

AJEDI in Science: Leveraging Instructor Communities to Create Antiracist Curricula

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Gateway college science courses continue to exclude students from science, disproportionately discriminating against students of color. As the higher education system strives to reduce discrimination, we need a deliberate, iterative process to modify, supplement, or replace current modalities. By incorporating antiracist, just, equitable, diverse, and inclusive (AJEDI) principles throughout course design, instructors create learning environments that provide an antidote to historically oppressive systems. In this paper, we describe how a community of microbiology instructors who all teach *Tiny Earth*, a course-based undergraduate research experience, created and rapidly integrated antiracist content and pivoted to an online format in response to the social unrest and pandemic of 2020. The effort strengthened an existing teaching community of practice and produced collective change in classrooms across the nation. We provide a perspective on how instructor communities of practice can be leveraged to design and disseminate AJEDI curriculum.

KEYWORDS antiracism, justice, equity, diversity, inclusion, structural racism, course-based undergraduate research experience (CURE), scientific teaching, microbiology instruction, instructor community of practice

INTRODUCTION: ARE SCIENCE COURSES RACIST?

Introductory biology courses for majors in the United States have a collective 56% failure rate (1). In *Talking About Leaving Revisited* (TALR), Seymour et al. (2) demonstrated that the proportion of students who leave science has remained high for 20 years; 90% of students who switched out of science blamed teaching methods as one of the primary reasons for leaving. As Elaine Seymour and her team studied the reasons students depart science, they uncovered a troubling truth: students of color have been disproportionately negatively affected, citing conceptual difficulty with the subject matter, inadequate high school preparation, and contending with obligations and identity issues. In TALR's foreword, Shirley Malcom called the loss of diverse

students "... a normalized process of structured wastage," providing a sharp summary of the findings:

In order to succeed in STEM majors, students of color often found it necessary to alter or override cultural values that were important to themselves, their families, and their communities. Those unable to ignore or discard cultural values that hindered their academic success were vulnerable to switching majors or abandoning the attempt to attain any degree. Interviewees of color reported that white instructors and students appeared to be unaware of the extra layers of difficulty with which they had to contend (2).

Abundant evidence shows that reducing racism in college science courses is possible, and the tools to do so exist. Students from underrepresented groups who survive the early college semesters have the skills and grit to succeed, illustrated by their greater likelihood to persist than their peers from the majority (3). Evidence-based instructional strategies enhance learning and persistence of PEERs (persons excluded because of their ethnicity or race) (4). Active learning methods in particular contribute to learning and student retention in science (5). Strategies that link science with real-world problems and engage students in hypothesis-driven research improve student performance and persistence in science (6). Course-based undergraduate research experiences (CUREs) engage students in several aspects of training in science: acquiring knowledge

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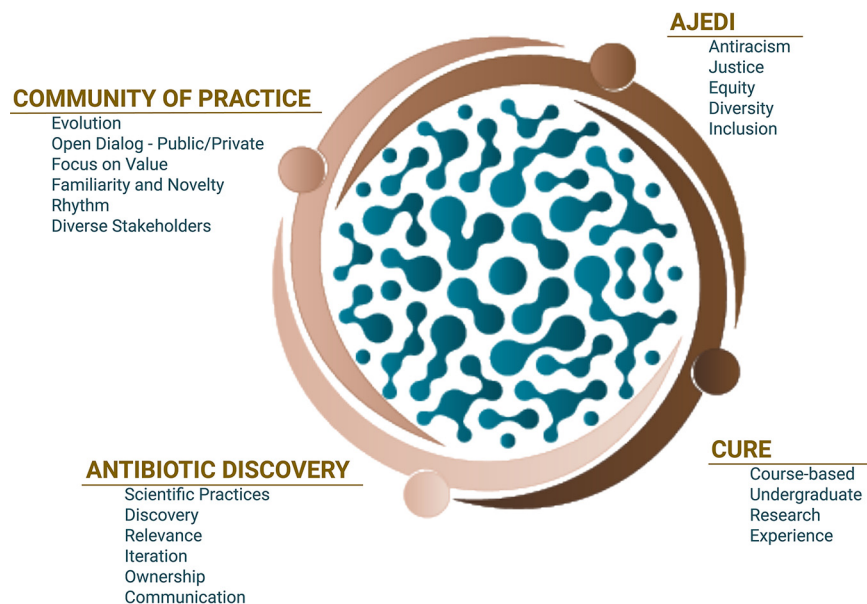


FIG 1. Our perspective: Leveraging a diverse community of practice can galvanize instructors to incorporate AJEDI principles throughout science courses, and in particular course-based undergraduate research experiences (CURE). The context in which we applied this approach is in *Tiny Earth*, a CURE designed around antibiotic discovery from soil bacteria that is taught in 30 countries by more than 700 instructors.

and skills, developing a positive attitude toward science, analyzing scientific outcomes, and imagining career paths (7).

