Chapter 15
Learning from the Many, Teaching to the Many: Applying Ecojustice Principles to Undergraduate Pedagogy in Environmental Science, Ecology, and Sustainability Classrooms

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15.1 Perspectives in and on Undergraduate Classrooms

This is at least the second rewrite of this chapter – at least. It is nearly unrecognizable from the first. I (Mary) am letting you in on this because, as an educator and a scientist, I view adjusting ideas and practices, welcoming change and diverse perspectives, and seeking out new ideas as part of the job. It is essential to remind ourselves to be adaptive, as the syllabi of our classes, curricula of our departments, and more broadly, our ideas on how students learn and apply knowledge often stagnate and age while we work vigorously to push the research of our labs forward.

Committing your teaching – through practices and content selection – to include authentic connections to Environmental Justice and EcoJustice can broaden the impact of your STEM (i.e., – science, technology, engineering, and mathematics) courses. While we often recognize the importance of human systems and their effects on ecological and environmental processes when teaching – most notably the impacts of climate change – it is less common for professors to expand into the structural inequalities of human systems and how they shape the science we practice and the content we deliver. This chapter encourages scientists, educators, and students to broaden their perspectives, critique historical biases and inequities in ecology and environmental science, and embrace the broad plurality of information available to us, with particular attention to the integration of Indigenous knowledge.

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15.2 Perspectives Matter – Here Are Ours

You are about to read the outcomes of our research and discussions as a writing team and our individual experiences in different roles in science education and practice. I (Mary) am currently an Assistant Professor of Ecology at a small liberal arts college. My background as an undergraduate and graduate student at large research institutions where innovative teaching was not highly prioritized; as a biology teacher at an under-resourced urban public high school where nurturing connections with students, clear expectations, and active learning were valued and promoted; and as a research scientist learning and navigating explicit and unwritten rules that dictate success, informs my perspectives on teaching and mentoring undergraduate students. However, in my current role, I find my perspective on teaching most informed by the students I teach – what are their goals for the course and for after college as emerging adults faced with challenges that include student debt, climate change, and anxiety over an uncertain future? I aim to develop courses that teach content and transferable skills and provide a space where students feel they are supported to grow and succeed. So, I have been doing a lot of listening and learning (Dewsbury & Brame, 2019), adjusting and adapting, and reading to create inclusive learning environments (Canning et al., 2019). As an ecologist, Environmental and EcoJustice can help with building inclusive learning environments through enacting their principles, informing content, and connecting students to broader impacts.

I (Jennings) have never been comfortable in science classrooms, not in my secondary education or college education. Make no mistake. I am fascinated by science and observing the natural world and always have been. However, the historical lineage of scientists that I have learned about in school does not include anyone who even remotely looks like me. I am also studying history, and while I would say that I enjoy *doing* science more, I am unquestionably more comfortable *being* in history. As a disabled and Indigenous person, I would traditionally be a subject of (or perhaps an inconvenience to) science rather than an active practitioner. Many of the science classrooms I have been in stressed that we (the students) were all fundamentally the same, all equals before the eyes of science. While this rather literal approach does serve to push back against historical 'race science,' it does not consider the different backgrounds of students and what traumas and experiences they bring into the classroom. This one-size-fits-all can alienate marginalized students, especially if the instructor does not share similar marginalized identities. I want to help change this approach and help create a framework for equity in science education.

15.3 A Role for Environmental Justice and EcoJustice in Undergraduate Science Classes

Environmental Justice and EcoJustice (hereafter, EJ) serve as frameworks to assess environmental laws, regulations and their implementation, decision-making, and natural resource use and distribution, with the guiding principle that there be 'fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income' (Environmental Justice Learning Center, 2019). Broader definitions include the identities of gender, sexuality, citizenship, and Indigeneity (Pellow, 2018). Tenets of EJ as listed by delegates to the First National People of Color Environmental Leadership Summit in 1991 (Bullard, 1999) emphasize the rights of all individuals to clean, protected, and accessible natural resources; the political, economic, cultural and environmental self-determination of all people; and sustainable practices to preserve resources for future generations and others. Also amongst the guiding principles of EJ are (1) equity in decision-making, (2) transparency of and access to information, and (3) education based on diverse cultural perspectives (Bullard, 1999). Those values can inform ways to teach EJ and incorporate it into undergraduate science classrooms through shifts in both pedagogy and content. As undergraduate classrooms and campuses embrace sustainability initiatives, they must be reconciled with an EJ perspective. Sustainability on its own does not always explicitly address the need to repair past and current harms of inequity. However, many sustainability tactics borrow (recognized or not) from marginalized cultures and populations to improve resource use.

