutritional, and other specific information about individual animals. One board in particular displayed daily updates on animals with short narrative descriptions of their behaviours, dispositions, and activities as well as recommended care practices. I scanned the array of detailed notes, bulletins, and charts. The scene resembled a laboratory, whose goal, of course, was to experiment humanely on individuals in order to care for them more fully. I made note of one bulletin which said 'Bruce is refusing to eat. Please hand feed him: don't forget his supplements.'

The note made me think of Barbara McClintock's work with maize, and how she strove to attain a 'feeling for the organism' she was studying. Her biographer, Evelyn Fox Keller (1984), quotes McClintock and the intimacy with which she learns about her plants: "one must understand 'how it grows, understand its parts, understand when something is going wrong with it. [An organism] … is constantly being affected by its environment, constantly showing attributes or disabilities in its growth. You have to be aware of all that" (p. 198). McClintock sought to understand the whole story of her individual organisms and, as such, she demonstrates an important distinction between the "casual spectator" wishing to learn about and the "motivated observer" working to learn-with. We can apply this logic to the sanctuary's care-based pedagogy that I witness on my regular visits. This type of learning may help us see, as McClintock did, "the objects of our study become subjects in their own right" (p. 200).

At the sanctuary, animals become subjects in stories. And these stories teach us about individual others and ourselves. Here, it is helpful, perhaps, to think with indigenous educator Jo-ann Archibald (2008), who noted that stories in education "become the teacher" (p. **x**). Stories teach us (how) to care. To consider this point alongside Maria Puig de la Bellacasa's (2012) article, stories help us "recognize the inevitable interdependency essential to the reliant and vulnerable beings that we are" (p. 198).

## 6.6 Becoming More: Attending to Evolving Relationships

As I piled up the steaming breakfast bowls, Anne told me how important it is to share experiences of my daily encounters with animals, both on the boards and orally with other volunteers and care providers. "We are trying to get to know these animals," she told me, "and that's an ongoing process."

Upon hearing this, I felt that providing care in this way represents more than just the survival of the individuals at the sanctuary. Our stories can help guide us to cre-

**Fig. 6.4** Goat Peek (Credit: Jordan Bentley)

ate happy and fulfilling lives for the animals as we learn more about them (and thereby learn more about ourselves).

In one more recent instance, some other care providers and I moved the sanctuary's four resident goats to a much larger paddock containing a newer and more spacious barn and multiple play structures. This space would have afforded them more exercise and more individual attention than in their previous space they shared with a half-dozen pot-bellied pigs. Over the following weeks, we began exchanging stories of the goats and the pot-bellies, which were exhibiting more lethargic behaviour. The goats spent much time near their gate, pushing on it with their hooves. After a while, we moved them back to their smaller space with their pot-bellied brothers and sisters, where they continued their usual playful behaviour (Fig. 6.4).

But during that first visit, I could only wait and listen and learn. I stood anxiously in the chilly barn with my numb fingers pressed against the warm food bowls, waiting for the grains within to finish softening so I could serve the animals a long-awaited breakfast. At this point, several more volunteers filed into the barn and began hugging Anne. They greeted me, too, and began sharing stories of their most recent encounters with the sanctuary's animal residents, which were met with surprised faces and affectionate laughter.

The way everyone shared and responded during the storytelling session reminded me of the work of social theorist, Brian Massumi (2014). He tells us that humans and nonhumans instinctively and collaboratively seek out *high-quality* lives, rather than simply means of survival: "surplus-value of life equals surplus-value of inventiveness" (p. 12). I could see this in the multispecies community at the sanctuary. Our collaborative stories and efforts at learning and interaction are directed along by promises of happy lives. As care providers we receive positive feedback when we "tinker" (Mol et al. 2010) with different and hopefully more effective care practices; sometimes met with apprehension at first, they often result in nuzzles, licks, play fights, invitations to belly-scratch, and even hugs from animals. The volunteers acted out these actions as they recounted their experiences. As Frank (1995) tells us, good stories are "told through the body" (p. 2).

As I listened, I became particularly affected by the story of Bruce, the sanctuary's resident rooster. Earlier that month, Bruce's two companion chickens, Thelma and Louise, died and Bruce began exhibiting uncharacteristically lethargic behaviour. To help him cope, the volunteers started inviting Bruce into human spaces, while also accompanying him in his usual spaces and on his everyday activities. With Bruce, the volunteers began sharing meals, going on walks, socializing, and even having naps, all to help him once again engage in positive social relationships. For all intents and purposes, the volunteers became more than Bruce's care providers: they became his flock.

This story inspired me to think with Donna Haraway and Vinciane Despret regarding a flock of sheep given an extra bowl of food by a researcher wanting to see how they would behave. The researcher was looking to "expand their repertoire of behaviours" beyond the predictable, competitive behaviours found in many ethological accounts (Despret 2010, para. 22). To the scholars, this act gives the animals an opportunity; it renders animals capable to "become more interesting," a scientific pursuit that allows us to learn-with, talk about, and care for animals more fully (Haraway 2015, p. 6). We feel Wishing Well sanctuary allows factory farmed animals, like Bruce, to become more, as we invite them into new multispecies communities in which humans and nonhumans together solve problems and tell even more meaningful stories.

Stories shape our work as researchers, and the work that I have undertaken at the sanctuary has effectively challenged some of my previously held notions about the creatures who occupy factory farms and sanctuaries. Stories about these animals and our dynamic multispecies relationships have dispelled any thinking of them as discrete or fixed predictable beings (McHugh 2011). We change and adapt, but not just for survival, but in the presence of one another: we make choices when given the opportunity. The choices and potential for learning is not clearly laid out, but might better be called a "mess" (Taylor 2012) to be explored (respectfully and responsibly) in communities like the sanctuary.

We think with Frank (2010) and notions of evolving stories as an invitation to consider factory farmed animals as "narratable" (p. 75). When it is possible to narrate individual lives it offers possibilities of recognising subjects which shape their own worlds, a step toward reclaiming subjectivities. We can start to see "what matters to them" (Haraway2015, p. 6). Our learning, perhaps, should not end there, however. In order to better care for these animals and our shared worlds, we acknowledge the incompleteness (Wemelsfelder 2012), unknowability (Woodward 2008), and openness (Haraway2007) of subjectivities. These elements of animal subjectivities in stories provide, in Frank's words, "suspense" or a "might have turned out differently quality" (p. 33) to hold our interest in learning and exploring further.

The sanctuary, and the multispecies relationships undertaken within, have given me opportunities to constantly (re)learn who these animals are, who we are to one another, and even what we need *from* one another. This would be much more difficult if we were not open to teaching and learning through emerging and dynamic narratives.

## 6.7 Life After the Fact(ory): Locating Science Education at an Animal Sanctuary

I made my way over the fences and trudged through thick snow towards the pig barns. I heaved the door open and the beasts barreled through the opening. Largest pigs first, they stampeded toward the bowls, as I watched safely from the other side of the fence. My eyes settled on Yoda, the famous pig with the famous Twitter account, which we previously mentioned. Once he finished eating, I reached in to grab the bowls and Yoda, albeit gently, bit me on the arm. I recoiled but laughed, deciding I had much to learn about these animals, their home, and myself as a care provider.

Francoise Wemelsfelder (2012) uses the term: "being-with" the animals. Being-with, for me, involves paying attention not only to the stories but to the way my relationships unfold in the process of interacting and providing care with others. Jinx the goat now nudges my hand until I scratch his favourite spot on his forehead. Kingston the pot-bellied pig responds when I call his name, and opens his mouth for daily medicine. As Wemelsfelder adds, animals "express themselves with unexpected creativity in unexpected moments, giving us a sense of who they are as individual beings" (p. 230). If we are present and attentive in these moments, we might learn from them.

Joanna Latimer and Lynda Birke (2009) discuss how animals take opportunities within interactions to learn about and invite in human companions. Perhaps this is what Yoda was doing when he bit me: inviting me into his world so that I might care. Often it is difficult to navigate these worlds once invited inside, however. We recently assimilated Petunia, the gigantic orange Tamworth raised among goats and potbellies, into the barn of the six American Landrace pigs. Our hope was that she would befriend Winston, whose bonded partner died shortly before. Yet, the opposite occurred and Winston began to bully the much meeker Petunia. We care providers frequently struggle to learn if, and how, to intervene in these situations with the utmost care in mind. It is not as though we have the answers readily available.

It is here we see a space to think on the relationship between care and pedagogy. The sanctuary has effectively shifted the way I think about this relationship. Here, teaching and learning does not take primacy over proper care, wherein the latter is sought but remains extraneous to the process. Instead pedagogy becomes a kind of caregiving, in that care, particularly effective care, cannot occur without learning and vice versa.

**Fig. 6.5** Jam (Credit: Jordan Bentley)

To share a final example, I think of Jam, who is a former laboratory test subject rescued by veterinary school students wishing to see him live out his life in peace. Perhaps these experiences contributed to his desire for attention and affection for humans. His preferred method is nuzzling his face on the lap of a stranger while receiving a deep massage on his neck and shoulder muscles. Most of the other sheep flee when humans get too close, while Jam stands still, or even moves closer to his human companions. For me, the learning was not finished once Jam left the laboratory, but continues as he lives out his life at the sanctuary. Only now, as we root our interactions in humane values, we are learning-with him, rather than simply about him, with an openness and sensitivity to learn more as our relationship unfolds (Fig. 6.5).

So to revisit Haraway (2007), as I move further into my doctoral research project, we ask: what might (science education) become "when species meet?" In other words, what does this project, characterized by care and storytelling, have to offer science education in all its various contexts? When we cast our gaze on our intertwined relationships with animals, while remaining open and sensitive to change, we move away from the unidirectional and anthropocentric goals of finding the best way to learn *about* animals. In allowing learning-*with* animals we wonder might humans and animals render one another even more interesting in science education, as individuals, as researchers, as species? Might revisiting the ways that animals are positioned in science education offer a way of nurturing ecological relationships?

Thinking more broadly, when science, or perhaps even environmental education emerges in a place that provides new kinds of opportunities to meet and interact with other species, the place becomes what Anna Tsing calls a "refuge." To Tsing (2015), these refuges represent collaborative survival within and among the ruins of biological and ecological decline. Haraway (2015), reading Tsing, suggests we "join forces (among species) to reconstitute refuges, to make possible… recuperation and recomposition, which must include mourning irreversible losses" (p. 160). This work seems to resonate with that of the sanctuary, mourning and recuperating, while telling stories along the way. As we have many more stories to tell, so too do we have much more to learn to protect, and live well within, our shared worlds.

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# Chapter 7
# Ethical-Ecological Holism in Science Pedagogy: In Honor of Sea Urchins

**Lee Beavington, Heesoon Bai, and Serenna Celeste Romanycia**

Using model animals in research "forms the core of biological knowledge" (Hedges 2002, p. 838) and this use has dramatically improved our understanding of and treatments for conditions such as heart disease, diabetes, and epilepsy. While we acknowledge the benefits to science and humankind, we also believe that animal usage for education must be considered carefully in the context of ethics. Such consideration, we argue, would be apropos to humans' self-identity that they have self-awareness as morally responsible beings. But this needed self-awareness undergirding moral responsibility is often misconstrued as sentimentality based on anthropocentricism. Herzog (2005) comments: "[s]cientists often assume that objections to the use of animals in science are based on sentiment and misplaced anthropomorphism"; however, "… the philosophical arguments both for and against the use of animals by humans are sophisticated and complex" (p. 15). We (the three authors of this chapter) are interested in developing a philosophical argument that offers an alternative paradigm for a scientific methodology that fully acknowledges the Other and takes humans' moral responsibility towards all earthly beings and our mutual flourishing. One such alternative that we would like to introduce in this chapter is a Goethean vision of science and scientific method wherein "[w]e develop the capacity to become *ethically responsive* to our obligations to the observed" (Robbins 2005, p. 123). This ethical responsiveness, it turns out, coincides with

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aesthetic considerations and sensibility in Goethean science. The philosophical theme of “ethics and aesthetic are one” (Bai 1997, p. 37) is pertinent here and will be explored in this chapter. Goethean science, as we will see, emerged during the so-called Romantic period in European history. Romanticism in science reminds us of the important “interrelationship of philosophy and science for science education” (Hadzigeorgiou and Shulz 2014, p. 1999).

This chapter develops the groundwork of holistic science pedagogy through exploring the Goethean scientific paradigm. We will share stories and poems of our reluctant participation or outright refusal in science labs involving animal experimentation. Through these embodied inquiries, we propose a philosophical rationale for moving away from anthropocentricism and an implied hierarchical worth of beings. We contend that students’ experiences with dissection, often vivisection, presumes and reinforces the idea that other-than-human animals have a lower moral status, if any status at all. Our collaborative work in this chapter calls for a shift to an ethical-ecological framework for science pedagogy by animating the world and imbuing it with sacredness through aesthetic and contemplative practices alongside Goethean scientific investigation.

We begin our foray into the new vision of science pedagogy with a brief look at the sea urchin, a model organism in North American biology labs. This look is then followed by narratives of our respective experiences of lab work.

## 7.1 The Sea Urchin: A Model Organism

Model organisms are used in science to research anatomical, behavioral, genetic, and other biological information about the human species (Hedges 2002). Most of these organisms are easy to care for, abundant, and have physiological functions similar to those of *Homo sapiens*, giving the construed data a certain comparative value. Despite the many limitations of using nonhuman animals to better understand human biology, the use of lower model organisms is not predicted to decline for at least another 20 years (Hunter 2008).

Sea urchins are model organisms for teaching and researching many biological concepts, including embryology (Vacquier 2011), genetics (Cameron et al. 2006), molecular biology (Killian et al. 2009), and evolutionary biology (Koga et al. 2014). Aristotle observed sea urchin anatomy and described these organisms in his *Historia Animalium*, circa 343 BCE. The urchin’s mouth is named Aristotle’s lantern, inspired by his writings and attributed by early zoologists to refer to the jaw structure. However, recent excavations in Greece (Voultsiadou and Chariton 2008) suggest that Aristotle originally intended his lamp metaphor to refer to the urchin’s test, or outer calcite shell. In the late 1870s, H. Fol and O. Hertwig investigated sea urchin fertilization, and in 2006, the purple sea urchin's genome—more than 23,000 genes—was sequenced by a team of over 200 scientists (Cameron et al. 2006).

The sea urchin belongs to the class Echinoidea, a group of marine invertebrates with just over 1,000 known extant members (Kroh and Mooi 2011). At the phylum level, sea urchins (Echinodermata) are closer to humans (Chordata) than any other phyla. Compared to all the genome-sequenced nonchordate animals to date, sea urchins bear the closest genetic relation to humans (Cameron et al. 2006). Despite their stark dissimilarities from *Homo sapiens*, such as radial symmetry, presence of tube feet, and lack of eyes and other mammalian sense organs, both sea urchins and humans possess complete digestive tracts, internal skeletons, and bilaterally symmetrical embryos (McClay 2011). This latter point is of importance to biology labs, because the early embryonic stages—from fertilized egg, to cleavage, morula, blastula and gastrula—bear significant likeness for humans and urchins.

A common biology experiment used to teach embryology involves students extracting sea urchin gametes, fertilizing the released eggs with sperm, and observing the results under a microscope. For this laboratory procedure "adults may require an electric shock of 6–10V to induce spawning" (Vacquier 2011, p. 554). Another option is to inject urchins with a potassium chloride solution to stimulate gamete release. In such teaching materials, there is no mention of sea urchin distress or limiting sea urchin mortality. Rather, the implicit assumption seems to be that the suffering of sea urchins (which possess a primitive nervous system compared to humans) is not only justified, but also not even worthy of ethical consideration—so far removed, in fact, to be omitted entirely from academic discourse. Science as epistemology assumes, as a matter of course, that this animal is merely an object, and its internal organs are mechanisms to be poked, prodded and studied without an ethical regard.

For studying embryology, purple sea urchins are often wild-caught, which can end their 70-year lifespan prematurely. Students place sperm and eggs on a slide, observe fertilization and the early developmental stages through a microscope, as a mandatory procedure in many North American high school and undergraduate biology classes. What is missing entirely in this performance of vivisection are ethical and attendant philosophical and psychological reflections on witnessing the miracle of new life, which then is merely washed down the drain at the end of the lab period. In this case, the dominance of the human species over all other beings is unquestioned and is an unquestionable assumption. So is the conception that our benefit eclipses the need and suffering of nonhuman species. The speciesism embedded in science curricula, and the definition of what is sentient or even alive, seem to have been completely unnoticed, let alone challenged.

However, as our narratives below will show, many young (and not so young) people experience their relationship with other life forms differently: with genuine love and respect, with empathy and care. Thus, their experience in the biology lab is often alienating and traumatic.

## 7.2 Killing the Wonder: Three Biology Lab Narratives

### A Study in Life

*by Lee Beavington*

*My trembling fingers inject the needle into the mouth of the sea urchin. The needle point is reluctant. I push the point until it slides deep into the soft tissue, then inject the potassium chloride, the same that Dr. Kavorkian used to stop melancholy hearts. But I am not after death. I am after gametes, the fruit of life. Will it be egg or sperm?*

*Under the microscope in the biology lab, first-year university students witness that most miraculous genesis called fertilization. A frenzy of sperm compete for a single egg. Of the millions of flagellated vessels of DNA, but one obtains that golden prize. My job, trumping my conscience, is to provide the fertile ingredients; students then play god on a microscopic level.*

*I watch the injected urchin before me. Is this sea hedgehog older than I? At first, the echinoderm offers no response. Then, slowly at first, its spines begin to undulate. An involuntary response that I perceive as a silent plea for help. In one final humiliation before the scientist, I place the urchin upside down over a beaker to allow gravity to collect the gametes.*

*Amber spheres emerge and drop into the safety of the beaker's saline solution. Eggs. A female. Somehow, this feels like a greater evil.*

*Once I have collected both ova and sperm, and placed them in the refrigerator like reproductive fast food, the lesson can begin. The young women are squeamish at having to carry sperm smeared on a slide. The young men poke fun at them. Magnified four hundred times, the sperm resemble vibrating carrots, while the eggs are solemn planets waiting to be colonized.*

*Most of the eggs reject sperm. Late autumn is not their usual season for fertility. Those that are receptive balloon outward, building a fertilization envelope to prevent subsequent suitors. This one cell divides into life. First into a berry-like morula, then a hollow blastula and—like a good model organism—all the same embryonic stages of a human baby. The students follow this development over the course of a week, when some of the virginal urchins start to move. Then they are washed down the sink.*

*My students have contrived life, acting as laboratory midwives, only to abort the urchin embryos once they look like something alive.*

*At the next biology meeting, surrounded by a dozen colleagues, I indicate that I have something to add to the agenda. "I cannot be involved in any activity where I consciously kill an animal."*

*Silence. Will my request be scoffed at? Will I be ridiculed for contemplating the life of lowly urchin? Have I threatened my job? The department chair sits to my right. Under my clammy but steady hands lies a folder with my next move, should I need it: a letter to the Dean of Science outlining in clear and concise terms my refusal to end life in the lab. Finally a fellow lab instructor says that he understands my request and is fine if I excuse myself from those activities. A brief discussion* *ensues. I sense others are uncomfortable with injecting the urchins, but they hesitate to agree with my position.*

*I leave the meeting relieved yet unsettled. I no longer have to compromise my conscience, at least not directly. I walk out of the lab, past the tarantulas, stick bugs and budgies, hermit crabs and hissing cockroaches, each in their own neat little cage. Finally, the saltwater tank with the purple sea urchins. There are five less than before. I watch the remainder in wretched triumph, waving their spines in a tender tremble.*

Aristotle's Lantern

blackhole mouth bares sea-shorn teeth
midnight raises her five-fanged pyramids
her radial world balances the tide
as she churns kelp to weed and rock to sand
she keeps the seafood chained

without eyes the urchin holds the sea
perception starbursts beyond her calcite shell
a skeletal test for otters to best
consumes this ecosystem engineer
her mouth made for seaweed

she nurtures the nocturnal intertides
her roving dome an outward panopticon
perhaps this urchin is a philosopher
with senses no mammal possesses
in phase with every rippled wave

what did Aristotle see
when he was entranced by her spines?
that entrance to a geometric jaw
simple mechanics or a radiant threshold
window into the urchin universe

the only law she abides is natural law
a reciprocal rule we have forgotten
to her wisdom we are blind
if we held her lantern high
what question would she ask of us?

**Encounter with Horror and Absurdity**
*by Heesoon Bai*

*My encounter with senseless killing and suffering took place more than four decades ago, during my teen years in Korea. It was in my biology class. My school, a top academic secondary institution in Korea, was delivering advanced academic courses* *to students. As part of such advanced modern (read: "westernized") curriculum, we performed vivisection. Thus, one day, I was faced with live frogs, rendered senseless with chloroform. There were some sixty of us in the class, and there must have been close to 100 frogs. I have no memory of exactly what it was that we were studying in frogs. All I remember is the sight and smell of a whole heap of frogs, whose chests and bellies were opened up, still breathing and palpitating. And that was the end of their short lives: no suturing, no bringing them back to life, just thrown in the garbage after our lab session. At this sickening sight of senseless killing of creatures, I was plunged into existential horror and despair. I loved little creatures! I was friendly towards them, played with them without hurting them, and rescued them if they were in trouble. This was an experience of deep wounding in my heart and soul. And it also illustrated for me what biology was, in the way this subject matter was conventionally taught: it certainly did not promote love of life phenomena.*

*Decades later, when I was teaching undergraduate and graduate students at my current university, I met quite a few students who told me that they went into biology because they loved life phenomena, but after studying biology (some of them graduating with a major in biology), the love of creatures they experienced throughout their growing years evaporated, and they were sorrowful about this loss.*

*We choose to study something because we love it; but in the process of studying, we often kill our love. The conclusion to be drawn here is not that study kills. Rather, we need to be aware of what studying may entail. There are different ways to study or research. I am reminded of the comparison that is made, by Erich Fromm (1976), of three poets whose contrasting worldviews and approaches to life phenomena illustrates different ways of studying. Lord Alfred Tennyson (1809–1892), Basho (1644–1694), and Goethe (1749–1832) are the three poets in reference here. I quote their respective poems:*

*First Tennyson:*
*Flower in a crannied wall,*
*I pluck you out of the crannies,*
*I hold you here, root and all, in my hand,*
*Little flower—but if I could understand*
*What you are, root and all, and all in all,*
*I should know what God and man is*

*Next, Basho:*
*When I look carefully*
*I see the*
*nazuna*
*blooming*
*By the hedge*

*And lastly, Goethe:*
*I walked in the woods*
*All by myself,*
*To seek nothing,*
*That was on my mind.*
*I saw in the shade*

*A little flower stand,*
*Bright like the stars*
*Like beautiful eyes.*
*I wanted to pluck it,*
*But it said sweetly:*
*Is it to wilt*
*That I must be broken?*
*I took it out*
*With all its roots,*
*Carried it to the garden*
*At the pretty house*

Now, Fromm's (1976) comments at length on the three different, what we may recognize as, research paradigms:

> *The difference is striking. Tennyson reacts to the flower by wanting to have it. He "plucks" it "root and all." And while he ends with an intellectual speculation about the flower's possible function for his attaining insight into the nature of God and man, the flower itself is killed as a result of his interest in it. Tennyson, as we see him in his poem, may be compared to the Western scientist who seeks the truth by means of dismembering life. …. What Basho wants is to see, and not only to look at the flower, but to be at one, to "one" himself with it—and to let it live. … For Goethe the flower is so much alive that it speaks and warns him; and he solves the problem differently from either Tennyson or Basho. He takes the flower "with all its roots" and plants it again so that its life is not destroyed. Goethe stands, as it were, between Tennyson and Basho: for him, at the crucial moment, the force of life is stronger than the force of mere intellectual curiosity. Needless to say that in this beautiful poem Goethe expresses the core of his concept of investigating nature*. (pp. 14–16)

*Is one paradigm more biophilic than another?*

**The Earthworm Protest**
*by Serenna Romanycia*

*When I was a child, I had many friends. They lived in deep green forests with mossy carpets, hot sun-bleached meadows filled with buzzing crickets, mysterious lakes, scummy warm ponds, and many other places. The particular friends I speak of in this story made their home in cool, nourishing soil: the earthworms. Sometimes, when my family would garden together, I'd encounter them suddenly unearthed, writhing and wriggling to get back into the safety of the ground. At other times, on rainy nights, I'd go for a walk and find them rain-bathing at the edge of the sidewalk. They'd be stretched out long, half in the grass and half on the pavement, perfectly still. One vibration from my footstep, and they would pull back instantly, disappearing in a heartbeat underground.*

*Yes, my earthworm friends were very sensitive, peaceful creatures, and they didn't particularly enjoy bright, exposed spaces. But sometimes, in the daytime, if it was rainy, I'd find them out and about, wriggling along at a speedy pace to some destination. I've read that worms travel in the rain, as it gives them an opportunity to travel along faster than they would through soil. But it seems to me that there's more danger in this method of travel, too. When I attended middle school, I spent a* *good deal of time at lunch patrolling the track and the sidewalks, where on rainy days my travelling friends would often be squished by careless or cruel kids, drowned in puddles, or run over by cars. A few of my human friends would help me in my efforts to save earthworms. We would run around and gather up all the worms that were stranded on the pavement or getting washed down the storm drains, and put them back into the soil around the school grounds.*

*I must confess my friendships with the earthworms, in fact with all of my animal friends, somewhat changed as I entered high school. I still considered them my friends and never lost my connection to and love of the wild. However, my attention was rather diverted to navigating human teenage culture. Most of my time was spent with human friends. I stopped making a concerted effort to save my old earthworm buddies at the track, and instead made a concerted effort to deal with fluctuating hormones, fluctuating friendships, and fluctuating grades. Yes, I must admit that earthworms were the last creatures on my mind.*

*Yet, an incident brought my old friends back into my heart, with a shocking jolt. Scene: science class, block before lunch. Me: sitting in the back row, angry. The teacher had just passed out beakers filled with some liquid. I gripped my beaker, feeling sick: here were a few of my old friends, floating around anesthetized, still barely alive, but numb and motionless. We were told we would be dissecting these "specimens" as they were now "slowed down" enough for us to study and learn about them.*

*Specimens? No, these weren't specimens! They were little living beings! They were my friends, and I was going to be damned before I cut them open alive to "learn" about some scientific fact that was also written right there in the textbook. I told the teacher this, which provoked laughter from my classmates, but a tinge of respect too. I looked around and saw several kids with the unmistakable uncomfortable look on their faces that so often reveals when our internal moral compasses get overridden by convention and pedagogy. It felt wrong, and that wrongness registered physically in my gut: a clenching, sickening, clammy sense of people being blind to the suffering and broken dignity of other living beings. My teacher told me firmly these were "just worms," and it was stupid to feel sorry or compassionate towards them. "Yeah," piped in some taunting kids: "It's not as if worms have brains, hearts or souls!"*

*I refused to participate in my classroom experiment on grounds that it was unethical, disturbing, and completely useless, revealing "information" that could easily have been found on the internet, as it was a high school experiment that had been performed thousands of times. The teacher responded angrily by docking me marks and offering other classmates higher marks if they would in fact eat a live worm. (I believe some of them actually did, if my memory serves me correctly.) Others, like myself, continued to boycott the experiment.*

*I still hear the kids' taunting: "It's not as if worms have brains, hearts or souls!" How ironic that they should say that. Worms actually have five hearts, and a "brain" that is a nerve cord that runs the length of their body (not a vertebrate brain); and I suppose it depends on how you define soul, but they certainly possess life energy that flows through them and responds to the world and the challenges to their sense of well being, just as does every other living being on earth. What was really stupid, I told my teacher, was that we were killing these creatures to "discover" and "study" them, but in doing so we were destroying what was actually of value to* *learn: the joy and mystery of how these creatures live their lives. I was sure I knew more about earthworms just from hanging out with them in my garden, saving their lives on my middle school track, and stepping around them carefully on a rainy night walk. These were all the times when my powers of "observation" were not detached from my relationship to the creatures themselves. Let us consider: how do we really get to know other people best? Is it by capturing people, drugging them, putting them in captivity, slowly cutting them open and demanding they reveal something to you about the nature of truth as they die? Or is by spending time together, eating food together, sharing good memories, stories, laughter, joy and tears, and developing emotional connections and loving relationships?*

*I hope the answer is obvious to my readers: it is the latter. The next question is then: why should this answer necessarily be any different if it is posed towards a member of a different species? I believe that, just like humans, other creatures should not be treated as objects to be used, experimented on and disposed of. And, just like studying humans, there are many other ethical alternatives to learning-about other life forms than capturing them and putting them under a microscope or a scalpel. We are vastly lacking an ethical-ecological framework within the current scientific pedagogy that recognizes the intrinsic value of all living beings. I suspect my perspective might resonate with many readers, showing up as a stirring of the heart, a shared wish between living beings to live full lives and to be treated ethically and compassionately.*

## 7.3 Goethean Science: Delicate Empiricism

The mainstream modernist western empirical science, based in Cartesian-Newtonian philosophy, is a worldview that postulated a mechanical universe devoid of sentience. In great contrast, Goethe's approach, known as *"zarte Empirie,"* meaning delicate empiricism (Wahl 2005, p. 58), was to know the thing-in-itself. His method observes with empathy and attentiveness, which can help reconnect us with our biophilic nature. Goethe explained that "[l]ife resides in wholes: when organisms are taken apart they are no longer alive. In order to understand, and hence engage with, the aliveness of nature, we have to understand it in terms of its wholeness" (Mathews 2008, p. 60). The Cartesian-Newtonian model of science obliges a positivist and mechanistic approach, whereby an organism is reduced to its individual components, which takes on primary importance. The breadth of biology covers subcellular components right up to the biosphere—and all levels of organization in between—yet lab dissections often completely omit this consideration. Students put on gloves, cut into an animal specimen, identify the individual mechanics, and finally discard the carcass. This anti-holistic attitude suppresses ethical and philosophical concerns, which can lead to an ontological reversal, whereby symbols and models are assigned greater significance than the actual phenomenon under study (Hadzigeorgiou and Shulz 2014). If "the search for a philosophy *of* science is imperative" (p. 1999), we need to find an appropriate approach to science pedagogy.

> The Goethean epistemology of conscious-process-participation does not negate the validity of reductionist science, it merely challenges its position as the exclusive source of reliable knowledge about the world and offers a way to overcome the limitations of the dualistic subject-object-separation epistemology. (Wahl 2005, p. 67)

Goethean science calls for contemplation, in which empathy and prolonged looking promote a participatory mode of consciousness. With reciprocity between the observer and observed, self and other, subject and object, this relationality elicits compassion and ethical consideration (Bai 2001; Bai 2004). Martha Craven Nussbaum mentions that for Aristotle "all animals are akin, in being made of organic materials; humans should not plume themselves on being special" (Nussbaum 2006, p. 348). This kinship is too often lacking in science education, where microscopes, scalpels, and needles become tools of separation. Michalinos Zembylas (2004) has explored the importance of emotional labor in science, where reason outweighs emotion, and suggests that learning science through emotion can allow us to follow students' interest and excitement.

Aesthetic and contemplative practices can help transform science education toward a more integrated curriculum. For example, rather than entering a lab where sea urchins have already been probed and their gametes extracted into beakers, students can be given an opportunity to understand the natural world of the sea urchin. How do they survive in the harsh intertidal environment? How do they fit into their environment, and in what ways do they affect the ecosystem? How might their perceptions of the world differ from ours? These types of questions can be explored through narrative, artwork, poetry or self-reflection. In studying earthworms, their outdoor habitat or even a well-maintained compost can be used so students can experience these annelids directly: recognizing the earthworm's essential need for a moist environment as it relates to support and their permeable skin, gently feeling their segmented movements, and discussing its important role as a detritivore in soil aeration and in recycling organic materials. Such activities, similar to the WormWatch program offered by NatureWatch in Canada, cover science learning objectives without the need for dissection.

Teaching respect for all life should precede any biology education. Our species' survival depends on pollinators, photosynthesizers, and bacterial digesters in our gut; to foster an ecocentric worldview we need a foundation that gives intrinsic value to all life forms. To this end, for example, a creative writing exercise may be undertaken with students to help cultivate this respect. The lesson plan is simple: students employ multiple senses to engage with an item from nature. Preferably, such an item is discovered by students' themselves, led by their own curiosity while exploring the natural world. Students then brainstorm key words, ideas, and make drawings or other art inspired by this sensory engagement. From these inspirations they are given space to write a short story, poetry, or personal reflection essay, either on-site or at a later time. This pedagogic activity follows Goethe's approach, where creative and artistic expression is inspired by receiving from the object under study, thereby having students learn both *about* and *from* nature. With such reciprocity, animal neglect and cruelty are less likely to be tolerated. If we want to respect and honor all life phenomena and cultivate reciprocity, we need to open our hearts to an alternative paradigm that considers humans to be but one species among many in the vast cauldron of life.

*A Conversation Between Sea Urchins*

Specimen — Species

I hear rumours of a sea beyond measure
whose borders slide with the moon.
Tell me of the ocean

Every wave delivers life,
the ebb brings barnacles and sunlight
the flow—fresh intertidals and brine, the world
in constant motion

All I perceive is a glass cube
that ends with the researcher's budget

Do you not see the world
in every direction, every
current from sediment to sky?

I have a filter and lab technician,
my body is an experiment.
What I fear is fertilization day
when what they call the Kavorkian needle
prods my gonads

Imagine such a way to release life
there must be a reason you were chosen

I heard them call me a "model" organism

A model for what?

A model to be cut, probed, vivisected
until every gene has been sequenced
and each eye to every microscope satisfied

Were you born in a lab?
When do we stop
being urchins?

Humans and urchins are kin,
my embryos resemble humans

So being similar causes you suffering

Being different causes my suffering

You said we come
from the same place

But I'm not human enough

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# Chapter 8
# A Story of Chicks, Science Fairs and the Ethics of Students' Biomedical Research

**Sophia (Sun Kyung) Jeong, Deborah J. Tippins, and Shakhnoza Kayumova**

## 8.1 Learning Opportunities Through Science Fairs

Science fairs at the secondary level provide students opportunities to create projects that are driven by their own interests and questions. In the process of conceptualizing and carrying out a science fair project, students learn to manage long-term research, foster their own curiosity, work through challenges that arise from doing scientific inquiry, and collaborate with others (Cutraro 2011). The exploratory and investigatory aspect of science fair projects can represent science as inquiry. In this capacity, science fair projects help transform classroom science into process-driven, inquiry-based areas of study in which students can be personally and directly involved in scientific investigation (Balas 1998). Crystal Miller-Spiegel (2004) emphasize that science fairs demand strong communication and cognitive skills, and intellectual development. Thus, by participating in science fairs, students can be encouraged to develop interests and pursue careers in science, technology, engineering, or mathematics fields.

When students participate in a science fair, their involvement typically includes conducting an investigation, writing a report, creating a visual display of the project, giving an oral presentation to an audience, and receiving evaluation and assessment from the judges. Through this process, students learn important scientific concepts and experience first-hand what it is like to carry out a scientific investigation.

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However, the mere aspect of doing science is not necessarily the primary educational aim for science fairs. According to Carl Tant (1992), the primary goal of involving students in science fairs is to teach them how to *think*. In light of this aim, we must consider the educational value of science fairs, particularly for students who design experiments using animals (live vertebrates) and ask the question, "Why use animals in science fair projects?" To this end, our chapter provides a case narrative of a student who used chicken embryos to compete at a regional level science fair.

The purpose of this chapter is to invite students, teachers, science educators, scientists, and other voices to participate in discussing the implications rising from this narrative. Through the case narrative, we raise the following questions: (a) Must we use animals in science fair projects to meet the educational aim of teaching students to critically think about anatomy and physiology, and learn engaging in such scientific exploration as a process of inquiry? (b) What perceptions of science are we impressing upon students when we deemphasize the ethical issues of using animals in scientific experiments, such as respect for all life and interactions between humans and animals? (c) Can we re-construct the educational aim of engaging in scientific exploration as a way to critically examine and understand the harmonizing interactions between human lives, nature and other living animals? When we socially construct an alternate aim of teaching and learning science, the authors posit that the need to use live animals in science fair projects will become obsolete for educational purposes and that students can learn to appreciate science as a way of inquiring into and understanding more meaningful interactions with the natural world.

## 8.2 The Historical Context of Science Fairs

In 1921, Science Service, a nonprofit membership organization, was founded by Edward W. Scripps, a journalist, and William Emerson Ritter, a California zoologist. The goal of Science Service was to inform the public about scientific achievements. In 1942, Science Service and Westinghouse launched the first and most prestigious science competition for high school seniors – the Science Talent Search (STS). In 1950, the first National Science Fair for high school winners from local and regional science fairs was launched in Philadelphia. In 1958, the National Science Fair became the first international competition, with participants from Japan, Canada, Germany and the U.S. Intel Corporation took over the sponsorship of STS in 1998. This annual international fair has grown into what is known today as the Intel International Science and Engineering Fair (ISEF). In 2008, Science Service became Society for Science & the Public (SSP) and has been the governing body to continue overseeing its two major science competitions in the United States - STS and ISEF (Society for Science & the Public 2000–2015).

## 8.3 Use of Animals in STS and ISEF: Early Years

Students who participate in science fairs can compete on local, regional, state and national levels. Most science fairs and competitions at different levels are organized according to the rules and guidelines established by the Intel ISEF. In this section, we will examine the rules and regulations of STS and ISEF pertaining to the use of animals in science fairs.

Since its inception in 1942, the STS encouraged and incentivized students to seek careers in science with grand cash awards and opportunities to travel when declared the winner of the competition. Another competition, Intel ISEF, was founded in 1950. As such, the two competitions became a competitive platform to engage in scientific endeavors for the aspiring young scientists. However, these efforts and eagerness to become a great scientist (and to win that grand prize) was sometimes at the great expense of animal suffering (Rowan 1984). John Hillaby (1970) called this widespread use of animals in science fair projects "sanctified torture." To illustrate, students bathed goldfish in detergents, and carried out splenectomies and heart transplants (Rowan 1984). To add to the grand flare of these prizewinners, students, who wore surgical gowns and masks, performed these procedures in front of television cameras. In 1968, the Mississippi State science fair award winner used twenty-five squirrel monkeys to demonstrate electric stimulation to the brain, which caused the death of one squirrel monkey with holes in its head and of others due to a variety of illnesses resulting from the project (Rowan 1984). The award winners at these science fairs were consistently those who deliberately used animals in their experiments, such as skin grafts on 1,000 mice, or bisection of the brains of mice at home, which resulted in the death of most of the animals (Rowan 1984). In response, the *New York Times* published an editorial titled, "Prizes for Torture," which argued that the adult organizations were thoughtlessly encouraging students to perform these atrocious experiments ("Prizes for Torture," 1969).