Despite their demonstrated value, however, widespread implementation of active learning strategies has been slow in coming as instructors continue to rely primarily on lectures as a teaching method (8, 9). Course content intended to enhance inclusion of particular groups is even less prevalent (8), and instructors often lack the confidence and support to incorporate it (10). Initial attempts to address some of these inadequacies in the classroom have focused on diversity and inclusion in one-time events, sporadic addition of activities and content, or extracurricular mentoring that may or may not have been meaningfully integrated into the curriculum (11–13). Several successful strategies include more diverse examples of scientists and the impact of science (14, 15), practices that promote student engagement and classroom equity. Techniques such as allowing students ample time to write and respond, asking students to write a values affirmation (16), and linking inclusive pedagogies to universal course design principles also enhance classroom inclusiveness (17, 18).

Yet efforts toward inclusivity are usually squeezed into a system designed to exclude (19, 20). Many “interventions center predominantly on equipping, changing, and fixing the student” (21), rather than addressing programmatic, departmental, and institutional racism (22, 23). The uneven department- or college-level support of instructor-level efforts leads to many being unnoticed and easily eliminated from the curriculum, a problem that is arguably exacerbated when teaching online. More work is needed to make the current system more equitable (24, 25). One important step is to expand use of CUREs, which enhance performance and retention of underrepresented

students in science (26–28). The inclusiveness of CUREs can be amplified by incorporating the principles of antiracism, justice, equity, diversity, and inclusion (AJEDI). Another step is to leverage instructor communities of practice so the work of building, testing, and evolving toward AJEDI environments is a shared endeavor. Research shows that diverse groups produce more robust and creative outcomes (29–33), making diverse communities of practice ideal vehicles for creating AJEDI learning environments. In this article, we provide a perspective on how instructor communities of practice can be leveraged to design and disseminate AJEDI curriculum in online, remote, hybrid, and face-to-face courses. We provide a sample use case with a CURE (Fig. 1) that was updated during the emergency pivot to remote learning with online AJEDI materials that were designed for flexible use in multiple modalities.

CONTEXT FOR OUR PERSPECTIVE

Scientific teaching refers to both the teaching of science and the science of teaching (34). It is grounded in inclusive learning and high-structure design (1, 35) that renders a course transparent, active, and equitable (36). Curriculum that is designed with scientific teaching principles incorporates active learning, assessment, and diversity (37, 38) and uses a backward design approach to course development that begins by articulating learning objectives followed by activities and assessments that meet the objectives (39).

Course-based undergraduate research experiences (CURE) happen “when all of the students enrolled in a course address research problems or questions that are

TABLE I
Defining AJEDI terms: antiracism, justice, equity, diversity, and inclusion (excerpted and adapted from 60–62)^a

Term	Definition
Antiracism (47)	Active efforts to reduce racism that are embodied in behaviors, actions, and policies that lead to racial equity and are substantiated by antiracist ideas. Practicing antiracism requires constantly identifying, challenging, and replacing existing racist acts and policies to foster equity between racial groups.
Justice	A concept of fair and just relations between the individual and society. This is measured by the explicit and tacit terms for the distribution of power, wealth, education, healthcare, and other opportunities for personal activity and social privileges, or the systematic fair treatment of people of all races, resulting in equitable opportunities and outcomes for all. Racial justice requires the presence of deliberate systems and supports to achieve and sustain racial equity through proactive and preventative measures.
Equity (48)	The condition in which individuals are provided the resources they need to have access to the same opportunities as the general population. Equity accounts for systematic inequalities, meaning the distribution of resources provides more for those who need them most.
Diversity	The myriad of ways in which people differ, including the psychological, physical, cognitive, and social differences that occur among all individuals, such as race, ethnicity, nationality, socioeconomic status, religion, education, age, gender, sexual orientation, marital status, mental and physical ability, immigration status, and learning preferences. Diversity is all-inclusive and supportive of the proposition that everyone and every group should be valued.
Inclusion	Authentically bringing traditionally excluded individuals or groups into processes, activities, and decision- and policy-making in a manner that shares power.