Exemplary case studies and 'textbook' examples of EJ are challenging to find, if existent, in practice. What gets more often observed, reported on, and studied, are the multitude of environmental and ecological *injustices* that marginalized communities have historically and continue to experience globally. While these injustices are widespread and deeply rooted in structural inequity (Pellow, 2018; Bullard, 2001), they do not often emerge as a focus in undergraduate environmental science, ecology, and sustainability classes. In environmental science, ecology, and sustainability classrooms, case studies, such as those on point source pollution in watersheds or deforestation of tropical forests, may not integrate discussions of the demographics of urban and rural areas where pollution is more common or how titling of land to Indigenous Peoples can serve to protect and conserve tropical rainforest biodiversity (Blackman et al., 2017). Rethinking case studies to include and apply EJ principles can serve as pedagogical innovation and as a guiding topic within environmental science and ecology courses.

One trove of resources that may help professors readily explore EJ principles is the InTeGrate community, hosted and supported by the Science Education Resource Center at Carleton College (SERC, 2021). This sustainability-focused community of educators creates and shares lessons, modules, discussion topics, and other resources that seek to engage undergraduate students in ecology, environmental science, and sustainability classrooms. The goals of this interdisciplinary and cross-institutional network emphasize the need for undergraduates to connect social sciences and natural sciences through a sustainability lens, promote systems thinking, and approach current and future environmental issues with a problem-solving mindset. Resources about InTeGrate can be found online via the SERC website and are all open access.

Science classrooms often espouse the importance of innovation and collaboration to identify new information and concepts within disciplines. As teachers, we also aim to incorporate best practices based on data to push our pedagogy from passive lecture halls to more interactive active learning and inclusive teaching approaches to make content more accessible and center students in their learning (Handelsman et al., 2004). This approach can transcend to activities such as practice reading journal articles (Hoskins et al., 2011) and interpreting graphs in small groups in classes, though recent evidence shows a reluctance amongst students to engage in this format of learning (Deslauriers et al., 2019). Principles of EJ mentioned above – equity, transparency, and inclusion of diverse cultural perspectives – can reinforce many objectives of an authentic, inclusive undergraduate STEM classroom. Equity, as practiced in the classroom, may translate into more student voice on the weight of assignments; democratizing student-led discussions by the random assignment of roles; soliciting anonymous student feedback regularly to identify areas in need of improvement. Even small teaching gestures, such as waiting a few minutes for students to collect their thoughts before calling for answers, enable instructors to be more inclusive and intentional about who contributes to discussions can lead to a more equitable learning environment (Handelsman et al., 2007).

The principles of transparency and diversity of cultural perspectives can broaden whole disciplines when we think about who is historically represented as the practitioners of science and which voices have emerged as dominant in their representation in texts and readings in science classrooms. Discussions on how science is practiced, documented, and taught can lead to new explorations of under-represented voices and perspectives and address implicit and explicit biases that continue to influence the environmental sciences (Ou & Romero-Olivares, 2019). Recently, in the spring of 2019, an essay published in the preeminent, globally-read weekly journal, *Science*, described how natural historians from Europe increased their specimen collections in the Americas and Africa due to their travels on ships transporting enslaved people (Kean, 2019). The stance and tone of the article made assumptions about who could be viewed as scientists, documentors, and keepers of natural history knowledge in the past (Kean, 2019). They strangely posed 'discoveries' as a potential side-benefit to the centuries-long trafficking and suffering of enslaved Africans. A response to the essay (also published in *Science*) by Dr. Rae Wynn-Grant, a carnivore ecologist, detailed the many oversights and biased perspectives of the essay, clarifying how the historical framing of science as for and by a single group of people was and continues to be damaging (Wynn-Grant, 2019). The editorial staff at *Science* would benefit from including and empowering writers, scientists, and editors of diverse backgrounds to question, critique, and confront historical and current biases in the practice of and documentation of science, as well as bring light to and elevate the understudied science and legacies of marginalized people. Democratizing science to reflect the principles of EJ requires action from professors and students and from gatekeepers that include journal editors, conference organizers, funding program officers, and reviewers of grant proposals.

In the undergraduate classroom, confronting historical biases can be discussed and addressed through student-led projects, such as the ongoing initiative to add and edit Wikipedia to include more women scientists (Wade & Zaringhalam, 2018). In this project, students choose or are assigned scientists who do not have a Wikipedia entry; through readings of their work and examinations of their training and background, students create new entries accessible to all with access to the internet. This exercise emphasizes the individuals and teams driving the research. It centers the work, progress, and growth, not just the outcome. Expanding on this existing Wikipedia project to include individual scientists from under-represented identities and groups and annotating Wikipedia entries on environmental science, ecological, and sustainability concepts to include Traditional Ecological Knowledge perspectives, are some ways to uphold and practice EJ principles through innovative student-focused teaching while simultaneously broadening the representation of who scientists are and what is considered science.