The singular project that caught the attention of animal advocates took place in 1969 when a high school student from Virginia used five house sparrows (Rowan 1984). At the University of Texas, the student had learned a technique of removing the eyeballs to blind the sparrows to see if they could find their food source in one arm of the Y-shaped box and avoid the source of the electric shock in the other arm of the box. When the sparrows would not move, they were starved for six days to increase the incentive to seek food. The student's conclusion from the study was that the birds were likely to die when starved up to 70% of their bodyweight (Rowan 1984). The student received a $250 prize even though three of the sparrows died as a result of the student's actions (Miller-Spiegel 2004). The *Chicago Tribune* responded to this event and strongly rebuked Westinghouse for considering such an experiment worthy of an award in the STS competition (Animal Welfare Institute1969). In summary, when the science competitions first began, there was little to no regulations on what was allowed or not allowed in science fair projects with respect to the ethics of use of live animal**.**

## 8.4 Rules and Guidelines: STS, ISEF, and Federal

In 1969, under pressures from the general public, Westinghouse changed its rules and guidelines for the STS. According to the STS Rules and Entry Instructions (Society for Science & the Public 2015):

No projects involving live non-human vertebrate animal experimentation will be eligible…

Live vertebrates are defined as any live, non-human vertebrate, mammalian embryo or fetus, bird or reptile eggs within three days (72 hours) of hatching, and all other vertebrates at hatching or birth. (p. 5)

The exceptions to this rule are only when projects: (a) involve observing animals in their natural environment, or (b) are conducted in a registered research institution in which the student will only have physical contact with the animals such as handling and husbandry conditions that meet the Institutional Animal Care and Use Committee (IACUC) standards; **and** the student works with non-living materials supplied by the supervising scientist; **and** animals are not sacrificed solely for the student's project; **and** the student's project begins with non-living material where no invasive procedures were conducted on live vertebrate animals; **and** the student is not involved in the collection of data directly or indirectly where the research involves invasive or intrusive experimentation causing pain and distress to the vertebrate animals (Society for Science & the Public 2015)

The ISEF rules set the guidelines and standards for science fairs at different levels as well as throughout the world. In contrast to the changes made by STS in its policies, the ISEF remained firm in its position to allow the use of animals in the competition. According to the ISEF's International Rules and Guidelines:

The use of vertebrate animals in science projects is allowable under the conditions and rules in the following sections. Vertebrate animals, as covered by these rules, are defined as:

(a) Live, nonhuman vertebrate mammalian embryos or fetuses
(b) Tadpoles
(c) Bird and reptile eggs within three days (72 hours) of hatching
(d) All other nonhuman vertebrates (including fish) at hatching or birth. (Intel International Science and Engineering Fair [Intel ISEF], 2015–2016, p. 9)

The Society for Science & the Public (SSP) encourages students to consider alternatives to using animals in their projects, and "if the use of vertebrate animals is necessary, students must consider additional alternatives to reduce and refine the use of animals" (Intel ISEF 2015–2016, p. 9). To this end, the ISEF provides guiding principles that include the "Four Rs":

(a) **Replace** vertebrate animals with invertebrates or lower life forms, tissue/cell cultures and/or computer simulations where possible.
(b) **Reduce** the number of animals without compromising statistical validity.
(c) **Refine** the experimental protocol to minimize pain or distress to the animals

(d) **Respect** animals and their contribution to research. (Intel ISEF 2015–2016, p. 9)

In addition to these guiding principles, the ISEF requires that projects involving vertebrate animals must be reviewed by and receive approval from the affiliated fair Scientific Review Committee (SRC). Certain experiments involving restrictions to the animal (i.e., food or fluid restriction) must be approved by the Institutional Animal Care and Use Committee (IACUC) and conducted at a Regulated Research Institution. All studies involving vertebrate animals, except for observational studies, must be supervised by a qualified scientist or designated supervisor. Studies involving vertebrate animals may be conducted at home, school, farm, ranch, or in the field when the project meets the four specific criteria: (a) studies of animals in their natural environment, (b) studies of animals in zoological parks, (c) studies of livestock that use standard agricultural practices, and (d) studies of fish that use standard aquaculture practices (Intel ISEF 2015–2016, p. 12). However, when a study does not meet the criteria delineated in this particular section, the research must be conducted at a Regulated Research Institution. To illustrate critical rules pertaining to the use of animals, the ISEF Rules state that students are prohibited from conducting induced toxicity studies that include known toxic substances such as alcohol, acid rain pesticides, or heavy metals (Intel ISEF 2015–2016, p. 12). Studies that anticipate causing the death of the animal are prohibited. If an illness or distress is caused by the study, the experiment must be terminated. If animal death results as part of the experimental procedure, the study must be terminated and will not qualify to compete (Intel ISEF 2015–2016, p. 11).

These ISEF rules were developed to guide student researchers to adhere to the federal regulations that guide the use of animals in scientific research by scientists themselves. These federal regulations are detailed, complex and continuously evolving. As such, a close examination of the historical development of these federal regulations would help us better understand the current status of what is and what is not acceptable in relation to the use of animals in scientific research. Originating from the Laboratory Animal Welfare Act (AWA) of 1966, the U.S. Animal Welfare Act is the only federal law in the United States that regulates the use and treatment of animals in research, exhibition, and transport settings and by dealers (Animal Welfare Act 2013a). Since the original law was passed in 1966, the AWA was amended in 1970, 1976, 1985, 1990, 2002, 2007 and 2008. Of the amendments, in 1985, the AWA improved standards for laboratory animals. To summarize key components of the amendment, "The Improved Standards for Laboratory Animals Act" delineates "humane care" to the animals, and specifies that pain and distress must be minimized during procedures and that alternatives to using such procedures be considered by the researcher (Food Security Act 1985). Operating under the AWA, the Animal Welfare Regulations (AWR) specify detailed standards and regulations that pertain to various aspects of animal care and use in research studies, including the registration and licensing of research facilities, meeting the standards of IACUCs, ensuring adequate veterinarian care, as well as delineating requirements for recordkeeping, reporting, procurement, handling, care, treatment, and transportation of animals (Animal Welfare Act 2013b, 9 CFR, Part 2). The U.S. Department of Agriculture (USDA) is the federal agency that implements and enforces the AWA and AWRs.

In 1973, the Public Health Service Policy on Human Care and Use of Laboratory Animals (PHS Policy) was introduced in order to "require institutions to establish and maintain proper measures to ensure the appropriate care and use of all animals involved in research, research training, and biological testing activities" (National Institutes of Health 2015, p. 7). Revised in 1979 and again in 1986, the Health Research Extension Act of 1985 provided the statutory mandate for the PHS policy (Health Research Extension Act of 1985). Similar to the AWA and AWRs, the PHS Policy mandates that research projects are reviewed by IACUC and recordkeeping and reporting requirements. Further, the PHS Policy requires institutions to comply with the National Research Council's (NRC) *Guide for the Care and Use of Laboratory Animals* known as The Guide (NRC 1996). The principles endorsed by The Guide support alternatives for reducing or replacing the use of animals; minimizing discomfort, distress, and pain; and, providing adequate veterinary care among others policies related to the appropriate handling and caring of the animals (NRC 1996).

When live animals are killed in a student's science project, it is important to consider the different contexts within which the local decisions are made. For instance, in our story, the student was from a rural school district. The factors (social, political, educational, values, and etc.) that may have gone into the decision making process to allow the project to advance to the regional level might not necessarily be the determinants in a different context (i.e., an urban school district). Nonetheless, the laws are explicit as to when and how the secondary students can use live animals in their science projects. As represented by these federal laws and regulations of the science fairs, the efforts to consider the interactions between humans and animals in the context of scientific research as well as in teaching are evident.

With these regulations in mind, let us explore the following case narrative.

## 8.5 An Impactful Encounter with a Student at a Science Fair

The case narrative that follows was developed by one of the authors who was reviewing displays of various research experiments at a regional-level science fair. The case narrative depicts the details of the student's experiment using 38 chicken embryos, the author's conversation with the student, and the author's subsequent reflections and thoughts. The case narrative is followed by a reaction from science educator Shaknoza Kayumova, whose response is grounded in feminist epistemologies.

> The story I'm telling – about what makes it possible for humans to use other animals as subjects in biomedical research projects – has been told many times before, and like all stories, it changes according to who is doing the telling. In some versions, the human

> scientists are the heroes and other-than-human animals are their experimental material or perhaps their silent partners, and the enemies are inhumans who protest on behalf of the animals. In other tellings, the animal advocates are the compassionate good guys, and the scientists are cruel tormentors of innocent, enslaved animals. These are always stories about good and evil, although what is good and what is evil depends on the particular telling (Weigand 2008, pp. 1–2).

Weigand eloquently articulates the controversial nature of using animals in research. Notwithstanding her considered opinion that human use of other animals for research and testing is wrong, Weigand's intention is "not to justify or logically demonstrate the truth of that position" (Weigand 2008, p. 2). Rather, her purpose is to tell a story that constructs the reality in which these controversial views exist. In our story, we also welcome constructive discussions about how we, as science teachers, should teach our students about animal research and ethics.

A poster whose title read, "The Effect of Alcohol on Chicks" soared above all the other posters in the room. Not only was the poster physically one of the tallest posters in the room, but also the project title, the underlying message of the title, as well as the photos of dead chicks personally caught my attention. There was a crowd of teachers who were whispering about the graphic nature of pictures of dead chicks on the poster and the methods by which ethyl alcohol was injected to assess its effect on the mortality rate of chicken embryos. I stood in front of the poster wondering how I could begin this conversation with the high school girl who seemed genuinely oblivious to the controversy that her poster had brought into the room.

After reviewing her methods and finding sections, I began with a comment, "your data are quite striking, Jenna. Out of 35 chicks, 33 died upon being injected with alcohol. Can you tell me a little bit more about how you designed your study?" Jenna, with much confidence, began describing the method she had used to conduct her experiment. Jenna described, "yes, ma'am. I followed the scientific method. First, I got chicken embryos and brought them home. Then, I cracked open each shell one-by-one just a little bit so that I could inject the alcohol. I injected different percentages of ethyl alcohol to a group of five chicks at a time. I made some observations and recorded how long it took for the chicks to respond to the alcohol. My graph and table here show you that all but two chicks died instantaneously. The remaining two chicks died after a while."

Then, I posed additional questions related to Jenna's methods. "Are the chicks fully developed at 18 days and alive in the shells? Where and how did you procure your chicks?" Jenna replied, "yes, ma'am. They are alive in the shells. I cracked open the eggs to take them out and injected them with rubbing alcohol. They can't live for very long once their shells are broken. So, they die off pretty quickly. I have a neighbor who has a chicken farm. I went over to him and asked if I could have some chicks for my project. He gave them to me." I replied, "oh that is very interesting, Jenna. You mentioned that the chicks died off pretty quickly after their shells were broken. Wouldn't the death rate be due to being taken out of their environment since they were most likely not ready to hatch? I guess what I am really curious is if breaking their shells before they were ready to hatch had something to do with their dying, and not solely due to the effects of the alcohol. What do you think?"

Jenna looked over to her board for a few seconds and explained, “Well, yes, that is possible. But, it is the alcohol that killed the chicks based on my science experiment, I think, because my result and my numbers are *significant*.” One of my male colleagues, Dakota, who was observing my interaction with Jenna in silence, spoke up, “Yeah, yes… You are technically right that your numbers are *significant* - yes, that is true. I mean, your data are striking – 33 of 35 are dead. Actually, all of them eventually died. But, you are breaking them out of their natural environment before they can survive on their own, right?” At this particular moment, in the unspoken agreement between the male teacher and I, we wanted to pose thought provoking questions that would guide Jenna to realize the confounding factors that were present in her study, notwithstanding that there was still the unspoken ethical controversy that somehow needed to be addressed. To his question, Jenna replied, “I made careful observations after I injected the alcohol. The chicks were alive when I took them out of their shells. After I injected the alcohol, I recorded how long it took them to respond to it. They died off minutes later, and I think that is due to the alcohol.” At this point, I decided to move forward from this conversation about the science behind her project. I wanted to address the ethical issues that no teachers quite knew how to address with this student.

I asked Jenna about how her project was approved, and she described the Institutional Review Board (IRB) process. “My teacher and the panel approved this study. I have a folder here with the completed forms.” I carefully flipped through several sheets of paper enclosed in the manila envelope and commented, “Oh wow, yes, I see that all these forms have been signed off and your panel approved the study. You must’ve been really excited to do this project! Whose idea was the project?” Jenna’s answer to this question was a lukewarm shrugging of her shoulders and a brief response, “my teacher suggested it.” I took her reaction as implying that this experiment was just a science fair project.

“So, Jenna, you don’t think you are hurting animals when you crack their shells and inject them with alcohol?” Jenna replied, “No, ma’am. I do not consider them as animals because I eat chickens. I don’t think I am hurting any animals. Oh, but I do have pet chickens that I take very good care of.” As a teacher and science educator, Jenna’s statement was extremely interesting. She did not consider the conducting of experiments on chick embryos as harmful because she viewed them primarily as a food source rather than living animal. Because she considered chicken as food, she was completely detached from realizing that she was injecting a toxic chemical into an animal that was breathing and living.

I wanted to continue this conversation after hearing Jenna’s response. Then, I asked, “Would you say you have a pretty convincing argument about the detrimental effect of alcohol on women?” Jenna confidently replied, “Yes, ma’am, I do. Based on my data, pregnant women should not be drinking alcohol.” I continued, “Jenna, let’s pretend for a moment that I am about two or three weeks pregnant with a baby inside of me. If I drink alcohol, would that *harm* my baby who is about 18 days old?” Jenna answered me with a strong conviction, “Oh, yes, ma’am. My research findings show that it will definitely harm your baby. When you are pregnant, you should not drink any alcohol.” I took this opportunity to bring our conversation back to her research and asked her, "Then, would you reconsider injecting rubbing alcohol into an 18-day old chick, who is about the same age as the baby inside of me? Could injecting alcohol into a chick embryo be also harming a life – an animal?" Jenna was genuinely shocked at my question, as her eyes widened and she was speechless for a moment. She was clearly a bright student who thought over these questions as I was posing them to her. After a moment of shock, she slowly answered, "Um, yes, … ma'am, I think so."

I determined that at this point our conversation had gone on long enough and I wanted to give Jenna some space and time to think about the response she just gave me. I did, however, ask where her teacher was, since the advising teachers were supposed to attend the competition. Jenna once again shrugged and said, "Oh, I am not sure. I think he is here somewhere." I lingered around the secondary level competitions for about an hour to see if I would see her teacher return; however, he never returned.

As I walked towards other posters, Dakota caught up with me. He mentioned, "You know, I could have never brought up that analogy as you have done with that student – about pregnancy. That would have been inappropriate if I did that. I am glad you brought it up with her. I really think she needed to understand what we were trying to get her to think about – that she was hurting and killing live animals simply to carry out scientific research. We can address and provide feedback on her scientific design, but what use is that when she is completely removed from understanding what she was *really doing* in her experiment? I can't believe her study was approved and got through. At my school, this would have never been approved. No, never. Oh, there – do you see someone going up to her poster? I think they are telling her to cover up the photos of the dead embryos. Finally!" I nodded and agreed with him without much word because I, too, was deep in my thoughts about Jenna and our conversation. I thought Dakota made a strong point – what use does providing a student feedback on his/her "scientific method," or on "science" behind the experiment, when the student has not been taught to consider the ethical issues and the view that doing science is not simply a matter of conducting "scientific experiment," but that it is a process of inquiry towards understanding our world better? Indeed, what use would there be in teaching science and, better yet, what are we teaching our students in our science classrooms? It seems that far too often these kinds of student projects begin with the science with the ethical issues only as an afterthought. Perhaps, I thought, a better approach to encouraging students' interest in the natural world would be to begin with the ethics.

I left the competition that day wondering what kind of learning experience this science fair project has been for Jenna – learning the science behind the experiment, but to what end and what educational goal and whose interest? As technology and scientific knowledge advance, what should we be emphasizing in our science classrooms and what kind of "science" should we teach our students? I could only hope that she would reflect on our conversation and evaluate for herself (not by anyone else, her teacher, or any other authority) whether doing this experiment truly benefitted her science education.

## 8.6 Animal Rights, Education, Present and Future of Science

As this story unfolds, it appears as if we are trying to wrap our heads around Jenna's decision to use and even kill chicks for the purposes of her scientific endeavor. The story reads as an example of an "insensible" and oppressive act by a student performed in the name of inquiry and science. However, the story also exemplifies how Jenna's understanding of the nature of science and science projects permitted her to make justifications on a very important socioscientific and ethical issue implicated through her decision to use chicks as objects of her science inquiry (Zeidler et al. 2002). Jenna, as an individual, shares the norms and practices of an anthropocentric society. An anthropocentric society privileges humans, and "regards humans as separate from and superior to nature and holds that human life has intrinsic value while other entities (including animals, plants, mineral resources, and so on) are resources that may justifiably be exploited for the benefit of humankind" (Boslaugh 2016, para. 1). Jenna positioned the chick as a source of food – a "thing" that is chopped, cooked, and eaten everyday (animal skin is also used as a commodity in a garment industry). If we take Jenna out of this story, then her decision about using the chicks for her scientific experiment does not seem so different than the ways in which other animals are used in research. Jenna's intentions may genuinely be tied to a scientific inquiry; our intentions for killing, chopping, and cooking chicks, fish, cows, pigs, dogs, and horses are instrumentally tied to our appetite and need to satiate our hunger. Chicks are raised mainly for their meat and eggs! Moreover, in context, the state of Georgia is known as a poultry capital of the world. To attest to this, one of the state's largest and flagship university systems includes a nationally renowned department dedicated to poultry science. If we take for example some of the research and educational efforts in the department the list includes the following topics:

*Physiology:* Regulation of Myogenesis in Avian Embryos; Sperm-egg Interaction in Birds; Role of Surface Carbohydrates.

*Genetics/molecular*: Genetic Relationships of Growth and Reproduction in Diverse Poultry Populations; Programmed Cell Death; Characterization of the Apoptosis Endonuclease.

*Microbiology*: Methods for Identifying Temperature Abused Broiler Chicken Carcasses.

*Processing Technology*: Development of New Processes and Technologies for the Processing of Poultry Products and Slaughter Technology.

To keep up with this kind of science research in poultry science, at least dozens of chicks are used daily. This also speaks to another complexity about the purposes of science and science education. Using animals for science is a complex socioscientific and ethical issue. Zeidler and Nicols (2009) argue that:

> Socioscientific issues involve the deliberate use of scientific topics that require students to engage in dialogue, discussion and debate. They are usually controversial in nature but have the added element of requiring a degree of moralreasoning or the evaluation of ethical

concerns in the process of arriving at decisions regarding possible resolution of those issues. (p. 49)

Jenna, as a student, is developing reasoning skills in science education, and she took a position on the issue and instrumentalized the chick as an object in her science project. Now questions that beg answers include: a) How on earth do we allow for chicks and chickens for the purposes of science every single day, and no one questions the intention and/or integrity of this field? b) Why and under what conditions is it acceptable to use animals as objects of science? c) We find it acceptable for animals to be raised and slaughtered for food, yet when an adolescent somehow replicates what we as adults and society do, why and how do we suddenly begin to recognize the dehumanized and oppressive nature of this act? d) What would be our own reaction to this project if it was performed by a renowned scientist, with important implications for human health, inventions, and scientific findings of the future (i.e., for saving lives of human fetuses)? e) Would we still be appalled by this project? Ecofeminism, a field which has emerged "from various fields of feminist inquiry and activism: peace movements, labor movements, women's health care, and the anti-nuclear, environmental, and animal liberation movements," has been raising these questions for the longest time (Gaard 1993, p. 1). According to ecofeminists, issues about animals and their rights is the question of living bodies. Looking at animals as living bodies is an ethical position, not necessarily lodged in individuals, but in a society and institutions that structure individuals' subjectivities about norms, ethics, responsibilities and so on. In this example, it is important to recognize that Jenna's subjectivities and her understanding of the world, science, and ethics are structured through social, cultural, economic, geographic, and political contexts, which also influence the assumptions and conventions of scientific practices. So there is a question of the *subject* (be it a student, teacher, scientist, and so on) and his/her relation to the world. The dilemma of the subject and ethics in this ever evolving techno-scientific era reminds us of what Rosi Bradiotti (2006), a feminist philosopher, says of how "the new global … requires a robust new theory of the subject as a multi-layered entity that is not unitary and still capable of ethical and political accountability" (p. 144). Although the subject is structured through dimensions of social, cultural, and institutional conventions, according to Bradiotti the shift in the frontiers of subjectivity is possible on the grounds of *affectivity*. We have argued elsewhere (Kayumova and Tippins 2016) that it is time to reconsider science practices as bodily and affective. Affect is understood not in a psychological term as emotions, but as a capacity to feel that emerges when the subject intra-acts (Barad 2003) with other physical, social, and cultural entities (bodies) in the world. Affectivity becomes the strength that targets the subject's power to make a decision that is not confounded to the rational. Jenna's rational thinking allowed her to treat the chicks without the involvement of any senses. The chick was considered to be a source of food, and object, compared to a value of human that science serves. According to Braidotti "what is mobilized is one's capacity to feel, sense, process and sustain the impact with the complex materiality of the outside" (p. 145). What we may need in science education is a shift that allows students the capacity to feel the relation to other entities (bodies). “This shift entails an ethical dimension … imposes a vision of the subject [the teacher and the student] as fully immersed in relations of power, but ethically compelled to strive after freedom” of thought and ethical decision making (Bradiotti 2006, pp. 148–151).

## 8.7 Understanding a Continuum of Positions

The movement in advocacy of animal welfare, which began receiving attention in the 1900s, has challenged us to reconsider the way we interact with other animals, connect to the environment, and recognize the symbiotic relationships between us and other organisms (Tsuzuki et al. 1998). While searching various databases for publications related to use of animals in science fairs, we found that the majority of the papers were published in the late 60s through the 90s. Using the key words, science fairs, vertebrate, and animals, the search resulted in about forty-nine articles published since 1996. Of these articles, about five articles were related to the use of animals in school science classes. Only one article by Michael Fox and Andrea Ward (1977) was directly related to the use of animals and the ethical issues surrounding them in the context of science fairs. *Alternatives to Laboratory Animals* (ATLA) is an international, peer-reviewed scientific journal that publishes articles on the latest research related to the development, validation, and use of alternatives to laboratory animals (ATLA 2014). In 2004, ATLA dedicated an entire supplemental volume of articles on the replacement, refinement and reduction alternatives in scientific research, and on ethical issues in using non-human primates in research as well as their use in education settings. However, only three of these articles were related to secondary school science education settings in the U.S., and of these, only one was related to the use of animals in the context of science fair projects (written by C. Miller-Spiegel 2004). As such, the authors of this chapter believe that the discussion surrounding the use of animals in science fairs needs to be revitalized, because participating in science fairs can significantly influence how students perceive the way science is done.

Our review of the literature suggests a continuum of positions on the use of vertebrate animals in secondary school science education settings (i.e., dissections, science classes, curriculum, and science fairs/competitions). The continuum begins with those who advocate for alternatives to animal experiments in high school science classes (Strauss and Kinzie 1991). According to Miller-Spiegel (2004), students often cannot extrapolate their results from animal experiments to humans, or make meaningful connections to humans and other animals. Barbara Orlans (1993) analyzed science fairs and supported the prohibition of animal use on the basis of the following arguments:

1. *Morally:* it is indefensible to hurt or kill animals unless original contributions that will advance human health and welfare can be expected. Elementary and secondary school studies do not meet this test.

2. *Psychologically:* it can be emotionally upsetting for youngsters to participate in harming or killing animals; even worse, it may be emotionally desensitising or hardening to immature minds.
3. *Socially:* in these days of widespread violence, fostering personal acquaintance with inflicting pain should be avoided.
4. *Educationally:* teaching about abnormal states before the student has a sound grasp of normal physiology is against common sense and does not advance scientific education.
5. *Scientifically:* promoting teenage animal surgery or induction of painful pathological conditions fosters an improper regard for animal life and an unbalanced view of biology that will rebound adversely when the next generation of scientists comes of age. (Orlans 1993, p. 206)

For instance, dissection activities can be observed in the science classroom, especially in the anatomy and physiology subject area. However, studies have shown that students at every educational level (i.e., secondary, undergraduate, medical) feel uncomfortable to a varying degree with the dissection or experimentation on live animals (Solot and Arluke 1997; Stanisstreet et al. 1993; Arluke and Hafferty 1996). In Solot and Arluke (1997), some students experienced feeling of "squeamishness" such that they chose to opt out of the dissection activity and/or leave the room, because they felt physically sick. One student reported, "I would, like, throw up" (p. 41). Other studies have shown that dissection even became the "turn-off" factor for students about science (Balcombe 2000; Bishop and Nolen 2001; Hug 2008; Oakley 2009, among others). As the discussion surrounding the ethics of killing live animals in a school setting continues, medical schools have responded to these concerns and began phasing out animal labs across the U.S. The medical schools have chosen alternate ways to study human anatomy such as using computer simulations and other technology. Today, only seven to eight schools still include live-animal experiments as part of the curriculum; however, the trend is being phased out around the world (Wadman 2008).

On the other end of the continuum, some educators defend the use of animals for teaching biology on the basis of arguments that experience with live animals is essential for biology education (Morrison 1993). For instance, Orlans (1993) found that these educators favored the use of animals in high school classrooms emphasizing that dissection of animals enabled students to learn the anatomical structures and interrelationships among tissues and organs, as well as develop manipulative skills and increase hands-on experience. Thurman Grafton (1980) cited other reasons for advocating the inclusion of animals in science fair projects, noting how they provide "challenging motivation to students to explore the excitement of research in the biological sciences" (p. 104). Grafton went onto explain how students could gain hands-on experience in detailed projects, which could encourage and motivate them to pursue scientific careers. As such, further restrictions on the use of animals in these competitions "would not be in the best interest of the public in terms of educational motivation, career development, and ultimate public service" (Grafton 1980, p. 104).

We do not intend to establish a dichotomy between these two positions. Reviewing how educators position themselves on this continuum calls us to consider one of the aforementioned questions, "Must we use animals in science fair projects to meet the educational aim of teaching students to critically think about anatomy and physiology, and learn engaging in such scientific exploration as a process of inquiry?" To answer this question, we first consider the seminal work of Joseph Schwab. In the 1960s, Schwab was one of the key figures who argued that a different approach to science teaching was needed and that such an approach would change the conception of science itself (Schwab and Brandwein 1962). Further, Schwab argued that school science curriculum should mirror the notion of science as "principles of enquiry" (Schwab and Brandwein 1962, p. 11). Joseph Schwab and Paul Brandwein (1962) stated:

> Scientific research has its origin, not in objectives facts alone, but in a conception, a construction of the mind. … Thus, the knowledge won through inquiry is not knowledge merely of the facts but of the facts interpreted. (pp. 12–14)

Taking his argument further, Schwab distinguished between "stable" and "fluid" *enquiry*. The stable *enquiry* was to fill a gap in a growing body of knowledge, while fluid *enquiry* entailed the development of new ideas and principles (Schwab and Brandwein 1962, p. 15). This changing notion of science as principles of *enquiry* had important implications in education, for it brought about a new aim – teaching science as a process of *inquiry* in order to improve students' abilities to reason scientifically. Thus, the authors of this chapter invite our readers to examine the position of advocating for the use of alternatives to animal experiments in the context of science fairs and consider the supporting arguments based on the moral, psychological, social, educational, and scientific grounds.

## 8.8 Assumptions Related to the Case Narrative

We use this platform to invite students, teachers, science educators, scientists, and other voices to participate in discussing the implications rising from this case narrative related to the use of animals in science fair projects. To do so, we conclude by delineating some theories and related assumptions that help us further our position.

First, our advocacy for alternatives to animal use in the context of science fairs is based on the concept that causing pain and suffering is problematic (Singer 1976). Peter Singer (1976) argued that stimuli that cause pain to humans can also cause pain to animals. Thus, higher animals share the right in not being subjected to pain and suffering. One of his most influential arguments was that equal harms should be counted equally and not downgraded for animals (Singer 1976). To illustrate, he provided an example:

> If I give a horse a hard slap across its rump with my open hand, the horse may start, but presumably feels little pain. Its skin is thick enough to protect it against a mere slap. If I slap

> a baby in the same way, however, the baby will cry and presumably does feel pain, for its skin is more sensitive. So it is worse to slap a baby than a horse, if both slaps are administered with equal force. But there must be some kind of blow - I don't know exactly what it would be, but perhaps a blow with a heavy stick - that would cause the horse as much pain as we cause a baby by slapping it with our hand. That is what I mean by the same amount of pain; and if we consider it wrong to inflict that much pain on a baby for no good reason then we must, unless we are speciesists, consider it equally wrong to inflict the same amount of pain on a horse for no good reason. (Singer 2004, p. 3)

In summary, Singer (1976)'s argument was not the question of whether animals can reason or talk, but whether animals can suffer and feel pain and whether it was ethical for humans to inflict such pain on other non-human animals. Not all scholars would agree with Singer's questioning and perspective on pain and suffering. Nonetheless, our thinking is informed by the tenets of ecojustice theory in that we do not position humans above other animals: therefore, animals share the right not to be subjected to pain and suffering.

Second, we view our relationships with animals and nature from the perspective of ecojustice. According to Teresa Shume (2015), an ecojustice perspective elucidates the root causes of unsustainable ecological practices (such as ideological, political, and cultural structures) that marginalize and oppress people. It "aims to unveil cultural metaphors carried by language that shape relationships with nature and impact the interdependence of social justice and environmental sustainability; it is a theory that poses thorny questions about *modernist thinking,* the *unsustainability of many current cultural assumptions and practice,* and *what it means to be educated*" (Shume 2015 p. 20). To this end, Shume (2015) calls for reevaluating cultural assumptions, which form the basis for human relationship with nature and with each other. Rebecca Martusewicz, Jeff Edmundson, and John Lupinacci (2011) provide six elements to define ecojustice. Of the six, the following two elements are relevant to our discussion of the ethical issues related to the use of animals in science fairs: (a) The recognition and analysis of deeply entrenched patterns of domination that unjustly define people of color, women, the poor, and other groups of humans as well as the natural world as inferior and thus less worthy of life, and (b) the recognition and protection of diverse cultural and environmental commons – the necessary interdependent relationship of humans with the land, air, water, and other species with whom we share this planet (p. 9–10). Ecojustice philosophy, thus, gives equal importance to both social and environmental concerns; in other words, it does not focus exclusively on social justice over environmental justice, or vice versa. Instead, ecojustice closely examines the common cultural roots of these issues (Shume 2015). Further, ecojustice focuses on issues of culture and community, rather than promoting individualism. As such, Princess Lucaj, Michael Mueller, and Deborah Tippins (2015) posit that this perspective, which moves away from solely focusing on the needs and concerns of humans, encourages us to more deeply consider injustices for all forms of life.

Operating under an ecojustice perspective, we align ourselves with environmental ideologies, namely, ethics and values-driven ideologies and transformative ideologies. Ethics and values-driven ideologies provide perspectives that "nonhuman entities have value that goes beyond utilitarian, scientific, aesthetic, or religious worth to possessing intrinsic value." According to Julie Corbett (2006), humans have moral and ethical duties to (some) nonhuman entities, which have a "right" to exist. (p. 28). Within this subset of ethics and values-driven ideologies, animal rights ideology maintains that animals are being subjected to unjustifiable discrimination by humans who can discriminate (Corbett 2006). Transformative ideologies "seek to transform anthropocentric relations and extensionism of 'right' into more eco-centric relationships" (Corbett 2006, p. 28). Within this subset of transformative ideologies, deep ecology echoes the importance of acknowledging, "all life on earth possesses equal intrinsic value, value that exists independently of human needs and desires" (Corbett 2006, p. 43).

Third, we operate under the two key propositions of social constructionism. Social constructionism is not a theory, but a set of ideas. It does not belong to a single person: rather, it is a confluence of ideas that emerge from conversations. It is not a fixed dialogue, for it continues to transform into new conversations. Kenneth J. Gergen (among others such as Vivien Burr) has been writing about social constructionism since the early 1980s (Gergen 1982; Gergen 1999, 2009, 2015) and, in his writing, he invites readers to think about social constructionism as a way of understanding the world. Once we accept this invitation, we begin to understand how social constructionism deconstructs traditional ideas and dialogues about objectivity, value neutrality, one's identity (self), relationships, power, knowledge, the truth and more.

First proposition of social constructionism is that scientific knowledge is socially constructed in ways that take into account good observations and defensible evidence**.** In his work *Ideology and Utopia*, Karl Mannheim (1985) proposed constructionist views of scientific knowledge in that: (a) "scientific theories do not spring from observation but from the scientist's social group," and (b) "scientific groups are often organized around certain theories," thereby, leading to the view of science as a social process (cited in Gergen 2015, p. 23). This proposition implies that anything we do or a construct that we characterize grows out of the traditions with which we are involved. Solot and Arluke (1997) eloquently demonstrate this point. In their study, consider the students who felt squeamish about dissecting, or, at first, felt ambivalent about the experimentation on live animal began to rationalize why the dissection was not as bad as they initially thought. Then, students began using humor as a way to get through the dissection activity by calling their specimen "Miss Piggy," or "Pudgy" (Solot and Arluke 1997, p.45). In other words, students became desensitized and detached, so that the dissection activity became acceptable as a way of knowing and learning science without the consideration of ethics in the process. In the later sections, we discuss science as a socially constructed. When we consider the enculturation and socialization of our youth into the scientific communities, we may be projecting the notion that the objectivity and detachment is the only model for understanding the physical world (Solot and Arluke 1997).

We perceive and understand the world within our knowledge system of which our previous experiences (as well as the experiences of others) have been a part. Therefore, these rules, structures and models that prescribe what we should do in a situation give us a sense of "social reality" that becomes reliable and can be also comprehended by others who experience this reality as we do (Jacobsen 2008, p. 106). As such, intersubjectivity is a critical component in how we create our social reality where exemplified assumptions, expectations, and prescriptions (such as rules and traditions) are socially constructed and socially accepted (Jacobsen 2008). This notion of what is accepted as normal (in other words, the notion of conventionality) pertains to not just one single individual, but it speaks to our relationships with others in society. As Jacobsen (2008) puts, "my background knowledge, implicit assumptions, expectations and so on, are hence not primarily *mine,* understood as my own personal and unique constructions. On the contrary, they are *social* constructions" (italic emphasis in original, p.106).

Second proposition of social constructionism is that any socially constructed description caries value, because values are created and sustained within forms of life. As we relate with one another, develop languages, and follow the traditions of the society in which we participate, we develop values. These values are often implicit and simply presented in the way we do things. Thus, there are no value-free or neutral accounts of things; everything we say or do in this world carries values. We may like to think that science is an objective and accurate accounting method for describing this world. However, scientists bring in their background assumptions when they report their findings and when they design and conduct experiments. When scientists write about their studies, even their use of language carries values and reflects their background assumptions.

In the context of science, scientific descriptions are anything but neutral: rather, they are value-laden (Gergen 2015). To illustrate this point, Emily Martin analyzed the way medical textbooks characterized the female reproductive system, especially the eggs (Martin 1987). She concluded that a woman's body was portrayed as having passive characterization and as a "factory" with the primary purpose of reproducing by way of being "conquered" by the male sperms. Through this example, the language that describes the scientific account of how human reproductive organs work is not so value free or neutral – it carries sexist views of scientists who operate within the traditions of Western science, which is heavily dominated by males. The data from the National Science Foundation (NSF) supports the gender disparities in the Science, Technology, Engineering and Mathematics (STEM) workforce, while we see the greatest gender disparities in engineering, computer science, and the physical sciences (NSF, Science & Engineering Indicators 2014). Further, when we accept a scientific account of one thing over another, we are making a choice, which carries certain social values. As such, descriptions that we construct carry certain ways of life and certain objectives that we would like to do with them as opposed to others.

Helen Longino (1990) is one of the seminal scholars who support the idea that science is both value-laden and a social process. As part of the social and cultural context with which we are involved, we bring value-laden assumptions that constrain scientific practice in certain ways (Longino 1990). For example, a potential conflict may arise between moral values of a researcher and specific ways of carrying out research, particularly research with human subjects, or in the instance of our case narrative, with vertebrate animals. To alleviate this tension, restrictions and regulations on experimentation have been developed, but are not always enacted or enforced, because the enclave of traditions in which we participate determines the directions of research and boundaries (Longino 1990). Similarly, the twenty-first century scientists share her view. To name a few, Anderson (2004)'s study explores how one's political values may guide scientific inquiry by using feminist science guided by feminist values as an example. Gaskell, Einsiedel, Hallman, and Priest (2005) discuss the tensions between science and society, as the increasingly number of scientific research pioneers into value-laden areas (i.e., socio-scientific issues) and engages society on the ethical, legal, and social implications.

To summarize the two discussed propositions of social constructionism: What we teach our students in the science classroom is often dominated by the traditions of western science – but we can deconstruct the traditions of science. Rather than viewing science as checking off steps in the scientific method, we can help students re-conceptualize science as a social process of inquiry. Our students have been enculturated and made to feel comfortable with the notion of scientism. Perhaps students and teachers have come to accept the way that things are, without the ethical consideration of doing scientific experiments by using animals, because we feel natural in our environment and are familiar with this very notion of scientism, as it has been the accepted and dominant practice in western science. Schutz (1967) describes this attunement with nature as taking things for granted without questioning or scrutinizing their validity. Schutz (1967) further explains that we take on this unsuspecting attitude, because we are naturally attuned to the system of knowledge to which we belong and that constitutes our background assumptions. This knowledge system is what we know and employ in our life to navigate the world. René Descartes urges us:

> to doubt things which we may continue to believe, and with good reason, such as the propositions that two and two equal four, or that there is an external world. We can be justified in acting upon these beliefs, we may even be unable to conceive of what it would be like for those beliefs to be false (this is particularly the case with mathematical beliefs), but our not being able to conceive how something could be false does not mean it cannot be false. (cited in Gaukroger 2002, p. 71).

50 years later, Schutz's position is still relevant today as evidenced by the prominent feminist science scholars such as Sandra Harding, Donna Haraway, and Evelyn Fox Keller, among others, who challenge the dominant practice in western science. The feminist science scholars encourage us to rethink and view science knowledges from a different point of view or perspective (i..e, standpoint epistemology, etc). In other words, we must be critical of how we accept the dominant discourse in science and understand our daily life by its traditions, which we take for granted. We must acknowledge that all our attempts at constructing knowledge are *socially situated*, and that cultural beliefs play a role at every step of scientific inquiry. This includes "the selection of problems, the formation of hypotheses, the design of research, the collection of data, the interpretation and sorting of data, decisions about when to stop research, the way results of research are reported" (Harding 1996, p. 244).

Further, science educators should aim to instill values of science that deemphasizes individualism, which is "a belief that humans are independent autonomous units, that pursuit of self-interest leads to the greatest good, and that competition is natural" (Martusewicz et al. 2011, p. 25). In this way, students may understand that the purpose of participating in science fairs is not to promote an individual student's pursuit of a grand prize or to "compete" against other individuals, but to learn the process of inquiry and critical problem solving skills. Only then, perhaps, can we start to convince students, teachers as well as other stakeholders in science education that the use of animals in science fairs does not meet these educational goals and is no longer necessary in the teaching and learning of science.