^aFor context, we provide a definition of structural racism: “The normalization and legitimization of an array of dynamics—historical, cultural, institutional, and interpersonal—that routinely advantage white people while producing cumulative and chronic adverse outcomes for people of color” (62).

of interest to stakeholders outside the course” (7). Hallmarks of a CURE include scientific practices, discovery, relevance, iteration, ownership, and authenticity (7). Several biology CUREs have been shown to have a powerful impact on learning and ownership of science, such as Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science (SEA-PHAGES), which focuses on isolation of bacteriophage from soil (40–42), or a course in which students discover biologically active compounds in the plant microbiome (43).

Tiny Earth is a CURE that brings scientific teaching principles to life. Tiny Earth has twin goals of discovering new antibiotics from soil bacteria and increasing persistence of diverse students in science (44, 45). The adaptable, semester-long curriculum is the core of a network of more than 700 instructors in 30 countries who teach at least 14,000 students annually. To date, 14% of Tiny Earth institutions are 2-year colleges, 56% are 4-year colleges, 11% are research universities, and 19% are other types of institutions such as high schools. Collectively, the Tiny Earth Partner Instructors (TEPIs) comprise a community of practice. Tiny Earth maps onto the hallmarks of a CURE as follows:

1. Students engage in hypothesis-driven research, learning scientific practices and skills.
2. Students choose their own soil samples and research questions, creating project ownership.
3. Students discover antibiotic-producing bacteria, highlighting a public-health crisis.
4. Students repeat experiments, developing experimental proficiency and problem-solving skills.

Incorporating AJEDI principles of antiracism, justice, equity, diversity, and inclusion into the classroom became a

visible goal in 2020. In response to the social unrest of 2020 and inspired by a list of student demands from black medical students at Stanford University (46) and emerging publications by Kendi, Wilkerson, and others (47, 48), the Tiny Earth community expanded its traditional diversity, equity, and inclusion (DEI) framework to include antiracism (A) and justice (J) (Table I). Incorporating antiracism and justice into the naming of our principles was intended to highlight the role of power dynamics, the historical impacts of privilege, and the legacies of racism in instructional design and learning environments—the elements of education that instructors control. The AJEDI principles continue to guide the instructor community of practice through iterative adaptation and adoption of a curriculum. Tiny Earth’s early AJEDI materials were created primarily for teaching digitally due to the COVID-19 pandemic, but many instructors have since adapted them for their face-to-face courses.

A ROADMAP GENERATED BY THE COMMUNITY

We began the process of incorporating AJEDI principles by first turning to the Tiny Earth community of instructors and students for guidance. We asked for feedback using real-time, online tools (Google docs and slides) because they enable contributions by many voices, rather than relying only on those who are typing the notes or who have the microphone to speak. At the 2020 Summer Tiny Earth Symposium, attended virtually by more than 200 students and instructors, we used live documents for all participants to share their (i) thoughts about how Tiny Earth already

addresses AJEDI and (ii) recommendations to make Tiny Earth more supportive of AJEDI principles. This provided immediate input with data points from our most engaged stakeholders: students and instructors who had just completed a Tiny Earth course the previous semester. This provided a real-time gap analysis to focus our efforts.

The collective document revealed that participants felt that Tiny Earth already addressed DEI principles, pointing to evidence such as a diversity session at the TEPI training, the international scope of the network, the accessibility that comes from being a low-cost CURE, the diversity of institutions that teach the course, and the active recruitment of minority-serving institutions and 2-year colleges. Others called out the willingness of the Tiny Earth network to have difficult conversations about DEI topics and take specific actions such as honoring #ShutDownSTEM and the fact that the first author of the lab manual is Latino.