Undergraduate environmental science, ecology, and sustainability classrooms will also benefit from integrating topical and recent EJ case studies as a ‘hook’ for further examination into discipline-based concepts. Once you are attuned to climate justice and EJ issues, it is challenging to get through a day’s worth of news without identifying how intersections of race, ethnicity, immigration status, religion, gender, sexuality, class, and other identities play a role in how individuals and communities are differentially impacted by environmental decisions. As I taught an introductory Ecology course during Spring 2019, there were too many current event topics to cover thoroughly in a class that met three times a week! Two major monsoons hit Mozambique, a country that does not contribute any substantial fossil fuel emissions and is increasingly threatened by more extensive and more frequent storms as ocean waters warm due to climate change (Fitchett, 2018). Fires rage in the Brazilian Amazon to clear land for ranching (Fearnside, 2015), soy farms, and mining (Sonter et al., 2017) that in many cases illegally and violently broach Indigenous land reserves (Blackman et al., 2017). Air pollution in the United States is more likely to impact low-income and marginalized populations, despite these groups contributing less demand to the production of fossil-fuel emitting industries (Tessum et al., 2019). Using EJ topics and case studies can engage students motivated by social justice and science, broaden classroom participation, and enrich the perspectives of all students introduced to environmental science, ecology, and sustainability at the undergraduate level.

A major tenet of EJ frameworks is to uphold equity in access, protection, and decision-making across all groups and stakeholders, especially those marginalized by historical and current practices (Bullard, 2001). In this chapter, we encourage the integration of EJ ideals to inform and restructure the undergraduate classroom to promote equity, authenticity, and inclusion amongst students and faculty. We detail the benefits of broadening science pedagogy and pivoting from a practice that emphasizes *single* actors and sources of knowledge to a more authentic, diverse, and democratic representation of science. We focus on the strengths of including multiple perspectives in terms of pedagogy and sources of knowledge.

15.4 Strengthening Teaching and Learning by Including Multiple Perspectives

15.4.1 Courses, Pedagogy, and Classroom Practice

Undergraduate coursework is often predominantly focused on content, not skills. In a world where surges of information flow from every screen in sight (Pennycook & Rand, 2019), it is more important than ever for students to practice one of the most fundamental skills offered by science – evidence-based critical thinking. This skill – basic information literacy – may be the most widely transferable amongst all practiced in undergraduate classrooms and one whose impact is felt everywhere, from elections to vaccination schedules (Scheufele & Krause, 2019). Instructors prioritize and present terms, definitions, processes, case studies, and systems, often at the expense of teaching process skills transferable and applicable to other courses. This content then is packaged into semester-long topics that become increasingly more specific in a hierarchical manner: *Biology* leads to *Ecology,* which leads to *Ecosystem Ecology,* or *Aquatic Ecology*. As a junior or senior undergraduate, students may have access to more interdisciplinary courses within the major – an *Urban Environmental Science* course may weave in sociology, urban planning, and climate science. A *Sustainable Agriculture* course may integrate political science, geography, economics, and plant biology. Placing these integrative courses at the end of a potentially grueling, years-long major sequence seems alienating and disheartening to first-year undergraduates who enter college enthused to learn about the syntheses and integration of ideas. For this reason, many institutions of higher education are re-thinking this building-block approach to better retain and expand the number of students entering STEM majors (Haak et al., 2011). Especially for students motivated by topics in EJ issues, integrating interests in social justice, applied and synthetic topics early in the course sequence may lead to higher retention in STEM majors.

Faculty may argue that the fundamentals are necessary to understand systems fully, and I agree. As a plant physiologist researching respiration, I (Mary) am the first to argue that some jobs require you to know the tri-carboxylic acid (Krebs) cycle! However, the traditional lecture-midterm-final format of many introductory survey courses does little to inspire, let alone teach students skills beyond memorization and high-anxiety studying. Further, many introductory classes are composed of students with a range of high school science backgrounds – and this variation can create uneven and potentially unwelcoming educational environments (Harackiewicz et al., 2014). To build an inclusive classroom that values equity of experience, you need assignments that provide creativity and individual personal perspectives (Tanner, 2013). Instead of content regurgitation, students need room for expansion and application of ideas, independent of background content knowledge (Dewsbury, 2019). We recommend a few of these in the following section. Introductory courses set the tone for a student's undergraduate education. Over-prioritizing memorization and high-stakes, 'make-or-break' exams can alienate students and create classrooms that lack the joy of curiosity that attracts many students to science in the first place. Alternatively, assignments that address original, student-generated questions can elicit curiosity about the content and generate novel explorations of information.