As we move towards these ideas, the authors believe that science can truly become a way of knowing and understanding the world enriched with new possibilities, new ideas and new ways of life for everyone.

## 8.9 Reflections and Implications for Science Educators

The advancement of scientific endeavors and progress is meaningless if we begin to consider scientific investigations ultimately superior to ethics and moral values. Another perspective could point to how the advances in sciences and technology have, in turn, influenced and shaped our ethical and moral values. Notwithstanding which perspective with which one may position, it is critical to engage students in constructive discussions about human use of animals in research and the controversial nature of ethics pertaining to such practice. As seen from Jenna's case, teachers and educators can, and should, create space for these types of discussions. The aim of guiding students to independently design a research study should be about teaching students how to critically think and inquire about the world around us. On this note, there are several important points to highlight from this case narrative. First, Jenna was confident in making a claim that drinking alcohol during one's pregnancy would be harmful to a living baby. She emphasized that she had used the "scientific method" to observe, gather data, and make key assertions based on findings. In this point, we begin to see the nature of science from the student's perspective. In her response, she made it clear that she viewed science as making a singular claim by employing a defined set of steps (i.e., the scientific method) and proving a point. Additionally, there was a major flaw in her study design, which was removing the embryos from their shells, significantly reducing their survival. Not realizing this critical flaw in the science behind the study, she was making "study-generated claims" and putting forth its significance onto humans. This was simply an example of bad science being taught to students, if we examine the science aspect alone.

Second, Jenna extrapolated the findings from her study and made assertions about issues related to the health of humans. However, this is not the optimal way of teaching the aim of doing science, as we inevitably portray that we produce scientific discoveries to better the lives of humans at the expense of other animals. Jenna's perspective on chickens as a food source allowed herself to be detached from seeing her experiment as harming live animals. The end result of her study justified the means of her study. Because she believed that her findings were significant and that this study gave a clear warning to females about the harmful effects of alcohol, and potentially deterring women from drinking during pregnancy, Jenna gave no consideration to realizing that she was killing the chicken embryos through a painful death. Any teachers or science educators would agree that the drastic number of embryos dying due to the injection of alcohol has no real implications or value to the health-related issues of humans – it is simply irrelevant, and the findings from this study did not apply to humans drinking alcohol during pregnancy. Even if the significance was carried over, the harmful effect of alcohol during pregnancy is widely known already, which Jenna simply repeated to confirm – but we must ask ourselves, to what end. Thus, science teachers must guide students to reflect and evaluate society's over-emphasis on the primacy of humans over other animals, and how such a notion has an impact on the negotiation of what is ethical, humane, and moral.

Lastly, science teachers and educators must be mindful of this question: what did the student learn, and to what end are we teaching science to our students? Our aim should always be that we are teaching students to critically think, inquire, and examine the world around us through science. In this process, we must engage in a concerted effort to share the message that individuals alone do not discover the Truth by way of empiricism, but that science is a process of inquiry and a social process that is richly laden with our values, ethics, morals, and background assumptions of society.

As teachers, we should be mindful about what science we teach. Science should not be taught as being positioned in society where humans inflicting pain and suffering on other animals is justified for the sake of scientific advancement. In science classrooms, we should aim to emphasize the symbiotic relationship between humans, environment and other animals and how science makes it possible for us to understand these interactions and provide a way of thinking to improve such relationships. If science teachers begin to deconstruct the notion that science is devoid of values, then students' science learning would be far more enriching and meaningful, and it could more likely result in positive long-term impacts on how they view science for the rest of their lives.

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# Chapter 9
# Spiders, Rats, and Education

**Jimmy Karlan**

When I visit environmental learning centers involved with wildlife rehabilitation, I can observe injured crows in small outdoor cages "sentenced to life" as teaching props. "Otherwise in the wild," it is explained, "they will be dinner." I watch the birds circling endlessly around and around in their small cages all daylong and I say to myself, "That is not crow." I feel the same way at a New England zoo when watching a polar bear circumnavigate its concrete enclosure. I say to myself, "That is not polar bear."

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I cringe for the countless laboratory rats when I hear about cosmetic, health, and food companies using rats to test for the harmful effects of their products. And I say to myself, “Those aren’t rats.”

And yet I continue to ask my teacher education students to consider how and why they challenge their middle and high school science students to confine and manipulate rats and spiders in the name of education and scientific progress.

“So what are you?” I ask myself. “A specieist or altruist?” How can I justify claiming empathy for the millions of animals used in scientific research and education every year *and* at the same time recommend to my science education students that they should have their students trap spiders and teach rats something they would never otherwise learn?

To consider the moral dimensions of these projects, let’s first examine what students are being asked to do with the spiders and rats.

## 9.1 Sustaining Spiders and Teaching Rats

### *9.1.1 TheBiosphere Challenge*

“Create whatever you think has to happen so that multiple generations of spiders can live inside a sealed five-gallon container for as long as possible.” Hundreds of students, middle through graduate school, have been captivated by this challenge. The Biosphere Challenge as it has come to be known, is an “inquiry-based, hands-on, minds-on, problem-solving, student centered curriculum that can help students of any age deepen their understanding of ecology… It is about challenging students to reflect on, to test and to rethink their most fundamental ideas about nature” (Karlan 2000, p. 13).

With shovels, trowels, and a 5-gallon container in hand, students between ages 12 and 50 are presented with this challenge. Most, with the right facilitation, are still designing after an hour and bargain for more time to debate and decide with their partner what else they can do before sealing their container. As teachers follow their students through the schoolyard, and fields and forest when available, they elicit their students' ideas about what they're collecting and why.

Intermittently, teachers ask their students to clarify, elaborate and respond to alternative suggestions. The first phase of the Biosphere Challenge invites students to reveal their theories about big questions like: Is nature a verb or noun; an object or a process; cyclical or linear; diverse or monochrome; cooperative or competitive; dynamic or steady; open or closed; inclusive or exclusive of humans; male or female? "Ultimately the story manifested in their biosphere constructions and accompanying explanations, reflects their conceptual 'thumbprint' – their most fundamental ideas about nature" (Karlan 2000, p. 14).

The second phase of the Biosphere Challenge presents discrepant events that challenge students' initial theories about the nature of nature. These discrepant events lead to opportunities for students to open and modify their biospheres. Discrepant events come from readings about ecology, a guest ecologist sharing why she thinks the amount of soil and water they included can lead to their biosphere's collapse, films about the lessons learned from Biosphere II's two attempts to sustain people in a completely sealed container (biosphere2.org), and ongoing observations of their own biospheres. These discrepant events can motivate students to rethink and redesign what they think has to happen to sustain nonhuman life. Every ecological principle from cycling to biodiversity, from carrying capacity to evolution, and from exponential growth to entropy is contained within the students' efforts at creating a working model for sustaining life in a closed system.

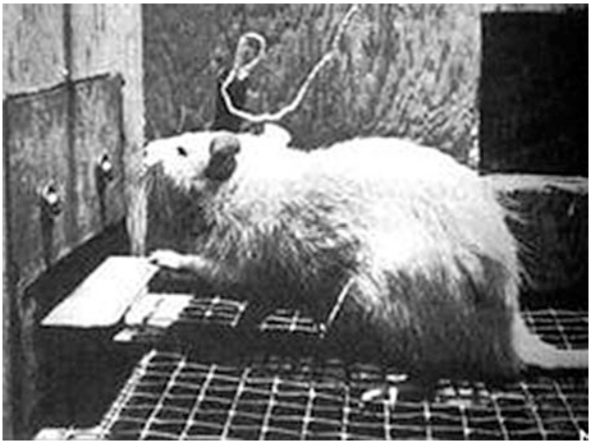
The Biosphere Challenge involves creating working models of very complex systems. Thus, it can involve the collection and containment of a diversity of organisms including spiders, earthworms, beetles, flying insects, ants, and countless microorganisms. My desire to use animals in classroom settings began about 34 years ago when I was a middle school science teacher. With my students' help, we turned our classroom into a museum with observation beehives and ant colonies, earthworm farms, snakes, and rats. Lots of rats!


### 9.1.2 *Teach a Rat*

Back then I challenged pairs of 7th graders to prove that they can teach a rat something new. This was the opening challenge to a unit on Learning. I chose rats because they are very friendly, rarely bite, and have the capacity to learn lots of behaviors like how to ride on someone's shoulder, jump through hoops, ride in a belly bag, come to its name, sit, stand up on hind legs, play with a ball, barrel race, open a gift, navigate a maze, step on a lever, and I'm sure much more.

Since every two students shared their own rat, we had some 14 white rats contained in 5–10 gallon terraria. I bought the rats from a local pet store that raises them primarily for snake food, and as pets. The pet store agreed to take back any rats that my students didn't take home at the end of the unit; consequently, all rats either became a student's pet, food for a student's pet snake, or were returned to the pet store for similar outcomes.

We discussed, debated, and decided on the parameters of the challenge like only using positive reinforcement to teach the rat something that would do it no harm. Of course we played with the meaning of positive reinforcement and what they would consider as causing no harm to other than human animals. While teaching their rats, students also learned about learning through readings, films, reflecting on their own learning abilities, and talking with guests about their various learning challenges.



## 9.2 Moral Objections Welcomed

Both the Biosphere Challenge and Teach a Rat activities invite students to discuss and debate the moral issues around using animals, including humans, in the name of education and science. One of my science teacher certification alumni reported back, "I set my students out on the Biosphere Challenge last week and it has been awesome in garnering active interest, genuine curiosity and today a passionate discussion on the ethics of keeping insects/ arachnids."

Inevitably, some students will raise moral issues on their own and assert that they'd like to decide whether or not to participate. I challenge my students to literally take a stand to indicate their position along a continuum of values and beliefs for why they should or should not participate in activities using domesticated or wild animals. This "Taking-a-Stand" exercise is orchestrated to bring out as many voices and values around the issues and is a prerequisite to deciding how to participate. Asking students to do a two-minute free-write on their initial position before taking a stand, literally, can help reduce the influence of peer pressure. And the activity often leads to students asking each other for what evidence they have to support their respective positions.

During "Taking-a-Stand," 7th grade students like Amy on the opposing side of the continuum exclaims, "It's not fair to make the spiders suffer!" All names are pseudonyms.

Ruth on the continuum's side "in favor of participating" responds in defense, "How do you know it's suffering? You're not a spider. And Mr. K (the teacher), anyway, asked us to keep the spider alive and well, not hurt it."

Bob (standing next to Amy): "If you were plucked from your house and locked up somewhere else, I bet you'd be feeling pain."

I interject to the class that this is the same position taken by the American Psychological Association's (APA) "Guidelines for Ethical Conduct in the Care and Use of Nonhuman Animals in Research" Their guidelines assume "that procedures that are likely to produce pain in humans may also do so in other animals, unless there is species-specific evidence of pain or stress to the contrary."

Ruth: "That's not fair. I don't think there's any reason to believe that spiders feel the same pain as humans."

Amy: "Certainly the humans who were sealed into Biosphere II say they felt a lot of pain and stress while confined inside their 3-acre globe. And they volunteered. The spiders and whatever else we trap did not."

Ruth: "It's not fair to think that putting spiders in a sealed container for just a month or so in a way that will help them thrive causes the same kind of suffering experienced by some of the Biosphere II inhabitants."

Bob: "Since we'll never know, we shouldn't risk harming them. I'm sure there are other ways we can learn about ecology."

Kristen (standing between Ruth and Steve): "That might be true, but I know I learn better when I'm using my hands and mind together. I'd rather create a working model of how to keep something alive than read about how to do that in a textbook."

Niki (near the middle): "I'm OK about reading a book to learn about this stuff."

I interrupt to remind folks that they each get to decide if they want to participate and that our goal is to understand each other's values and beliefs behind their decision.

Ruth: You know it's likely you killed or harmed dozens of spiders and insects on your ride to school this morning. Just check your windshield and tires. And even if you didn't, one blue jay alone ate more spiders than all of us are at risk of killing during this exercise.

Amy: "Yeah but the bus didn't kill them on purpose. And it's natural for a blue jay to eat spiders."

Kristen: "So why should choosing to trap a spider for the sake of learning have any less value than the accidental or natural killing of them?"

Amy: "Because accidents and predation are the natural order of things. They are not choices. We can choose to do something else to learn about the same thing."

Ruth: "I'm going to try and keep the spider alive. If it dies during this activity, I'm trusting that what we learn about sustaining life is as worthy as spiders dying from the bus' windshield, or by hungry chickadees."

Rob (near the middle): "I wonder if any of our positions would change if instead of trying to sustain a spider we were trying to sustain an earthworm, a frog, or a mouse."

Amy: "Yeah Kristen. What if we were trying to sustain multiple generations of mice in a completely sealed container?"

Kristen: "I'd probably not be in favor of the activity. For even though I don't like to admit it I probably value a mouse's life over an earthworms or a fruit fly."

Amy: "And I'd probably be OK with sustaining multiple generations of earthworms in a sealed container.'

Mr. K (teacher): "In this regard, the two of you sound like you're in agreement. You both believe that different kinds of animals have different life values. Invertebrates are not legislated in Massachusetts, however, the Center for Laboratory Animal Welfare (CLAW) advocates that invertebrates be treated the same as vertebrates. Specieism is a great issue to ponder and I promise we'll do so throughout this project."

Kristen: "I plan to be very careful and respectful with everything we put into our terrarium. And you already told us that we could release the spiders and other organisms at any time. So I'm not worried about harming the spider."

Kathryn (near the opposing side): "A captive spider sealed inside even the best-made biospheres is no more a spider than a caged fox at a zoo is a fox."

The values and beliefs around the use of the spiders in the Biosphere Challenge are similar to those when deciding whether or not to participate in the Teach a Rat project. The rat-based lesson, however, opens up new issues around the use of vertebrates versus invertebrates in education and research, as well as the rights and protections of domesticated animals.

During the first ½-hour of either the Biosphere or Teach a Rat challenge, my students articulate a wide range of values and beliefs around using invertebrate wildlife like spiders or domesticated vertebrates like rats, for education and research. "This multiplicity blooms dissonance, which in turn increases students' moral breadth. Since students can return everything they collect at any time, they are faced continually with determining their own evolving moral responsibility. Students who oppose the exercise on moral grounds are invited to collaborate with their teacher in designing alternative ways to meet their curriculum goals without compromising their moral position" (Karlan 2000, p. 17).

Throughout both projects, students are introduced to ethical guidelines for using nonhuman animals for education and research by organizations like the American Psychological Association (APA) and the BBC. And with the current 1979 animal protection laws protecting vertebrates from suffering at school or at school-related functions as well as protecting classroom pets students are periodically asked to reconsider if and how their values and beliefs have changed during the course of the project. No matter what my students decide, we've come a long way since the early 1800's when rats were used in Rat-Baiting, a sport where people bet on which terrier would kill the most rats trapped in a rat-infested pit.

As soon as most students are clear about how they want to participate, they begin collecting materials for their biospheres or figuring out what they want to teach their rat. This is when you hear them buzzing away with their partners trying to figure out where they can find food for the spider or brainstorming how they are going to teach a rat to press a lever when it hears a bell. This is when I can walk out of my middle school science or graduate school classes and no one notices. These are the beginnings of very engaging, constructivist-based, student-centered and directed inquiries into ecology and learning.

## 9.3 Learning Goals

Knowing the learning potential from these projects can help one determine whether they believe the benefits of using these animals in education outweigh any risks of suffering.

### *9.3.1 Biosphere Challenge*

With a dozen Biosphere's surrounding their classrooms, students have opportunities to observe intimately a close approximation of the ecological dynamics necessary for sustaining life. It allows teachers to facilitate deeper investigations into the meaning of balance, cycles, relationships, biodiversity, adaptation and evolution. And perhaps as importantly, these small terraria in concert with direct experiences in nature can help create a more process-oriented worldview. We need to help students celebrate and understand that while the spider is an individual, the spider is actually "both manifestation and raison d'être innumerable processes – air, water, and inorganic and organic cycling – whose interactions with one another are the meaning of life." (Karlan 2000, p. 18) I am an advocate for any curriculum that helps create a paradigm shift toward a more process-centered view of nature.


Here's what one of my students wrote when reflecting on how the Biosphere Challenge engaged her:

> I found that the biosphere activity opened the doors for a plethora of lessons and discussion beyond the obvious challenge and experience. First and foremost, as a student I was entertained, my attention was held, and my brain was cooking trying to figure out what we needed. I was thinking critically, trying to think ahead and sequence our actions, and trying to think of all the important biological factors that we may have been overlooking. Julia and I were raking through our stores of scientific knowledge and applying it to the situation and trying to prevent a potential arachnid catastrophe. (Science Teacher Certification Alumni, October 2006)

With the vivaria as backdrop to all classroom activity, students can learn about any ecological principle: carrying capacity, feedback loops, cycling, exponential growth, adaptation, evolution, living soils, symbiosis, waste, and entropy. It's a great opportunity to teach about the role of microorganisms for I've often been struck by their general absence in the development of students' biospheres. Since invertebrates represent "more than 90% of the planet's biological diversity, they perform most of the critical ecological functions of pollination, seed dispersal, parasitism, predation, decomposition, energy and nutrient transfer, the provision of edible materials for adjacent tropic levels, and the maintenance of biotic communities through mutualism, host-restricted food webs, and a variety of other functions and processes. (Kellert and Wilson 1993) Understanding the role of microorganisms is a prerequisite to understanding sustainability.

Ecologist Tom Wessels participated in the Biosphere Challenge as a thought experiment. Toward the end of his explanation of what he would create to sustain multiple generations of spiders he indicated that

> a domed football stadium would be the minimum size necessary in which to create a stable, self-sustaining system for the spider. The size of this space would allow for the greater complexity and therefore greater stability. In a large system a lot of nutrients can get tied up in different parts of the ecosystem without catastrophic consequences, because there would be plenty of available nutrients left in the soil. The dome would also help resolve the water problem." (Karlan 1995, p. 463)

Explanations like these from professional ecologists help create additional cognitive dissonance and motivate students to 'challenge the expert' by trying to create self-sustaining systems within their small contained environments.

### 9.3.2 *Teach a Rat*

With a dozen terraria surrounding their classrooms, each containing a couple of white rats, the Teach a Rat project can help students learn about the science of learning. Behaviorism, cognitivism, constructivism, educational neuroscience, and learning styles are just a few of the arenas students can explore while teaching their rats to learn something new. Like the Biosphere Challenge, Teach a Rat is a living, vibrant constructivist-based, student-centered, and student-directed inquiry.

Inevitably students' investigations into what and how to teach their rats lead to energetic discussions about what and how they are taught. Discussions can become quite animated as they reflect on their personal experiences of schools using behaviorist approaches to motivate their learning. This is when I hear students comparing how they taught their rats to teachers giving them good grades in response to them doing well on a test or assignment. This comparison often leads to more debates about whether traditional grading systems are the most effective motivators for student learning.

When students notice that their rats seem to have different capacities to learn and learn at different rates, they reflect on their own learning styles and processing speeds. These questions can often lead them to further investigations on learning styles, multiple intelligences, and learning differences.

I often close the unit by challenging the entire class to work together to use a positive behaviorist approach to change my own classroom behavior. It isn't long before I am only writing on the left side of the board or smiling throughout most of the class – without me ever knowing these were behaviors they intentionally tried to teach me. Of course all this becomes more grist for the mill of morality.

## 9.4 5-Gallons of Powerful Learning

It's extraordinary what one can learn from what's inside a 5-gallon container. One could argue the triteness of the moral question on whether or not it is right for dozens of spiders or rats to be put at risk of dying at the hands of innocent school children. At a quick glance, it seems defensible that everyone's travel, diets, and other product choices have far greater impact on the health of wildlife and their ecosystems than the risks of what might happen to a classroom of spiders and rats. What doesn't make the use of the spiders or rats trite is that the exercise puts a lot of power into students' hands by inviting them to reflect on what it means to control or take another life other than for sustenance. Inevitably the students at some point turn the activity itself inward when they discuss how the very premise of these exercises may inadvertently send messages condoning human control over other species. And these discussions lead to interesting questions concerning the "rights" of nonhuman animals.

One could argue there's nothing better than learning about wildlife in nature. There are however, millions of children worldwide in schools surrounded by miles of asphalt. The opportunity to experience first-hand the meaning of ecology in ecosystems relatively untouched by the human hand is extremely challenging, if not impossible. The Biosphere Challenge and Teach A Rat are two compelling examples among many others that can bring a variety of life into science classrooms so students can learn more about themselves, the meaning of life, along with the principles of sustainability and ecology.

Using wild and domesticated animals in the classroom in ways that challenge students to discover big ideas about how the world works is undeniably engaging. I encourage all science educators to figure out how to engage their students with learning scientific concepts and processes, along with their moral corollaries, through student-centered, student-directed, hands-on, minds-on, relevant problem solving based lessons which use wild or domesticated animals in ways that are compassionate, mindful, and learning-full like the Biosphere Challenge and Teach A Rat.

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# Chapter 10
# How Technology Can Replace Animals in Lab Practices

**Eduardo Dopico and Eva Garcia-Vazquez**

In the permanent struggle between instinct and culture, science and education can help us combat ignorance. Through education, we receive in a way the cumulative universal culture from the past to the present. We also have developed social patterns that enable us to find finding out our personal space within our respective communities. Curiosity and the extension of the knowledge is a human characteristic. We always want to know more, we solve problems in order to survive, and we imagine possible alternatives. Science helps us to progress and has the power to questioning itself every day, it takes us forward in the reasoned explanations of conditions and it offers possible solutions to the multiple challenges we encounter as a species. One of these challenges is that of developing a keen awareness that we are not the only important species on Earth. Peter Singer (2005) promotes in his works the concept of *speciesism*, noting critically human intolerance or discrimination among species. The net result of this concept is the tendency for humans to thing that all non-human animals are intrinsically inferior to humans, just because they are not humans. Such perspectives are easily refutable from a biological point of view. Intelligence is measured on a continuous scale. At the lowest level in animals we find the slime mold, a unicellular organism that is halfway between *fungus* and animal. Though it lacks a nervous system, a slime mold still finds the shortest path through a maze and can interconnect two food sources, which evidences, as Nakagaki says (2000) that it is able to process information. From this minimal

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evolutionary structure it is unquestionable to claim that all animals, humans too (even though sometimes it may not seem true), have intelligence at varying grades.

As a species, we do not treat well at all other species. We do domesticate and breed hundreds of animal species for food or transportation, and use them for entertainment (circus animals, cock fighting, bullfights), we hunt them (deer; fox; rabbits; elephants), we use them for clothing and accessories, exhibit them in zoos, and increasingly, by means direct and indirect, we have driven many species to extinction. We also care for them, protect them, and even adopt them as members of their own families. And these people are precisely those who most closely are questioning that science even today continues to use animals in research and clinical trials.

The scientific arguments for using animals in research are clear. Clinical trials with animals allow us to develop hypotheses about living organisms to find possible solutions to problems related to our health and quality of life. From one point of view or another, the debate on animal research remains polarized between those in favor and those against all animal research (Perry 2007). Animal testing is based on procedures performed with live animals for research purposes. The animals most commonly used for such purposes are: mice, rats, birds (pigeons), rabbits, guinea pigs, hamsters, fish (zebra fish is the common model), farm animals such as pigs, sheep, and chickens), dogs, primates (including orangutans, chimpanzees and bonobos), cats, and frogs. Most of these animals are purpose-bred, that is, specifically bred to be used for experimental purposes in areas as diverse as teaching, industry or biomedicine. In teaching, animal experiments in basic biology, animal behavior or medicine can help students gain knowledge of the physiological, morphological, behavioral and anatomical characteristics of living beings. In industry, animals are used to check the safety of materials in various household products (such as cosmetics, cleaning agents and food additives) and lawn-care and agrochemicals. Animals also are used in military tests, and in the biomedical domain, tests with animals are used to evaluate the effectiveness of new drugs to treat diseases, and to conduct research in diverse areas of medicine, dentistry and veterinary. Liebsch et al. (2011) estimate that annually, more than 115 million animals worldwide are used in lab experiments (Humane Society International 2015). The consequences for the animals used in such experiments are often very severe. The pain inflicted on an animal should follow the principle of analogy, that is, that the same pain caused to the animal could be suffered by a human, and pain will be infringed only if it cannot be excluded from the test (Hedenqvist and Hellebrekers 2003). But we must not be naïve, all procedures, including those classified as mild, have the potential to cause physical injury, psychological distress and suffering. Most of these animals are euthanized and sacrificed at the end of an experiment; a few may be re-used in subsequent experiments.

## 10.1 Animal Testing

In Europe, since 1985, there are laws to protect vertebrate animals used in scientific experiments. An example is the Directive 2010/63/EU that establishes basic rules for protecting animals that are bred for scientific use, and other purposes, including teaching. The following rules are from this Directive: minimize the number of animals used in procedures, and wherever possible use alternative methods; do not cause the animals unnecessary pain, suffering, distress or lasting harm; avoid any unnecessary duplication of procedures; and ensure that the animals have the proper care. In 2010, the European Commission published data on the number of animals used in experiments by the Member States of the European Union. These data showed that in 2008, mice, rats and rabbits accounted for more than 80% of the total number of animals used in laboratories. These three groups of mammals were followed by various poikilothermic animals (reptiles, amphibians and fish), which accounted for 9.6% of the animals used. Birds represented 6.3% of all animals used. At a finer scale, the vertebrate animals used in these procedures were: Mouse (*Mus musculus*), Rat (*Rattus norvegicus*), Guinea pig (*Cavia porcellus*), Golden hamster (*Mesocricetus auratus*), *Chinese dwarf hamsters* (*Cricetulus griseus*), *Mongolian gerbil* (*Meriones unguiculatus*), Rabbit (*Oryctolagus cuniculus*), Dog (*Canis familiaris*), Cat (*Felis catus*), all species of nonhuman primates, F*rogs* (*Xenopus laevis*, *X. tropicalis*, *Rana temporaria*, *R. pipiens*) and zebrafish (*Danio rerio*).

The European Commission report indicates that both fundamental biology and research and development in human and veterinary medicine are, by far, the fields that use the largest number of laboratory animals (Fig. 10.1). The number of animals used for research and development in medicine, dentistry and veterinary declined from 3.7 million in 2005 to 2.7 million in 2008. Over the same time interval, the percentage of animals used for fundamental biological research increased, from about 4.0 million in 2005 to nearly 4.6 million in 2010. The number of animals used for toxicological evaluations and other safety assessments in the European Union remained unchanged, at about 1.0 million per year.

From the data provided by the report we can see a substantial increase in the use of mice and rabbits for the production and quality control of products and medical instruments and dentistry, as well as some increase in the use of mice, pigs and birds for basic biological research, anatomy, developmental biology, physiology, genetics and cancer research, immunology and microbiology. It seems that the increase registered in the use of mice is attributed to the new research possibilities offered by the transgenic species, used for studies about health.

## 10.2 Ethics in Animal-Study Research

Anyone who cares for or uses animals in research must assume responsibility for their general welfare (National Research Council 2011). This objective is feasible, but we should not forget that the general welfare of animals can be contradicted by the fact that in the end, they are killed, although "as humanely as possible". There it is important to note that there are rules governing research objectives when they involve animals in testing (Resnik 2012). The International Committee for Laboratory Animal Science (ICLAS) brings together some 100 countries around the

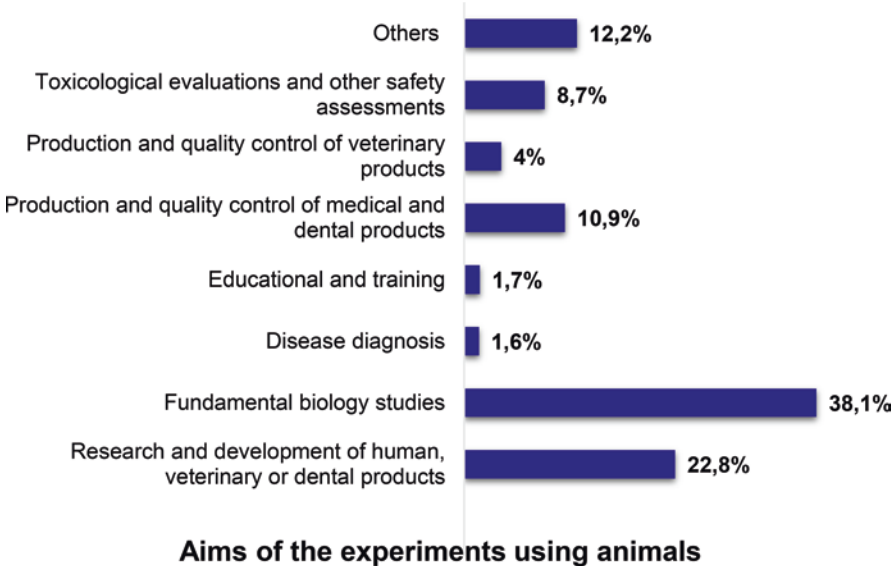


**Fig. 10.1** Uses of animals for experimentation in the European Union. (Source: European Commission 2010)

world and provides guidelines for procedures when using animals in experiments (Demers et al. 2006). And this is where ethics in research come into play.

Ethics may help establish a basis for how animals should be treated and used in science frameworks (Carenzi and Verga 2009). Undoubtedly this also relates to ideas about animal welfare (Fraser 2008), as well as to the way we understand the principles of scientific ethics. Various studies have shown how the pressures to produce results can encourage misconduct in observing basic ethic norms in scientific research (De Vries et al. 2006). Kilkenny et al. (2009), for example, found that 4% of 271 journal articles the researchers reviewed did not report the number of animals used anywhere in the methods or results sections

The review process defined by the Institutional Animal Care and Use Committee (IACUC), an American system to oversee vertebrate animal use and ensure compliance with federal regulations and guidelines, has occasionally dealt with vested interests in animal experiments that have resulted in unnecessary animal use and suffering (Hansen et al. 2012).

Assuming that animal tests for different experimental procedures are necessary, two English biologists, Bill Russell and Rex Burch (2015) tried to do animal testing in an ethical way. Showing concern for animals' welfare, they suggest in their book, *The Principle of Humane Experimental Technique,* the '*Three Rs principle'* -- replacement, reduction and refinement. These two investigators proposed : *replacing* animal experimentation by other methods not involving their use (such as replacing animals with by *computer*-based *models* or by replacing vertebrate animals with invertebrate species, which may have less pain perception); *reducing* the number of animals used, when possible, through strategies that make more efficient statistical use of animal-based data; and by *refining* techniques used to minimize animal pain and distress while improving animal care and welfare, from birth to death (Nuffield Council on Bioethics 2005). Jharna Mandal and Subhash Chandra Parija (2013) believe that all researchers using experimental animals have a moral responsibility to the animals after their use, and suggest that rehabilitating experimental animals should be a legal requirement in India. These two authors proposed to add a fourth R, *rehabilitation*, related to the after-care and/or rehabilitation of animals post-experimentation.

## 10.3 Social Awareness Against Animal Abuse

Currently, social awareness of and resistance to animal abuse has grown exponentially, promoted by the Universal Declaration on Animal Welfare (UDAW), which was conceived in 1977 by the International League of Animal Rights and recognized by the Food and Agriculture Organization of the United Nations in 2009 (Haas 2014). In terms of scientific scope, students referring to themselves as *objectors of lab practices* involving animals intervention and sacrifice have helped reject previous animal-care practices and put into question continuation of such practices. They have initiated discussion about, and seek alternatives to, animal testing. But ethical considerations and arguments alone are unlikely to initiate movement or social change (Gruber and Hartung 2004): financial incentive usually is an essential driver for changing procedures in basic research to animal-free procedures.

We are against the use of animals in experiments. However, that option is not always possible. We expect few people would choose to use a new chemical compound, not previously tested either for efficacy or safety, unless it had been evaluated first using animals metabolically similar to humans. Respecting strictly the recommendations of the Committees of Ethics in Research, and following the 'good old strategy' of 4R, with adequate anesthetics and a compassion for other living beings, we suppose that research with animals could be compatible with methods used to avoid or reduce animal suffering. Let's be honest: by far most animals that are bred for human use are those that are used as food, and these animals likely are exposed to a level of suffering that is similar to, or higher than, that of lab animals.

But animals used for teaching pose another and a very different issue. Animal experiments are unnecessary in most colleges and careers. If teaching situations in which animals is absolutely necessary – for example for practicing a new chirurgical technique that requires (without known alternatives) the use of living animals – the number of experimental animals can be reduced by sharing them between experiments, or using videoconference systems to limit the number of animals used. Even in cases that absolutely require animals for teaching, we can improve the statistical designs so as to avoid the use of more animals than actually needed. Alternatively, or in addition to, teachers can sometimes replace animals with other animals lower on the phylogenetic scale, using "simpler" or "less sensitive" animals whenever possible (this could be discussed because we don't know yet how to measure animal suffering); refine the techniques that reduce animal pain; use techniques such as magnetic resonance imaging to minimize invasive procedures, as we do in human surgery; and so on.

Animal experiments are also used in large numbers in industry, particularly for producing confectionery, cosmetics and pharmaceutical products. In vitro assays can replace animal testing some or many cases, even as a progressively aware society demands cruelty-free products. Cruelty-free brands offer various cosmetics, personal care and household products that have not been assayed, or obtained from animals (https://www.crueltyfreeinternational.org/). Brands can be certified as cruelty-free, and their sales can benefit from such branding. However, fraud can occur at this step, as well, because the label per se may not warrant a product is actually animal-free. In at least a few cases, the labels do not accurately describe the product. For example, pork traces have been found in products labeled as apt for vegetarians (e.g., Muñoz-Colmenero et al. 2015). The good intentions therefore should be accompanied by appropriate systems to monitor and report such that consumers can reliably and accurately choose to buy what they intend to buy.

## 10.4 Animal-Free Teaching Alternatives

The goal to achieve should be to eliminate the animals from the experimental procedure in teaching practices. Let's think about current teaching practices still conducted in many genetics labs, worldwide. Experiments with fruit flies (*Drosophila melanogaster)* involve rearing and killing millions of flies, for the sake of teaching students principles of Mendelian inheritance, epistasis and the heritability of sex-linked traits. These principles could be easily learned from plants. Mendel inferred the inheritance laws from peas. But we don't need to go back in time, and we don't need to develop a botany lab, although it might well be welcomed by students. Science itself has progressed enough such that methods are available to reduce or avoid using animals in many teaching practices. Here are several specific examples. Alternatives-to-animals methods now include in vitro procedures for cultivating cells, tissues and organs; immunochemical techniques are available for cell, tissue and organ cultures; physical and/or mechanical systems are available for analyzing reactions in a defined set of predetermined circumstances; we have 3D representations of key anatomical features of animals, in plastic or other materials; and we have computer simulations, videos, and movies that capture, both in real time and in slow-motion, many functional operations of animals. Many areas of genetics, cytology, and toxicology also can be taught from a student's own cells and DNA (e.g., Pardiñas et al. 2010), and mucosa cells for obtaining DNA or for making cytological observations can be obtained simply rubbing the inner mouth with a cotton swab

**Fig. 10.2** A genetics laboratory at the University of Oviedo

(Fig. 10.2). We suggest the primary limiting aspect of limiting or reducing animals use for teaching is that of teacher imagination (Dopico et al. 2014).

Other subjects, such as behavioral or field ecology, ornithology, aquaculture, or fisheries ecology, can depend on fieldwork, observations, and collecting and analyzing animals. How can students learn ecology, which can include animal sampling, without practice? Again, technology sometimes can help us. Animals leave traces of themselves in the space they inhabit: hairs, saliva, feces, footprints, fecal or urine deposits, and cells. A recent technique for isolating and analyzing DNA from water or soil might help in this regard. DNA from such sources can be referred to as *environmental DNA* (eDNA). From DNA sequences in the environment, investigators can identify the organisms that inhabit or which have passed through the environment. Such studies have been done now in different ecosystems (e.g., Taberlet et al. 2012). The method for sequencing eDNA is still relatively expensive, and analyzing eDNA sequences requires specialized bioinformatics skills (c.f. Zaiko et al. 2015). However, costs for these analyses are going down rapidly as the method becomes more popular, and we anticipate user-friendly software will soon be developed. Soon, it will not be necessary to disturb many fish to obtain a fish-species inventory for a pond; rather, the information can be obtained through eDNA analysis from a single one-liter water sample. If you want your students to observe animal behavior, underwater cameras and hydrophones can be positioned to record pond denizens (e.g., http://uw-observatory.loven.gu.se/about.shtml). Silent mini-robots with recording and data-reporting capabilities may be controlled by students and driven here and there within a pond, capturing animal images and sounds. If a species is extremely interesting, we don't need to kill and stuff a specimen for each college. Rather, replicates can be obtained by scanning and 3D printing, and the replicas can be distributed to the interested institutions. Although the current technique for doing this is expensive, new more affordable prototypes are being developed now and likely will become available soon (https://www.newscientist.com/article/dn7165-3d-printer-to-churn-out-copies-of-itself/).

Fine chemical analyses of the biosphere and virtual simulation and physical replication models can let teachers teach about nature without using or disturbing living animals. The challenges posed by rapid developments in biotechnology afford a hopeful track that may become generalized in the very near future. If the hopeful monster is a cruelty-free world, the hopeful monsterette could be science applied to cruelty-free methodologies.

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# Chapter 11
# Using Object-Based Learning to Understand Animal Evolution

**Paul Davies and Joanne Nicholl**

In London in 1828 in Bloomsbury, then, as now, a fashionable district of central London, home to the British Museum and Library and University College London (UCL), Robert Edmund Grant established the Grant Museum of Zoology at UCL (see Fig. 11.1), a collection designed to support students of zoology in understanding comparative anatomy and dissection. Prior to moving to London, Grant has lectured at Edinburgh University, during which time he tutored Charles Darwin, assisting him collecting specimens and encouraged his early thinking about evolution. Grant's interests then moved further towards zoology and, in 1827, he was appointed Professor of Comparative Anatomy at University College London. He was the first Professor of Zoology in England and campaigned for the development of a zoological collection, the first in the U.K., the fruits of which we see in the Grant Museum of Zoology, UCL.

This chapter explores why places like the Grant Museum are important, not just for specialist, learned activities, but also for their role in fostering cultural awareness of the natural world and how influential they can be in helping people understand what it means to be human and our relationship with other animals. By considering the rise of natural history collections and the special place that objects play in teaching and learning about animals, we examine a project designed to support pre-service teachers in their thinking about how animal material can help them, and their students learn about biological evolution and argue for a renewed analysis of how we think about collections and their meaning to society.