The recommendations generated by the participants provided the roadmap to guide incorporation of more sophisticated antiracism (A) and justice (J) principles into Tiny Earth. The recommendations addressed the Tiny Earth course, TEPI training, and leadership. Suggestions for the course included incorporating time to discuss race and inclusivity, content-specific examples such as linking health care disparities to antibiotic resistance, examples of women and scientists of color, cultural perspectives on soil science, and the ethics of bioprospecting and natural products discovery. Recommendations for the TEPI training included sessions in which to share AJEDI activities and antidiscrimination policies for courses. General ideas for the training were to increase representation of minority-serving and 2-year institutions in the network and add tools for recruiting and retaining students of color in science. Ideas for Tiny Earth leadership included increasing representation and amplifying voices of people of color or from minority-serving or 2-year institutions and regularly reviewing network approaches and policies. This detailed roadmap enabled the working groups to prioritize their efforts based on broad input from students and instructors.

FOLLOWING THE ROADMAP: A RAPID PIVOT LED BY AN INSTRUCTOR COMMUNITY OF PRACTICE

Curriculum change doesn't happen spontaneously, it is a process driven by thoughtful instructors and instructional teams who invest time to design, share, train, evolve, and evaluate. Therefore, changing instructor approaches through professional development matters. In college science instruction, a commonly cited change model (49) accounts for (i) the individual instructors and (ii) the environments, structures, and institutions in which they teach; it then differentiates prescribed or emergent outcomes. In Tiny Earth, the international instructor network provides a third component of change: (iii) a community of practice. Communities of practice are defined as "groups of people who share a

concern, set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (50). Seven principles guide the cultivation of a community of practice: design for evolutionary change, maintain an open dialog within the community and with those outside of it, invite different levels of participation, develop both public and private community spaces, focus on value, combine familiarity and novelty, and create a rhythm for the community (50).

The Tiny Earth instructor community comprises Tiny Earth Partner Instructors (TEPIs) who share three experiences. They attend an immersive, week-long TEPI training (44), teach the Tiny Earth course at their institution, and engage regularly in Tiny Earth network offerings such as teaching workshops, instructor committees, and student research symposia. The community of practice enabled the TEPI network to respond nimbly to the COVID-19 pandemic and concurrent social unrest. The upcoming semester quickly galvanized a working group (dubbed the pivot curriculum committee) to realize the first round of design, development, and dissemination in summer 2020 so that instructors could implement both AJEDI and remote learning adaptations by the fall semester. The Tiny Earth pivot to remote learning is described in another article in this issue (51). This shared focus mobilized the community toward improvements then and continues to drive it forward today (Fig. 1). Moreover, the community, who exclusively met online during this time, capitalized on the diversity of members that embodied a range of institutions (including 2-year colleges, minority-serving institutions, primarily undergraduate institutions, and research universities), situational factors related to instruction (ranging from small to large courses, from wet lab to remote learning), and racial and gender identities. Group diversity has been shown to generate more defensible solutions, robust deliberations, and creative outcomes (29–33); what better way to address AJEDI principles than with a diverse group of instructors?

To incorporate AJEDI principles in a digital format while upholding the Tiny Earth learning objectives, the pivot curriculum committee focused on finding, adapting, adopting, and developing curriculum. They used the community-generated roadmap to prioritize pre-existing or low-effort adaptations to curriculum. Next, they enacted a backward design approach (39) to tease apart the Tiny Earth curriculum section-by-section and adapt learning objectives to incorporate AJEDI principles. The familiarity of the backward design approach gave the team a framework within which to build the new content, providing a roadmap for development of the materials as well as a course map that the rest of the instructors could use to incorporate the materials into their courses. AJEDI materials were developed for all Tiny Earth modules, providing clear, actionable items and material that provided units spanning several weeks or the entire course (52). The goal was to provide an array of detailed, evidence-based activities that could fit into each part of the course, accommodate the diverse Tiny Earth institutions, and support different levels of engagement or stakes. Many assessments simultaneously

served as an activity or assignment. Some activities were simple, such as discussion-based interactions or short essays, whereas others led to formal, summative assessments such as lab reports or final presentations. According to the principles of backward design, each assessment and activity was aligned to a corresponding learning objective. In Tables 2 and 3, we provide examples using publicly available online content that addresses all five aspects of AJEDI. In the first example in Table 1, antiracism (A) is the focus of the reading and applied in the subsequent activities, and justice (J) and equity (E) are incorporated into students' analyses and the recommendations for change. Diversity (D) and inclusion (I) are part of the design to include examples with diverse perspectives and representation in science. Our goal with these activities was to provide instructors with several actionable ways to weave AJEDI flexibly throughout the fabric of the course (Fig. 2).