A shift in perspectives informed by principles of EJ can enhance introductory and more discipline-specific courses. Decentralizing the classroom from a teacher-centric model to a student- and team-focused model reinforces the concept that all voices and perspectives are valued. Classroom architecture can often limit or promote this approach – and can be the most challenging element to change; a stadium-style lecture hall emphasizes that everyone should be focused on the board or the professor, not on themselves or each other as students. Bypassing this can be extremely difficult, and it is unlikely that many colleges and universities have the facilities for classrooms to be spatially decentralized. This challenge puts more pressure and more focus on the teaching models – how can faculty reinforce the concept that students themselves are the drivers of change in their studies and the course? How can faculty promote the message that what students bring into the classroom – their experiences, perspectives, interests, and backgrounds – are all assets to learn from and not deficits to work around (Montgomery, 2017)? How can larger introductory classrooms be re-modeled and re-configured to enhance individual learning and build community (Dewsbury & Brame, 2019)? How can undergraduate science classrooms be designed to include marginalized students and faculty authentically? These questions do not have easy answers, though lessons and principles from EJ may serve as a framework to approach thinking about potential solutions.

Active learning is a term that encompasses pedagogy that engages students in their learning (Handelsman et al., 2007). At the heart of active learning is peer collaboration – students working closely with other students to go through problems, questions, and concepts; a practice that mirrors the process of science in the field, lab, at conferences, or in journal clubs. Building self-confidence, relationships, and feelings of belonging in the classroom can be an essential aspect of learning (Dewsbury, 2019) that distinguishes learning in a traditional undergraduate classroom surrounded by peers from an online degree program. EcoJustice espouses inclusion and democratic decision making, transparency in information, and equity amongst resources; in active learning classrooms, information is decentralized, distributed amongst students in small groups where they work together (Haak et al., 2011). Active learning can meet resistance amongst students used to a more passive format but has proven to yield stronger learning outcomes (Deslauriers et al., 2019). Since earlier generations of science classrooms did not apply active learning widely, this newness will be not only for the students but also the professor as well – and the challenges will be felt and approached differently by both.

Individual and small-group active learning may also yield new approaches – by distributing challenges and activities to students and delivering responsibility to them, the diversity of perspectives, experiences, and learning styles can result in new ideas (Tanner, 2013). An example activity could be the development of a metaphor or analogy for an ecological concept like the successional development of an ecosystem. A sole professor might describe and teach the one metaphor that ‘clicked’ for them, which is unlikely to resonate with students with different cultural experiences and familiarities. Suppose ten small groups of students worked together to develop a working metaphor for succession to explain and teach, using metacognitive practices to justify and explain their reasoning. In that case, the classroom is likely to develop ten distinct, potentially helpful metaphors. When studying succession, there are now many examples to draw from for reinforcement of ideas as a class. This practice further integrates science as a team-based effort that often yields diverse results that reinforce each other (or not!) and lead to future explorations that include more nuance and critical analysis.

15.4.2 Sources of Knowledge

In the classroom, the instructor serves as the legitimizer of knowledge. The perspectives and observations of white men are the sources of knowledge and expertise most legitimized in science classrooms (von Roten, 2011), (classically regarded as the only group capable of doing 'Science') (White, 2016). As historically viewed, science is assimilative, and knowledge sources must be made to fit within the pre-existing framework of 'science' (Kimmerer, 2019). However, when considered at its essentials, science is based on observable evidence. Colonial biases only enter when we consider *who* is doing the observation, leading to the creation of the category, 'traditional knowledge,' posited as subjective and fallible compared to 'Western' science (Mistry & Berardi, 2016). I (Jennings) will continue to use the term Indigenous science throughout this article, as it complicates the implicit assumption that science is a purely 'Western' concept. This assumption is to the detriment of science as a field. We can find numerous examples of observations that were previously deemed traditional and unscientific but later found credible and of merit (Bonta et al., 2017). In reality, this dichotomy between Indigenous and 'Western' science is a false one (Kimmerer, 2019); science is a value-neutral term to which no worldview has a monopoly ("Indigenous Science Statement for the March for Science," 2017).