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**Fig. 11.1** The Grant Museum of Zoology, UCL

## 11.1 What Are Natural History Collections?

The early incarnations of natural history collections were not designed for rigorous academic study. Rather, they were used to either begin making sense of the natural world, as in the collections of Aristotle, or as a way to better understand God's great design, as in the collections of Albertus Magnus (Ashworth 1996). The contrast here is stark. For Aristole, it was for humans to describe and order nature, for Albertus, the 'natural law' of nature displays the omnificence of God and help him argue for cases of design and creation. These collections evolved slowly to become, by the mid seventeenth century, celebrated 'cabinets of curiosities'. One of the earliest and most important of these collections was established by Ferrante Imperato, who made it famous through his *Dell'Historia Naturale* (Fig. 11.2). Established in Renaissance Naples, this collection of gems, rocks, plants and animal materials, plus published catalogues, was the first to organize and use specimens to try and better understand how nature itself is arranged in the natural world.

Cataloguing and making sense of the living world was epitomized in collections of Linnaeus, both through his personal collections and the natural history collection he established at the University of Uppsala, Sweden (Koerner 1996). The collections of Linnaeus were developed to reflect his notion that 'the earth is then nothing else but a museum of the all-wise creator's masterpieces, divided into three chambers' (Linnaeus 1754). And through this we are left with a powerful effort to organize the natural world in Linnaeus classification, as revealed in his *Philosophia botanica* in 1751. Of course, the Linnaean classification systems does not come about through


**Fig. 11.2** Engraving from Ferrante Imperato. The Cabinet of Curiosities. (Image from Wiki: "RitrattoMuseoFerranteImperato" by (Anonymous, for Ferrante Imperato). Original uploader was Wetman at en.wikipedia – Transferred from en.wikipedia; transferred to Commons by User:Shakko using CommonsHelper.(Original text: http://www.ausgepackt.uni-erlangen.de/presse/download/index.shtml). Licensed under Public Domain via Commons

chance. Using his collections, Linnaeus worked hard with his students in Uppsala, struggling between using folk and common species names, towards a universal and highly organized system which recognized relationships and gave a common language to classification (Koerner 1996).

At about the same time, in England, Hans Sloane was establishing his collection of anthropological and biological objects. As a cabinet of curiosity, this collection was housed in his London home, which was something of a spectacle in eighteenth century London. Upon his death, Sloane bequeathed his vast collection of over 71,000 manuscripts, drawings, objects, gems, minerals and animal and plant material to the nation – an event which ultimately resulted in the founding of the British Museum, the world's first 'universal museum' (De Beer 1953). Continuing to expand its collection, in 1887, almost 60 years after Grant had established his collection, the British Museum moved its natural history collections to a new site in South Kensington, thus establishing the Natural History Museum. At the Natural History Museum, the general public was given access to 'rare materials' – objects that are not commonly seen in everyday life (Braund and Reiss 2006). These objects opened the eyes of many people to the wonders of the natural world. It is here, too, that a shift occurred in the focus and purpose of natural history collections. On one hand, the Grant Museum, and others like it, such as the Ashmolean in Oxford, were largely 'teaching' collections, with specimens displayed in taxonomic groups or dioramas. Such displays were designed to recreate nature in its natural form and were used many by academics. On the other hand, the Natural History Museum was designed to entertain and teach the public about science. About when major museums were shifting towards engaging with the general public, a marked change occurred in the focus of collections, from solely taxonomic to understanding physiological systems: museums started dividing their collections into galleries of physiology and paleonotology (Outram 1996). This change was coupled with a move away from seeing collections as having links with theology and moving, instead, towards viewing natural history as an expert science. Good examples of where this occurred are collections such as the Natural History museums in London and Philadelphia and the Museum of Zoology and Geology in Berlin. Perhaps the best example of this trend was that of the Museum national d'Histoire Naturelle in Paris. Here natural history academicians, such as Cuvier and Lamarck, amassed and studied collections to support their emerging ideas about the relationships between living things and how the natural world works, even as they were building a collection that was open to the public, designed to immerse them in the living world through a botanical garden, a zoological garden, and a specimen collection (Limoges et al. 1980).

Museums and collections continued to evolve and change, sometimes driving public opinion of their use. A significant moment for this came through the rise of 'Science Centers' with a more 'hands on' experiential design. The first of these was the Exploratorium in San Francisco. Founded by Frank Oppenhiemer, this museum allowed the public to interact with materials and explore the galleries with less focus on guided learning and with greater reliance on curiosity and exploration (1972). It was at this time, too, that many curators of natural history collections began to shift their focus from one of learning about taxonomy, evolution and physiology, to one where the central message was one of conservation (Millar et al. 2004). This new message was conveyed both through the research associated with the collections and also redirection ofthe the income they generated from admission charges and public donation towards conservation activities. This 'new' message for collections initially conflicted with the specimen acquisition processes of many collections – it is difficult to drive home a message about conserving species when many of those in the collection bear the hunting scars (Fig. 11.3). However, the new message slowly has taken hold, and the 'public' now largely recognizes conservation as a key justifier of collections; this message now helps justify public money funding many of these institutions (Turnhout et al. 2012).

**Fig. 11.3** Rhinoceros skeleton at the Grant Museum of Zoology, with a bullet hole in left scapula (shoulder blade)

## 11.2 Learning About Natural History Through Objects

Serving a range of purposes, the use of natural history collections has changed in response to public opinion, funding and research foci, but at their heart they are places of objects. Whether they are preserved in jars, mounted skeletons, fossils or intricately arranged dioramic scenes, specimens remain at the very center of museum design and experience. The Grant Museum of Zoology contains a large number of 'wet' specimens, fossils and taxidermy animals. Among these are some very rare specimens, including the quagga (an extinct species of zebra), the dodo and the Tasmanian tiger (Chatterjee 2009). The objects of the museum are key to learning and interaction, but an object-based pedagogy is a more recent development in thinking (Chatterjee 2011).

Object-Based Learning (OBL) offers a range of experiences and supports learning and skill development across subject specific content, communication and teamwork, and observation and 'noticing', and it promotes curiosity and inquiry (Were 2008). Central to OBL is the role of touch. This means that OBL needs to be interactive. That is, the learner and the object need to exist in a dynamic relationship, with the learner having access to the object and receiving tactile feedback from touching it. Christos Giachritsis (2008 p. 75) argues that touch is the "ultimate sense which allows use to build a complete representation of the world." Certainly, touch plays a significant role in human development; the importance of touch is evident in watching infants explore their physical world through hand-on interaction (Paulus and Hauf 2011).

Touch is more than just a method of learning about the physicality of an object: it also islinked to an emotive response – the so called 'touch emotion'. As Solway et al. (2015) explains in detail, when holding something, the brain receives information about the object's weight, texture, size and temperature, which helps 'build a picture' of what the object is like. These sensations parallel affective responses, such as feelings of pleasure or excitement, and can evoke memories, much in way that smells can (Critchley 2008). These preliminary findings in OBL have suggestive, important therapeutic implications, and early work shows that interaction with objects can help with both physical and mental health problems. For example, Martin and Jones (2009) showed that using objects can help young people convey their emotions and identify the emotional states and needs of others. A key feature of the success of OBL comes in its role in multisensory experience. Clearly, for most people touch is accompanied by visual, auditory, verbal, and in some cases, olfactory interactions. This multimodal approach is potentially beneficial, for itprovides alternative approaches to interaction for learning and the development of mental models and memory (Baddeley et al. 2009). Alberto Gallace and Charles Spence (2008) provide a useful overview of the mechanisms of 'tactile memory systems' and show how sensory inputs from touch lead to long term, possibly even lifetime, changes that take place within a dynamic relationship between tactile stimulation and the brain. An important finding of their work is that the three-dimensional nature of an object affects learning. When presented with two-dimensional, or even 'raised' objects, learners struggle much more with visualizing the object, as well as with carrying out spatial manipulations in their brain. It seems that touching, holding and manipulating objects can help maximize learning. This outcome can be enhanced when the experiences take place in a social environment where talk, exchange of ideas and discussion can take place.

This framework for thinking about OBL is useful only if applied in real situations and, for the natural history collection, real situations take different forms. The Grant Museum of Zoology has a long history of using objects for education. For example, one aspect of the undergraduate biology degree program taught at the Grant Museum of Zoology involves students working with a 'mystery' object, which could be an entire specimen or part of a specimen. Taking an inquiry approach, through handling and drawing the specimen, and comparing it to other material in the museum, the students develop a hypothesis about its identity. The hypothesis then is written up with additional context, in the style of a scientific article, with the intent being to explore the evidence students think supports their conclusions. Another example, aimed at school students, involves students examining and handling a series of animal skulls and complete specimens to try and categorize them into feeding adaptations (Fig. 11.4). By touching the teeth, manipulating the jaws and comparing the specimens to others in the museum, the students develop insights into how biologists build up and use evidence to develop scientific theory. Such experiences scarcely resemble those of visitors staring at specimens behind glass doors, or looking at articulated skeletons devoid from any biological context! And it is one such experience that we now go onto explore.

**Fig. 11.4** Skull adaptation activity at the Grant Museum of Zoology, UCL

## 11.3 Using OBL at the Grant Museum of Zoology

> Learning through argumentation at a place like this is really powerful, especially when you can imagine naturalists actually arguing it out in this building years ago. Peter, PGCE Science Secondary student (Biology)

Peter's impromptu comment was music to the museum curator's ears. Peter was at the museum, taking part in a project aimed at improving pre-service teachers' understanding and teaching of evolution. But here was the 'special' part. Not only was Peter at the only remaining university zoological museum in London, in an area not much bigger than a large living room – it was home to over 68,000 specimens representing the entire animal kingdom. Further, the participants were allowed to touch some of the specimens. They were able to pick them up, take them apart (where possible) and connect with them in ways that go far beyond simple observations.

Peter wasn't accurate in his statement regarding the use of argumentation[1], but his statement did showcase how the nature of the space influences people's ideas and enthusiasm for learning. He was not the only one that began this journey of realization; many of the pre-service teachers (PSTs) demonstrated a change in their perspective towards evolution and learning, some of which will be discussed later in this chapter.

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[1] Rather than using argumentation, the workshops had an exploratory nature to them, and thus model 'inquiry science' rather than specifically argumentation.

All participants taking part in the project were trainee teachers, near the end of their one-year training on the UK post-graduate certificate of education (PGCE) course. The project attracted many different personalities and varied expertise; some of the trainees were training to be biology teachers, including Katerina who specialized in palaeontology, and Peter – a trainee physics teacher with a basic knowledge of biology but a passion to learn. The PSTs attended three workshops during the project, and each workshop encouraged them to engage in some way with the animal specimens. The main activities involved studying animal skulls, exploring the evidence for evolution using anatomical structures; and constructing phylogenetic trees – a branching diagram showing the relationship between various species based on their physical or genetic characteristics.

The workshop activities deliberately shifted from the passive transmission of knowledge, towards a more active approach in acquiring knowledge. This 'exploratory' nature of the workshops at first made many of the students feel uncomfortable. Vanessa, for example, kept repeating, 'but what animal skull actually is it?' Selima confirmed her facial expressions by stating 'I feel frustrated that I don't know this,' and Anna portrayed the anxieties of many science teachers; 'I am just pleased that I wasn't wrong *all* the time.' These conversations initially led to a tense atmosphere in the museum. The students were attempting to learn *about* the objects rather than learn *from* the objects. However, as time went on, their goals changed. The PSTs began to explore ideas more openly and they began to consider connections between the different animals and the stories the specimens could tell about the natural world.

Observing anatomical structures is one way that scientists review evidence for evolution. This approach was one that Charles Darwin used when he proposed his idea of natural selection. Homologous structures are those that appear in different animals that have similar anatomical characteristics that have derived from the same evolutionary origin. The homologous structures may not perform the same function (such as a dolphin's flipper and a human arm), but they have a common ancestral origin. Conversely, analogous structures are those that are not closely related, but do perform similar functions, or look as if they are similar in origin. The typical examples are the wings of bats, birds and insects. Structures that have lost most, if not indeed all, of their original functions, but still remain a structure on the species (such as the human little toe or the appendix), are referred to as vestigial structures. Allowing the PSTs to explore these structures through the specimens at the museum was a particularly effective way of getting them to recognise the concept of common ancestry. The PSTs became engrossed in comparing different structures such as a manatee and human's appendage. There was even debate surrounding the use of vestigial structures in providing evidence for evolution, where Karl highlighted:

> I disagree with what you guys are saying. With the coccyx, it shows there was some link to our evolutionary history. There is an element there that shows a hint of what we used to look like.

Using the museum to explore anatomical structures of different organisms brought to life the idea of divergent evolution. Being able to identify the similarities in animals set the tone to a more open and investigative atmosphere within the museum. Anna commented, upon returning:

> I liked looking at the snake. Even though it was completely different [to us], there is an echo of our ancestry in there and it is powerful.

The students had enlightening conversations about the paws of a wombat compared to the paws of a cat, and about a sea lion's skull compared to a lion's skull. They explored the size and similarities of a gibbon skull, and compared it compared to the skull of a chimpanzee, and they compared the skulls of a tiger and a lion. The opportunities seemed endless – but one aspect appeared to drive it: the 'knowledgeable other'. In retrospect, we under-estimated how little subject knowledge the PSTs were going to have on biological evolution. We expected the students to direct their own learning and understanding more than they actually did. Nevertheless, modelling to the students how to support them on their journey of discovery was useful, and it showed the PSTs what they would need to do later with their own high school students. It instilled the teachers with a drive to want to learn more, so they could evoke curiosity in others. The PST commented that being in a place such as the Grant Museum provided "proof of the similarities between animals," and they noted that "seeing the same bone on different species in the same position helped you see the links."

> I have never really been exposed to animal biology, I have just been immersed in human biology. Give me an alveoli any day and there would be no problem! Outside of school has really been my only experience of this type of biology rather than in school, which is pretty bad. Selima, PGCE science secondary student (Biologist)

A story such as Selima's is unfortunately common among biologists, especially when it comes to considering the concepts of evolution (Crawford et al. 2004). The problem continues for trainee biology teachers (Nehm et al. 2009). Those that study undergraduate degrees such as molecular biology, biochemistry and genetics sometimes may feel far removed from the natural world and the animals that live and have lived within it. I say this as a person speaking from experience: specialising in such topics as an undergraduate and then working as an editor for a drug-related journal meant that I was slowly detaching from the natural world. However, fortunately for me, that was true only until I became a Biology teacher.

Subject knowledge often has been identified as a crucial component of effective inquiry-based learning (Capps and Crawford 2013). When the PSTs were considering how to use the space and objects around them for future visits, they kept coming back to needing a 'knowledgeable other' or an 'information pack' which they could read before their visit. Discussing their subject knowledge led to a reflection by the PSTs on how much they really knew about evolution. The workshops taught some of the PSTs a few of the basic ideas spanning animal biology, such that turtles are vertebrates and snakes have ribcages. The workshops also evoked an enthusiasm from the PSTs in wanting to deepen their knowledge about animal biology and evolution. Interestingly, most of the PSTs did not know what homologous, analogous or vestigial structures were, and some were still struggling with these concepts at the end. For example, two of the PSTs identified a worm and a snake as analogous structures, even after the third workshop.

Evolution is a complex topic and harbours many misconceptions (Pazza et al. 2009). Research shows that an active approach to learning results in fewer misconceptions in students, but the results of active learning still can have limited gains (Nehm and Reilly 2007). However, active-infused learning, such as inquiry instruction, has a much more positive impact on student engagement and performance (Veall 2015). Evolution is now introduced to students in the UK primary curriculum, at age 9 years. Thus, many teachers, not just those specializing in Biology, need to understand the basics of evolution. Further, given the structure of many science departments at secondary school, many physics and chemistry teachers also will be expected to teach core concepts in evolution, with an aim of inspiring children to understand their connection to the natural world. And if this doesn't sound challenging enough, various philosophical and social issues create additional barriers for teachers who teach evolution. Added resistance stem from some religions, and in some parts of the world a large fraction of the population thinks that creationism should be taught alongside the theory of evolution (Coyne 2009). This situations can place teachers in difficult positions, where the subject turns from an exciting theory towards a more sensitive and awkward subject.

Motivating teachers in ways such as visiting the Grant Museum to encourage them to delve further into this complex notion, allowing them to develop a better appreciation of our connections to other animals. This type of activity does not just seem an added bonus: rather, it seems a necessity. Exploring novel approaches such as using and touching animal specimens provides opportunities for teachers and students alike to perceive evolution in a fresh light and potentially from a different perspective.

> For me, it was about the physical more than it was about the physical being 'real.' I wouldn't have cared if it was plastic, it was just more about the fact that I could see it and touch it, and that really meant something. Adam, PGCE science secondary student (Physicist)

Adam showed passion for learning in the museum from the start. He appreciated the historical events that had led up to the moment of him standing within the museum. He was aware of the opportunities that surrounded him in the forms of the various specimens. But his most memorable experience was the physical contact he had with the animal specimens.

Adam was not the only one who came to this conclusion. Vanessa and Fatima both placed touching the specimens as high on their priority list if they were to bring students to the museum. Perhaps of most interest was the overwhelming power these specimens seemed to have had when the PSTs were asked what aspects of the workshop they would use in their future practice. Inevitably, some mentioned the depressing time constraints due to the overloaded science curriculum content (Ellis and McNicholl 2015). However, almost all the PSTs commented on how the objects would provide another dimension for learning. Given this discussion, we suggested that loan boxes would be a good alternative to bringing students to the museum. Kate commented, "Touching and moving the specimens is useful no matter where you are," whilst Fatima stated "It would be good if we could integrate these objects into the curriculum." Interestingly, Katerina, also shared her experience of having skulls when she was at school:

> I remember learning about adaptations and skeletons with skulls in our classroom. It was great having them in there.

No one can 'learn evolution' in three workshops. The topic is vast and resides within an area that contests the realist nature of science. It spans the sphere of the 'unknown' and involves looking for clues and then piecing it all together. Seeing and touching specimens brought to life the idea of evolution and how animals have changed through time . It helped the PSTs understand the concepts that are at the base of evolution, such as common ancestry. The project also instilled a sense of curiosity within the PSTs, and encouraged them to want to learn more about this fascinating topic. Just as importantly, the workshops inspired them to integrate pedagogical approaches such as inquiry science and object-based learning more into their future teaching careers.

## 11.4 The Power of Animal Specimens in Learning Biology

Animal specimens are central to learning biology. The OBL approach takes the use of specimens beyond the passive and puts them actively at the forefront of understanding. Touch, and the sensory experiences associated with touching provide opportunities for new learning experiences, which allow the learner to enter new and exciting worlds. Museums throughout the world are embracing this approach to teaching, learning and inquiry (Roberts 2014) with opportunities for visitors to fully interact with biological material and replicas. But not everyone can experience OBL in a museum setting. So, how can the objects be brought to the learners?

Museums have a long history of using loan boxes that schools borrow and use within the classroom (Gurian 2004). The boxes can offer a variety of theme-based objects that can be chosen by the teacher or an existing loan box that has been premade by the museum, such as 'fabulous fossil' boxes including a range of fossils from all different species and ages. Loan boxes offer unique experiences for the student, but the logistics of this innovation, and the expertise required to make the most of the experience, may be challenging for the teacher and learner.

So where next? Technology offers new opportunities that allow teachers and learners access to rare materials with support from museum experts. A good example of how emerging technology is being used in this way comes from innovative work with fossil specimens from Victoria Cave, North Yorkshire, U.K. Here, specimens have been digitised and made available for exploration through a web-based platform (Digventures 2015). Through this platform, members of the public can 'handle', in a virtually environment, materials that they would not normally have access too. Beyond this, the emerging world of augmented reality makes experiences of this type richer and more accessible. And, as Harald Kraemer and Norbert Kanter (2014) argue, it is there where museums will almost certainly look to in the future.

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# Chapter 12
# Death in a Jar: The Study of Life

**Mary Rebecca Warbington Wells**

## 12.1 Biology: The Study of Life

I chose to become a biologist because I recognized early on and developed a complete fascination with the interconnectedness of life, and how every being is reliant on every other being, including humans, as well as reliant on the life-nourishing qualities of the earth that sustain us. As Henry David Thoreau (2000) reminds us,

> The earth is not a mere fragment of dead history, stratum upon stratum like the leaves of a book, to be studied by geologists and antiquaries chiefly, but living poetry like the leaves of a tree, which precede flowers and fruit—not a fossil earth, but a living earth. (p. 246)

The earth is a living entity and to study biology, to study life on earth, essentially means to study the earth itself. For living creatures are born of the earth and return to the earth when they die. To understand the earth and the creatures that dwell among her it is necessary to study the interactions that living organisms have with each other and with the earth. This study of natural relationships of living organisms is *ecology*, a branch off the larger field of biology.

However, as I advanced in my studies and became a biology educator, I was shocked when I discovered that biologists tend to do more studying of the dead than studying of the living when assessing ecological relationships. Even the biologists who study live animals in captivity are still studying the dead, what I like to call the living dead. Another disturbing realization for me was, as Anthony Kronman (2007) puts it, "within the realm of academic study, the research ideal devalues death" (p. 128). The research ideal also devalues life as I soon discovered in my early classroom years. It was my awakening to this truth of biology education that stimulated my need to find understanding in its ironic traditions.

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## 12.2 Biology: The Study of the Dead

> It is not easy to cut through a human head with a hacksaw. The blade kept snagging the skin, and slipping off the smooth bone of the forehead. If I made a mistake, I slid to one side or the other, and I would not saw precisely down the center of the nose, the mouth, the chin, the throat. It required tremendous concentration. I had to pay close attention, and at the same time I could not really acknowledge what I was doing, because it was so horrible. (Crichton 1988, p. 3)

It was 12 years ago that I read this passage in Michael Crichton's (1988) autobiography *Travels*. Until that time, and my recent re-visitation of the text, I never really realized the gruesomeness that first year medical students have to endure to learn the basic anatomy of the human body. Cutting open a cadaver, a dead human being, must be so unnerving, so "horrible" as Crichton puts it, that I would be surprised to hear if these medical students did not suffer from some type of posttraumatic stress syndrome. Chopping a human head open in such a manner, without the intent of putting it back together, without the intent to heal, is just not a *normal* thing to do, even for practicing neurosurgeons.

When reading an account such as this one, the first question that comes to mind is WHY do such a horrible thing; which is promptly answered by a professor of Crichton's, Dr. Don Fawcett. " 'You can no more become a good doctor without a thorough understanding of gross anatomy than you can become a good mechanic without opening the hood of a car' " (Crichton 1988, p. 5). The professor has a point, the only way you can know the ins and outs of the human body is to crack one open and take a look but it is definitely not a pleasant thing to do; hence the term *gross* anatomy. And, because medical students are required to do such an unpleasant task, what does such a right-of-passage do to your mind and your perception of others?

Crichton (1988) indicates that laughter was the only way that he and his fellow classmates could withstand their horrific actions. They gave their cadavers silly names like "King Kong" and "The Jolly Green Giant" and on one occasion played football with the liver of one of the cadavers:

> A few students pretended to be horrified but nobody really was…We could see that this was a human body, a dead person laid out on the table before us. We were continuously reminded of what we were doing—we could see the form clearly. There was no way to get the necessary distance, to detach, except to be outrageous and disrespectful. There was no way to survive except to laugh. (Crichton 1988, p. 10)

Indeed, laughter is a defense mechanism and often the only way our psyche can cope with such serious, dramatic, and gruesome events. A police officer friend of mine once told me that it is not uncommon to see homicide detectives standing around a murder scene laughing and joking; it's the only way they can cope with the deaths, many horrific, that they investigate on a daily basis.

However, the problem I see with making jest of studying the dead, especially in the doctor-cadaver relationship, is the possibility of viewing living patients in the same light as cadavers. "The preclinical curriculum in American medical schools has become a pressure cooker—too much information, too little time, too many attempts to repackage, and too few clear educational goals" (Coulehan and Williams 2000, p. 66). Could poking fun at cadavers be yet another factor contributing to a decline in the bedside manners and compassion of young doctors? Do these new doctors see their living patients as no more than slabs of meat to be studied, cut, poked, prodded, sewn up, and laughed about just as they did to the cadavers on whom they *learned* the basic anatomy of the human body? As the character Minerva from the movie *Midnight in the Garden of Good and Evil* says, "To understand the living, you got to commune with the dead" (Eastwood 1997). Maybe medical students aren't communing enough with the dead people they study. I'm not talking conducting séances, but if these doctors-in-training were given the personal backgrounds of the cadavers they dissect they would treat them more as deceased patients, which would allow them to develop a greater sense of compassion for their future living patients. Understanding the former lives of cadavers may help medical students better understand medical and lifestyle causes of death as well as help them learn to cope with the issue of patients who die under their care.

Despite the intensity of communing with the dead, medical students today are doing a lot more communing with the living, as they should; after all, it's the living who will be their patients. Studying live people is different from studying dead cadavers, which is why medical schools also teach students how to interview, and talk to real, living patients in an ethical and responsible manner. Stanley Reiser (2000) states,

> Students coming to the bedside of a patient to develop skills in taking a history, doing a physical exam, or drawing blood should acknowledge their limits to patients and follow the 'do no harm' ethic. Students must ask patients for permission to learn on them, and patients must give their consent. (p. 5)

Teaching such ethics would hopefully counteract the "cadaver effect" that many first year medical students experience, the utter disconnect between doctor and deceased patient due to the gruesome acts of dismemberment. Sandra Gilbert (2006) observes that such disconnect has a trickle-down effect that can be seen in the hospitals in which our doctors work:

> If the hospital as a bureaucracy, or, for that matter, a sort of factory assembly line designed to process illnesses rather than people, fosters a steely clinical demeanor, it's important to remember that this demeanor is actually *formed*, and later encouraged, by the nature and structure of medical training. The virtually ritual dissection of a 'first' cadaver in the anatomy lab is not only a learning experience but a rite of passage for the neophyte physician. (p. 191)

Even with medical education including training for associating with living patients, the bulk of the training still primarily focuses on the illness of a patient. Patients become named based on their illness (woman with the breast cancer, man with the bedsores, grouchy man in room 416). Hospital staff rudely wake patients from the valuable sleep necessary for the healing process by turning on the bright ceiling lights above the patient's bed just for the sake of a blood pressure, pulse, and temperature check….data collection to determine the progression or regression of the illness. Illness is scheduled for surgery at 5:00 am, receives medication from the cart every two hours, and has a visit by the doctor during early morning rounds. Maybe an especially compassionate physician will visit the patient later on in the day.

But, how does a doctor truly view the patient, especially in light of an illness that is winning, beating the skills of the doctor and taking over the body of the patient? If "what the doctor sees when he gazes at the dying patient is not a human being in extremity but rather an alien marauder who has been an indomitable foe…it isn't surprising if he treats the sufferer coldly, even with some hostility" (Gilbert 2006, p. 193). Ultimately, this *treatment* becomes a displacement of the doctor's frustration at the inability to cure, to win, and a disconnect between doctor and soon-to-be deceased patient, which can be contributed to the bruised intellectual ego of the doctor, the assembly line nature of the hospital factory, and the post-medical training cadaver effect.

Though studying dead people is virtually a necessity for upcoming doctors, is studying any dead organism a necessity for the rest of us? I pose this question because it is an issue I have grappled with as a biology instructor. I have a problem with dead things in jars. Yet, dead things in jars are the traditional methodologies I have experienced in biology classrooms to study/observe the sundry of animals, plants, and fungi commonly associated with "life science" laboratory activities.

In the university-level introductory biology course I taught for several years, only one lab session was devoted to "Biodiversity," or examining the diverse amount of species living in our environment. This particular lab is an example of what Jacob Bronowski (1978/1985) means when he says, "you cannot be certain how to design something well, but you can be certain how to design it badly" (p. 38). This newly revamped lab activity was an atrocity from the time it went to print because it aimed for superficial recognition of multiple species, some not even indigenous to our area, rather than an in-depth understanding of a few more relevant to our ecosystem. Though I mention just this one instance, superficial knowledge of biodiversity is nothing new to any institution where life sciences are taught. In fact, it is superficiality that perpetuates the contradictory approach to studying biodiversity. When an educator takes this approach it is problematic in two respects.

Problem number one: Diversity is not something that can be analyzed and appreciated in a week's time. These quick "surveys" are lackadaisical approaches to learning about the diversity of our planet. Not only does this quickness dismiss majority of the species in our biosphere but it also implies that the diversity found within our own species is also not worth contemplating. Problem number two: Biodiversity is about studying the rich diversity of *living* species, not how many dead species we can fit in jars and show students (as biodiversity labs frequently boast). Instructors show students a dead frog and say, "this IS a frog." I show my students the dead frog and say, "this WAS a frog." I say "was a frog" because that dead thing in the jar is no longer a frog. It no longer hops, croaks, and eats insects, mates, or does the things that make it known as "frog." A dead frog in a jar is nothing more than a dead piece of flesh, a dead *thing* in a jar. It is not alive, no longer part of *bios*, the living that constitute the discipline of *biology*, the study of *LIFE*.

I am not dismissing dead frogs in jars or any other animal that is sacrificed for the sake of scientific study. Instead, I am sympathetic toward them because their lives were dismissed as unworthy of being lived. They are dismissed by the biological supply company that killed and preserved their bodies, by the instructors who display their corpses in jars or on dissection trays, and by the students who are utterly grossed out at the sight of them. As a student of biology, and early in my career as a biology educator, I would tell myself that the deaths of the *specimens* were not in vain because their bodies are used for educational purposes. For many years I managed to convince myself of what can be called "death for education;" but, such deaths really are in vain because these organisms are killed annually, by the thousands, and for money nonetheless. No one ever gives them a second thought or feels badly about killing a *lesser* species if it's for *educational purposes* or money for that matter. Derrick Jensen (2004) states,

> Death is, and must be, deeply emotional. To intentionally cause death is to engender a form of intimacy, one that we're not used to thinking about. To kill without emotion and without respect, or to ignore the intimacy inherent in the act, is to rob it of its dignity, and to rob the life that you are ending of its significance. (p. 35–36)

Sacrificing species in an emotionless manner trivializes the life that was ended. When we trivialize the lives of others, same species as us or not, our lives too become trivialized because the act of emotionless killing is neither fruitful nor does it nourish our spirit. Is it any wonder that students panic at the thought of dissections? Dead things can be scary to begin with but they become especially creepy when they become discolored and juicy from the preservation fluids, pumped with dyes to map blood vessels, and develop a characteristic odor that doesn't smell like how death should smell.

## 12.3 Biology: The Study of the Living Dead

Understanding life is not limited to studying carcasses and slabs of dead flesh sprawled for the world to see in a dissection pan. Biologists actually do study living organisms, which obviously provides a better understanding of the living than studying the dead does. However, the capacity at which the living is studied could be problematic because, as I see it, there are two types of living organisms, the living-live and the living dead. Most biologists do not recognize these two states of life because of the given, if you are alive then you must be living. But I argue that there is indeed such a difference between living organisms. I also argue that since biologists have the propensity to study death over life, the study of the living dead becomes the preferred choice of studying the living because we can conduct our studies in a controlled environment.

You may be thinking that it is impossible for something to be alive and dead at the same time, which is a quandary for most biologists. However, the living dead are very possible, very real, and exist among us at this very moment. Many people in this world will *die* long before they physically die; in a sense they are walking zombies. The living live and the living dead are alike in that they are both considered to be *alive.* Their difference is that the living live are free, able to live the natural course that evolution set forth for them, whereas the living dead live the contrary. Mary Aswell Doll (2000) describes these two states of living life:

> How to live a life? How not to? To not live is to be tied up and boxed in. To live is to open out to each suffering moment without regret…To suffer loss, craving, and yearning is to be alive as never before; it is to be alive in the empty now. It is to feel the shadows of the self. (p. 164)

The living dead are creatures held captive by others, the others who think they are superior, or they are held captive by their own devices. In the following paragraphs I will give you an example of both states of living, beginning with the state of being living-live.

Farley Mowat (1963) had the right idea when he studied wolves in the arctic. Be a quiet observer. Let the animals go about their daily lives without interference by humans. Just wait patiently and see what happens. This is what studying the living live is, letting nature and natural selection run their course, unaided, unhampered. One may consider Mowat's presence to be interfering with the natural order of the wolves' way of life, but he was by no means intrusive in the sense that zoos and research stations are. Instead, he existed more like another animal living in close proximity to the parameters of the wolf territory, an area he named "Wolf House Bay." Mowat documented his observations of the wolf family at Wolf House Bay in his book *Never Cry Wolf* (1963). He obtained a vast amount of knowledge about wolf life and even discovered some surprising information about wolves and how closely they resemble humans in rearing their young. Early in his observations, Mowat discovered that wolves too adopt the adage of *it takes a community to raise a child*. On one particular day he observed the mother wolf, who he named Angelina, become exasperated by her over-exuberant pups and call for help from an adult wolf (Uncle Albert) who lived with her and her mate (George):

> Within seconds of her *cri-de-coeur*, and before the mob of pups could reach her, a savior appeared. It was the third wolf…He jumped to his feet…intercepting the pups as they prepared to scale the last slope to reach their mother…he used his shoulder to bowl the leading pup over on its back and send it skidding down the lower slope toward the den. Having broken the charge…he shepherded the lot of them back to what I later came to recognize as the playground area…'If it's a workout you kids want,' he might have said, 'then I'm your wolf!' (Mowat 1963, p. 64–65)

What this event showed is the cooperation and caring nature with which a wolf pack cares for its pups. As the pups got older, Mowat also witnessed the adult wolves collectively working to teach their pups how to hunt and chase caribou. Though the wolves occasionally had their spats, they would come back together as a family unit and work together to help each other survive.

Captive wolves tell a much different story from what the wolves at Wolf House Bay do. In her book *Shadow Mountain,* Renee Askins (2003) discusses some of the events she witnessed in a captive wolf pack that revealed an obvious collapse in the natural social structure of the pack. One instance she documents is the attack on the alpha female of the pack:

> Perhaps it was hearing a yelp from their invincible leader [Cassie], or perhaps the tension was so great that any event could have triggered the brawl that ensued—no one knows why, but in a split second the pack erupted in a gang attack on their unchallenged leader of eight years. Two minutes later Cassie was left barely breathing and paralyzed from a spinal bite. (Askins 2003, p. 12)

Another unnatural occurrence in the pack happened when a subordinate female had to leave her day-old pups unattended in her den while she got a drink of water. A young male wolf snuck in the den and stole one of the puppies. The wolf's brother came to see what the young male had found and the two of them proceeded to play "a brief game of tug-of-war and the day-old puppy died almost instantly from the trauma" (Askins 2003, p. 14).

Both of the instances described by Askins are not normal behaviors for a wolf pack. They are definitely not the loving and nurturing behaviors witnessed by Mowat at Wolf House Bay. Thus, we see the difference between the living-live and the living dead. Though the animals Askins described are not physically dead they are psychologically, emotionally, and spiritually dead because they cannot live out their lives how their lives have evolved to be lived. Thus, they kill one another over a situation that if they were free would not have even occurred in the first place. Or they are careless with their young, killing them by accident or on purpose, instead of nurturing their pups as nature intended, as a community. Askins (2003) recognizes this discrepancy:

> Rarely is it appropriate to extrapolate what we witness in captive situations to the wild because behaviors are radically altered by the adaptations and stresses inherent in captivity. It would be much like putting a human child in solitary confinement, without social contact or nurturing, and assuming that the behavior exhibited under those circumstances represents the full spectrum of what it is to be human. (p. 13)

What makes us think that we can truly learn about the lives of animals when the animals are behind security fences, unable to do what they were meant to do? Friedrich Schiller (1795/2004) provides an answer in terms of the human ego's annoyance that we share many basic instincts with other animals:

> Ignorant of his own human dignity, he is far removed from honoring it in others, and conscious of his own savage greed, he fears it in every creature that resembles him. He never perceives others in himself, only himself in others; and society, instead of expanding him into the species, only confines him ever more closely inside his individuality. (p. 114)

The assumption that studying captive animals is the only way to understand their true nature or is the only way to protect those still roaming wild is narrow-minded and egotistical. Who are we to think that we can re-create their natural habitat? The animals will adapt to the confines in which we put them, defying their natural behaviors; just as humans adapt to the surroundings into which they are forced.

## 12.4 A New Covenant with Animals: Combatting Biophobia

I recognize this discussion may raise a few hairs; nevertheless, it's an important "complicated conversation," as William Pinar (2004) would say. A conversation that I hope will illuminate one of the possible reasons for the increased level of biophobia in today's society. David Orr (2004) describes biophobia as ranging "from discomfort in 'natural' places to active scorn for whatever is not manmade, managed, or air-conditioned" (p. 131). Biophobia plagues our society because we have incubated conditions that are optimal for its growth. We are reared to fear the natural and covet the artificial.

Neighborhoods are erected in treeless subdivisions so residents don't have to worry about tree roots uplifting their sidewalks (what a real-estate agent told my cousin) or the continuous work of bagging leaves. Interactions with animals other than domesticated pets are limited to zoos where the animals are behind bars, in an unnaturally controlled environment, apparently caged for our own safety; or floating lifeless in jars. Don't forget the bugs; there's products to take care of them too. Why eat fruits and veggies that bugs *might* have nibbled on when you can have bug-free fruits and veggies doused in toxic manmade pesticides…Gee, they're so much prettier. What about spiders? People hate spiders because they are ugly and weird looking and crawl around on eight legs instead of the "normal" two or four. Spider-haters fail to realize that without them we would be overrun by worse pests like mosquitoes and other biting insects. But is it really any wonder that biophobia is rampant in our society? Ralph Waldo Emerson (1839/2003) describes it well:

> We are shut up in schools & college recitation rooms for ten or fifteen years & come out at last with a bellyful of words & do not know a thing…We are afraid of a horse, of a cow, of a dog, of a cat, of a spider." (p. 60)

We become so reliant on our captors, just as other captive animals do, that we have a difficult time getting along in the natural world. Thus, biophobia sets in and the corporate giants with their miracle products are here to save us. Fear the natural, covet the artificial.

How can we possibly combat biophobia? The answer is simple, return to a biophilic state of mind, but the process is not. Biophilia, as defined by E. O. Wilson (1984) is "the innate tendency to focus on life and lifelike processes" (p. 1). As biophobics, our focus is not on life and the natural course of life; instead we focus on our immediate selves and maintaining control of our surroundings often in utter disregard for what consequences our actions may have in store for us and our environment. The process will be difficult because we must shift from "the opinion that the world exists solely for the sake of man" (Abbey 1968, p. 306). We must acknowledge that we are not the only living organisms on this planet that matter. Indeed, this process will be a difficult one because as Marla Morris (2002) alludes, "we as human beings are interconnected to the wilderness, but we feel alienated from it" (p. 584). What alienates us from the wilderness is the fact that we consciously recognize how different we are from other organisms. It is this recognition of difference, or what Morris (2002) calls "co-consciousness," that often blocks our ability to see how truly related and interdependent we are to the earth and all her inhabitants. We must understand that co-consciousness does not mean we are superior or above the rank of *animal* and can do with *real* animals as we please. We must recognize that fact, that humans are also animals, related to all the other animals, and serve an equally important role as do all the other creatures in our ecosystem.