When a critical mass of AJEDI content was ready pre-semester, the pivot curriculum committee turned to disseminate materials to the rest of the TEPI network. This was accomplished by coordinating with several other TEPI groups that had emerged to address the massive movement from wet lab to digital and remote learning (51). These teams hosted virtual workshops and webinars for veteran TEPIs, integrated the AJEDI content into the week-long virtual training for new TEPIs, and provided content in a learning management system (Canvas) and a password-protected TEPI website to ensure asynchronous and persistent accessibility. These events were collectively attended by more than 390 instructor participants, and 170 TEPIs have access to the ~20 pages of AJEDI content on the Tiny Earth virtual course in Canvas, averaging 47 views per page.

The hand-off from the pivot curriculum committee to the other TEPI groups served more than the purpose of dissemination; it also provided the opportunity to seek more examples and get feedback from the broader community of instructors about implementation. As the pandemic and social unrest raged on, TEPIs taught the AJEDI curriculum while balancing a rapidly changing landscape of online, remote, and hybrid learning, sometimes oscillating between formats at 2-week intervals. The community activities throughout the year included adaptation to teaching in hybrid modalities or addressing antiracism in the course syllabus, and iterative review and revision of materials. Because the materials were created to be flexible, we anticipate that the effort that these communities of practice dedicated to the student curriculum and corresponding instructor professional development will enable the AJEDI-based curriculum to evolve and be integrated into the broader Tiny Earth network with flipped, hybrid, and face-to-face teaching. A future study would track the scope of implementation and evaluate the impact that AJEDI material has on student outcomes, engagement, and perceptions.

A SPECTRUM OF IMPLEMENTATION

Most of the areas on the roadmap have been addressed with a first round of changes and are being used in a variety

of ways. TEPIs have implemented the AJEDI materials in formal activities that address course learning objectives, multiple informal touch points across a semester, and new courses and modules that incorporate AJEDI principles.

Not surprisingly, given Tiny Earth begins with students gathering a soil sample, many courses have integrated land acknowledgments, which continue to evolve in purpose and sophistication (as described below). Instructors reported a range of implementations for the objective, *Recognize the soil on which we stand, its historical legacies of violence, and its use toward science advancement*. A Wisconsin TEPI stated, "My Tiny Earth students and I read and had a productive discussion about this article: <https://www.smithsonianmag.com/science-nature/astonishing-medical-potential-soil-northern-ireland-graveyard-180973741/>. We made connections to non-Western medicine and cultural values of soil. It was a very productive discussion!" A California instructor shared their story, which expanded the activities to include the ethics of bioprospecting:

We used the Native Land Digital website (<https://native-land.ca/>) to determine the Indigenous origins of the lands they sampled for their Tiny Earth project. In addition, we used a case study written by fellow TEPI Adam Kleinschmit, entitled "Bioprospecting or Biopiracy? Navigating the Fine Line of Equitable Benefits Sharing and Researcher-Takes-All Exploitation of Biodiversity Resources" to understand why it is vital to have permissions to sample land and the implications of extracting materials from the soil by Tiny Earth scientists. Together these activities illuminated the need to recognize the history of the lands where we live, work, and play and how to be careful stewards of the land. Students reflected that they enjoyed these activities that asked them to think more deeply about how their science impacts the world around them, not just for the future, but what it means for past generations. I will continue to use these activities in the future with my Tiny Earth class, and I will try to incorporate more AJEDI principles that I've learned via the Tiny Earth community into my classroom.

Several instructors described their past struggles to incorporate DEI into their classrooms and how the community-generated materials helped them expand to AJEDI. A Minnesota instructor stated:

As I have been doing my own personal work on DEI, I have also been infusing DEI into my genetics class where I teach Tiny Earth. In the past, students seemed engaged, but these discussions weren't connected to any tangible learning objectives or assessments. That changed, however, thanks to Tiny Earth's materials about land acknowledgments. Having the larger Tiny Earth community behind me helped initiate a discussion with my students, who tend to be conservative both politically and religiously, in a very non-threatening way. Furthermore, the students saw the resources as coming from an internationally recognized initiative and felt compelled to keep up with their peers at other colleges.