This stance is not, by any means, to advocate the wholescale or uncritical inclusion of 'alternative' sources of knowledge (such as those that have recently manifested in opposition/skepticism towards vaccines and as Bible-based 'creation science'). Rather this greater inclusivity is intended to broaden mental models of who historically has done science (Nicholas, 2018). The lineage of "Western thinkers" have never been the only ones doing science. When science instructors assume a universal and monolithic background of student prior experience and values, they alienate students who are not privy to these values, students who generally tend to be marginalized in any number of ways (Roy, 2018). To present Western science as the only standard of a completely objective, purely empirical tool can further this harm and alienation, especially as it intersects with personal and family histories. We will thus continue to use the term Indigenous Science in lieu of 'Indigenizing', as the latter may subtly imply a distinction between Science and Indigenous Science, which we hope to make clear are not, in fact, distinct.

15.4.3 Token Inclusion of TEK and Indigenous Perspectives

Though discussion of Indigenous science and Indigenous perspectives in the classroom context has increased, such actions are nearly meaningless if Indigenous science is seen as entirely separate and only occasionally complementary (or supplementary) to Western science. Inclusion only matters if perspectives of Indigenous science are fully integrated and respected as legitimate scientific viewpoints. When concepts of Indigenous science are included in curricula, in my (Jennings) experience, it gets relegated to one of two categories:

1. As a framing text for a discussion of science as international or transcultural. These concepts are never brought up again or used to challenge dominant narratives or examine the science in a broader context; or
2. As supplementary materials that support a conclusion that has been drawn by 'Western science.'

Category one approaches lack meaningful or authentic inclusion. For example, opening a curriculum by mentioning an Indigenous, "observation-based tradition" does little to challenge dominant narratives. Instead, these approaches comprise token moves towards innocence, towards ways to claim to value diverse perspectives without actually complicating the worldview of science as a purely Western phenomenon (Smith et al., 2019). Category two approaches are exemplified by coverage of the 'discovery' that hawks in Australia will carry burning branches to start fires. This phenomenon, originally observed by Aboriginal Australians, was only considered credible when the conclusions were separately reached by Western scientists (Bonta et al., 2017). This example speaks to Kimmerer's point about the assimilative nature of science when the observations are remade to fit within the confines of Western science (Kimmerer, 2019). Observation-based traditional knowledge should be recognized under a broader and more holistic definition of science.

Though these two categories have predominated approaches to incorporating Indigenous science, there are ways to include perspectives and promote equity and critical thinking, which can vary significantly based on the scope and content of the curriculum. Examples of Indigenous, observation-based practices that can be included are the domestication of New World crops like maize, pumpkins, and potatoes, or exploring the rich history of Indigenous mariculture (Smith et al., 2019).

To increase the local content, examine the land you are on and its history, both in terms of people and the environmental ecology. Contact Indigenous groups with histories on the land to inform yourself and your students. Do not expect any single source to be the sum of all knowledge or speak for any group as a monolith, but remain open to the resources and histories of local experts.

Some of the foundational narratives to push back on include the view that environments and ecosystems exist independently of humans and that the only legitimate observations are those recorded via Western science methods. However, there are numerous counterexamples to these narratives, including:

- Practices of sea level and ice level observation among Indigenous nations in the Arctic (Igor & Jolly, 2002)
- The shaping of the Amazon rainforest through agroforestry practices (Miller & Nair, 2006)
- Use of controlled burns as a land management practice in North America and Australia (Kimmerer & Kanawha, 2001)
- Timing and extent of mammalian biodiversity declines in Australia (Ziembicki et al., 2013)
- The impacts of Indigenous land stewardship and sovereignty on biodiversity conservation across continents (O'Bryan et al., 2020; Garnett et al., 2018; Schuster et al., 2019)

15.4.4 Assessments That Connect Authenticity with Curiosity, Inclusion, and Identity

Introducing and emphasizing EJ principles and concepts in biology, environmental science, ecology, and sustainability classrooms may be met with some resistance. Traditional undergraduate classroom structures and assessments are often framed around high-stakes exams, with students anxiously studying to provide the single correct answer to each question. Any practitioner of science – especially any science based on field observations – would cringe to think there is a single, consistent, predictable response for many of the variables we measure. If the answers are all available, what is left to explore? Further, this approach leaves little to no room for authentic, individualized explorations of the content that push students and professors to form new questions and ideas.

I (Mary) often fielded questions from students in an introductory ecology course with multiple caveats – does elevated carbon dioxide lead to more significant plant growth? Sure, but more so in plants that employ C3 photosynthesis than C4 photosynthesis – though maybe not over the long term in grasslands. And we need to keep in mind that elevated carbon dioxide drives climate change, which is likely to lead to extended drought periods and increased insect herbivory. And fertilization effects by elevated carbon dioxide may be limited by nitrogen and soil moisture. Also, with soaring rates of deforestation and fires in important ecosystems like the peat forests of Borneo and the Amazon, carbon loss to the atmosphere and removal from forests may negate fertilization effects elsewhere in the world. Oh – you just wanted a yes or no? Acknowledging and addressing unknowns is a challenge for many students in introductory science classrooms and an abrupt change from the formulas and standardized tests that often occupy much of students' time as high schoolers.