To help us reclaim our biophilic nature we need to create a *New Covenant with Animals* as David Orr (2004) describes:

> We need animals, not locked up in zoos, but living free on their own terms. We need them for what they can tell us about ourselves and about our world…A new covenant with animals requires that we decide to limit the human domain in order to establish their rights in law, custom, and daily habit. (p. 149)

Our new covenant with animals is that we help them to live in a state if living-live. In return, what we can learn from them through subtle observation is how we too can live in a state of living-live. Likewise we should refrain from gross dissections where animals, humans or other, are displayed as nothing more than slabs of meat, the meaning of their once flowing life-blood trivialized. These animal slabs send us the subliminal message that life is not sacred; it is expendable if you are not a superior species. Ultimately, "to explore and affiliate with life is a deep and complicated process in mental development…our existence depends on this propensity, our spirit is woven from it, hope rises on its currents" (Wilson 1984, p. 1). Only when our innate sense of biophilia is reclaimed, and we can once again associate with nature in the way that Mother Earth intended it to be, can the living dead be resurrected.

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# Chapter 13
# Socio-scientific Issues for Scientific Literacy – The Evolution of an Environmental Education Program with a Focus on Birds

**Andrew T. Kinslow and Troy D. Sadler**

## 13.1 Introduction

> *Perhaps the greatest threat is losing our connection with the natural environment. Too many children are now raised indoors with no knowledge or appreciation of nature and no incentive to retain any part of their natural environment. Who will carry on the fight to reduce atmospheric and oceanic pollution, to conserve productive farmland and clean water, and to work toward slowing the rising sea levels?* – Chandler Robbins (Strycker 2012, p. 19)

Birds and humans share common spaces the world over. There are over 9800 species of birds worldwide and just under 1000 species within North America (Clements 2007). The United States Fish and Wildlife Service conducts regular national surveys related to wildlife-associated recreation activities, and observing wild birds is the leading non-consumptive wildlife related activity (United States Fish and Wildlife Service, USFS 2013). The 2011 survey indicates that over 46 million people engage in birding and bird watching. Birds are one of the most accessible groups of animals by students and teachers. Students' connections to birds may range from casual observations in the schoolyard to keeping birds as pets or engaging in bird identification projects, and it is common for outdoor classroom areas to feature gardens that attract birds, bird feeders, and nesting structures. Many organizations such as the American Birding Association (ABA 2015) and Cornell University (eBird 2015) have been actively building youth outreach programs for some time now. Given this natural familiarity and for many students' inherent interest, birds are an animal group with great potential for science education.

In this chapter, we discuss a program that provides opportunities for high school learners to interact with birds through a citizen science initiative. The work is presented from the perspective of Andrew, the first author, who created the program.

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The chapter begins with a brief review of the literature on citizen science around bird monitoring and habitats, and then presents early versions of the avian citizen science program at Andrew's school. After several years with the initiative, Andrew was looking to improve the program with the goal of impacting student learning and experiences with science in more profound ways. He started working with Troy, the second author, and together they considered how the bird research experiences might be coupled with a socio-scientific issues (SSI) approach. The chapter focuses on how the program evolved to engage learners in science research on natural populations, ecology, and meaningful SSI.

## 13.2 Research Experiences for Students Through Citizen Science

A major challenge for science teachers is finding methods that engage students in scientific investigation that allow for exploration of science content and practices in settings that are authentic (Schwab and Brandwein 1962). Asking students to follow instructions in a lab handout to a scripted end rarely leads to meaningful experiences that embody science. Most students do not experience research opportunities until they move beyond their secondary education (Feldman et al. 2013).

Citizen science dates back to the 1800s in the United States. Science educators began exploring the concept of citizen science in the 1990s as a way to make school science more relevant to children's lives. Citizen science varies widely in its implementation. Generally it can be described as a collaboration between members of the public and scientists investigating and collecting data on real world problems (Wiggins and Crowston 2012). Dickenson and colleagues emphasize that citizen science also "addresses broader societal impacts in a profound way by engaging members of the public in authentic research experiences" (2012, p. 291). Oberhauser and Lebuhn (2012) present citizen science as a way to enhance education through data collection, research opportunities, and class projects. These projects have also been described as 'Public Participation in Scientific Research' (PPSR) (Bonney et al. 2009; Cooper 2012). Bonney and Cooper have extensive background with citizen science and informal science education and described three categories of PPSR:

A. Contributory – Designed by scientists, in which the public primarily collects data.
B. Collaborative – Designed by scientists, with public collaborators given some freedom to refine, analyze data, or communicate results.
C. Co-Creative – Fully collaborative in which the public and scientists design and participate together in most aspects of the project. (Bonney et al. 2009; Cooper 2012)

Most citizen science/PPSR projects fall within the contributory category (Bonney et al. 2009). Gray et al. (2012) suggest a rationale for this may include the lack of common frameworks available for researchers and other participants to engage in collaborative or co-creative PPSR.

The vision for citizen science/PPSR in classroom settings promotes the idea of building scientific literacy, especially among youth and the public. Scientific literacy is a broad concept with diverse, sometimes conflicting interpretations, and yet is often referenced as a goal of science curriculum design and instruction. Roberts addresses the concept of scientific literacy as a way of conceptualizing outcomes of science education in his chapter in the *Handbook of Researchon Science Education* (Roberts 2007; Roberts and Bybee 2014). He proposes two broad visions of scientific literacy at opposite ends of a continuum. Vision I refers to scientific literacy with traditional science content and practices that focus on the internal knowledge of science products and processes. This type of literacy is often decontextualized from specific events or issues. In contrast, Vision II refers to external sources of scientific literacy. An example of this type of literacy might involve students in the context of societal issues impacted by scientific phenomena. In other words, the complex and sometimes controversial issues of science are illuminated by understandings of scientific processes and content woven together. Both ends of this scientific literacy continuum have relevance to citizen science and PPSR.

Mueller et al. (2012) expand the definition of citizen science and envision that CS/PPSR serves as a means for more democratic science to affect change for future generations. Mueller and his colleagues ask educators to:

> Find ways to include youths not only in pedagogy that heightens epistemic development, but also in schooling where they have opportunities to engage real issues through their activism. Thus we promote youth activism through citizen science as a pedagogy in which teachers and their students gather information to make the most informed decisions about potential consequences and collaborate with others to increase the degrees of confidence surrounding these choices (p. 11).

## 13.3 Andrew's Evolution with Citizen Science and Bird Banding

My first experiences with research occurred during my undergraduate work in biology, working briefly in a laboratory and later in the field. Following college graduation, I worked for two years on a variety of ecological research projects and became adept at bird banding, nest searching, conducting bird surveys, as well as habitat analysis and water quality techniques. One of the most influential moments was at Whitefish Point Bird Observatory in the Upper Peninsula of Michigan where part of my job was to provide banding demonstrations for the public. Introverted with no prior teaching experience, I dreaded that part of the job at first. In fact on the morning of my first public banding demonstration, I faced 15 birdwatchers and stumbled through an interpretive demonstration about the purpose of bird banding and research in general. During this first teaching experience, I gravitated towards a little girl whose body language suggested that she and I were equally uncomfortable with the lesson. I knelt in front of her with a Cedar Waxwing that had been banded. She touched the bird. I asked whether she would like to hold it herself. As her demeanor softened, she agreed. Her face vibrantly lit up as she held the bird for the first time and safely released it. It was clear that she had connected to that bird and the natural environment as never before. This was an experience that changed both of us. It was in that moment, that I realized the power of a bird in the hand as well as sharing my passion for science and research with young people. I decided to become a teacher and returned to school to complete a master's degree and initial teaching certification with the goal of finding a way to innovatively teach science with birds and share that moment of discovery.

During the early years of my teaching career, I kept looked for ways to continue working in research and share my passion for research with my students. In 1998, I earned a bird banding certificate and partnered with the Institute for Bird Populations (IBP) in Point Reyes, California to establish a local research station as part of the IBP's Monitoring Avian Productivity and Survivorship (MAPS) program (DeSante et al. 2008). I entered into a partnership with leading ornithologists and established a bird-banding program based on their researchprotocols (DeSante, et al. 2008). I had previously worked on several bird banding projects such as MAPS as a field biologist, and I knew that I could use this as a platform for teaching core ecology and research techniques.

In 1999, I created a summer Field Research class for high school students with bird banding as the central element. A regional Environmental Protection Agency (EPA) grant provided funds for purchasing equipment. I offered my class as a summer school course in which students documented 120 hours of work toward science credit. The class was situated almost entirely in the field with work beginning at sunrise and extending into mid-afternoon. The banding station was situated on my family farm, providing a safe venue on private property to run mist nets and perform habitat analysis. The goal of this project was to engage students in actual science research projects so they could come to think of themselves as citizen scientists and apprentice researchers in stark contrast to the scripted, predictable nature of laboratory events traditionally used in typical science instruction. I expected students would gain ornithological and botanical knowledge in addition to research skills.

I taught the class alone for the first two years with 6–10 students each year. The class focused only on ornithology in the early years, banding for six consecutive hours at least once every ten days throughout the summer. Our research together was often unpredictable and unscripted. Students were not simply following directions in a laboratory manual but rather using content knowledge in conjunction with problem solving skills to complete daily research. For example, when students captured and analyzed birds (following the bird banding protocol) they identified the species, sex, aged the bird using skull ossification and plumage characteristics, and made basic measurements for statistical analysis. I guided students through the research protocols and gradually faded these supports as students became more proficient with the science. Each day presented different challenges, and we worked through them together to achieve the goals of our partner agencies and, just as importantly, to develop a greater understanding of the science ideas and processes.

My students and I learned much as we battled rainouts, severe weather, early morning starts, and hot summer weather. I was excited as a young teacher, and feedback from the students was positive despite the physical hardships.

In my third year running the program, a chemistry teacher colleague, Alan Reed, joined me to teach the field course. Alan suggested adding water quality monitoring as a new component of the course by using the guided protocols from the Missouri Stream Team (Missouri Department of Conservation, MDC 2007). These protocols are similar to many other state programs and feature a combined biological and chemical assessment of water quality. Students surveyed stream invertebrates, which provided insights into the long-term conditions of the stream. Water chemistry assessments provided a snapshot of immediate stream health. Our students responded well to the water quality monitoring component and working in the streams provided a convenient way to deal with the summer heat. Alan and I continued to fine-tune the bird and water quality research until his retirement in 2004. For example, we developed a portfolio assessment design for grading with a summative public presentation of our research findings to the parents and school administrators.

Another colleague from physics and technology, Brandon Kovach, joined me after Alan retired. Brandon brought a strong physics background to the class, which afforded the addition of astronomy and geo-orienteering components to the curriculum. The program picked up momentum during this time with enrollment increases and tremendous support from the community. Much of the success for the program was due to a desire to continuously analyze and improve the course on our part. We employed a reflexive approach to the class by continuously examining our goals and reflecting on outcomes from students. Students were actively engaged in meaningful learning experiences, and pre/post testing documented significant gains in science knowledge. At the same time, it was clear that students perceived bird banding, stream quality, orienteering, and astronomy as disconnected contents. Perhaps, this was due in part to the compartmentalized approach for science instruction that students have grown familiar with in the traditional classroom model at our school. I was dissatisfied with this disconnect and turned to the empirical literature to inform my instruction.

## 13.4 Best Practices for Citizen Science

Classrooms in the United States and abroad often feature science inquiry activities that are oriented to be "hands-on, but infrequently minds-on" (Burgin et al. 2012, p. 440) based on the assumption that involving students in inquiry activities is adequate for effective instruction. Thus, creating learning experiences in the midst of doing science should allow for productive science learning. However, this notion may inadvertently inhibit realizing more extensive student gains. Empirical studies of citizen science programs and other approaches for engaging students in inquiry suggests that incorporating explicit foci on learning goals within these programs can significantly increase the extent to which these goals are actually achieved (Sadler et al. 2010). Some students who are naturally introspective and analytical may indeed learn target outcomes from more traditional, implicit approaches. However, in order to maximize the significant effort and financial expenditure that goes into the curricular design and implementation of citizen science projects, it is better to make learning goals explicit. In other words, it is better for teachers to be purposeful in their design and implementation of these programs and to communicate these goals with their students (Sadler et al. 2010). With these thoughts in mind, I identified two areas of improvement for the field research program: Increasing the epistemic involvement of students in research processes and engagement with reflective practice.

### 13.4.1 Epistemic Involvement

Ryder and Leach (1999) introduced *epistemic involvement* as a way of thinking about the extent to which learners, involved in research, are engaged in the meaning-making dimensions of science. The construct helps to distinguish between low epistemic activities such as recording data, to high epistemic activities, such as generating research questions. Sadler and his colleagues (2010) later used the idea to interpret authentic research experiences as contexts for learning. Consider the following,

> Involving students in ongoing research projects such that they follow established routines may be the most practical way of engaging the relative novices. However, if the participant's experience doesn't include a range of epistemically demanding practices…learning gains on higher order outcomes will likely be limited. (Sadler et al. 2010)

Education research shows students' understandings about the nature of science (NOS), science content, and interest in science careers increase when students are actively engaged in analyzing data, developing and refining hypotheses, and questioning their findings. In the beginning stages of a student research program it is necessary to guide students through protocols, but efforts should be taken to scaffold students into more epistemically active roles. If possible, they should be allowed to explore research problems on their own with independent projects. In the case of my field research program, it was important to me to maximize students' epistemic involvement and ownership of their research.

### 13.4.2 Reflection

Reflective practices often are peripheral in science classrooms. When engaging students in citizen science projects, reflection activities should be designed into the projects to maximize educational benefits garnered over time. Consider several studies that promote building reflection activities into science apprenticeships. For example, Schwartz, Lederman, and Crawford identify reflective journal writing and seminar reflection as having the greatest impact on NOS understandings (2004). Stake and Mares (2005) use a mixed-methods analysis to document the impact of reflection that occurs following an apprenticeship. White et al. (2009) write extensively about the valuable role reflection plays in metacognition in science inquiry. These scholars promote the idea of infusing metacognitive practices into scientific inquiry, specifically reflectivepractices, in order to address science content knowledge, NOS, and development of autonomous learners and communities (2009). Reflective journals also encourage creative expression and can provide instructors unique insights into student's perceptions.

Increasing student's epistemic involvement and using reflexive practices in our class are best practices that maximize the potential impacts of teaching through citizen science projects. A significant challenge remained: How to unify and conceptualize the disparate components of the class? Socio-scientific issues provide a context around which the curriculum can be connected.

## 13.5 Why Socio-scientific Issues?

Socio-scientific issues (SSI) are complex, open-ended and often controversial issues blending science content and practices with complex societal issues (Zeidler 2014). SSI-based instruction has been presented as a way of conceptualizing science content and practices within social issues and problems, such as hydraulic fracturing (fracking), climate change, genetic engineering, nuclear power, among others (Zohar and Nemet 2002; Sadler 2011; Zeidler 2014). Interweaving SSI with the unique opportunities presented by citizen science projects can capitalize on the strengths of both pedagogies. We briefly explore three areas in which the SSI approach has been shown to benefit student's science knowledge and practice.

### *13.5.1 SSI & Science Content Knowledge*

Citizen science projects often engage students in novel learning experiences, which by their nature set the stage for gains in content knowledge. Students in my field research class have an opportunity to interact with birds directly and learn unique ornithological and ecological content knowledge through interacting with meaningful research. SSI instruction has been shown to promote gains in science content knowledge. For example, Dori et al. (2003) engaged students in controversial biotechnology cases and documented improvements in knowledge and understanding of these topics as well as higher order thinking skills. Several studies have examined genetics and related concepts taught through SSI instruction and show gains in student understanding of the content (Dawson et al. 2010; Lewis and Leach 2006;

Zohar and Nemet 2002). Additional SSI research has documented improvements in environmental, ecology, and chemistry content knowledge (Barab et al. 2010; Klosterman and Sadler 2010; Sadler et al. 2011).

### 13.5.2 SSI and the Nature of Science

The nature of science (NOS) is generally agreed to be "the epistemology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development" (Lederman 2007, p. 833). Both of Robert's visions of scientific literacy require understanding NOS (2007). Sadler et al. (2010) examined the literature for impacts of authentic research opportunities on student understandings of NOS. In their review they found 16 empirical studies showing gains in student understandings of NOS. Recently, Burgin and Sadler found that engaging students in highly authentic investigations can "support student learning of some NOS aspects and that coupling these opportunities to "do science" with explicit NOS instruction including reflecting on the ways in which students' research experiences connect with more general NOS themes maximizes NOS learning outcomes (Burgin and Sadler 2016, p. 22). SSI based instruction also has been shown to support NOS understandings. For example, two studies examining the impact of NOS instruction with high school students within SSI investigations around the topic of global climate change reported gains in NOS understanding (Khishfe and Lederman 2006; Sadler et al. 2004).

### 13.5.3 Citizen Science Through SSI to Improve Vision II Science Literacy

In the previous two sections we examined the documented SSI gains in content and NOS understanding. These are primarily vision I perspectives as per Roberts (2007), and Roberts and Bybee (2014). We position SSI as a means to elevate citizen science projects beyond the basic contributory category (based on Bonney and Cooper's categorizations of citizen science). Furthermore, we advocate that utilizing SSI instructional approaches within citizen science projects may provide the potential to improve scientific literacy around science content and NOS in a social context. The social factors of SSI allow students to engage in vision II scientific perspectives finding meaning and understandings of science within larger social contexts (Zeidler et al. 2009). The complexity inherent in measuring vision II scientific literacy perspectives does not negate their importance. "Vision II emphasizes an approach that is broader in scope, involving personal decision-making about contextually embedded issues. These 'real life' situations relate to science and are influenced by other perspectives such as social, political, economic and ethical ones" (Sadler and Zeidler 2009, p. 910). We advocate that utilizing SSI instruction within citizen science projects may address the struggle instructors have elevating projects beyond the contributory category. We propose that SSI may serve as a framework for addressing these issues and provide a vehicle through which citizen science projects can be elevated to collaborative or co-created models of instruction. The implementation of an SSI approach within my environmental education field research class is presented as an example.

## 13.6 Citizen Science SSI (CS-SSI)

My first step in incorporating an SSI orientation into the field research course was to identify socio-scientific themes, which connected with the bird research and water quality monitoring citizen science. Two frameworks for SSI instruction provided guidance to shape instructional revisions. (Friedrichsen et al. 2016; Presley et al. 2013).

So how does this work? The selection of a central SSI is critically important. The issue must feature complex and contentious societal components with substantive connections to science. We recommend instructors be very intentional with issue selection considering the specific science content and practices of their curriculum, the context of their student population, and state and national standards. The issue is introduced at the beginning of the instructional sequence and this socio-scientific issue itself becomes a context for students to explore fundamental science concepts (see Fig. 13.1). Science concepts and practices are explored along with the social connections associated with the issue. These connections are made at the research site while students perform avian and water quality research. Additionally student research of the SSI through use of information and communications technology (ICT) such as researching the issue in print and electronic media and interviewing stakeholders provides opportunities for connections with the science and social issues. A culminating experience provides an opportunity for students to synthesize their ideas, perspectives, and research related to the issue being explored.

My field research class occurs in the Missouri Ozarks. This is a geologic area featuring karst topography. Karst geology is composed of porous limestone and dolomite and is characterized by numerous caves and sinkholes which create extensive surface and groundwater connections. This complexity presents a myriad of socio-scientific issues through which to explore water quality and connections to the ecosystem. Consider, for example, where the high school building for my students is located. During construction the building required significant geologic siting in order to avoid multiple sinkholes on the property. We are able to examine this situation together and talk to the architect who designed the building and discuss the challenges involved in construction in Karst ecosystems. Students commute between the research site and the high school building on a highway that literally transits through the middle of a small sinkhole. Most students in the district obtain potable water from wells and have on-site septic wastewater treatment systems. Clearly,

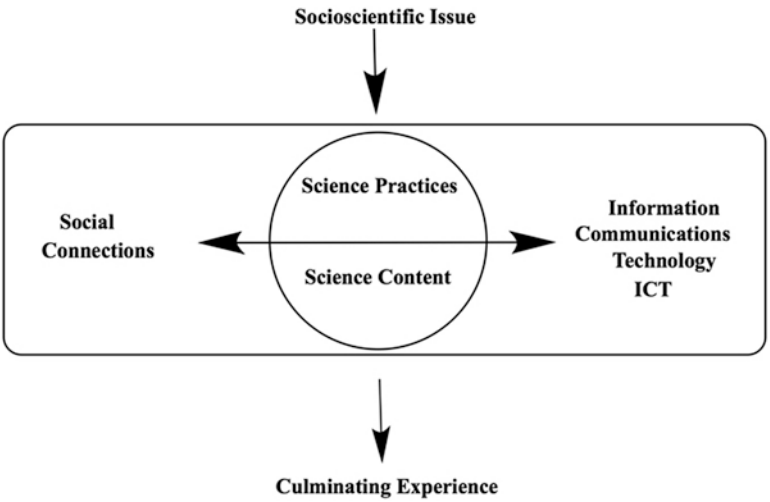


**Fig. 13.1** Model for SSI Instruction, adapted from (Friedrichsen et al. 2016)

karst topography is everywhere in these students' lives and yet most are unaware of the significance and fragility of these systems.

Karst topography became a logical way to begin exploring SSI infusion in my field research class during the summer of 2015. The issue needs to be as realistic as possible and place-based within the local community. Interestingly, a timely local issue occurred when developers proposed the construction of a groundwater based ethanol plant several miles from the high school. This proposal provided the perfect opportunity to explore science through a local SSI.

I seeded the ethanol plant proposal early in the instructional sequence. The overall instructional sequence is shown in Fig. 13.2. The ethanol plant SSI was revisited throughout the month long class. We visited the test well that was drilled and discussed the implications of commercial scale use of groundwater in the Midwest. Throughout the course, students engaged in bird banding and water quality monitoring. The bird banding station sits within a riparian corridor and the birds that are banded there are important biological indicators of water quality and forest health (Latta et al. 2015). Students engaged in purposeful ICT explorations of science concepts around karst topography, ethanol production, potable water wells, wastewater treatment as well as societal issues such as subsidies and planning and zoning. Students completed personal reflection journals approximately twice weekly, where they were given specific prompts to help summarize their learning, identify questions and areas of confusion, and validate learning and its importance. There were two related culminating activities for the course. Students created PowerPoint and Keynote presentations of the bird and water quality research and presented these to parents and the school administration. The SSI was presented as a feature of the class in which they were tasked making a recommendation to the community on the feasibility of the proposed ethanol plant.

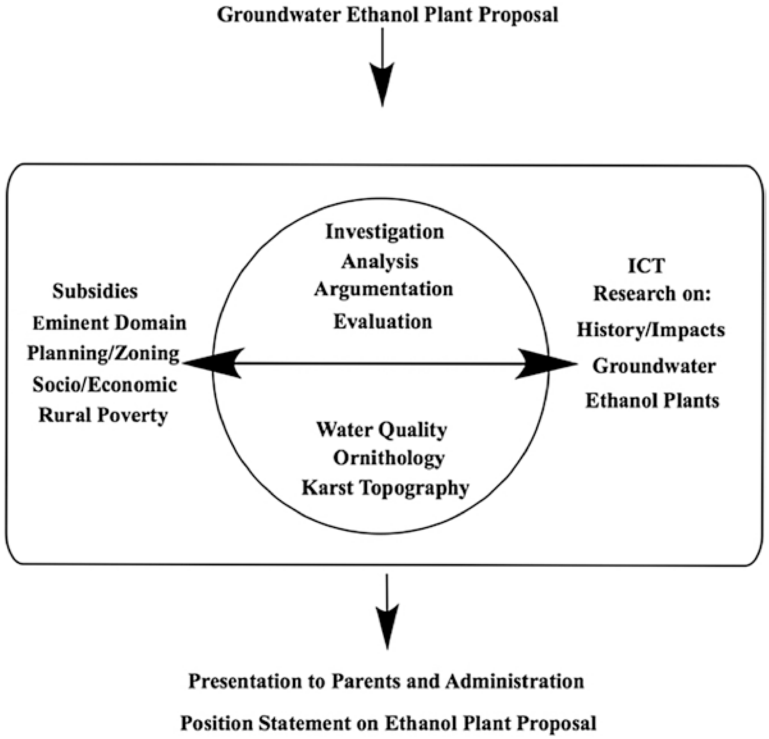


**Fig. 13.2** Model for SSI Instruction, adapted from (Friedrichsen et al. 2016)

The class was unanimous in recommending against a groundwater ethanol plant situated in the Ozarks. Students also completed a summative reflective journal activity in which they were asked to reflect on the totality of their class experiences and specifically asked to address how the bird bandingresearch connected to the water quality monitoring and the ethanol plant proposal.

## 13.7 The Power of a Bird in Hand

In the 17 years since I gave that little girl a bird to hold in her hand, I have gained so much from working with students and birds. I look back with great satisfaction and drive to continue exploring citizen science through SSI. Involving students in authentic research and working with animals is a powerful platform to teach science concepts and practices. Holding a wild bird and connecting with its fragility and power as a learning experience is a powerful moment for student and instructor. SSI reciprocally strengthens citizen science engagement and provides a vehicle for contextualizing investigations of science content and practices within the larger interwoven social and political world we live in.


**Fig. 13.3** Student Drawing. Used with permission from Berea Flatness (2007)

Consider several excerpts from student reflection journals and summary projects. These excerpts provide evidence of students forming connections between the ornithology research, water quality monitoring, and the SSI. *(Note: Student names provided here are pseudonyms.)*

> What I learned today matters because I now understand how something small can affect the whole watershed and the animals like the birds that depend on it. I can use it to inform others about the importance of keeping all waterways clean, because you never know what it connects to. (Mandy)

> Missouri's karst topography is the reason for all of the problems with runoff. But as long as smart practices are kept in place our water will be safer for all in the watershed, the birds, and our wells. (A.J.)

> It is especially important to understand karst landscapes to be aware of waste treatment and not pollute your water supply. In the Ozarks, acres and acres of farmland, residential, commercial are all connected through water systems and it is imperative to be working with your natural surroundings. (Eric)

> The birds are amazing to hold. You can feel their heart beat and how delicate and fragile they are. They are like the bugs we study in the streams, like larger (water quality) indicators because they feed on the bugs. Everything that happens to the stream happens to the birds also. (Tamara)

A drawing from a students' journal is shown in Fig. 13.3. The drawing illustrates a connected viewpoint of the various elements of the class (bird banding, stream quality, orienteering, and astronomy).

The environmental issues we face today and in the future require citizens with a solid grasp of science and equally the ability to negotiate the complex issues that shape our society. These citizens need the passion and drive to make a difference. Science experiences situated within socio-scientific investigations provide a vehicle for students to develop the understanding and passion to affect positive change. Our future depends on those who have deep and profound connections with the Earth. These connections do not come easily from a textbook. They do, however, present themselves readily to a group of young people early in the morning in feathered form.

## Photos

**Photo by A.D. Daniels**

**Photo by Dawn Huber**

**Photo by Andrew Kinslow**


**Photo by Troy Sadler**

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# Chapter 14
# Hawaiian Citizen Science: Journeys of Self-Discovery and Understanding of Scientific Concepts Through Culture and Nature Study in School Science Classes

**Jennifer L.H. Kuwahara**

This is a place backed up against the mountains
A place that is a paradise for the invasive
Where fires rage and the dry winds blow
And water is nowhere to be found

This is a place of learning
And damage, and recovery
Where ancient values matter
Where we can help each other
And learn from one another

Fresh soil under our feet
The feel of the sun's heat
We cut trees, grass and even weeds,
Cockroaches and praying mantis crawling up our knees,
Sweat dripping down our backs
So much to do, no time to relax

A place where looming mountains sit,
In the backdrop of clear blue skies.
Wind speaks as it flows past you
Whispering,
Inviting you,
To the open forest.

Feelings of gratitude, sounds of sickles, and happy smiles.
This isn't just any ordinary place
It's the Wai'anae Mountains Watershed

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In their *This is a place…* poem excerpts above, students use the poem *I am From* by George Ella Lyon as a model for their work. The compilation expresses the students' perspectives on work they did to create a vegetative fire break with the Wai‘anae Mountains Watershed Partnership (WMWP) in the Wai‘anae Kai Forest Reserve on O‘ahu, Hawai‘i. They Students show strong connections to place, and a commitment to the restoration work in which they participated. Student participation in these field trips is highly encouraged, but optional. However, most of the students take part in nursery and field work in 7th and 8th grades. On the field trips, students use hand saws and sickles, often working in sweltering heat to remove Haole koa (*Leucaena leucocephala*) and Guinea grass (*Megathyrsus maximus*) in creating the firebreak comprised of native plants. Students propagate the native plants they plant in the area from seed at the campus greenhouse and collect data on germination rates and scarification techniques. Each group of students only makes a dent in the sea of Haole koa trees in the forest reserve. But, monitoring shows the "dent" expands as more groups of students participate. Students feel encouraged when they revisit the site and see the change from dry and brittle invasive tinder to a growing patch of lush native plants. Some of the native plants are already taller than the students and soon will provide shade as future students continue the work.

## 14.1 Mount Ka‘ala

By the end of the school year the WMWP coordinator takes me, and a small group of my students, on a special field trip. I selected these students because they have shown high-interest in this sort of work and each of them participated in weekend fieldwork in addition to the in-school work. The coordinator took us to the highest peak on O‘ahu in state vehicles, on a road that is restricted to the public by the Federal Aviation Administration (FAA) and the National Guard. Driving rather than hiking means this field trip is easy: and it is a reward for the group of students who participated one Saturday a month in the fieldwork. Instead of sleeping in or hanging out with friends, the students spend their Saturday planting native plants, collecting seeds, cutting down invasive species, or removing marine debris from the shoreline. These students did not miss a workday throughout the school year, and they experienced all sorts of habitats – but none as unique as this one.

At the end of the restricted road in the Wai‘anae Mountain range is Mount Ka‘ala, part of Hawai‘i's Natural Area Reserves System. The Wai‘anae Mountain Range is on the Western (or Leeward) side of O‘ahu and is what remains of the older of two shield volcanoes that formed the island (the younger is Ko‘olau). The eruptions that formed the main Wai‘anae shield occurred 3.8–2.95 million years ago. The plateau at the summit and the frequent rainfall make for bog conditions. The bog, and the 1100 acres that surround it, form a reserve established in 1981 that now protects the flora and fauna of the relatively intact native ecosystem.

When we arrive at the top, the FAA tracking station, a big white ball that can be seen from our school campus on a clear day, is about 50 feet from the car. But we do not even notice the monstrosity of that instrument, right in front of us. Visibility is poor. We cannot see more than 10 feet in front of us! As students exit the vehicles, we are surrounded by *Ka ua Kolowao o Kaʻala*, the mountain-creeper rain of Kaʻala. Before we enter the bog, our host points out *Trematolobelia macrostachys*, one of the many species of endemic plants around us. It is in bloom now, with pink, curved, tubular, and terminal flowers. The curves of the flowers match the beaks of the coevolved Hawaiian Honeycreepers, which served as prime pollinator of this species and other Lobeliads. The many species that make up the Lobeliads and Honeycreepers are impressive examples of adaptive radiation --that is, species derived from a common ancestor. Unfortunately, native animals and plants have either gone extinct or have experienced declines in populations due factors such as habitat degradation, loss of pollinators and competition by introduced species, initially by Polynesian settlers and to a greater extend by Westerners and modern society.

The moist air dampens our t-shirts and cools us as we listen to the WMWP coordinator. He explains how less-effective introduced "novel" pollinator species do visit the Lobeliads in place of the many extinct honeycreepers (i.e., Japanese White-eye,*Zosterops japonicus*) and can successfully pollinate some species (Aslan et al. 2014). There is a quiet excitement among the students as we wait to enter the bog. Students face the bog and *oli* (chant), stating our good intentions, asking for permission and protection while visiting Kaʽala. After students finish the chant, we stand in silence waiting for our *hoʽailona*, or sign.

The wind picks up.
We hear a bird's call as it flies overhead.
Permission is granted.

This is *Wao Maʻukele*, named for its wet, soggy ground. The place above *Wao Akua*, the realm of the gods. Entry is allowed only for specific purposes and permission must be granted. The students remain silent as they enter the bog. It is fenced to keep feral ungulates out of the mostly intact native ecosystem. The students walk quietly along the boardwalk: the only noise is the sound of wooden planks slurping in the mud, hiking boots hitting the metal traction grating and ʻōlapa leaves (*Cheirodendron sp.*) dancing, rustling in the gentle breeze. I interpret the students' silence to mean they realize how lucky they are. They are never this quiet. *Paʽa ka waha* (observe, be silent and learn).

### *14.1.1 Happy Face Spider*

Kanawao (*Broussaisia arguta*), Hawaii's endemic hydrangea, catches our attention. It is a fairly common plant along the boardwalk of the bog, with distinct slightly leathery and thick leaves, clusters of terminal pink flowers, and dark red fleshy fruits. It is beautiful, but that is not why we are interested in the plant. We are more interested in what lurks on the underside of its leaves. We delicately turn over Kanawao leaf after Kanawao leaf in what seems like a fruitless search of the seemingly elusive charismatic "microfauna," the endemic Happy Face Spider (*Theridion grallator*).

We reach the end of the bog trail, unsuccessful and disappointed. I had promised these students a Happy Face Spider sighting and I wanted to deliver. After the students had peek-a-boo glimpses of the leeward coast through the quickly moving clouds, the WMWP coordinator tells us it is time to head to the car. I hang back as most of the group trudges along. *E ʻoluʻolu oe*, please, may we see a spider. A few of the students stay with me, but I feel less than hopeful we will find one, as if I had already turned over every Kanawao leaf. But, very quickly into our walk back, I turn over a leaf and there we find her -- a spider guarding her eggs. What a treat! We take pictures. I still the desire to shout out to the others to come back to see it in person. We must not cause a disturbance. Instead, we walk back beaming with appreciation, *mahalo e Nā Akua*.

### *14.1.2 Cultural Significance of Kaʻala*

Culturally and historically, Mount Kaʻala has not been home to the FAA. It is not only part of *Wao Akua*, the upland forest watershed that purifies and stores water for *Wao Kanaka* (realm of man), it is the home of Kaiona. Kaiona is a kind goddess, who guides lost travelers out of the forest with the help of an *ʻiwa* (frigatebird) (Pukui 1983). What is now a bog, was once Laukini fishpond, home to Kamaoha the *moʻo* (lizard); a pond where fish were cultivated, along with *Hihiwai* (freshwater limpets) and crabs; a place likely accessed only by *aliʻi* (chiefs). Additionally, Pele's (Fire Goddess in Hawaiian culture) sister, Hiʻiaka, chants praises for Mt. Kaʻala on her journey to fetch her sister's lover from Kauaʻi.

### 14.1.3 O'ahu Tree Snails

On our way back down the mountain we stop at an unassuming spot along the road where a small population of *Kahuli*, the federally listed endangered O'ahu tree snails (*Achatinella spp.*), are known to live. *Kahuli* are nocturnal and hermaphroditic; they feed on fungus that grows on the leaves of trees. The ancestors of O'ahu tree snails are believed to have hitched rides to Hawaiʻi on birds. Their shells were used in lei and for other ornamental purposes, and are mentioned in Hawaii's oral history. *Kahuli* were once so abundant they are said to have rained from the trees, when the trees were shaken. But they, too, have since succumbed to some of the same threats as other native species, as well as too over-collection by post-Western contact.

The WMWP coordinator speaks little about the history and ecology of the snails, but the students and I would not have heard much of it anyway. We are all engrossed in the beauty and diversity of the shells: we count our blessings to have met these creatures, alive and in their natural environment. Again, the typical teenage chatter is silenced by quiet whispers of "I found one" and "look at the colors on that one" or "wow, that one is huge" as we move gingerly around the trees making observations. After the brief yet intimate encounter with *Kahuli*, we get back into the vehicles and travel down the winding road, leaving the cool temperature, mist, and the native forest behind.

Mount Ka'ala is a place to become lost: a place to be enveloped in native species; a place to feel spiritually and culturally rooted in Hawaiʻi – a place of transcendent experiences. When students get to learn about and experience Kaʻala first-hand, they realize how rare the native species sightings are compared to the alien forests and landscapes. The students now have memories and pictures to share with their parents and peers. Hopefully, this experience is important enough to the students to ignite and fuel a fire within them to *mālama i ka 'āina*, to help fight the fight for these rare and endangered species.

## 14.2 Connecting Students to Nature

My passion for restoration work guides my curriculum and collaboration with community partners. For example, in the on-going project with the Waiʻanae Mountains Watershed Partnership (WMWP), students help to monitor germination rates of native seeds, as well as plant growth and survival in the vegetative fire break outplanting site. They also learn about native plants and their uses, traditional planting methods, and Hawaiian ways of understanding the natural world. I hope to replicate some of the experiences I had in my youth, creating a similar space that fosters the love I developed for the land. Getting students to know, care, and act (goals of Global Citizen Education) about the place they are connected to has shaped the way I approach teaching. My personal transcendent experiences in nature as well as my observations of students having such experiences on field trips fuel my approach to teaching. The experiences continually remind me of the importance of removing students from their concrete jungle and unplugging them from (all or most) technology where they can learn and be in the field without distractions. This approach to education enables students to connect with the social, cultural and ecological aspects of their communities, and in so doing, they gain valuable knowledge and skills (know) to help them develop opinions (care) and make decisions (act) about their environment (Banks 1993). Further, when this sort of educational experience includes a community service or citizen science component, learners see themselves as agents of change in their community's environmental health.

As the students' world becomes more technological and the top-down push for science, technology, engineering, and mathematics (STEM) education increases, I find it increasingly critical to engage students in citizen science projects to reestablish or connect their identities to the natural environment. Humans have a "fundamental, genetically based" tendency to affiliate with other living things and systems (Kahn 1997, pp. 1) – a tendency that E.O. Wilson (2002) terms *biophilia* (p. 214). *I kua na'u*, an *'Ōlelo No'eau* (Hawaiian proverb) which literally translates to "a burden for me" was often said to a dying person as a request for his/her dying wishes but also simply implies "let me help" or "let me bear the responsibilities" (Pukui 1983). This is an appropriate thing to ask the *'āina* (land/that which feeds us), particularly in its current state and society's current relationship with it. As we continue distancing ourselves from the *'āina*, so too do we distance ourselves from our identities as humans. As Roy Alameida (1996) states, "The *'āina* upon which we live, the *'āina* that we love, the *'āina* that we *mālama* (care for, protect), this is our identity" -- or at least for a long time it was, and we need to return to that mindset (p.87).

### *14.2.1 Disconnected*

The comforts afforded by modern society no longer requires most of us to interact with, inquire about, and understand the interconnectedness of life on Earth. The issue of being so far removed from the environment is particularly resonant in urban, suburban, and inner-city areas. There, the natural surroundings in students' communities sometimes are considered to be off-limits, dirty, or scary, as they can be places of criminal activities and community neglect (Kahn 1997). Richard Louv's book, *Last Child in the Woods Saving our children from nature deficit disorder* (2005), provides numerous reasons for, and examples of, humans' disconnect with nature and the subsequent need to reconnect students with nature. We have conditioned ourselves to become detached and disinterested in the natural world. He discusses such a disconnection with the environment as a "nature-deficit disorder."