Another commonly cited objective that the instructor community used is *Describe the historical context of racial oppression in relation to clinical research in microbiology* and its corresponding

TABLE 2

Sample learning objectives for antiracism, justice, equity, diversity, and inclusion (AJEDI) in Tiny Earth, a course-based undergraduate research experience (CURE), with recommended assessments and activities that students can do to achieve the learning objectives

Sample CURE learning objective	AJEDI adaptation for the learning objective	Recommended assessment or activity to address the AJEDI adaptation	AJEDI principle addressed
Distinguish between control and treatment groups in experiments	Explain how racism, bias, and white centering in research design lead to health inequities	How has racism and bias in experimental design led to negative changes in health care access or outcomes? Read <i>Conducting Research through an Antiracism Lens</i> (https://libguides.umn.edu/antiracism/lens). Based on the article, select one example of how racism and bias in experimental design has led to negative changes in health care access or outcomes. On the online class discussion board, explain how it led to negative outcomes and propose one way it could be improved. Post a follow-up question on two other students' posts to expand the conversation about experimental design.	AJEDI
Explain the importance of studying clinically relevant microbes	Describe the historical context of racial oppression in relation to clinical research in microbiology	How has racial oppression impacted clinical research on clinically relevant microbes, antibiotics, or antibiotic resistance? Review posts about historical or current black microbiologists from <i>Scientists Spotlight Initiative</i> (https://scientistspotlights.org/), the American Society for Microbiology (63, 64) or the Black Microbiologists Association (https://www.blackinmicrobiology.org/). Provide three examples that show how racial oppression has impacted clinical research. One example should be about clinically relevant microbes, antibiotics, or antibiotic resistance. Post your answers on the course discussion board.	AJEDI
Connect the discovery of antibiotics with the rise of antibiotic resistance	Propose roles of microbiologists in addressing and dismantling racism	How, from a racial perspective, could a new antibiotic be tested fairly and available equitably? How is that different from historical experiments? Read <i>Medical Apartheid: Teaching the Tuskegee Syphilis Study</i> (65) and watch <i>The Unknowns</i> about the Tuskegee Syphilis Study (https://www.youtube.com/watch?v=J3tQ93fQf8U). Imagine your Tiny Earth research leads to the next new antibiotic discovery. In the conclusions section of your final lab report, include a statement that proposes how, from a racial perspective, your new antibiotic would be (i) tested fairly and (ii) available equitably. Explain how your proposed approach is different from what happened in the Tuskegee experiments.	AJEDI
Record and interpret experimental results	Deconstruct how scientific records influence race and systems of oppression	How do deaths attributable to antibiotic resistance compare across race, income level, or access to health care? Why should you care about how science is recorded and presented to the public?	AJEDI

(Continued on next page)

TABLE 2 (Continued)

Sample CURE learning objective	AJEDI adaptation for the learning objective	Recommended assessment or activity to address the AJEDI adaptation	AJEDI principle addressed
		Find a reputable scientific data set about deaths due to antibiotic resistance. Compare the number of deaths within the entire group with the number distinguished according to one of the following groups: race, income level, or access to health care. Graph your analysis and post it on Twitter or Instagram with a statement about how interpretation or outcomes change relative to race. Comment on how systems of oppression influenced these results. Include the class twitter hashtag in your post.	
Determine whether and how soil properties correlate with microbial abundance	Analyze ways in which racism acts as a barrier to health equity based on differential access to soil and spaces (66)	What is the correlation between income, race, and access to green spaces and soil? Read <i>Income, Race are Associated with Disparities in Access to Green Spaces</i> (67). Enter the location of your soil sample in the Tiny Earth database. In small groups, share where your Tiny Earth soil samples came from. Discuss: How are income and race associated with disparities in access to green spaces, soil, and health equity? Report out to the large group in 10 min. (Instructors: Review the considerations for this type of discussion [55–58, 68]).	AJEDI
	Recognize the soil on which we stand, its historical legacies of violence, and its use towards science advancement	What are the historical legacies of the land from where you took your soil sample? Read <i>How Soil Acts as a Living Witness to Racial Violence</i> (69). Use the <i>Map of Racial Terror Lynchings</i> (https://lynchinginamerica.eji.org/explore) and <i>Native Land</i> tool (https://native-land.ca/) to identify the historical legacies of the land from where you took your soil sample. Include these historical perspectives in your final presentation. (Instructors: Review the considerations for this type of mapping exercise in <i>The Land You Live On</i> [54]).	AJEDI

resource, *Scientists Spotlight Initiative*. A Michigan professor relayed that their students watched a short video each week to highlight women and minority scientists, with the goal of rectifying the prevalence of white men represented in science. Several students commented on the importance of learning relevant science being done by someone who looks like them. Other instructors reported that they incorporated diverse guest speakers into their courses or used AJEDI activities for reaching a broader community. For example, a Florida university professor and a high school teacher paired their Tiny Earth students: the high school students researched diverse scientists of interest, created storyboards about them, and presented them to the college students.