Teaching STEM at the K12 and undergraduate levels should be as much or more about learning practices and approaches as learning content. Learning which questions to ask and how to ask them is fundamental to being a scientist, and at the root of these skills are curiosity and creativity. Lecture-heavy, professor-centric undergraduate classrooms encourage passive learning and the messaging that students do not need to push the conversations or question further into unknowns (Deslauriers et al., 2019). Training the next generation of scientists requires students to be comfortable knowing that not all the answers exist yet and to be confident to formulate and follow their own questions. This seemingly small step – to ask a new question and develop a way to address it – is not only at the heart of all science, but can be incredibly empowering to students who have been taught in a way that showcases science as a set of established hard facts and rules to memorize.

Traditional STEM classroom structures and formats do not emphasize or reward curiosity, despite it being so essential to progress in and process of science. Students curious about a topic may be unsatisfied with traditional assessments; their unique interests may not be directly covered in lectures or centered in exams or lab reports. Student curiosity may emerge and develop more in informal discussions, in follow-up questions after class, or be relegated to the summer months or outside of classes when a select few students get to work on research projects or pursue internships. If we value curiosity, and want to teach in a way that allows *all* students to explore their interests and original questions, we need to design assessments that encourage, nourish, and support those traits. Assessments that value individual voice and perspective, firmly place the student in the role of knowledge-creator and scientist, affirming their place in the classroom, especially for students more likely to experience imposter syndrome (Kolligian & Sternberg, 1991). Further, explicitly valuing curiosity – in the syllabus, in assessments, and in-class meetings – provides students with room and freedom to explore with support and may eliminate some anxiety around failure in science.

Traditional secondary education can have a way of making students partition themselves into either humanities or STEM 'types,' and these trajectories often continue into undergraduate education. Unfortunately, students associate creativity more with humanities subjects, but STEM fields such as environmental science, offer so much room for creative thought. New approaches or uses of methods can lead to whole subfields of environmental science. Take, for instance, the use of increased radiocarbon in the atmosphere caused by the proliferation of nuclear weapons testing in the 1960s as a short timescale proxy for dating organic material. This 'bomb spike' is a measurable isotopic signature of the extensive above ground nuclear testing during that period; as bomb-derived atmospheric radiocarbon was assimilated by photosynthetic organisms, it changed the carbon isotope ratios of their organic compounds, which can then be used for short-term dating to track flows of carbon pools through plants and soils (Uno et al., 2013). A recent highlight of these studies examined the age of maple syrup to understand the movement of slow pools of sugars and carbon through trees (Muhr et al., 2016). However, one can not teach about the 'bomb spike' in comfortable scientific isolation – nuclear weapons devastated cities, killed thousands, and decimated tropical, desert, and marine ecosystems. Our job as professors is to highlight creativity and new applications of methods, but we must also provide the whole context of how science emerges. Rather than just covering the shiny advances, we must explore and discuss the difficult and painful histories and current states.

In environmental science and ecology classrooms, assessments that encourage and support creativity, curiosity, individuality, and inclusion can take many forms. Assessments in undergraduate classrooms should be a mix of high-, mid-, and low-stakes, allow students to build up their confidence and understanding through formative assessments, and provide opportunities for students to contribute their voices and perspectives (Handelsman et al., 2007). Assessments can also be areas in the class to emphasize the inclusion of diverse and marginalized perspectives that may not be showcased in textbooks by including readings or topics that integrate EJ concepts and perspectives. Here we provide a variety of examples that apply to introductory and upper-level undergraduate courses.

Mini-Quizzes. Formative assessments are not common in science classrooms – where semester grades are often calculated as the average of a few, large exams. However, research shows that providing ‘low-stakes,’ formative assessments that test content knowledge and understanding without the added anxiety of grades can improve student outcomes (Handelsman et al., 2007). In the last few semesters, I (Mary) have implemented ungraded quizzes at the beginning of class 1 day a week. Some quizzes assess content and understanding of the previous class meeting, a concept from reading, or a graph to be interpreted. Other questions prompt creative approaches to a concept – how to design an experiment around an idea, create a helpful metaphor for a complex topic, or apply understanding of an idea to a novel system.