Yet there exists a top-down push to reform STEM education that follows the high-stakes testing movement such that our country does not "fall behind" other nations. High-stakes tests provide the scores usually reported in the media and fuel, in part, the sense of urgency to “fix” the educational system. Such tests are generally “ineffective in achieving their intended purposes” (Berliner 2006, p. 949) and have many negative effects on student achievement and curriculum. This push can overshadow the importance of students connecting with, learning about, and developing values and actions that can help sustain the natural environment. I believe that citizen science projects benefit administrators that need to ‘check many boxes’ needed to show their school remains in good standing, maintain funding, and/or ensure accreditation status. Such “boxes” include STEM education, community partnerships, and service learning. Citizen science projects permit teachers to engage students in real-world issues and practice science as scientists. But another fundamental part of citizen science projects is that of cultural: a cultural component can guide efforts to build personal connections to the natural environment and engage students in authentic but not necessarily Western-centric science. Getting students to care about citizen science projects often involves engaging them in the stories, as well as the historical and cultural significance, of the areas in which the projects take place.

## 14.3 Hawai‘i’s Advantage

Students in Hawai‘i are lucky, with respect to developing or reconciling relationships with the natural environment. Students in public elementary schools have weekly lessons taught by Hawaiian elders through the Kūpuna Program, and social studies classes focus on Hawaiian history in 4$^{th}$, 7$^{th}$, and 9$^{th}$ grades. So, from early on, students in Hawai‘i are exposed to Hawaiian culture through things like *mo‘olelo* (stories, legends), *oli* (chants), *olelo no‘eau* (proverbs), and deities associated with natural entities such as volcanoes, animals, plants, and places.. Students benefit too from the fact that the revival of Hawaiian language and culture occurred relatively recently in history. The wounds of Native Hawaiians are still fresh, as are the desires to regain and/or maintain political power and cultural recognition. Even while Hawaiian culture and language were oppressed and traditions were lost in some populations before the “Hawaiian renaissance” (e.g. Hawaiian language was banned in school in 1896), the recognition of Hawaiian culture and language in education and the community has since become ubiquitous, if only at a superficial level in many regards.

After many years of struggle and effort, there is now an understanding that Hawaiian culture and language are important for all students, pre-K and beyond, in the State of Hawai‘i. Most recently, this value was reinforced in things such as the Hawai‘i Department of Education’s (HiDOE) creation of an Office of Hawaiian Education and Nā Hopena A‘o, an “ends policy” in which learning outcomes grounded in a holistic Hawaiian worldview provide a framework for student and school community success. The HiDOE’s commitment to culturally and place-based sustainability education is also shown through a partnership with the Polynesian Voyaging Society’s worldwide voyage of sailing canoes, Hokule‘a and

Hikianalia. This formal mainstreaming and recognition of the importance of knowing and learning about indigenous culture for *all* students is something which Hawai'i can be proud. It also can serve as a model for other states in which indigenous cultures are not addressed in the school system.

Hawaiian-language newspapers may be another tool: these newspapers allow teachers to include stories, historical observations and science into the classroom. Such newspapers can be attributed with some of the cultural, historical, and scientific record-keeping that support and help revive language, cultural, and traditional ecological knowledge. *Mo'olelo*, "repositories of ancestral wisdom," were among the history stories recorded in Hawaiian-language newspapers that were published from the 1830s until the mid 1900s. During that time over 100 newspapers were published (Wurdeman-Thurston and Kaomea 2015, p.429; Kahua A'o 2011). Before missionaries helping Hawaiians develop a written language, *mo'olelo* were part of the oral traditions that told the history of the Hawaiian people and significant natural events, such as lava flows, tsunamis and storms. Hawaiian-language newspapers contain those *mo'olelo* as well as traditional ecological knowledge (TEK) that, if recognized in a formal education setting (such as Kahua A'o Curriculum Project), could help empower Hawaiian students' identities to include that of scientist.

## 14.4 Hawaiian Science

Being so remote from major land masses, the Hawaiian Islands have quite a story to tell. They are home to active volcanoes and have the greatest percentage of endemic species on Earth. Many of these endemic organisms are derived from single ancestral species that arrived by wind, or by wings or waves and currents. As a result of much endemism, the Hawaiian Islands have, sadly, become the extinction capital of the world, as well. Citizen science projects enable educators to teach ecology and incorporate local examples of adaptive radiation, symbiosis, and invasion biology using concrete local examples, within the comfort zones of most science teachers and scientists. Further, citizen science projects allow students to gain experiences in potential career pathways and engage with scientists in the fields they may be interested in pursuing. Students often get the chance to work with rare, threatened or endangered organisms that they might otherwise not be able to work with in a typical science class. For example, through collaboration with community partners, my students have been able to propagate and monitor rare and sometimes endangered plant species, and raise and collect growth data on caterpillars on an endangered native butterfly species. They also monitored plankton levels and diversity after a molasses spill that garnered national headlines, and determine the abundance of micoplastics in the near-shore urban environment, and use professional water quality monitoring equipment to monitor local streams, and collect data on freshwater diatoms and native and invasive fish and invertebrate animals in local streams. However, depending on the teacher and community partnerships available, different citizen science opportunities will present themselves, and teachers must determine the best way to use them as the foundation for their curricula.

Especially in Hawaiʻi, where access to native species is limited and most of the spaces schools occupy are dominated instead by invasive or naturalized species, students are often surprised to learn that the landscapes around their homes and at school contain few to no native species. The islands are home to very few large native animals, and certainly very few charismatic megafauna: the latter are limited to sea animals, such as the Hawaiian Monk Seal. In fact, many native animals are rare, endangered, or extinct, making it difficult for teachers to provide firsthand experiences with native animal species. Instead, Hawaiʻi has a collection of what could be termed charismatic "microfauna," like the Oʻahu Tree Snails and the Happy Face Spider.

Yet, the natural history and physical landscape are filled with animal (including human) representations whose stories pass down the cultural and natural history of the islands (c.f. Aranda 2008). An example of how science and *moʻolelo* are intertwined is shown in Donald Swanson's (2008) description of the travels of Pele and her sister Hiʻiaka, as told in *The Epic Tale of Hiʻiakaikapoliopele*. Swanson shows how the story matches the two largest volcanic events since human settlement of the Hawaiian Islands: the timelines for these events are remarkably similar. The tale details Pele's migration to Kīlauea and her sister's journey to reunite Pele with her lover, Lohiau. Not only does the *moʻolelo* relay information about Hawaiian cultural practices and society, it gives insight into the volcanic history of the islands. In particular, the destruction of Hiʻiaka's ʻōhiʻa forest on Hawaiʻi Island that could be seen from Oʻahu was referencing the ʻAilāʻau flow, a large lava flow event that covered most of Kīlauea north of the east rift zone that was believed to have lasted 60 years. Swanson also suggests interpreting Hiʻiaka's digging for Lohiau's body and "flying" rocks as the initial formation of Kīlauea's caldeira.

In Hawaiʻi, animals can take the form of biotic and abiotic features in *moʻolelo*. Prominent animals in Hawaiian legends include *manō* (sharks), *moʻo* (lizards), and *manu* (birds). Kāneana (lit. Kāne's cave), an old sea cave on the west side of Oʻahu, was carved by waves when the sea level was higher. This cave is said to have been where Pele first emerged on Oʻahu from Kauaʻi via undersea lava tube**.** Geologically speaking, this cave coincides with the rift zone of the original shield volcano and where eruptions actively occurred before mass wasting of part of the Waiʻanae range (Clark 2002). The cave was also home to Nanaue, born half-man and half-shark from the shark god Kamohoaliʻi, who preyed on humans and took them to the cave to eat them (Sterling and Summers 1978).

All of us are surrounded by storied places, celebrated places, places that names and legends tell histories, both pre- and post-modern or Western contact. We all come from and connect to places because of personal place-based connections. It is through *moʻolelo* that science can be communicated to "non-experts" (e.g., students) to interest and engage them in science (Dahlstrom 2014). *Moʻolelo* have been used by teachers in many subject areas to engage students, although less frequently in secondary science classes. Integrating storytelling or narratives in science is a relatively new activity in western science, as it walks the socioscientific line and the traditional idea that science does not necessitate a story. Further, it may even be considered biased or unethical to incorporate "the other" perspective that deviates from the objective scientist self. That "self" is stereotypically built on a white, western, Christian, male perspective (Carlone 2003; Young 1997).

Schools are typically comprised by a western worldview in content and pedagogy, but a different model for the nature of science recognizes "science as culturally determined but retaining objectivity, is needed to make science more inclusive (Vira 1997, p.32). While other states might be slowly coming around to recognizing and the including *mo'olelo* and TEK of indigenous cultures into what have historically been typical western science classes, the *mo'olelo* may be more difficult to uncover in places that have been more westernized or oppressed longer than others. Further, the use of storytelling may face more resistance in places where westerners have resisted reviving or incorporating indigenous culture(s) into the education system and communities.

### *14.4.1 Citizen Science Projects*

Citizen science projects are inherently value-laden. Community partners that help teachers engage their students in citizen science projects (such as watershed restoration projects, invasive species removal) vie for funding too, and must justify that the work they do is worth the money their funders provide. They must get teachers, students, and volunteers to believe that the work is worth the time, effort, and sweat it costs.

Researchers or community partners doing native species restoration projects need to show their funders that the projects are "successful," which translates to clear deliverables, metrics, and tangible stories of success. Students need to buy in to the projects presented by teachers, or they are unlikely to be productive in the fieldwork or make the connections between science and their personal lives. Researchers, too, must justify to themselves that their life's work is not in vain, and that working to protect endangered species is worth the commitment of time and resources. By participating in citizen science projects, students can develop personal connections and find relevance in the science they learn in the classroom. In Hawai'i, such projects also tend to be culturally-centered, working to ground students in place and Hawaiian culture.

Citizen science projects should require students to take action. Students must understand, determine the worth of, and justify their actions on both personal and cultural levels. Such introspection likely would not otherwise be covered in a science class limited to only "objectivity" but it is necessary in order to reconnect students to the natural environment. Without a psychological investment in a place, we cannot expect changes in behavior towards Earth's sustainability.

## 14.5 Making Connections

Students need to feel a connection to what they are learning in order to for them to take action for the benefit of the environment. Citizen science projects that incorporate local species, culture, and language enable students to develop a connection, regardless of their personal cultural backgrounds. The future is promising when students reflect about their experiences participating in citizen science ecological restoration projects and make comments like *"The experience was insightful and liberating"* or *"The land is your grandmother and she loves you"* or *"This is a place I know to come someday to think about things."*

This may seem fluffy to those who operate exclusively in the objective, western zone of science. I do not want my passion for science education to be misconstrued. I love enabling students to participate in research projects, science fairs, and poster sessions at national and international conferences – these activities, too, can help them become successful in a western-dominated science world. However, students can and should be "multilingual" in science. Students' hidden cultural literacies often enhance their learning experiences and "serve as springboards to *authentic academic* and *transformative* literacies" (Perry 2006, p. 330). Further, multilingualism may promote higher levels of achievement in western science, as it does in multilingual language arts classes (Goldenberg 2008). Finally, representing students' home and indigenous cultures and languages in formal science education protects them against feelings of discouragement and alienation. Negative feelings contribute to poor performance in school, as students may feel they cannot relate to the content in science (Menken and Kleyn 2010).

Incorporating multiple literacies into citizen science projects can make learning more meaningful. When students interact with the environment in a more intimate manner, they will hopefully take actions to keep native Hawaiian species alive, rather than just through *mo'olelo* and textbooks. Citizen science projects help students develop a vested interest in place, to *mālama honua*.

Where connections were made
The shared sense of pride was unplanned
At the place of the newly revived land

Where peace, respect, and love flow
And fill our bodies, our souls
To realize that your loved ones are by your side, working hard
Where the land is your grandmother
We care for her and she hugs you back

Where inspiration is born,
People's spirits are no longer torn,
A place where love will always be,
One of the greatest of all Hawai'i.

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# Chapter 15
# Care-Based Citizen Science: Nurturing an Ethic of Care to Support the Preservation of Biodiversity

**Renée Lyons, Cassie F. Quigley, and Michelle Cook**

## 15.1 Conservation and Ecojustice

Many significant issues surround the topic of animal care and preservation. The Endangered Species Act of 1973 recognizes human-induced environmental changes are causing plant and animal species extinctions at rates far higher than rates of natural speciation (Goble et al. 2006). Human activities such as agricultural intensification, oil and gas exploration, commercial development and urban sprawl are destroying natural habitats (Norton 1986). Industrialization of agriculture and intense selection pressure on characteristics within species have greatly reduced the genetic diversity of animals, and more and more domestic breeds now face extinction (Pizzi et al. 2013). Pollutants such as pesticides, fertilizers, light, and pet waste (Lee et al. 2008) negatively affect biodiversity and contribute to habitat loss for many species. Further, human activities such as the unsustainable use of animals (Trathan et al. 2015), or which introduce invasive species into new habitats (Gibbons et al. 2000), or which increase emissions of refrigerants, methane or $CO_2$, also affect biodiversity (Pachauri and Reisinger 2007). In order to sustain life, humans must preserve biodiversity (Bowers 2001). As science educators, we have the unique opportunity to raise student awareness of conservation issues and to show students that they have a "significant role to play in shaping the prospects of the future and present community" (Mueller and Tippins 2012, p. 11).

*Ecojustice* is the "condition or principle of being just or equitable with respect to ecological sustainability and protection of the environment, as well as social and

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economic issues" (n.d. Oxford English Dictionary). Ecojustice recognizes that preserving biodiversity is a complex issue with many conflicting interests and politics (Seebacher and Franklin 2012). It involves questions of when to intervene in an environment and when to leave things alone (c.f., Sterba 2001). As science educators, we teach our students the political and social complexity of conservation efforts and hope they develop a cognitive understanding of the importance of protecting biodiversity (Hungerford et al. 1980). We also hope to nurture "wide-reaching community and environmental responsibility" (Mueller and Pickering 2010, p. 151). Ecojustice pedagogy hopes to inspire students to act and support the integrity of living beings (Mueller 2009). Producing environmentally literate students and advocates for life requires more than a cognitive understanding of issues. Rather, it requires a cognitive and affective understanding, learning which supports students emotionally connecting with the environment (Holt 2002). As Rita Turner (2015) notes, "To teach for ecojustice is to demand that students look courageously at the world, think deeply about the forces that have created things as they are, and creatively re-envision what their world can be in the future" (p.xix).

Here, we continue conversations on pedagogy specific for ecojustice--citizen science projects. We believe citizen science can provide students with opportunities to care for and influence the well-being of living organisms in their local communities and beyond, yet caution educators that not all citizen science projects support ecojustice. We argue that citizen science projects supporting ecojustice will be care-based citizen science projects. Our work adds to the current body of literature by defining what care-based citizen science is and by discussing how care-based citizen science projects can be used to develop an ethical care. We conclude by introducing four vital elements to teaching under an ethic of care, and we provide the reader with specific examples of care-based citizen science projects.

## 15.2 Citizen Science

Rick Bonney of the Cornell Lab of Ornithology originally introduced the term citizen science. Most often the term refers to a collaborative research effort between scientists and members of the public, focused on an authentic scientific problem. A citizen science project asks individuals with little to no formal science training to collect data for scientists (Bonney et al. 2009). Citizen science projects often involve monitoring natural resources and local species (Bonter and Cooper 2012). The citizens' volunteer efforts are especially valuable because the monitoring process is expensive and time consuming for scientists to do alone ( Dickinson et al. 2010). The data collected by citizens can help scientist understand species distributions (Cronje et al. 2011), evaluate the effects of invasive species on local species populations (Delaney et al. 2008) and characterize how changes in ecosystems structure and function affect species (Miller-Rushing et al. 2012). Scientists can use data collected by citizen scientists to inform states' endangered species consultation process (Havens et al. 2012), create species distribution maps (McCaffrey 2005), inform public health initiatives (Wing et al. 2008), establish more accurate maps of the breeding ranges of bird species, and formulate guidelines for land management and habitat preservation (Cohn 2008).

Teachers can use citizen science projects as a pedagogy for ecojustice, but Bonney et al. (2009) note significant efforts may be required to design citizen science projects that have both scientific and educational goals. As a result of this challenge, some citizen science projects tend to focus on data collection and others tend to focus on educational aims. Despite the unique goals of each citizen science project, "The broad aim of any citizen science program is to promote learners' scientific and ecological literacy (Karrow and Fazio, p. 81). Bowers (2002) explains that a key strategy for implementing ecojustice pedagogy is making science accessible to all. Britton and Tippins (2015, p.211) agree, stating "Citizen science can be used as a "pedagogical approach consistent with justice, which results, by its very nature, in aims for democratizing science education."

Before making decisions about sustainability and environmental protection, students need a basic cognitive understanding of conservation issues. Before a person decides to adopt sustainability practices, they need an understanding of the impacts of urbanization and issues surrounding biodiversity preservation (Devictor et al. 2010). Citizen science projects allow participants to become producers of environmental information, not just consumers of it (Becker et al. 2013). Thus citizen science projects can increase student awareness of local environmental issues (Bonney et al. 2009). Citizen science provides an infrastructure for conservation efforts. Well-designed projects can become powerful tools when the people involved in data collection are the people whose actions can also cause change (Dickinson et al. 2012). The actions of local residents can drive preservation of residential lands and local habitats (Cooper et al. 2007). Citizen science projects can be built upon the idea of a "participatory democracy" with the goal of demonstrating to participants the impact humans have on the environment. This strategy provides the project participants opportunities to collect information and decide on a course of action to solve local issues (Mueller and Tippins 2012, p.2).

Although citizen science projects can be used as a pedagogy for ecojustice, how educational experiences engage students is vital: the experiences can have lasting effects on how students relate to the natural world as adults (Thayer-Bacon 2004). In evaluating NatureWatch citizen science programs, "Educating-Within-Place: Care, Citizen Science, and Ecojustice," Doug Karrow and Xavier Fazio (2010) caution that not all citizen science projects are suitable for teaching students about ecojustice. The usefulness of projects for this purpose depends on the nature of student involvement. Karrow and Fazio advocate strongly for designing projects that support students in establishing relationships *with* animals and local environments: simply securing data *about* animals in their environment is not sufficient. Karrow and Fazio build their work upon a relational approach to education similar to Barbara Thayer-Bacon (2004), who advises that educational experiences should provide opportunities to become aware of the context in which we live, while exploring the similarities and differences between ourselves and other living beings. We, along with our students, will benefit from these "chances for us to critique and change ourselves (p. 177).” Karrow and Fazio recommend allowing students time and opportunity to engage with animals in ways other than mere observations. For example, having students describe the animal from their own point of view, or reporting their own personal experience with the animal, can help nurture care and respect for the animals involved in the scientific study. The focus of citizen science for ecojustice shifts away from learning about animals or the environment as objects to be studied and instead approaches scientific knowledge as a “kind of concernful dealing with the world” (Karrow and Fazio 2010, p. 209).

## 15.3 Conceptualizing Care

This chapter continues the conversation started by Karrow and Fazio (2010) by exploring in greater detail how citizen science projects can be projects for ecojustice, projects we describe as “care-based citizen science”. Karrow and Fazio (2010) argue that when teachers give students opportunities to discover meaning behind “being in the world”(p. 205), care naturally results. The primordial care described in their work results in students giving attention to, emotionally connecting with and gaining a more personal knowledge of animal life. Karrow and Fazio suggest that care is an existential of human existence, and that primordial care leads humans to naturally deal with “other entities with concern and familiarity” (p. 209). When given opportunities to “be in the world” (p. 205) students will naturally demonstrate care towards animal life, by paying attention to the animal and showing concern for their fate. As an illustration of the type of care nurtured through “being in the world” Karrow and Fazio offer the example of students “gently touching their worms, rehydrating them as they dry in the air, re-placing them in their home and covering the soil carefully upon them, or acquiring empathetic understandings about their precarious fates” (p. 210). When students experience the mystery, joy, wonder, and awe of discovering the meanings of animal life, they “forge a relationship” with them and care for them (p. 209).

Yet this term “relationship” is ambiguous. Barbara Thayer-Bacon (2004) explains taking relation to life can refer to “existential connections” or “a dynamic and functional interaction” (p. 165). John Fien (2003) warns that talking about relationships and care in vague terms will not solve environmental problems. With this in mind, we want to be clear about the type of “care” guiding care-based citizen science projects. There are two meanings to the word “care,” the distinction of which is of great importance to our work. The first definition relates to the type of care Karrow and Fazio (2010) seem to be describing and is defined as “ serious attention” or consideration given to someone or something (Cambridge online dictionary n.d.). Care-based citizen science involves the second definition of care: the provision of what is necessary for the health, welfare, maintenance, and protection of someone or something (Cambridge online dictionary n.d.). Notice the necessity for action in this second definition of care. Working to preserve biodiversity involves the decisions to act and accept the responsibility to actively care for the earth (Mueller 2009).

We extend Karrow and Fazio's work by arguing the primordial care they describe is only the starting point for the type of care necessary to motivate actions for social and environmental responsibility. Before educators ask students to get involved and take action toward sustaining life, teachers must cultivate within their students an *ethic of care* for life (Sobel 1996). Pedagogy for ecojustice involves stewardship; it goes beyond recognizing the importance of protecting living systems: it requires students to "examine and respond to what degrades them" (Lowenstein et al. 2010, p. 102). Citizen science projects need to nurture a consciousness of place and connection to local ecosystems and animal life, but this is only the starting point for transforming beliefs and behaviors necessary for ecojustice. As Anna Peterson (2009, p. 97) explains "Our choice is not about whether to be connected but about what to do with those connections, how to acknowledge and interpret them."

In the following section, we turn to the ethical realm to begin building upon Karrow and Fazio's work. There, we suggest care-based citizen science must nurture a type of care that moves beyond the human foundational capacity to care and to an ethical care—care that involves action and thus choice. We introduce the philosophy of Nel Noddings and explain how her conceptualization of care distinguishes between the primordial care (described by Karrow and Fazio) and the ethical care informing care-based citizen science. We then outline specific recommendations for nurturing an ethic of care and conclude by showing how care-based citizen science projects use the four vital elements for teaching to support an ethic of care (Noddings 2013).

## 15.4 Nodding's Ethic of Care

Pedagogy for ecojustice establishes within youths the "knowledge, skills and capacities needed to be ecologically and socially responsible community builders (Reis, Ng-A-Fook and Glithero, p. 40). With values involved in decisions about environmentally responsible behavior, the ethical realm can help guide teachers to structure learning activities that will teach students stewardship of the earth. Nel Noddings (2002) believes educators are misguided when they put all their efforts into teaching content knowledge and neglect devotion towards nurturing caring characteristics. Noddings urges educators to take a committed stance towards teaching children to care for other human beings, for animals, plants and the physical environment. In regards to environmental education she notes "We should encourage a way of caring for animals, plants, and the environment that is consistent with caring for humans" (Noddings 1995, p. 368).

According to Noddings (2013, p. 709), "love and goodness found in the warmest and best human relations" generate any standard of right or wrong. Noddings (1988, p. 219) explains that humans exist in relation to other beings, including other humans, other animal species and the environment. We behave ethically when we work to “preserve or convert a given relation into a caring relation.” A person must decide whether to take action to preserve a relation or to avoid the action that would preserve the relation. Acting in care involves treating the other being with respect and working to support their growth. As Noddings (2013, p. 711) notes, “Everything depends, then, upon the will to be good, to remain in caring relation to the other.”

Noddings (1988, p. 219) also defines acting in care. According to Noddings, caring exists in different forms, with “natural caring” on one end of the continuum and “ethical caring” on the other. Natural care is innate and unconscious. Natural care doesn’t require extra effort; it occurs when a person cares because they want to care (i.e., the motive is personal enjoyment). For example, in the science classroom, students naturally care for certain things, and they therefore tend to dedicate more time and effort to those things. By way of example, consider a science teacher who has a pet rabbit in the classroom. Many students will naturally take an interest in the cute, furry rabbit and may volunteer to feed or bathe it. These students naturally care about the rabbit, and they are willing to expend time and energy taking care of the rabbit because they get personal pleasure and enjoyment from interacting with the rabbit.

Ethical care is on the other end of the care spectrum. Ethical care involves obligation; it involves caring even when the “I want” may not be present. Ethical care results in the commitment to act on behalf of the one being cared for. The feeling of obligation comes from a respect for the worth of the other and a responsibility to protect the other (Noddings 2012). Ethical care occurs when a student may not naturally want to give their time or efforts to care for something or someone in need, but they choose to do so anyway. As an example of ethical care, consider a child dedicating their Saturday afternoon to help cleanup a local park, rather than sitting at the pool with their friends. Noddings explains that in order for a person to have the emotional commitment to care for the environment and work towards enhancing the well-being of it, they need to be guided by an ethic of care (Noddings 1995). Noddings’ description of ethical care aligns well with the type of care necessary for ecojustice. Recall that pedagogy for ecojustice hopes to educate students for “responsibility and activism” (Mueller 2009, p. 1050). Ecojustice also inspires a care that acts and supports the integrity of living beings. When students develop an ethical care for another, they feel an obligation to take actions necessary to support the growth of the one cared for (Noddings 2002). An ethic of care is not a set of principles to be learned. Rather, an ethic of care guides students towards a relationally constructed, ethical life (Noddings 1995). Based on Nodding’s philosophy, the question we hope to answer in this chapter is, how can citizen science projects for ecojustice, through care-based citizen science, nurture an ethic of care in students? In the next section, we explore Noddings’ recommendations for nurturing an ethical care and explain how care-based citizen science projects use these recommendations.

## 15.5 Taking Relation: Situating Karrow and Fazio's Work in an Ethic of Care

An ethic of care is not simple. It does not consist of a set of rules to follow, because each relation is context bound and the particular needs to preserve a relation differ, depending on the specific situation. Noddings explains a person's obligation to take action and support the growth of another, depends upon the extent to which the person is able to establish relation to the other being (Noddings 2013). Humans care for things they relate to. For this reason, pedagogy emphasizing the interconnectedness between humans and other living organisms can foster empathetic understandings of living creatures (Littledyke 2008). To nurture an ethic of care, teachers should encourage students to explore and understand the context in which all living organisms exist and interact. As Michael Mueller (2009, p. 1053) explains, "Conceptualizing how individuals, communities, and environments work together as relational parts of the whole, teachers and youth will see themselves as producers of knowledge, which is a shift towards valuing the contexts that sustain all our existences."

Care-based citizen science projects begin with students taking relation and experiencing the awe, wonder, and sense of place described by Karrow and Fazio. The natural concern resulting from these interactions has the potential to grow an ethical care. When students encounter species living around them, they can better connect and relate to the species and their habitats. As a result of these connections, students become concerned about the wellbeing of these species (Willem Postma and Smeyers 2012). Childhood experiences in nature affect a person's concern and willingness to help preserve the environment (Chawla 1999). Direct experiences with animal life, because they nurture a deeper emotional learning, can more strongly influence a person's behavior, compared to indirect experiences, in which students solely learn *about* life. Care-based citizen science projects give students experience and personal encounters with living creatures and environmental issues, nurturing an emotional connection with the environment. Thus rather than teaching students *about* the animal as an object to be studied or described, the direct experience of care-based citizen science provides opportunities for students to develop a relationship *with* animal life around them. As humans experience animals and ecosystems in non-technical ways, care becomes a natural byproduct of this connection, and relationships are developed. But what next? How can this natural care be nurtured to lead our students to ethically care for life?

## 15.6 Recommendations for Nurturing an Ethical Care

Thought, planning, and purpose drive curricula that support the adoption of an ethic of care (Fien 1997). We propose care-based scientific work can accomplish this objective. We define care-based scientific work as "developing of critical

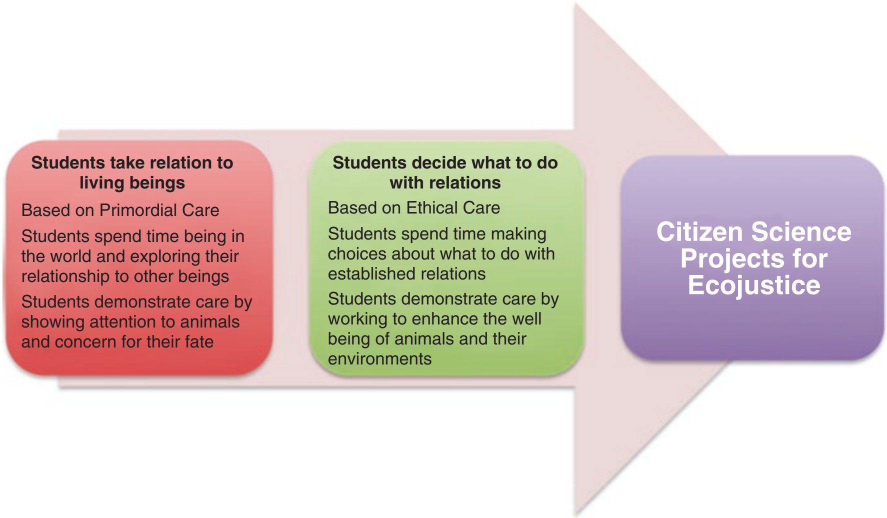


**Fig. 15.1** The formation of an ethic of care. This figure illustrates how the ethical care, which informs citizen science projects for ecojustice, grows from primordial care

environmental consciousness based on the evidence garnered duringscientific investigations focused on care" (Quigley and Lyons 2015, p. 8). Education for ecojustice cultivates relationships with the life that sustains humans (Kulnieks et al. 2014). Care based scientific work establishes an infrastructure for cultivating those relationships and nurtures the growth of those relationships into ethical caring relations. As Fig. 15.1 shows, the type of care informing care based citizen science starts with the primordial care described by Karrow and Fazio. An ethic of care is the foundation for care-based citizen science. Students spend time exploring animal life in non-technical ways in order to establish a relation to life, but they are also given opportunities to make decisions about what to do with those relationships.

An ethic of care is not superior to natural care; rather an ethic of care grows from a natural care. According to Noddings (2013), teachers can nurture an ethical care by basing educational activities in things children already naturally care for and are interested in. A person's care grows based on the value they place on the caring relation (Noddings 2013). Accordingly, care-based citizen science projects begin with something students naturally care for and give students opportunities to work to preserve those caring relations. Care-based citizen science does not attempt to teach students what to care about. Rather these projects start with issues students already care about and guide them to see how what they care about is connected to the environment and their own and others' actions. One way projects can do this is by framing project activities around animal life and giving kids contact with animals in their community and abroad. Environmental projects such as citizen science likely sustain students' interest because they capitalize on children's natural eagerness to learn about living creatures (Alexander and Russo 2010). Meaningful experiences children have with animals increase children's natural affinity towards animals (Wandersee and Schussler 1999) and attune them to conservation issues surrounding animals (Greaves et al. 1993).

An ethic of care focuses on relationships, and we judge our actions based on the reactions of the other. Noddings explains another way to nurture ethical care is to provide opportunities for students to see a response in the one they are caring for. Noddings explains a person's obligation to care grows if a person is able to see a response from the one being cared for (Noddings 2013). Noddings warns that with animals and nature we may refuse relation if there is no possibility of reciprocity (Noddings 2013). If there is no possibility for students to see a response, then they may feel an initial "I ought to act" but their motivation will wane if they believe there is little they can do. For this reason Noddings believes issues impacting a student's own backyard will have greater value and warns that TV programs about global issues, with which students have no direct experience, are not as effective to developing an ethic of care (Noddings 1995). Citizen science projects focusing on local issues, in which students directly contact animal species, may make it easier for students to see a response to their caring. Such projects then, are ideal for care based citizen science. When projects focus on issues located in a student's own community, students can see the impact of their actions (Willem Postma and Smeyers 2012). But care-based citizen science is not limited to local projects. In an ethic of care "the growth of those cared for is a matter of central importance"(Noddings 1995, p. 219). Later in this chapter, in our discussion of virtual care-based citizen science, we will demonstrate that students can establish relation and perceive growth in the one cared for even when an environmental issue is not local. The key component to nurturing an ethical care is to provide students opportunities to perceive a response to their care (Martin 2007), and we will show how science educators can help their students feel responses to their caring, even if they are caring from afar.

## 15.7 Designing Care-Based Citizen Science

Care-based citizen science is intentionally designed. As Fien (1997) notes, teachers need to pro-actively plan experiences to promote an ethic of care. Here we provide six examples to illustrate how citizen science projects can incorporate the four elements needed to support an ethic of care in students: modeling, dialogue, practice and confirmation. Although many of these projects are framed around animal life, we also include two projects, which are not tied to a specific animal, but are rather focused on broader environmental issues.

### 15.7.1 Modeling

It is important to model what caring for species and habitats looks like. When students encounter situations in which the "I want" to act is not naturally there, having seen how others have demonstrated care for animals and their habitats can increase the students' felt obligation to care and to act. This modeling is important because ethical care can develop by watching others exhibit care (Noddings 2013). Care-based citizen science projects present opportunities for students to work alongside scientists who are acting to preserve biodiversity (Littledyke 2008).

In our review of citizen science projects, we found many projects fall short on modeling from a care-based perspective. The Chicago Area Pollinator Study (CAPS), a citizen science project, serves as an example. CAPS asks citizens to collect data on urban bee diversity and abundance. Citizen scientists helped scientists collect 1,146 bees representing 65 species. However, Caroline Druschke and Carrie Seltzer (2012) report that after being involved in the project, participants did not demonstrate any change in attitudes towards bees or the environment. They conclude that citizen science projects may focus too much on data collection, and too little on how scientists become "ambassadors for the scientific community" (p. 184). Druschke and Seltzer recommend citizen science projects should include time for scientists to work alongside citizens and plan project events focused on the citizens' questions and understandings of environmental processes.

We offer here a citizen-science project that used modeling to nurture an ethical care in project participants. Peter Dohrenwend (2012) involved his middle school science class in The International Pellet Watch, a citizen science project in which citizens monitored local beaches for plastic resin pellets. The project involved a local scientist, and Dohrenwend attributes the huge impact of the project on his students' attitudes towards the environment, to the scientist who modeled passion for preserving aquatic environments. Before asking students to participate in the data collection, the scientist spoke to Dohrenwend's class, making students aware of the environmental problems of plastic pollution in marine environments and telling them about the work he was doing to conserve the environments of marine species. Dohrenwend found nurturing positive relationships between the scientist and the students helped motivate his students to collect the project data. The passion of the scientists and his care for marine environments motivated students to perform "hard" work on their local beaches—using tweezers students spent the afternoon picking up tiny plastic pellets from the sand. The experience in the end changed the way these students viewed local marine environments (p. 52). This example shows how modeling care for the environment can inspire and nurture others to care, as well (Palmer and Suggate 1996).

### *15.7.2 Dialogue*

Critical thinking and reflection are key to developing an ethic of care, because each caring relation is context bound, so actions needed to preserve the caring relation are also context dependent. Teachers can use open dialogue with their students to encourage students to consider the best way to preserve the caring relations in their lives (Noddings 2006). In an open dialogue, the teacher does not hold the conclusions: rather, teacher and students together explore what the responsible and ethical choice may be, constructing a fuller understanding of issues (Noddings 1995). Care-based citizen science projects provide some ambiguity, which allows students to explore the issues. In addition, care-based citizen science projects promote conversations that challenge students to reflect and critically apply the values they learned in order to make decisions about what actions they "ought" to take. Open discussions and explorations will help students develop a critical environmental consciousness (Fien 1997). Ecojustice recognizes the complexity of preserving biodiversity and engages students in conversations about how humans can be respectful of the Earth's other species and how to decide what "right relationships" are (Jickling and Wals 2008, p. 18). Similarly, citizen science projects can be "a good route to integrate public views and values concerning what conservation actions should be taken, why and how" (Devictor et al. 2010, p.355).

Care-based pedagogical approaches can be somewhat contentious. Edward Johnson and Michael Mappin (2005) warn that teaching students to care involves values and conclusions about what ought to be done. Likewise, Bob Jickling (2003) advises educators to remove elements of care from their teaching. In contrast, we agree with Fien (1997)'s conclusion: values in education cannot be avoided. Thus, rather than attempt to remove values, we recommend carefully considering them in the context of care-based scientific work. We take what Elizabeth Venter and Jonathan Ferreira (2014) describe as a committed value stance, teaching our students an ethic of care based on the values of social and ecological justice. In an effort to avoid indoctrination, we apply the advice of John Newfield and Virginia McEylea (1984) and promote the values in an ethic of care but let students critically examine evidence and decide what attitudes and actions they determine are right relations.

We offer here a citizen-science project that used dialogue to nurture an ethical care in project participants: Turtle Conservation and Citizen Science. Susan Summers (2012) reports on this citizen science project, led by the Virginia Living Museum. In this project, middle school students' investigated the effects of an invasive turtle species on native species. Scientists, along with student groups of 15, "processed" turtles. Processing turtles involved trapping; identifying; measuring turtles plastron and carapace; and filing a small notch in each turtle's shell. This allowed the team to determine the relative abundance of invasive turtle species in local ponds. Participating in the project made students aware of problems that occur when pet owners release pets into the wild and sensitized them to the potential for the non-native species to introduce disease or take over ecosystems by outcompeting local species. The students learned about scientific inquiry skills, taxonomy, factors affecting population size, adaptations, morphological adaptations, and about survival of organisms as different populations interacting in biological communities. Participating in the project also opened conversations about the ethical treatment of turtles that were trapped. Science educators had discussions with students about proper handling procedures, safety for turtles, and respect for animals while working with them. Students also engaged in conversations about problems and concerns for wild turtles and issues of having pets and releasing them into the wild (Summers 2012). Participating in citizen science projects allows for discussion and speculation about data being collected. Science teachers can use such discussions to help students develop a critical environmental consciousness (Trautmann et al. 2012).

Care-based citizen science projects incorporate opportunities for science educators to engage students in the types of co-generative dialogue described by Kenneth Tobin and Wolff-Michael Roth (2005). Tobin and Roth explain co-generative dialogue repositions students to a more active role in conversations, helping strengthen students' beliefs in their own ability to affect change. Pedagogy for ecojustice engages teachers and students in open dialogue in which they co-generate knowledge (Turner 2015). Open dialogue hopes to guide students to be critical as they apply values, making decisions about what constitutes right actions to preserve caring relations (Fien 1997).

### *15.7.3 Practice*

An ethic of care is a way of living that must be practiced (Noddings 1995). Thus, care-based citizen science projects should provide students hands-on opportunities to be advocates for species and their habitats. Noddings (2013) advises educators should avoid presenting issues, such as conservation, as far away global issues that students may feel their actions have no impact on. Rather, care-based citizen science gives students specific tasks and actions in which students can practice ethically caring for environmental problems. In reviewing citizen science projects, we found two projects in particular that used practice to nurture an ethical care in project participants. The first of these projects is a citizen science project described by Anchana Thancharoen, Marc Branham and James Lloyd (2008), which involved students in firefly conservation. In this project, students collected data on firefly populations in their community, and science educators guided them in the construction of inexpensive light sensors to monitor the effect of light pollution on firefly numbers. The project invited students to monitor the quality of their own environment and learn first-hand about some effects of urbanization and pollution on firefly abundance and activity. Through a series of guided experiments with varying amounts of artificial lights, students observed the impacts these lights had on animal behavior. Students counted the number of flashing male fireflies that flew between two light sensors per minute. After several nights of recording and graphing firefly activity, students concluded artificial light negatively impacts firefly activity. The project ended with class discussions on what students believe should be done to help firefly populations and what, if any, actions should be taken to reduce light pollution. In this example, students practiced care by building sensors and setting up experiments to monitor the local firefly species. Students engaged in specific tasks and worked to determine the health of the one being cared for--the firefly.