Once students have completed the short quizzes (aimed to take 5–10 min), they work in small groups to compare answers and make edits and revisions based on consensus. This collaborative learning helps students practice explaining their understanding, defending their responses, and taking alternative approaches to a prompt. The discussion of answers in small groups can turn into a short ‘studying in class’ moment, since many of the quiz questions reflect the topics and difficulty of what students will experience in more summative, formalized assessments like exams. After group collaboration, we work as a whole class and share answers and ideas aloud for all to learn. At this point, I aim to clarify questions and concepts, especially when there may be more than one acceptable response. Mini-quizzes can be collected and checked to make sure the completed quizzes contain answers that students can study from; then they are returned.

Knowing what to expect on exams lowers test anxiety, and I hope the collaborative answering supports student interactions that build community. Providing ungraded formative assessments also allows room to ‘fail,’ space to explore ideas, and can be a place to encourage students to challenge themselves without risk. From a student’s perspective (Jennings), mini-quizzes allow students to learn constructively from failure without being penalized. Furthermore, they serve as a way to build classroom community through collaborative learning and ultimately lower test anxiety by increasing familiarity with materials and how the instructor asks questions.

Further, the mini-quizzes can be used as a pedagogical tool to introduce and engage large science classrooms in discussing and applying ecological and environmental science concepts to EJ topics and marginalized perspectives. For instance, we had recently covered remote sensing techniques in a Plant Ecophysiology course. I (Mary) gave students an abstract, and a summary of a remote-sensing paper focused on the natural resource use of forests by adjacent refugee settlements in Rwanda before, during, and after armed conflict in the country (Ordway, 2015). The mini-quiz prompted students to think of other regions and questions where remote-sensing methods could be used to test a hypothesis about forests and land use. The results of that quiz were diverse, creative, and fully integrated the methods while focusing on EJ issues: forest cover in urban vs. suburban regions in the midwest; how a large land-fill site in Mexico impacted adjacent forest cover over time, and who might be most impacted; changes in vegetation and development in North Korea at the DMZ, and palm-oil plantation expansion in Indonesia, among others. While applications of environmental science, ecology, and sustainability can often be apparent to professors, the content covered in class keeps them isolated in idealized, undisturbed (perhaps fantasized) ecosystems distinct from the current 'real world.' This inaccuracy can be discussed and confronted and can empower students to design questions about topics of interest. Removing grading, and the anxiety around it, from this challenge, unleashes more creativity.

'Future of the field' exploratory essay. One way to encourage student perspectives is to create an assessment that values student voice and opinion. Science assessments (essays and exams) are often designed so that there is only one correct answer and approach (or at most, a few). This approach can limit the creativity of the classroom and does not value alternative perspectives, minimizing the potential authentic inclusion of diverse ideas and strategies. For a large introductory Ecology and the Environment course, I (Mary) developed an assessment to invite student opinion on the discipline. As newcomers to Ecology and Environmental Science, it is likely that undergraduate students can be more objective about its shortcomings as a discipline. While I provided base guidelines for the length and the need to include supporting evidence, students could approach the essay in different styles and cover various topics. The only prompt was: "*The future of Ecology is…*".

The responses to this prompt ranged widely, capturing topics from the lack of Black and Indigenous People of Color and their research in textbooks, to the colonialism implied by much land-based conservation research, to how zoos can provide conservation outreach in urban areas, to the need for a re-thinking of agricultural systems, and the oversight of the whole continent of Africa in many 'global' studies on ecosystem responses. In almost every essay, the current and impending threat of climate change was present. Overall, the essays were stimulating, thoughtful, and enjoyable to read while also providing students with the freedom to explore and organize their thoughts on the fields of environmental science, ecology, and sustainability.

Discussions of future developments occur at conferences and in journals - how we as scholars look to the future of the field, where change is most likely to occur, where change is most needed, what ideas are no longer valid, and so on. However, we rarely empower students to take on that forward-looking vantage point, even though they are most likely to lead the next generation of the discipline. Through student-centered assessments like this essay, students can engage in the intellectual criticism of a field, open avenues for new ideas, and provide fresh, needed perspectives without relying on a single viewpoint.

Zines. Zines are informal, cheaply produced portfolios of creative ideas and share perspectives and viewpoints that are less likely to be promoted by mainstream publishing. Zines can be a collection of essays and pictures with many pages or a short eight-panel folded brochure that guides a reader through a topic. In Ecology and Environmental Science classrooms, zines can be used as individual or small-group projects to showcase new perspectives on a topic covered (or not!) in class. Zines emphasize unique and novel perspectives – the goal is to create, not necessarily imitate, what has been published or made previously, and for this reason can take many forms – cartoons, essays, photos, diagrams, character-driven, or a mix of many elements. Christine Liu (see examples at www.twophotonart.com), a science communicator and neuroscientist, has produced multiple zines to communicate science ideas and make them more accessible to a non-science audience. I owe my inspiration to use zines as a low-stakes assessment to her and other science zine makers.

The mix of science, communication, art, and individual perspective that encompass zines can extend into EJ frameworks in undergraduate classrooms. Unlike many more formalized science communication assessments that assume a certain standard that may not be familiar to all in the class – the production of a podcast, website, op-ed article, or oral presentation – zines are grounded in counter-culture and rejecting norms (Duncombe, 1997). Using zines as an assessment to integrate and communicate concepts in science may indirectly signal enhanced freedom of exploration to students with marginalized and underrepresented identities. Zines do not have a predetermined standard or model to which you need to measure against – a major goal of this format is to express your individuality and share amongst the community (Duncombe, 1997).

In ecology, environmental science, and sustainability classrooms, I encourage professors to keep zine guidelines loose to allow greater creativity and expression amongst students. This freedom can be emphasized by grading that acknowledges the flexibility and individuality of this format. Recently, I assigned students to form small groups based on topic interest (theirs to describe and choose, with an association to the content covered in class) and create an 8-panel zine. Topics included why leaves change color, how animals and plants co-evolved, and deciduous and evergreen tree adaptations. I even contributed one, myself, on the use of isotopes in determining the kind of food you eat. The zines emphasize the need for concise, accessible science communication in a format that eschews norms and invites under-represented viewpoints. Also, zines allow students to welcome elements of 'fun' back into the curriculum – something sorely missing from undergraduate STEM curricula. This is a creative and authentic way to highlight and express messages about a concept that students most connect to (Fig. 15.1).

All too often in K-12 education, science is taught as the accomplishments of a singular genius working alone (or two singular geniuses at odds with each other, e.g., Calvin and Benson, Cope and Marsh). The collaborative aspects of science and discovery are rarely acknowledged, which is harmful. When science is taught as the achievements and accomplishments of individuals, it perpetrates a worldview of

Fig. 15.1 Science communication does not need to be based around stale presentations; zines allow students to play with broad audience science communication

individual exceptionalism that has little bearing on how science, especially ecology, is done. Science is done by teams of flawed and limited people doing their best and working together. Challenge your students to push back against this individualistic worldview by examining the collaborative nature of science through

- Encouraging multi-person lab work *and* a collaborative writeup
- Discussion groups about the content/ethical implications of applications of science.
- A group project about scientists who made discoveries as a group (the Human Genome Project team, for example)

15.5 Guiding Questions for Developing Classrooms That Integrate EcoJustice

When developing new or re-visiting the design of existing classes, we encourage faculty to reflect on ways EJ can be integrated into classroom content and practices. The following prompts for reflection may be most effective when considered before and during course development but can also be applied through the semester to re-tool content, pedagogy, and activities to promote an inclusive classroom.

- Do the learning objectives of the course promote the inclusion of all students? Do they encourage collaboration amongst students or only individual efforts? Are the learning objectives of the course grounded in EJ principles of transparency and sharing of information, equitable decision making, and the incorporation of multiple sources of knowledge? How can the guidelines of the course better reflect EJ principles?
- Do the course assessments encourage and require the integration of multiple perspectives, especially those of marginalized communities? How can assessments be designed to place value on the integration of multiple knowledge sources, especially those not represented at the forefront of standard STEM texts and examples?
- Am I designing a class where all students can thrive? Are the assessments and content designed to serve students from non-marginalized communities due to historical biases of science teaching? How can professors design activities, classes, and assessments that benefit the whole student population and promote authentic inclusion and success of all students?
- Does the content delivered in the class reflect implicit biases, or is it harmful to certain communities? Can content be improved to incorporate perspectives and experiences that reflect the student population more? Are there open-ended, low-stakes activities or assessments that allow students to identify and interact personally with content?

We also recognize that integrating EJ concepts into an undergraduate classroom is a challenge many faculty are not prepared for, especially in STEM courses (see Pfirman & Winckler, this volume). However, we encourage faculty to seek guidance from experts at their institutions – potentially faculty and staff housed in their campus Teaching and Learning Centers or Multicultural Centers. They can offer substantive feedback on how to improve their practice to be more inclusive. The benefit of integrating EJ concepts authentically in these courses can be profound. We are not just providing content piece-meal, hoping students will connect environmental and social issues; we are responsible for providing the tools, information, and space to think critically about how many of the world's current issues can be viewed and addressed more effectively when EJ and sustainability are at the forefront. The current generation of college students will be tasked with so much in the next century to address climate change, resource over-extraction, income inequality, and other issues that affect life from the local to global scales. By involving EJ principles in science classes, we can start thinking together about moving toward a more sustainable, equitable future.

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