Another example of care-based scientific work is a citizen science project called Communities, Cameras, and Conservation. In this project, 80 high school students, their instructors, and master naturalists installed and monitored self-trigger cameras on local hiking trails. Each week students hiked to change photo cards and batteries and searched through the hundreds of photos for evidence of mountain lions and other animals. By participating in the project, students learned about wildlife signs and identified potential travel corridors of mountain lions. After searching through 4, 763 photos with 20 mountain lion siting's, many students commented on how amazed they were at the types of wildlife walking across the same paths they hike and bike on. In this project students practiced care by spending hours of time and effort installing cameras and searching through photos to find evidence of wildlife for local park managers, which will be used to inform land-management decisions and preservation efforts. Participating in the project increased students' scientific interest of students and stimulated additional independent research projects. After participating, the students demonstrated a deeper understanding both for the scientific research process and the effects of urbanization on animal populations (Patterson 2012).

### *15.7.4 Confirmation*

As Noddings (1984, p. 193) explains, "In education, what we reveal to a student about himself as an ethical and intellectual being has the power to nurture the ethical ideal or to destroy it." Confirmation is the final element of care-based citizen science, and it highlights the importance of a student's identity in making decisions to participate in preservation efforts. Confirmation occurs when we give our students a picture of what the ideal image of themselves looks like, so they can see themselves as ethical persons dedicated to caring (Noddings 1995). Étienne Wenger (2003) presents identity in terms of engagement with a community of practice. There exists a community of people dedicated to ecojustice and working to preserve the earth's biodiversity. A student forms their ecojustice identity as they make sense of their position within or outside of this community. Wenger explains that a person can strongly identify with a community and see himself or herself as a full participant, or the person can dis-identify with a community and not participate at all. The narratives we give to students about themselves and their everyday experiences occupying certain roles can have a large impact on students' beliefs about roles being for them and their ability to make a difference (Giddens 1991). As Michael Mueller, Deborah Tippins and Lynn Bryan (2012, p. 2) explain, "At the core of science education, students' identities influence everything from how they view ecojustice issues to whether they offer agency and advocacy for affected parties of their choices." Care-based citizen science does more than encourage students to care for animals or for the environment: it allows students to see themselves being part of the effort to conserve nature and care for animals. Bronwyn Davies and Rom Harré (1990, p. 43) introduced the concept of "positionality," explaining that a person forms their identity with a community of practice based on the positions they see available for themselves within that community. When educators provide students opportunities to take an active role in the community of people working to preserve biodiversity, they reposition students as active participants in preservation efforts.

The citizen science project Creekwatch is an example of a care-based citizen science project using confirmation. Participants in Creekwatch help scientists monitor water quality and aquatic biota in local creeks. Using a mobile application, students participating in Creekwatch collect data on water level, water flow and trash sightings and take a photo of the creek. With each submission having a GPS location and timestamp, scientists have used data collected by citizens to determine water quality and identify creek reaches in need of trash clean up. Student participants become key players in a community-based effort to care and take action to preserve local aquatic ecosystems (Kim et al. 2011). Care based citizen science challenges students to sense their belonging in a world of creatures but also to sense their belonging in a community working to preserve these creatures and their environments.

A person's imagination, or how a person sees oneself fitting in a community will influence aspirations, directions and plans for future participation within that community (Wenger 2003). Being a part of a citizen science project often motivates students to seek other ways to care for animals and their habitats, inspiring students to take part in habitat improvement or conservation efforts (Fee and Trautmann 2012). Science educators with 5$^{th}$ grade students participating in Cornell's citizen science project, eBird, reported after participating in the project their students developed such a strong connection to birds, they began noticing and seeking out other ways to help local birds. Upon learning about an injured eagle in their area, students rallied together to raise money for an operation to put a pin in the eagle's broken wing (Fee and Trautmann 2012). Students became dedicated to the effort of caring for birds, and they educated others in their families and social circles about birds and bird habitat improvement projects. When students understand and practice care for each other and the environment they can discover their own personal environmental ethic.

## 15.8 Virtual Care-Based Citizen Science Projects

Science educators may not have the option of a local citizen science project. In such cases, they may be able to implement a virtual citizen science projects to nurture an ethic of care. The first question we address in this regard is, is a virtual experience with animal life sufficient for students to establish a relation with that animal? Recall Karrow and Fazio's description of direct experiences, which nurture an emotional connection with animals and their natural environments. Direct experiences provide opportunities for students to understand their relationship *with* animals rather than studying animals as objects to learn facts *about*. We propose virtual experiences can be direct experiences. The important distinction between direct and indirect experiences is the manner in which the child encounters life. For example, asking a child to watch a YouTube video of a tiger and challenging the student to consider the tiger's needs and relations it has to other living beings it encounters such as humans can do far more to nurture an ethic of care than a personal encounter in a zoo in which the child may not be challenged to consider such questions. A child can have a personal encounter with a creature but still be asked to learn *about* the tiger as an object to be studied. The key to establishing relation is allowing students to see animals in non-technical ways. Students need to encounter the world of the creature and discover their own relationship to that world (Karrow and Fazio 2010).

In order to consider if virtual citizen science projects allow students to perceive a response to their caring, we consider a virtual citizen science project by Zooniverse, the world's largest citizen science platform. We conclude by outlining how modeling, dialogue, practice and confirmation can be incorporated to nurture an ethic of care through participation in this project.

### *15.8.1 Citizen Science Project CondorWatch*

The California Condor (*Gymnogyps californianus*) is critically endangered and is now considered one of the rarest birds on Earth. Scientists are trying to understand mortality factors in these birds and are currently investigating human-induced challenges facing condors, such as lead poisoning. Participants in CondorWatch make observations of video footage taken by motion-activated cameras, record the tag numbers of condors, and make notes on what condors are eating and how they behave socially during the recording. The goal of CondorWatch is to help scientists understand if the eating behaviors and social behavior of condors provide evidence for lead poisoning. Recall Noddings' warning that if students do not perceive a response to their caring, their motivation may wane, and they may believe there is little they can do. We propose that in this virtual project and others, the response to the caring can come from the scientists of the citizen science projects. When project leaders give students small, doable tasks and show the students how these tasks are vital to the larger work of caring for these creatures, they are showing students exactly what they can do to care for the condor.

Students can see growth in the Condor when scientists communicate back to project participants; the scientists share results, photos, and study findings, all of which demonstrate that the caring efforts of students are valuable and are being used to help preserve the condors. Thus, an important aspect in care-based citizen science

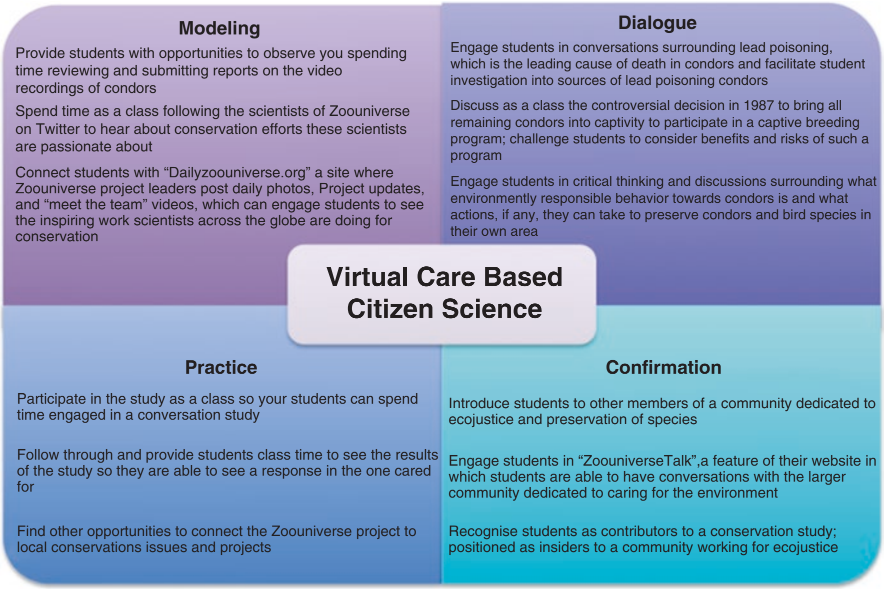


**Fig. 15.2** Supporting an ethical care through virtual citizen science projects. This figures illustrates how virtual citizen science projects can incorporate the modeling, dialogue, practice and confirmation, which promote an ethic of care in students

is sustained communication between the project participants and the scientists leading the project. Sustained communication allows participants to see growth in the project they are contributing to as well as to see the results of their efforts (Chu, Leonard, & Stevenson, 2012). With just over two hundred individual free-flying condors now living in Arizona, Utah, and Baja California (Kelly et al. 2015), it is unlikely the students will ever have the opportunity to observe these birds in person--but as shown in Fig. 15.2, with the guidance of science educators, virtual citizen science projects can incorporate the four elements vital for teaching to support an ethic of care in students, even when the animal is not in a student's local environment.

## 15.9 Conclusion

Environmental education seeks to develop within students a sense of relationship to the natural world and other living beings. It is this felt concern and affective knowledge that cultivates “life-long understandings, attitudes, and behaviors vital to restoring a healthy relationship with our Earth” (Karrow and Fazio 2010, p. 210). Producing students willing to be advocates for life will require more than a cognitive and relational understanding of issues. In this chapter we argue students need opportunities to make choices about what to do with those understandings. Using Noddings' (1995) vital elements for teaching under an ethic of care, we describe how care-based citizen science projects can be used to nurture an ethical care in students.

Educational experiences need to promote both cognitive and empathetic understandings in order to foster within students a responsibility to ethically care for our world (Littledyke 2008). Emotionally connecting to the environment and developing a respect and obligation to work towards its preservation establishes deep learning of issues (Goralnik et al. 2012). Teaching under an ethic of care nurtures relationships with animal life and fosters a deeper connection with other living beings and the environmental issues surrounding their preservation. We want to challenge our students to develop a sense of belonging and relatedness with the Earth, but we do not want to stop there. Our desire is to help students develop a critical environmental consciousness, so they can make informed and ethical decisions about how to best care for life. The goal of care-based citizen science is to guide students to a relationally constructed life in which they take relation to other beings and accept the commitment to ethically care to preserve them.

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# Chapter 16
# Mapping Conceptions of Wolf Hunting onto an Ecological Worldview Conceptual Framework—Hunting for a Worldview Theory

**Teresa J. Shume**

> *We reached the old wolf in time to watch a fierce green fire dying in her eyes. I realized then, and have known ever since, that there was something new to me in those eyes—something known only to her and to the mountain. I was young then, and full of trigger-itch; I thought that because fewer wolves meant more deer, that no wolves would mean hunters' paradise. But after seeing the green fire die, I sensed that neither the wolf nor the mountain agreed with such a view.*
>
> *(Aldo Leopold, A Sand County Almanac, 1949, p. 130)*

From the prehistoric wolf paintings in France's Font-de-Gaume cave, to enduring cultural symbols of indigenous tribes such as the Arikara, Obijwe, Haida, and Nez Perce, to the "Big Bad Wolf" archetype of fairytales, wolves have long served as cultural icons evoking strong emotional responses. In the lower 48 states of the United States, a 150-year campaign to shoot, trap, and poison wolves reduced their population numbers to near extinction. However, conservation efforts since the mid-1960s have fueled wolf population recovery. Notably, in 1995–1997, 41 gray wolves captured in Canada were released into the greater Yellowstone ecosystem. By 2014, there were 11 packs totaling 104 wolves living in Yellowstone National Park (Smith et al. 2015). Protection under the Endangered Species Act of 1973, first granted to gray wolves in 1974, has been the subject of protracted and heated legal battles since 2003. In 2009, Idaho and Montana implemented the first state-managed wolf hunting seasons after gray wolves were delisted from the Endangered Species Act; other states, including Wyoming, Minnesota, and Michigan, followed soon after

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(International Wolf Center [IWC] 2015). Legal disputes have continued. In December of 2014, for example, wolf hunts in Minnesota, Wisconsin, and Michigan were suspended when a federal judge restored wolves' Endangered Species status (McKinney and Kennedy 2014).

In Minnesota and other states, contentious questions stemming from the dilemma of whether to organize a wolf hunt have sparked spirited public debate. Have wolf populations recovered sufficiently to support a hunt? Should both hunting and trapping be included? How should harvest limits and other hunting regulations be determined? How might the elimination of an alpha male or female affect pack dynamics or impact behaviors such as depredation of livestock? How should farmers, ranchers, and other private landowners be compensated for depredation? What are the economic benefits of wolf hunting? How do economic benefits of wolf hunting compare to economic benefits of wolf-related ecotourism? How should indigenous cultural beliefs about wolves factor into local and state decision-making processes? What are some of the scientific, social, cultural, ethical, and economic dimensions of the wolf hunt dilemma, and how do they impact the key question: should there be a wolf hunt?

To study these and other thorny questions, my university biology students undertook a case study about wolf hunting (Wallace et al. 2014) that provided potent opportunities for students to reflect on their own views about wolves and to grapple with vexing questions arising at the interface of complex ecological and social systems. After a slide presentation to introduce background information and questions about wolf hunting, students engaged in a jigsaw instructional model. Through individual research, students identified a range of concerns commonly expressed by one of four community stakeholder groups: hunters and trappers, wildlife advocates, farmers and ranchers, or indigenous groups. Students who had researched like stakeholders then formed teams to discuss individual findings and plan a short presentation. Next, new teams of four were formed where each member gave a presentation about a different community stakeholder group. These mixed teams became "task forces" assigned to provide a recommendation about whether to continue, end, or modify wolf hunting in the state. After each task force presented justifications for its recommendation, the class debriefed from the experience. Last, students wrote (and sometimes mailed) individual letters expressing their personal views to a public official of their choice related to wolf management. Of note is that this was not a role-play activity where students assumed the identity of community stakeholders. Nor was it a class debate where students were assigned to argue for or against a certain position. Rather, students sought to explore a constellation of concerns commonly raised by various stances across each stakeholder group. This approach required students to avoid binary thinking and to grapple with reconciling their own emerging views with a wide variety of sometimes-conflicting perspectives.

My curiosity increased about factors that influence students' reasoning about wolf hunting and shape their perspectives on wolves. I wondered about connections between participation in the wolf hunt case study and students' ideas about human relationships with nature. Contributing to the development of this case study together with the experience of teaching it multiple times prompted me to ponder worldviews that underpin various orientations toward wolf hunting, to reflect on pertinent scholarly literature, and ultimately to construct the adapted ecological worldview conceptual framework that is introduced in this chapter.

## 16.1 Taxonomies of Socio-environmental Thought

Scholarly endeavors to model taxonomies of socio-environmental thought have yielded a variety of constructs that explore human relationships with the natural world. Chrisna Du Plessis (2008) proposes an integrated framework for understanding socio-environmental systems within an ecological paradigm. Her analysis of 40 research articles studying socio-environmental systems published in the journal *Ecology and Society* over a 10-year period generated four propositions that formed the basis for uniting three existing frameworks into a single, integrated construct that encompasses matter, life, and mind. While her work discusses human relationships with nature, the ultimate goal of her framework is to proffer a sophisticated model for understanding socio-environmental systems rather than a model that explores how humans think and act towards nature.

Another notable taxonomy of socio-environmental thought can be found in the work of Julia Corbett (2006). She explores environmental beliefs systems and offers a spectrum of environmental ideologies. Corbett defines environmental ideology as "a way of thinking about the natural world that a person uses to justify actions towards it" (p.26). She situates five broad ideological positions on a spectrum from anthropocentrism to ecocentrism. Corbett's spectrum ranges from "Unrestrained

Instrumentalism," a view that posits nature exists solely to satiate human needs and wants, to "Transformative Ideologies," perspectives such as deep ecology, ecofeminism, and other ideologies that question dominant environmental ideals and call for social change. Corbett's spectrum aptly delineates values, beliefs, and power gradients that underpin human relationships with nature, but its scope does not explicitly classify epistemological and ontological components.

Another noteworthy taxonomy of socio-environmental thought originates from the field of sustainable agricultural education. As part of the Hawkesbury Critical Learning Systems model (Bawden 2000), Arjen Wals and Richard Bawden (2000) suggest a conceptual framework comprised of four "conceptual windows on the world" (p.12) that capture divergent interpretations of the meaning of sustainability within the context of agricultural food production. Each worldview is situated in a quadrant formed by the intersection of two axes, an ontological axis describing the nature of the natural world, and an epistemological axis describing how the nature of the natural world is known. Wals and Bawden's model elegantly elucidates epistemological and ontological elements of perspectives on sustainable food production, but does not explicitly address axiological value judgments. Additionally, the epistemological axis targets knowledge about conceptions of agricultural sustainability, a construct suitable for Wals and Bawden's educational purposes, but not congruent with dimensions of knowledge valued for decision-making about socio-environmental issues such as wolf hunting. Moreover, each "conceptual window" (p.12) aims to capture a separate worldview, but in practice I knew my students' worldviews contained elements that ranged across multiple epistemological and ontological positions.

## 16.2 An Adapted Ecological Worldview Conceptual Framework

With each iterative experience of implementing the wolf hunting case study with undergraduate biology students, my understanding of student thinking and my knowledge of community stakeholder groups' perspectives deepened. I came to recognize there were discernable patterns in the epistemological, ontological, and axiological components of various responses to wolf hunting and other complexsocio-environmental issues. I also realized that these patterns could scale up from wolf hunting to the broader construct of ecological worldview. Eventually, I sought to develop a corresponding taxonomy of socio-environmental thought that describes ecological worldviews.

The term, *worldview*, can evoke assorted meanings, but the definition that underpins the ecological worldview framework introduced in this chapter is borrowed from William Cobern, (1991, p.7): "Each person can be seen as having a fundamental, epistemological macrostructure which forms the basis for his or her view of reality. The more common term is world view." Cobern (p.19) goes on to explain,

> World view undergirds rationality. To be rational means to think and act with reason, or in other words to have an explanation or justification for thought and action. Such explanations

> and justifications ultimately rest upon one's presuppositions about the world. In other words, a world view inclines one to a particular way of thinking.

John Kok (1988, p. 19–20) distinguishes between *lived* worldviews, intuitive "world pictures" that shape our daily thoughts and actions regardless of our degree of consciousness about them, and *articulated* worldviews, "a more carefully examined and systematically formulated conceptual scheme" that is produced through processes that are "conscious, coherent, [and] unambiguous." Worldviews described in the present framework exist in a dialectical relationship between lived and articulated worldviews, and are anchored in ontological commitments about the nature of reality, epistemological commitments about the nature of knowledge, and axiological commitments that guide ethical or aesthetic value judgments.

The term *ecology* can refer to a branch of biological science that studies relationships between organisms and their environment. In this scientific sense, an ecological worldview that focuses on understanding the world on an organismal level can be distinguished from a biochemical worldview that focuses on understanding the world on a molecular level. The term *ecological*, however, can also be used metaphorically to characterize human relationships with nature, as in *ecological identity* (Thomashow 1996). For the purposes of the framework introduced in this chapter, the term *ecological* is used metaphorically to signify that an ecological worldview shapes and is shaped by our relationships with the earth.

This chapter presents a promising ecological worldview conceptual framework that can elucidate valuable aspects of ontological, epistemological, and axiological assumptions that underpin perspectives on wolf hunting and other thorny socio-environmental issues. The framework is adapted from Wals and Bawden's conceptual framework for worldviews related to sustainable agricultural food production (2000), part of the Hawkesbury Critical Learning Systems model (Bawden 2000). The framework's axiological component resonates with Corbett's (2006) definitions of anthropocentrism and biocentrism. Depicted in Fig. 16.1, the adapted framework includes four dimensions: egocentrism (Us vs. Nature), technocentrism (Us over Nature), ecocentrism (Us in Nature), and resiliocentrism (Us within Nature). These dimensions are situated within the context of three components: an ontological axis, ranging from reductionism to holism; an epistemological axis, ranging from pragmatism to idealism; and an axiological continuum, ranging from anthropocentrism to biocentrism. Each dimension resonates with a fundamentally different relationship between humans and nature, but all dimensions can be present in a single person's ecological worldview.

### *16.2.1 Ontological Axis*

The ontological axis distinguishes reductionism from holism and focuses on perceptions of nature as a system. Reductionist ontology represents a core belief that systems are essentially comprised of collections of parts. Inputs are constituents taken up by the system and outputs are products generated by the system. To

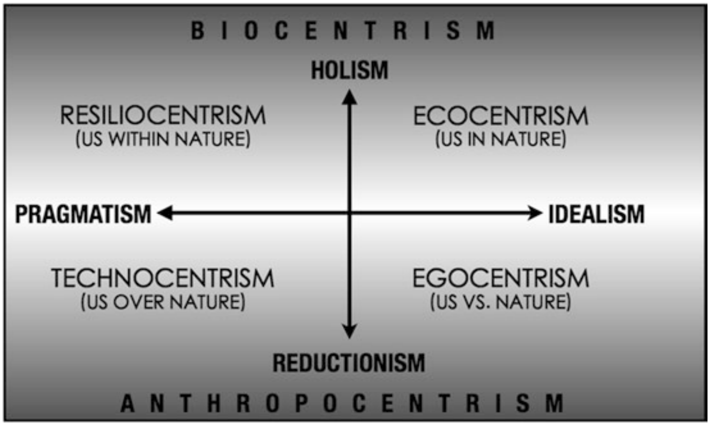


**Fig. 16.1** An ecological worldview conceptual framework

understand a system from this perspective, the parts should be isolated and studied individually. If an unanticipated output or property emerges from a system, a reductionist perspective concludes that the system has not yet been studied in sufficient detail. Uncertainty regarding the system's functions, then, can be resolved by parsing the system into still smaller parts for closer inspection. When a system is conceived as a collection of parts, it follows that a system's nature and behaviors can be known by reducing it to its constituent elements.

When applied to nature, perspectives grounded in a reductionist ontology view natural systems as a complicated collection of parts that works together to perform various functions such as water purification and soil production. Indeed, ecosystem goods and services on which humans depend such as forestry products and pollination are regarded as system outputs. Reductionist ontology is grounded in a core belief that nature functions essentially like a machine where inputs can be controlled and managed to optimize outputs.

In contrast, a holistic ontology is grounded in a belief that systems are not simply collections of parts, but rather whole entities from which emergent properties arise when parts interact (Meadows 2008). The essence of a holistic ontology can be captured by the well-known adage commonly attributed to Aristotle, "The whole is greater than the sum of its parts." Rather than focusing on the parts, this perspective focuses primarily on interactions between the parts. Perspectives anchored in holistic ontology also acknowledge the impact of scale, the notion that structural and temporal boundaries of systems can shift when sub-systems become nested within each other or when they form internal feedback loops. The output of one subsystem can become the input of another, as when a thermostat regulates room temperature (an output) by responding to room temperature (an input). Another important characteristic of systems grounded in a holistic ontology is the role of thresholds. Systems can usually exist in more than one stable state and may shift to a different stable state when certain thresholds are exceeded; these shifts may take place abruptly and sometimes cannot be reversed (Allen et al. 2014). When committed to an ontological view that focuses on dynamic interactions between parts, it follows that the system's nature and behaviors can only be known by studying the system holistically.

When viewed from a holistic perspective, nature is regarded as a complex adaptive system where myriad interactions within and between biotic and abiotic components result in a dynamic stability that is subject to disruption when certain thresholds are exceeded. For example, Brian Walker and David Salk (2006) explain that when spruce and fir forests are young, the density of needles on trees is low and predators such as birds and insects can easily locate and prey on the larvae of spruce budworms. As the forest matures, the needle density increases and it becomes harder for predators to locate their prey. Eventually, the efficiency of the predators drops below a certain threshold and the spruce budworm larva population breaks free from predator control. The result is an explosion of spruce budworms that consume so much tree foliage that the mature forest declines and returns to a new forest state. Nature is more than a collection of living and nonliving parts; natural ecosystems are rife with dynamic interactions occurring at several levels of scale simultaneously, and sometimes producing emergent outcomes that are difficult to foresee.

### *16.2.2 Epistemological Axis*

The epistemological axis of the framework distinguishes pragmatism from idealism and focuses on the nature of knowledge most highly valued for seeking solutions to controversial socio-environmental issues. Within the scope of the framework, pragmatist epistemology constitutes a conviction that the value of knowledge claims is most effectively evaluated based on success in practical application. Describing Dewey's philosophical pragmatism, Gert Biesta and Nicholas Burbules (2003 p.12) state,

> It is only when we actually do respond that we can know whether the suggested line of action was appropriate. While the use of symbols can make our decision making more intelligent, the ultimate proof is to be found in the field of action. We must act in order to find out whether a suggested response is indeed appropriate for the situation in which we are engaged.

Pragmatic epistemological stances reject the need to unveil and resolve the interface between the immaterial mind and the material world, and might even be described as "anti-epistemology" (Biesta and Burbules 2003, p. 10), because practical application is regarded as more valuable than any type of knowledge. At the pragmatic end of the conceptual framework's epistemological axis, knowledge claims are considered valid and legitimate based on ability to achieve intended outcomes in practical application.

When applied to problem-solving in the context of controversial socio-environmental issues, pragmatic epistemological stances are more likely to favor practical solutions supported by knowledge gained through application and experience. For example, a natural resource manager whose evaluation of socio-environmental knowledge claims is underpinned by a pragmatic epistemology is more likely to rely on quantitative data to justify practical outcomes such as optimized resource production or increased ecosystem resilience, rather than to rely on contemplation or reflection to justify outcomes such as preservation of beautiful vistas in natural places. When exploring potential solutions to controversial socio-environmental issues, many knotty questions center on the debate about what constitutes an "improvement" to any particular socio-environmental system. For example, pragmatic solutions anchored in ontologically reductive views of nature typically seek to maximize an ecosystem's outputs, whereas pragmatic solutions anchored in ontologically holistic views of nature usually aims to maximize an ecosystem's resilience. No matter the location on the ontological axis, however, perspectives grounded in a pragmatic epistemology invariably privilege knowledge claims that can be supported with evidence grounded in practical application of solutions to socio-environmental problems.

In contrast, idealist epistemology is grounded in the belief that knowledge claims are best evaluated on the extent to which they resonate with a particular vision for "how things should be" in the world, an ideal held in the mind's eye. Broadly, *Idealism* is a school of thought within the field of philosophy that is underpinned with a fundamental belief that reality and truth are immaterial, mental constructs (Maritain 2005). Similarly, idealist epistemological perspectives within the scope of the framework hold that a mentally constructed ideal rather than evidence from practical application should function as the principal evaluative criterion for identifying knowledge that is reasonable, credible and plausible.

When directed toward problem solving for controversial socio-environmental issues, idealist epistemological stances seek solutions that resonate with a particular mental construct of what is ideal given particular ontological conceptions of nature. Viewing nature reductively as a machine and viewing nature holistically as a superorganism (e.g., *The Gaia Hypothesis*; Lovelock 1987) represent contrasting commitments along the ontological axis, and thus will invariably resonate with different mental constructs of what constitutes appropriate responses and ideal solutions for socio-environmental issues. For example, a reductive ontological stance might underpin a belief that a certain forest should ideally be clear-cut to produce the maximum quantity of forest products possible, while a holistic ontological stance might underpin a belief that the forest in question should ideally be left to function in the wild with little to no human intervention. Regardless of the character of the "ideal" response to a controversial socio-environmental issue and the ontological conception of nature in which it is anchored, perspectives situated on the idealist side of the epistemological axis can be contrasted with ones on the pragmatic side. A mental construct of some type is held as an ideal for the purpose of evaluating the validity and legitimacy of knowledge claims, rather than evidence gleaned from practical application.

### 16.2.3 Axiological Continuum

The axiological continuum distinguishes between contrasting value judgments about nature's ethical and aesthetic worth. The range from anthropocentrism to biocentrism resonates with the endpoints of Corbett's (2006) spectrum of environmental ideologies. Anthropocentrism is a human-centered orientation toward nature that regards humans as separate and superior to non-human life. Corbett (2006) writes, "If a shape represented anthropocentrism, it would be a pyramid with humans at the top and the rest of the natural world beneath" (p.27). Nature is essentially a repository of natural resources that exists to serve human needs and wants. Conversely, biocentrism is a stance that recognizes inherent value in all forms of life, human and other-than-human. Corbett (2006, p.27) states, "The ecocentric (sometimes called biocentric) end of the spectrum can be represented by a circle, a nonhierarchical mix of interdependent relationships or a web of all life."

Within the context of problem-solving for controversial socio-environmental issues, perspectives imbued with anthropocentric values reside near the bottom of the framework, and are generally congruent with reductionist ontological stances. The more nature is reduced to a machine that produces consumable resources for humans, the more rational it seems that humans can learn to manage nature to optimize natural resource production and efficiency. A deep belief that it is possible for humans to control nature logically resonates with a desire to do so, and ultimately generates a tendency to do so (Vitek and Jackson 2008). On the framework, an increasingly reductionist ontological view of nature correlates with an increasingly anthropocentric axiological value judgments about humans' dominance over nature.

Conversely, perspectives instilled with biocentric values toward nature reside near the top of the framework, and these perspectives resonate with holistic ontological perspectives. The more nature is regarded as a complex adaptive system from which emergent properties can arise unexpectedly, the more it seems reasonable that humans are but a part of a much larger and vastly complex system. A steadfast belief that humans and social systems are inherently and inextricably intertwined with natural systems is congruent with a curiosity to understand socio-environmental system structures and behaviors, and ultimately a cautious or even humble recognition of humanity's place within nature's immense complexity (Vitek and Jackson 2008). On the framework, increasingly holistic ontological views of nature correlate with increasingly biocentric axiological value judgments about human relationships with nature.

## 16.3 Dimensions of Ecological Worldviews

Egocentrism, technocentrism, ecocentrism, and resiliocentrism are ecological worldview dimensions represented on the framework that resonate with fundamentally different relationships between humans and nature, and point toward divergent beliefs and actions in response to controversial environmental issues such as wolf hunting. To further elucidate the framework, Fig. 16.2 maps juxtaposed responses to the dilemma of wolf hunting onto the framework. Further, each dimension is assigned a brief caption that distills the human and nature relationship to its essence. Two of the captions, "Us vs. Nature" and "Us in Nature," are borrowed from the three-category classification scheme for dimensions of ecological interconnectedness devised by Benjamin Herman, Mark Newton, and Dana Zeidler to describe "how one perceives inter-connectedness between human beings and ecological systems" (2015, p.22). The other two captions, "Us over Nature" and "Us within Nature," are novel categories that follow a similar pattern but resonate with other dimensions of the framework.

As with any conceptual model, the framework strives to capture an essential distillation of core components, but cannot fully replicate the richness of the subject being modeled. Each quadrant is comprised of a constellation of beliefs clustered around a particular range of ontological, epistemological, and axiological commitments, but for simplicity, each orientation is sometimes described in the singular rather than the plural. Further, the various responses to wolf hunting associated with each quadrant, explained later in this chapter, are described broadly and thus do not capture the full depth and complexity of the complete range of perspectives in each quadrant.

### *16.3.1 Egocentric Dimension*

Egocentrism, located in the bottom right quadrant of Fig. 16.2, is characterized by a reductionist ontological orientation, an idealist epistemological orientation, and an anthropocentric orientation toward nature. This perspective pits humans against

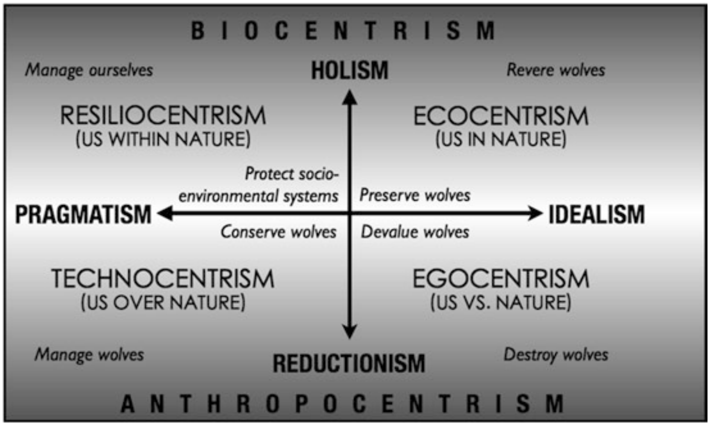


**Fig. 16.2** Various responses to wolf hunting

nature, aspiring for the struggle to result in human dominance. "Us vs. Nature," a term used by Herman et al. (2015, p. 22), aptly captures the framework's dimension of egocentrism because a win/lose dichotomy represents human-nature relationships. Ideal solutions for socio-environmental problems, then, are ones where fulfillment of human needs and wants is squarely prioritized whereas the needs of other-than-human life are discounted or disdained.

When applied to the dilemma of wolf hunting, egocentric responses generally result in devaluing or destroying wolves for human gain. Historically, early European settlers feared and despised wolves, baiting and trapping them for sport and for livestock protection (Schullery 2003). Bounty systems intended to systematically wipe out wolves were begun as early as 1630 (e.g., Massachusetts Bay Colony) and became commonplace as laws were passed in various states (e.g., Michigan in 1838, Minnesota in 1849, Iowa in 1858, Wyoming in 1875, Montana in 1884) (IWC 2015). The heyday for "Wolfers," professional and civilian hunters committed to wolf destruction, occurred from approximately 1850 to 1880, with estimates exceeding 100,000 wolves killed annually between 1870 and 1877 (IWC 2015). In 1906, the U.S. Forest Service together with the U.S. Bureau of Biological Survey undertook a wolf-extermination campaign with intent to maximize protection for cattle ranges. For the next six decades, wolves were shot, baited with poisoned carcasses, trapped, hunted with dogs, hunted from airplanes, and dug from their dens (Schullery 2003). By the 1960s, wolves occupied less than 1% of their original range in the lower 48 U.S. states, and the few remaining populations in Minnesota and Michigan were near extinction (IWC 2015).

The Endangered Species Act, passed by the U.S. Congress in 1973, marked an important milestone in the large-scale shift in government policy and public perception, from wolf extermination to wolf conservation. However, egocentric orientations are still ensconced in current policy debates, public discussion, and individual practices regarding human-wolf interactions. Egocentric perspectives are evident, for example, when private landowners attempt to kill wolves that trespass onto their land, by poachers who disregard hunting and trapping regulations, and by the Facebook group named "The Only Good Wolf is a Dead Wolf" (c.f., Bordon 2015 for more information). Egocentrism also may compel some to advocate for hunting and trapping regulations that relax restrictions in order to optimize chances for a wolf kill, provide minimal protection for wolves, or permit particularly non-humane lethal practices such as neck snares and leg-hold traps.

### *16.3.2 Technocentric Dimension*

Technocentrism, the ecological worldview dimension represented in the bottom left quadrant of Fig. 16.2, is characterized by a reductionist ontological stance, a pragmatic epistemological stance, and an anthropocentric orientation toward nature. Technocentric perspectives value nature for its instrumental uses, and regard natural resources as utilitarian building blocks for technological endeavors that alter the natural world to meet human needs and wants. Human ingenuity has produced numerous technological artifacts, including products such as pesticides, plastic, antibiotics, cell phones, and vehicles for space exploration. The raw materials used to produce technological artifacts, as well as those needed for production and distribution processes, ultimately can be traced back to natural resources. Further, humans use technology to manage natural systems to optimize the efficiency of ecosystem outputs (e.g., irrigation water, forest products, seafood), or maximize the ability of ecosystems to absorb disruptive inputs (e.g., water pollution, toxic waste, carbon dioxide).

From a technocentric perspective, humans hold the power and responsibility to manage natural systems to ensure that sufficient natural resources are produced and conserved to meet current and future human demands. An "Us over Nature" orientation describes technocentrism, because a power differential places human in a position separate from and superior to other-than-human life. These perspectives do not pit humans in a battle against nature, but are still steeped in an anthropocentric belief that human ingenuity can outwit nature by developing technological solutions to environmental problems faster than new problems arise. A quote from Bill Vitek and Wes Jackson (2008) aptly captures the essence of a technocentric approach: "The recipe for success is simple: unleash human ingenuity; utilize it to harness and commodify nature's immense and complex forces; enjoy the new and improved world that results; repeat" (p. 8). Within the continuum of perspectives that range across the technocentric quadrant, some beliefs regard technology as tools of environmental stewardship for managing nature to meet human needs and wants, while other beliefs are more "fundamentalist" in character (Orr 2002), reflecting an unexamined optimism that science and engineering will generate solutions to control and propagate natural resources sufficiently to avoid the need for humans to curb high-impact consumptive lifestyle habits.

Technocentric responses to the wolf-hunting dilemma revolve around the use of science and technology for wolf management, conserving sufficient wolf populations to fulfill various human needs and wants. Wolves are valued because of their utilitarian and economic worth in terms of hunting, wildlife viewing and ecotourism. While egocentrist responses stem from a vision for humans to vanquish the wolf, technocentric responses are more pragmatic and can include ecosystem management practices that accord functional value to the wolf's ecological role as top predator. Paul Schullery (2003, p. xii) captures the essence of the broad, historical shift in the U.S. from egocentrism to technocentrism when he states, "For a long time after they [wolves] had shed much of their demonic image, they were still respected only begrudgingly, as necessary evils placed on earth to serve as balance wheels in some intricate and clock-like natural machine." In contemporary American society, technocentric perspectives undergird the scientific and technological ecosystem management practices of state and national government agencies, and the corresponding legal and policy mandates that drive them. Such practices include setting harvest limits and regulations for wolf hunting based on quantitative data analysis.

### *16.3.3 Ecocentric Dimension*

Ecocentrism, the ecological worldview dimension represented by the top right quadrant of Fig. 16.2, is grounded in a holistic ontological stance, an idealist epistemological stance, and a biocentric disposition toward nature. An "Us in Nature" orientation (Herman et al. 2015) describes ecocentrism because humans are regarded as an integral part of nature, participating in the diversity of life rather than reigning over it. In terms of axiological commitments, ecocentric orientations are imbued with humility toward humans' place in the natural world, empathy for living organisms regardless of their utilitarian or instrumental value, and respect or even reverence for all parts of ecosystems, both living and nonliving. People holding these perspectives seek solutions to socio-environmental problems that are congruent with an ideal that recognizes fundamental, inherent value in all living things and respects the dynamic integrity of natural systems.

Within the context of the wolf-hunting dilemma, ecocentric responses center on efforts to preserve wolves and wolf habitat with minimal human disruption to wolf-pack dynamics and natural ecosystem processes. While humans dominate and subdue wolves in an ideal held by egocentrists, humans protect and revere wolves in an ideal held by ecocentrists. Because wolves are respected sentient beings that interact within complex social hierarchies, lethal practices such as hunting and trapping are rejected, sometimes vehemently. Axiological commitments of reverence, humility, and profound respect for wolves can been found within the traditional creation story and sacred beliefs of the Anishinaabe (Chippewa, Ojibwe) peoples of Minnesota (Benton-Banai 2010). Robert Desjarlait, a member of the Red Lake Ojibwe-Anishinaabe Nation who is a member of the University of Minnesota Council of Elders said, “If you take the fur of ma’iingan [traditional name for the gray wolf], you take the flesh off my back” (Nienaber 2012, para. 1). The constellation of perspectives located within the ecocentric quadrant of the framework includes not only many traditional Native American perspectives, but also those who work within and outside of the law to advocate for preserving wolves and wolf habitat. In particular, many wildlife advocates monitor legislative actions carefully and lobby politicians to vote for wolf protection. Others deploy strategies of direct action, going so far as to disable corporate assets through vandalism to save wolves.

### 16.3.4 *Resiliocentric Dimension*

Represented in the top left quadrant (Fig. 16.2), the resiliocentric dimension is characterized by a holistic ontological stance, a pragmatic epistemological stance, and a biocentric orientation toward nature. Within this perspective, system resilience is not defined as expediency of returning to an initial state after a disturbance, but rather as the capacity for a complex adaptive system to absorb disturbances and continue functioning without exceeding thresholds vital to keeping the system in a particular state (Allen et al. 2014). For example, how much carbon dioxide can the atmosphere absorb before global warming results in unstoppable cascades of environmental and social changes on a global scale? Rather than managing ecosystems to optimize outputs for human use, resiliocentrism aims to assure nature's resilience is protected by seeking to understand and monitor ecosystems, identifying crucial ecological thresholds, and encouraging adaptive and flexible human responses. Resiliocentrism pragmatically considers humans' nascent capacities for identifying and estimating pivotal thresholds in natural systems, and embraces the crucial role of diverse human orientations to social, economic, and cultural values in resolving thorny socio-environmental issues. "Us within Nature" captures the essence of resiliocentrism because while human and natural systems are regarded as inextricably intertwined, the immense magnitude of human impacts to natural systems on a global scale ineluctably necessitates system management decisions by humans. Such management decisions, however, need not be directed entirely toward nature; managing ourselves with intent to reduce the risk of key system components transgressing critical thresholds is an important aspect of resiliocentrism.

The precautionary principle (UNCED 1992), part of a resiliocentric axiology, acknowledges that the Earth's biogeochemical systems are finite and interconnected in complex ways that humans do not fully understand. Thus, human actions toward nature should reflect a degree of humility, uncertainty, and precaution. Resiliocentrism is infused in the Panarchy framework developed by the Resilience Alliance, a worldwide network of ecologists, economists, and social scientists researching resilience in social, ecological, and socio-ecological systems as pathways to sustainability. Panarchy "provides a framework to understand the cycles of change in complex systems, and to gauge if, when, and how they can be influenced" (Wuethrich 2002, p. vii). Resiliocentrism also underpins the work of the Center for Socio-Environmental Synthesis, an organization funded by the National Science Foundation and "dedicated to accelerating scientific discovery at the interface of human and ecological systems...and support[ing] new interdisciplinary collaborations that pursue data-driven solutions to pressing socio-environmental problems" (SESYNC 2015, para. 1).

When used to examine the wolf-hunting dilemma, resiliocentric responses first seek to situate the role of the wolf in multiple natural and social systems, and to understand how those various systems are structured, nested, and interconnected. After wolves were reintroduced to Yellowstone National Park in 1995, for example, ecologists were astonished at the trophic cascades that transformed the ecosystem and ultimately the very physical geography of the park (National Park Service 2011). Wolf predation lowered the number of elk and changed grazing patterns, reducing grazing pressure on vegetation. Regenerating forests and increased vegetation cover along streams resulted in the return of beaver populations; beaver dams altered the park's hydrology producing increased habitat for otters, muskrat, fish, reptiles and other animals, which in turn triggered additional trophic cascades. Increased vegetation cover stabilized riverbanks and mountainsides, resulting in less soil erosion and altered river flow patterns. These extensive and interconnected changes were traced back to the introduction of a small number of wolves.

Resiliocentric responses, however, go further and contextualize wolves in social, economic, historical, and cultural systems as well, samples of which have been briefly described in other parts of this chapter. Rather than managing wolves to optimize the fulfillment of human demands, resiliocentrism focuses on managing the impacts of human actions on interconnected natural and human systems centered on the wolf, ultimately monitoring and protecting the resilience of intertwined natural and human systems. An "Us within Nature" perspective requires many ecological, social, economic, and cultural voices be given careful consideration across different scales of time and impacts; indeed, such thinking necessitates a solid understanding of a diversity of perspectives that ranges widely across the framework.

Community-based discussions on how upper and lower thresholds of wolf populations influence the resilience of particular natural and human systems are vital for deciding how to coordinate a collective response to the wolf-hunting dilemma. For example, how do wolf hunting regulations and harvest limits alter trophic cascades in ecosystems? What are the social, economic, and cultural impacts of those trophic cascades on various stakeholders in wolf-human systems, including rural communities and indigenous groups? In what ways do increased or decreased wolf numbers impact changes in trophic cascades due to other causes such as natural resource development, wilderness protection, or climate change? These are challenging and complex questions, but resiliocentrism can offer a powerful approach to understanding and ultimately managing personal and collective responses to wolf hunting.

## 16.4 Next Steps

The value of the framework presented in this chapter resides in its potential to underpin methodological tools to investigate student learning and pedagogical tools to support student learning and curriculum evaluation. Three directions for next steps are being explored. First, a mixed methods pre-and-post research design would be suitable for gauging potential shifts in students' ecological worldviews that may occur in relationship with learning experiences. A survey comprised of Likert items could be designed to measure constructs for the ontological, epistemological, and axiological components of the framework. An interview protocol could yield findings that capture some of the multiple layers of meaning that permeate individual worldviews.

Second, the framework could be adapted into a reflection tool for use by secondary or post-secondary students engaged in instruction about wolf hunting or other socio-environmental issues. For example, students participating in the wolf hunt case study described previously could use such a reflection tool to evaluate the extent to which their task force recommendations engage with the four ecological worldview dimensions.

Third, the framework could be adapted into a curriculum evaluation tool to gauge the breadth of the ontological, epistemological, and axiological continuums represented or not represented in science curriculum materials. For example, discourse analysis methods (Fairclough, 2003) could be deployed to examine the extent to which other-than-human life is portrayed anthropocentrically as having instrumental value to humans, and/or biocentrically as having inherent value regardless of economic significance. Such an analysis would unveil an array of ontological, epistemological, and axiological assumptions about other-than-human life that are implicitly normalized in various kinds of science curriculum materials.

## 16.5 A Promising Conceptual Framework for Ecological Worldviews

The adapted framework introduced in this chapter provides a means for exploring ontological, epistemological, and axiological commitments that underpin ecological worldviews. Each of the four dimensions: egocentrism (Us vs. Nature), technocentrism (Us over Nature), ecocentrism (Us in Nature), and resiliocentrism (Us within Nature), draws upon divergent presuppositions about the world in order to justify certain beliefs and actions that contribute toward solutions for complex socio-environmental issues such as the dilemma of wolf hunting. This nascent conceptual framework offers rich potential for developing an instrument for research purposes, and a pedagogical tool to support instruction and evaluate curricula. On a planet that is moving toward an increasingly uncertain future, the promising framework presented in this chapter may help equip students to recognize and navigate the complex interfaces within and between human and natural systems, ultimately contributing to a more ecologically sustainable and socially just world.

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# Chapter 17
# A Framework Within Which to Determine How We Should Use Animals in Science Education

**Michael J. Reiss**

One of the more remarkable features of the Earth is that it supports millions of different species of organisms, the great majority of which are animals, including an amazing number of insects! Accordingly, one might imagine that non-human animals would play a central role in school science education. But this seems not to be the case, even though a rigorous survey of biology curricula worldwide has yet to be undertaken. Rather, biology curricula are weighted heavily towards humans. There are a number of reasons for this, including health and safety concerns, the fact that many teachers of biology have little experience of ecology or whole organisms, a pressure on resources including technician time, and the influence from animal charities. But one of the more important reasons why animals are not included much in curricula is uncertainty within the science education community about how animals might most appropriately be used in school science.

Here, I seek to provide a coherent framework within which to consider how animals should be used in science education, examining two main issues: the purposes of science education, and an ethical analysis of how humans should use animals. My contention is that unless these two major issues are addressed, arguments about how we should use animals in science education lack a solid foundation. My focus is K-12, but the principles explored in this chapter also apply to pre- and post-school education.

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## 17.1 The Purposes of Science Education

The purposes of science education can be thought of as a subset of the purposes of education (Reiss and White 2014). What therefore might be the purposes or aims of education? Some philosophers of education have argued that education would do well to have no aims. Paul Standish (1999) was exercised by what he saw as a 'grammatical oddness' here: asking what the aims of education are is like asking about the aims of a city. There is not much sense, he argued, in asking 'What are the aims of Aberdeen?'

Despite this argument, it is difficult to defend the notion that education should be aimless. People do design school curricula, run schools and decide how to train teachers with purposes in mind. And if we look at things historically, we can see even from a cursory survey that education has been credited with diverse aims over the years. Nevertheless, two broad groupings can be discerned. First, those where the intention is to develop the individual for her/his own benefit; and second, those where the intention is to develop individuals so that they may collectively contribute to making the world a better place (Reiss 2007). These two groupings are typical of much social policy in many countries. So, for example, in the west, under-age pregnancy, illicit drug use and speeding in cars are generally seen as bad both for the individuals concerned (loss of opportunities, mental and physical harm, risk of injury or death) and for the rest of society (financial cost, more burglaries, harm and upset caused to families and friends).

John White and I have argued that there are two fundamental aims of school education: namely, to enable each learner to lead a life that is personally flourishing and to help others to do so too (Reiss and White 2013).

### *17.1.1 What Constitutes a Flourishing Life?*

The notion that humans should lead flourishing lives is among the oldest of ethical principles, one that is emphasised particularly by Aristotle in his *Nicomachean Ethics* and *Politics*. There are many accounts as to what precisely constitutes a flourishing life. A hedonist sees it in terms of maximising pleasurable feelings and minimising painful ones. More everyday perspectives may tie it to wealth, fame, consumption or, more generally, satisfying one's major desires, whatever these may be. Admittedly, there are difficulties with all these accounts (White 2011). A problem besetting desire satisfaction is that it allows ways of life that virtually all of us would deny were flourishing, a life wholly devoted to spread betting, for instance.

A life filled with whole-hearted and successful involvement in more worthwhile pursuits – such things as significant relationships, meaningful work, other activities one enjoys doing – is on a different plane. Virtually all of us would rate it fulfilling.

A central aim of the school should therefore be to prepare students for a life of whole-hearted and successful engagement in worthwhile relationships, activities and experiences that they have not had foisted upon them. This aim also involves acquainting students with a wide range of possible options from which to choose. With their development towards increasingly autonomous adulthood in mind, schools should provide students with increasing opportunities to choose among the pursuits that best suit them. Young children are likely to need greater guidance from their teachers, just as they do from their parents. Part of the function of schooling, and indeed parenting, is to prepare children for the time when they will need to, and be able to, make decisions more independently.

### *17.1.2 Equipping Every Student to Help Others to Lead Personally Fulfilling Lives*

We want students to want other people, as well as themselves, to lead fulfilling lives. Negatively, this means not hurting them, not lying to them, not breaking one's word or in other ways impeding them in this. Positively, it means helping them to reach their goals, respecting their capacity to make informed choices and being fair, friendly and cooperative in one's dealings with them. Schools can reinforce and extend what parents and others in families do in developing morality in children. Schools can widen students' moral sensitivity beyond the domestic circle to those in other communities, locally, nationally and globally. They can also help students to think about moral conflicts in their own lives and in the wider spheres just mentioned. They can encourage students to reflect on the basis of morality, including whether this is religious or non-religious.

As part of their moral education, schools should help students to become informed and active citizens. Dispositionally, this means encouraging them to take an interest in political affairs at local, national and global levels from the standpoint of a concern for the general good; and to do this with due regard to framework values of liberal democracy such as freedom, individual autonomy, equal consideration and cooperation. Young people also need to possess whatever sorts of understanding these dispositions entail, e.g., an understanding of the nature of liberal democracy in general, of divergences of opinion about it, and of its application to the circumstances of their own society.

As future citizens, the great majority of students will contribute to the general wellbeing, as well as to their own, through work. This will often be remunerated, though much of it, e.g., caring for children or elderly relatives, may not be. As rational beings, students will eventually have to make choices about what kind of work to engage in. Schools should be helping them in this by making them aware of a wide range of vocational possibilities and routes into them, as well as their advantages and disadvantages.

### 17.1.3 The Possible Aims of School Science Education

There are a multiplicity of aims for school science education (Reiss 2007) though these are often implicit. A frequent aim of many science courses has been for them to provide a preparatory education for the small proportion of individuals who will become future scientists (in the commonly understood sense as employed professionals). This aim has been widely critiqued on democratic grounds (e.g., Millar and Osborne 1998). After all, what of the great majority of school students who will not become such scientists?

Another aim is to enable ‘scientific literacy’. Although there has been a long-running debate as to the meaning of the term, generally scientific literacy is seen as a vehicle to help tomorrow’s adults to understand scientific issues (Gräber and Bolte 1997). The basic notion is that science education should aim to enhance understanding of key ideas about the nature and practice of science as well as some of the central conclusions reached by science. Perhaps to be included within this category is the argument that to be an educated person in the twenty-first century is to understand something of science (e.g., Shamos 1995). This is the ‘science as culture’ argument; that science is as worth studying in itself, as are, for example, literature and the arts.

A further aim is that many science courses hope that as a result of what is learnt, students both now and in the future, as adults, will be able to gain practical benefit from it. At its most straightforward this might be by entering paid employment that draws on what they have learnt in science. Although, as noted above, most students do not enter such careers, they too may still benefit individually from their school science. For example, in most science courses, in countries round the world, it has long been accepted that one of the justifications for the inclusion of certain topics is that knowledge and understanding of them can promote human health. Such topics may include infectious diseases, diet, reproduction and contraception, exercise and the use of drugs (including smoking and alcohol).

Another argument that science education should be for public understanding (American Association for the Advancement of Science 1990). Somewhat related to this is the view that school science education should facilitate democracy. John Longbottom and Philip Butler (1999) argue that:

> If citizens have some knowledge of the natural world and of the process of gaining that knowledge, then they may be empowered to view critically the social world. Citizens who are critically minded, and who can analyze and challenge social structures, will be better able to implement democratic ideals. In this way, science education, in combination with a general education that teaches democratic ideals, can play a valuable part in equipping citizens with knowledge for action. (p. 489)

The argument that school science education should promote democracy is related to the argument that it should be for citizenship (Jenkins 1999). In both cases there is what has been termed a ‘weak version’ and a ‘strong version’ (Reiss 2007). The weak versions consist of learning about what a democracy is and what it is to be a citizen. The strong versions entail using such knowledge in action to bring about change. These strong versions are closely allied to claims that the aim of school science education should be to effect social justice, ecological justice or socio-political action.

For example, Angela Calabrese Barton has worked with homeless children in the USA to develop more appropriate science learning. She has shown that active participation in science lessons, and real learning about science, take place when children believe that their work can bring about improvements for themselves, their friends and their families (Calabrese Barton 2001). She draws on feminist approaches to show that many of the students with whom she and her colleagues worked, whilst seen in school as not doing well in science, were actually perfectly capable of high quality science work provided they were given real choice in the science they worked at.

It is evident that there are currently diverse aims for school science education. It is important, though, to emphasise that most teaching of school science proceeds on the assumption that such knowledge is good for students, without the precise aims having been thought through with any rigour and without the science curriculum beginning from such aims. Instead, science curricula generally begin with science. It might be thought that this is a sensible starting point but it leads all too often to disengagement (Schreiner 2006) as many students fail to understand the point of what they are learning (Reiss 2000). Hence, the argument for starting with the overall aims of education and then seeing, within these, what science might contribute.

It is clear that school science can indeed contribute to human flourishing. The amount of science and type of school science in the curriculum that is necessary for human flourishing is another matter (Reiss and White 2014). So far as I am aware, the school curricula of all countries have science as a mandatory, core subject to be taught, typically, from the start of schooling (e.g., 5 or 6 years of age) up to the end of compulsory schooling (e.g., 15 or 16 years of age). Whilst what precisely is included within 'science' varies a bit from country to country, and while it isn't always called 'science' for younger pupils, the presence of school science is nearly always accepted as a given.

Furthermore, what gets included within the school science curriculum is typically determined mainly by curriculum history – i.e., what has previously been included – and by occasional battles; for instance, in England and Wales, about the extent to which the earth sciences should be included within science, within geography, or omitted from the school curriculum.

The analysis presented so far is human-focused; education is presumed to enable humans to flourish. This is not, of course, to ignore animals, plants or even inanimate objects – after all, your and my flourishing may be enhanced by the wellbeing of any companion animals we have; indeed, if either of us gets upset at the poor treatment of animals we consume for food, at the extinction of wild species or at more general damage to the environment, an argument centering on human flourishing can still lead to a great deal of concern being expressed and action being taken in defense of animals, plants and the environment more generally.

The broader question is whether we (humans) have any duties to non-humans for reasons that are not to do with human flourishing. This is one of the issues that I address in the next section, on how we should use animals.

## 17.2 How Should Humans Use Animals?

Although it may be tempting to dive straight in and attempt to answer the question 'How should humans use animals?', the question is an ethical question and therefore consideration of how, in general, ethical questions can be answered is needed first. Otherwise one may simply end up in a classroom, as many teachers of school biology know from experience, with one group of students maintaining that it's fine to eat animals and use them in medical experiments while another group passionately disagrees – and neither group is helped by their teacher to provide arguments in support of their position.

Ethics is the branch of philosophy concerned with how we should decide what is morally wrong and what is morally right. We all have to make moral decisions daily on matters great or (more often) small about what is the right thing to do: Should I continue to talk to someone for their benefit or make my excuse and leave to do something else? Should I give money to animal charities or to medical charities? Should I give more weight to my interests than to those of others when choosing for whom to vote in an election?

We may give much thought, little thought or practically no thought at all to such questions. Ethics, though, is a specific discipline that tries to probe the reasoning behind our moral life, particularly by critically examining and analyzing the thinking which is or could be used to justify our moral choices and actions in particular situations (Reiss 2002).

### *17.2.1 The Way Ethics Is Done*

Ethics is a branch of knowledge just as other intellectual disciplines, such as science, mathematics and history. Ethical thinking is not wholly distinct from thinking in other disciplines but it cannot simply be reduced to them. In particular, ethical conclusions cannot be unambiguously proved in the way that mathematical theorems can. However, this does not mean that all ethical conclusions are equally valid. Some ethical conclusions – as in science – are more likely to be valid than others. It is a common fault in ethics courses to assert that there are no rights or wrongs in ethics.

One can be most confident about the validity and worth of an ethical conclusion if three criteria are met (Reiss 1999a). First, if the arguments that lead to the particular conclusion are convincingly supported by reason. Second, if the arguments are conducted within a well established ethical framework. Thirdly, if a reasonable degree of consensus exists about the validity of the conclusions, arising from a process of genuine debate.

It might be supposed that reason alone is sufficient for one to be confident about an ethical conclusion. However, there are problems in relying on reason alone when thinking ethically. In particular, there still does not exist a single universally accepted framework within which ethical questions can be decided by reason (Parfit 2011). Indeed, it is unlikely that such a single universally accepted framework will exist in the foreseeable future, if ever. This is not to say that reason is unnecessary but to acknowledge that reason alone is insufficient. For instance, reason cannot decide between an ethical system which looks only at the consequences of actions and one which considers whether certain actions are right or wrong in themselves, whatever their consequences. Then feminists and others have cautioned against too great an emphasis upon reason. Much of ethics still boils done to views about right and wrong informed more about what seems ‘reasonable' than what follows from formal reasoning.

The insufficiency of reason is a strong argument for conducting debates within well established ethical frameworks, when this is possible. Traditionally, the ethical frameworks most widely accepted in most cultures arose within systems of religious belief. Consider, for example, the questions "Is it wrong to lie? If so, why?". There was a time when the majority of people in many countries would have accepted the answer "Yes, because scripture forbids it". Nowadays, though, not everyone accepts scripture(s) as a source of authority. Another problem, of particular relevance for school science, is that while the various scriptures of the world's religions have a great deal to say about such issues as theft, killing people and sexual behaviour, they say rather less that can directly be applied to the debates that surround many of today's ethical issues in science, for example those involving modern biotechnology. A further issue is that we are more conscious nowadays that we live in multicultural or pluralist societies. Within most countries there is no longer a single shared set of moral values.

Nevertheless, there is still great value in taking seriously the various traditions – religious and otherwise – that have given rise to ethical conclusions. People do not live their lives in ethical isolation: they grow up within particular moral traditions. Even if we end up departing somewhat from the values we received from our families and those around us as we grew up, none of us derives our moral beliefs from first principles, *ex nihilo*, as it were.

Given, then, the difficulties in relying solely on either reason or any one particular ethical tradition, we are forced to consider the approach of consensus (Moreno 1995). It is true that consensus does not solve everything. After all, what does one do when consensus cannot be arrived at? Nor can one be certain that consensus always arrives at the right answer – a consensus once existed that women should not have the vote and that beating was good for children.

Nonetheless, there are good reasons both in principle and in practice in searching for consensus. Such a consensus should be based on reason and genuine debate and take into account long established practices of ethical reasoning. At the same time, it should be open to criticism, refutation and the possibility of change. Finally, consensus should not be equated with majority voting. Consideration needs to be given to the interests of minorities, particularly if they are especially affected by the outcomes, and to those – such as young children, the mentally infirm and non-humans – unable to participate directly in the decision-making process. At the same time, it needs to be born in mind that while a consensus may eventually emerge there is an interim period when what is more important is simply to engage in valid debate in which the participants respect one another, so far as is possible (c.f. Martin 1999), and seek for truth through dialogue (Habermas 1983). School education has an important role to play here.

### *17.2.2 Is It Enough to Look at Consequences?*

The simplest approach to deciding whether an action would be right or wrong is to look at what its consequences would be. No one supposes that we can ignore the consequences of an action before deciding whether or not it is right. This is obvious when we try to consider, for example, whether imprisonment is the appropriate punishment for certain offences – e.g., robbery. We would need to look at the consequences of imprisonment, as opposed to alternative courses of action such as imposing a fine or requiring community service. Even when complete agreement exists about a moral question, consequences may still have been taken into account.

The deeper question then is not whether we need to take consequences into account when making ethical decisions but whether that is all that we need to do. Are there certain actions that are morally required – such as telling the truth – whatever their consequences? Are there other actions – such as betraying confidences – that are wrong whatever their consequences? This is about the most basic question that can be asked in ethics and it might be expected by anyone who is not an ethicist that agreement as to the answer would have arisen. However, this is not the case. There still exists genuine academic disagreement amongst moral philosophers as to whether or not one needs only to know about the consequences of an action to decide whether it is morally right or wrong.

Those who believe that consequences alone are sufficient to let one decide the rightness or otherwise of a course of action are called consequentialists. The most widespread form of consequentialism is known as utilitarianism. Utilitarianism begins with the assumption that most actions lead to pleasure (typically understood, at least for humans, as happiness) and/or displeasure. In a situation in which there are alternative courses of action, the desirable (i.e., right) action is the one that leads to the greatest net increase in pleasure (i.e., excess of pleasure over displeasure, where displeasure means the opposite of pleasure, i.e., harm).

Utilitarianism as a significant movement arose in Britain at the end of the eighteenth century with the work of Jeremy Bentham and John Stuart Mill. However, its roots are much earlier. In the fifth century BCE, Mo Tzu in China argued that all actions should be evaluated by their fruitfulness and that love should be all-embracing.

Utilitarianism now exists in various forms. For example, preference utilitarians argue for a subjective understanding of pleasure in terms of an individual's own conception of his/her well-being. What all utilitarians hold in common is the rejection of the view that certain things are right or wrong in themselves, irrespective of their consequences. Consider, for example, the question as to whether or not we should tell the truth. A utilitarian would hesitate to provide an unqualified 'yes' as a universal answer. Utilitarians have no moral absolutes beyond the maximization of pleasure principle. Instead, it might be necessary for a utilitarian to look in some detail at particular cases and see in each of them whether telling the truth would indeed lead to the greatest net increase in pleasure.

There are at least two great strengths of utilitarianism. First, it provides a single ethical framework in which, in principle, any moral question may be answered. It doesn't matter whether we are talking about the legalization of cannabis, the age of sexual consent or the use of frogs in science fairs; a utilitarian perspective exists. Second, utilitarianism takes pleasure and happiness seriously. The general public may sometimes suspect that ethics is all about telling people what not to do. Utilitarians proclaim the positive message that people should simply do what maximizes the total amount of pleasure in the world.

However, there are difficulties with utilitarianism as the sole arbiter in ethical decision making. For one thing, an extreme form of utilitarianism in which every possible course of action would have consciously to be analyzed in terms of its countless consequences would quickly bring practically all human activity to a stop. Then there is the question as to how pleasure can be measured. For a start, is pleasure to be equated with well-being, the subjective experience of happiness or the fulfilment of choice? And, anyway, what are its units? How can we compare different types of pleasure, for example sexual and aesthetic? Then, is it always the case that two units of pleasure should outweigh one unit of displeasure? Suppose two people each need a single kidney. Should one person (with two kidneys) be killed so that two may live (each with one kidney)?

Utilitarians claim to provide answers to all such objections (e.g., Singer 1993). For example, rule-based utilitarianism accepts that the best course of action is often served by following certain rules – such as 'Tell the truth', for example. Then, a deeper analysis of the kidney example suggests that if society really did allow one person to be killed so that two others could live, many of us might spend so much of our time going around fearful that the sum total of human happiness would be less than if we outlawed such practices.

### *17.2.3 Intrinsic Rights and Wrongs*

The major alternative to utilitarianism is a form of ethical thinking in which certain actions are considered right and others wrong in themselves, i.e., intrinsically, regardless of the consequences. Consider, for example, the question as to whether a society should introduce capital punishment. A utilitarian would decide whether or not capital punishment was morally right by attempting to quantify the effects it would have on the society. Large amounts of empirical data would probably need to be collected, comparing societies with capital punishment and those without it with regard to such things as crime rates, the level of fear experienced by people worried about crime and the use to which any money saved by the introduction of capital punishment might be put. On the other hand, someone could argue that regardless of the consequences of introducing capital punishment, it is simply wrong to take a person's life, whatever the circumstances. Equally, someone could argue that certain crimes, for example first degree murder, should result in the death penalty – that this simply is the right way to punish such a crime.

There are a number of possible intrinsic ethical principles and because these are normally concerned with rights and obligations of various kinds, this approach to ethics is often named 'deontological' (i.e., 'rights discourse'). Perhaps the most important such principles are thought to be those of autonomy and justice.

People act autonomously if they are able to make their own informed decisions and then put them into practice. At a common sense level, the principle of autonomy is why people need to have access to relevant information, for example before consenting to a medical procedure.

Autonomy is concerned with an individual's rights; justice is construed more broadly. Essentially, justice is about fair treatment and the fair distribution of resources or opportunities. Considerable disagreement exists about what precisely counts as fair treatment and a fair distribution of resources. For example, some people accept that an unequal distribution of certain resources (e.g., educational opportunities) may be fair provided certain other criteria are satisfied (e.g., the educational opportunities are purchased with money legally earned or inherited). At the other extreme, it can be argued that we should all be completely non egoistic or nepotistic.

Rights are accompanied by duties but the relationship between rights and duties is often misunderstood. It is typically supposed that if I have rights then I also have duties – as in the political slogan that rights need to be accompanied by responsibilities. To see the logical error in this, consider a newborn baby. If ever a creature had rights it is surely a newborn baby. It presumably has the right to be fed, kept warm, protected and loved. But what duties does it have? Surely none. A newborn baby is simply too young to have duties. It is not yet responsible for its actions. However, others have duties to it – namely to feed it, keep it warm, protect it and love it. Normally such duties are fulfilled by the child's parent(s) but if neither parent is able to undertake these duties, for whatever reason, the duties pass to others, for example other relatives, foster parents, adoptive parents or social services. In general, if A has a right, there is a B who has a duty to ensure that A's rights are met.

If it is the case that arguments about ethics should be conducted solely within a consequentialist framework, then the issues are considerably simplified. Deciding whether anything is right or wrong now reduces to a series of detailed, in depth studies of particular cases. Much energy can be wasted when utilitarians and deontologists argue. There is little common ground on which the argument can take place. The safest conclusion is that it is best to look both at the consequences of any proposed course of action and at any relevant intrinsic considerations before reaching an ethical conclusion.

### *17.2.4 Virtue Ethics*

A rather different approach to the whole issue of ethics is provided by virtue ethics. Instead of starting from particular actions and trying to decide whether they fail to maximise the amount of happiness in the world, are divinely forbidden or infringe someone's rights, virtue ethics focuses on the moral characteristics of good people. For example, think about a good teacher. What characteristics might we expect them to manifest? We might want them to know their subject, to treat all students fairly, to be able to maintain order in the classroom, to maximise students' chances of doing well in any examinations, to be able to communicate clearly, to have a sense of humour and so on. Some of these are skills – for example the ability to maintain order – but some are personality traits that we call virtues – notably treating all students fairly, rather than, for example, favouring males, Asians, high attaining students or those who are good at baseball.

Virtue ethics has an ancient pedigree – receiving considerable impetus from Aristotle – and has undergone something of a revival since the 1970s. Part of the reason for this may be connected with a somewhat instrumental tendency in much of the training of such professionals as doctors, nurses, lawyers, accountants and so on, in which the idea of moral goodness features little. And yet many people who have to deal with such professionals (as patients and clients) want them to manifest virtues as well as be knowledgeable and technically skilled.

### *17.2.5 Widening the Moral Community*

Traditionally, ethics has concentrated mainly upon actions that take place between people at one point in time. In recent decades, however, moral philosophy has widened its scope in two important ways. First, intergenerational issues are recognised as being important (Cooper and Palmer 1995), and second, interspecific issues are now increasingly taken into account (e.g., Rachels 1991).

Nowadays we are more aware of the possibility that our actions may affect not only those a long way away from us in space (e.g., pollutants produced in one country affecting another) but also those a long way away from us in time (e.g., increasing atmospheric carbon dioxide levels altering the climate for generations to come). Human nature being what it is, it is all too easy to forget the interests of those a long way away from ourselves. Accordingly, a conscious effort needs to be made so that we think about the consequences of our actions not only for those alive today and living near us, about whom it is easiest to be most concerned.

Interspecific issues are of obvious importance when considering our use of animals and ecological questions. Put at its starkest, is it sufficient only to consider humans or do other species need also to be taken into account? Consider, for example, the use of new practices (such as the use of growth promoters or embryo transfer) to increase the productivity of farm animals. Many people feel that the effects of such new practices on the farm animals themselves need to be considered as at least part of the ethical equation before reaching a conclusion. This is not, of course, to accept that the interests of non-humans are equal to those of humans. While a small proportion of people do argue that this is the case, many accept that while non-humans have interests these are generally less morally significant than those of humans.

Accepting that interspecific issues need to be considered leads one to ask 'How?' A standard utilitarian answer is that we should consider just the pleasures and pains that would result from any action but is this sufficient? For example, would it be right to produce, whether by conventional breeding or modern biotechnology, a breed of chicken unable to detect pain and unresponsive to other chickens? Such a breed would not be able to suffer and its use might well lead to significant productivity gains: it might, for example, be possible to keep it at very high stocking densities. Someone arguing that such a course of action would be wrong would not be able to argue thus on the grounds of animal suffering. Other criteria would have to be invoked. It might be argued that such a course of action would be disrespectful to chickens or that it would involve treating them only as means to human ends and not, even to a limited extent, as ends in themselves.

## 17.3 The Use of Animals in Science Education: Some Examples

Students come to their science lessons with all sorts of views about how animals, plants and the physical environment should be treated by humans (e.g., Lock and Millett 1992). There are many aspects to the questions of how science education should deal with animals. I will start with animal dissection (Lock and Reiss 1996) and then go on to consider the issue as to whether animals should be brought into or kept in schools. Finally, I consider the more general issue as to what we might hope, as educators, that students would gain from considering how humans should use animals, using some of the ethical tools described above.

### *17.3.1 Dissection in Schools*

Dissection is the act of cutting up a plant or dead animal in order to investigate its internal structures and, by careful anatomical exploration, to reveal its organs and tissues. The dissection of whole animals in schools has become less common than it once was, partly because of changing perceptions by many students and some biology teachers about whether dissection is right, in part because of campaigning by organizations such as Animal Aid, PETA and the Royal Society for the Protection of Animals.

The main arguments in favor of animal dissection, whether of whole organisms (e.g., rats, fish, frogs, earthworms, cockroaches) or parts of organisms killed for other purposes (e.g., sheep's hearts, sheep's kidneys, bull's eyes, pig's trotters, unfertilized hen's eggs, skeletal muscle), are that such dissection:

- Provides a knowledge of the internal structure of tissues, organs and whole organisms better than can be provided by alternatives (e.g., three-dimensional models, computer software, videos).
- Enables students to learn through active involvement.
- Helps students better to appreciate what certain careers might entail (e.g., medicine, veterinary medicine, animal technician).

The main arguments against animal dissection are that this:

- Involves the taking of life.
- Involves the rearing and killing of animals in circumstances that may cause suffering (e.g., physical and mental pain in battery chickens, boredom in laboratory rats).
- Lessens respect for life and so cheapens it.
- Offends some fellow students.
- Puts some students off biology.

Some of these arguments apply with less force when only parts of organisms killed for other purposes (e.g., for food) are used for dissection.

In a review of the science curriculum in England that was designed and undertaken by 16–19 year-olds, when 16–17 year-olds were asked 'Should students be given the choice to do dissection? [and the term will have been understood to refer to animals]', 86% of 1469 questionnaire responses said 'Yes', 7% said 'No' and 7% expressed no opinion (Murray and Reiss 2005). A decade before this study, Lock and Reiss (1996) recommended that the following practices be followed if animal dissection is undertaken in schools:

- Each school should formulate its own policy on dissection and make it freely available to students and parents.
- Students should be told that dissection is not required by any of the Examining Boards in the UK.
- Students should be told, in advance, when dissection is to take place.

- In advance of dissection, students should be encouraged to discuss the ethical implications of dissection in an atmosphere that allows them to develop their thinking without being afraid that their views will be ridiculed.
- Dissection of parts of organisms obtained for other purposes should, in most cases, be used in preference to the dissection of whole organisms.
- Alternative work must always be provided. Such work should, so far as is possible, be of the same intellectual worth and interest as the dissection.
- Dissection of any sort is inappropriate for children under the age of 11. Dissection of whole organisms should only be undertaken by students over the age of 16. Little is gained by a teacher demonstrating a dissection to a whole class unless this is to instruct students or students prior to their doing their own dissection.

### *17.3.2 Animals in Schools*

Animal dissection is not, of course, the only issue in respect of how animals should be used in schools. In many schools, animals are kept or brought into classrooms. In addition, students may be taken on visits to zoos or to field centers; more indirectly, students watch animals on film and consider them in such contexts as biodiversity, genetics and agriculture.

Some campaigning organizations have argued that animals should neither be kept in schools nor brought into them. There are two main reasons advanced for such a stance: first, that a school is unable to provide an environment in which animals can be kept well (even for short periods of time); second, that such actions are simply morally wrong. It is difficult to find the first reason wholly convincing for all schools. Schools can do as good a job of keeping animals as homes can – and few of us would outlaw the keeping of all companion animals on utilitarian / animal welfare grounds. The second reason can be held consistently, for example by arguing that animals have rights so that just as it is wrong for us to enslave people (even if they are kept well), so it is wrong to keep animals.

It seems evident that if schools do keep animals on the premises, they have a duty to ensure that they are well-looked after. It is harder to look after mammals and birds well than some other taxa. Schools should certainly consider carefully the arguments for and against keeping animals in schools, or allowing them to be brought in for educational purposes. More generally, schools should encourage students to discuss these matters, as I now go on to argue.

### *17.3.3 What Might Student Gain by Considering How Humans Should Use Animals?*

I have my own views about the validity of the moral arguments outlined above in respect of dissection and the place of living animals in schools. However, educationally, it seems difficult to defend the notion that any one view should prevail when a range of views can rationally be held. Accordingly, I end by maintaining that students themselves should consider the use of animals by humans (ethical issues being a sub-set of sociocultural issues) (Reiss 1999b). There are a number of educational arguments in favor of students undertaking such considerations (Davis 1999).

First, such teaching might heighten the ethical *sensitivity* of students. For example, students who have never thought about whether certain breeds of dogs should have their tails removed ('docked') or whether there is a right age at which calves should be removed from their mothers might be encouraged to think about such issues. Such thinking can result in students becoming more aware and thus more sensitive. It is not unusual, as a result, to find students saying 'I hadn't thought of that before'.

Second, such teaching might increase the ethical *knowledge* of students. The arguments in favor of this aim are much the same as the arguments in favor of teaching any knowledge – in part that such knowledge is intrinsically worth possessing, in part that possession of such knowledge has useful consequences. For example, appropriate teaching about the issue of rights might help students to distinguish between legal and moral rights, to understand something of the connections between rights and duties and to be able to identify fallacies in arguments for or against the notion of animal rights. Consider, for example, the issue of whether we should be concerned, on welfare grounds, about fishing. Relevant considerations, in addition to moral philosophy, include the possibilities of pain detection by fish and fish consciousness. To understand these well requires some knowledge of animal behavior, of neurophysiology, of psychology and of epistemology. More generally, we might want students to know whether there are morally relevant differences between animals and most humans – including the capacity to imagine a future life for oneself and to keep the concerns of others in mind.

Thirdly, such teaching might improve the ethical *judgment* of students. As Michael Davis, writing about students at university, puts it:

> The course might, that is, try to increase the likelihood that students who apply what they know about ethics to a decision they recognize as ethical will get the right answer. All university courses teach judgment of one sort of another. Most find that discussing how to apply general principles helps students to apply those principles better; many also find that giving students practice in applying them helps too. Cases are an opportunity to exercise judgement. The student who has had to decide how to resolve an ethics case is better equipped to decide a case of that kind than one who has never thought about the subject. (Davis 1999, pp. 164–5)

Finally, and perhaps most ambitiously, such teaching of ethics might make students *better people* in the sense of making them more virtuous or otherwise more likely to implement normatively right choices. It might, for instance, result in students reflecting more on the possibilities open to them, leading them to be less pressured by the views of others and so resulting in improved animal welfare or conservation of endangered species.

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