Some instructors addressed AJEDI principles through teaching and assessment methods. One Ohio instructor

provided options for presentation formats that promoted inclusion and equity, accommodating students of different backgrounds and experience. Some instructors chose to communicate their intentions about inclusion directly in the course syllabus. A Maryland professor implemented collaboration agreements at the beginning of the year that were designed to give students ownership of shaping a compassionate and productive classroom environment. In Minnesota, another instructor added the following statement to the syllabus:

It is my intent to create a community of learners that values diverse thoughts, perspectives, and experiences while respecting individual identities. In fact, the diversity that we each bring to this class is a rich resource and strength and by interacting with

TABLE 3
Suggested AJEDI learning objectives (adapted from 70) for Tiny Earth, a microbiology CURE, with actions that instructors can take to address them

AJEDI objective	Recommended instructor actions to address the AJEDI learning objective	AJEDI principle addressed
Develop and document a common language and understanding to create a safe environment to openly discuss race and systems of oppression (71)	<ul style="list-style-type: none"> Share an inclusive learning statement in the syllabus Post rules for effective collaboration on the course learning management system Do a land acknowledgement on the first day of class Pause for 3 s after posing a question 	DI DI AJEDI EDI
Describe the historical context of racial oppression in relation to basic science and clinical research	<ul style="list-style-type: none"> Spotlight examples of historically underrepresented and excluded scientists in lectures and assignments 	AJEDI
Explain how racism influences the social determinants of health (72)	<ul style="list-style-type: none"> Include examples of health equity and disparities in the context of the science (73) 	AJEDI
Recognize students' roles as agents to address and fight against oppression in their own classroom and programs (74)	<ul style="list-style-type: none"> Highlight social media campaigns that address racism in science, research, and higher education 	ADI
Analyze ways in which racism acts as a barrier to health equity	<ul style="list-style-type: none"> Point out the correlation between access to green spaces and health outcomes 	AJEDI
Consider roles in addressing and dismantling racism as scientists, and be willing to question the status quo in science	<ul style="list-style-type: none"> Engage in timely social media campaigns such as #ShutDownSTEM or #BlackInSTEM Show examples of how scientists can change communication (75) and interpretation of science, emphasizing any differential impact on historically underrepresented and excluded scientists 	AJEDI
Integrate skills to demonstrate increased capacity to work across diverse cultures, perspectives, and backgrounds	<p>Provide regular opportunities for exploration, discussion, and creation of methods and activities that lead to increased capacity to work across diverse cultures, perspectives, and backgrounds (76). Example activities:</p> <ul style="list-style-type: none"> Discuss how science communication is “packaged” to engage various audiences. Who is targeted? Who is excluded? <i>Inquiry Cube</i> (https://passionatelycurioussci.weebly.com/blog/patterns-in-science-inquiry-cubes): Work individually, in pairs, and finally in groups to communicate and interpret mock data. Discuss how interpretation of “data” changes as it is communicated. What are the consequences? How does your communication style differ from your partner and the whole group? Did you come to the same or different conclusions of the same data set? How will this influence your perspective moving forward in research? 	DI

people from diverse perspectives, we will experience personal and intellectual growth. Showing respect to everyone in the class is expected and racist language or hurtful behavior will not be tolerated. As we seek to create a positive classroom community, your feedback is encouraged and appreciated.

The TEPI community now routinely incorporates AJEDI principles into new course content during development. For example, a new course (Tiny Earth Chemistry) and module (the bioprospecting module described above) address AJEDI

principles through the ethics of natural products discovery. TEPIs continue to use the community for guidance and feedback on new materials, which remain on a password-protected site until they are ready for broad dissemination through the Tiny Earth student guidebook (43) or other future publications. The TEPI community also continues to adapt the materials for ever-evolving modalities. The AJEDI materials were initially created for online and remote teaching and therefore relied solely on digital adaptations and

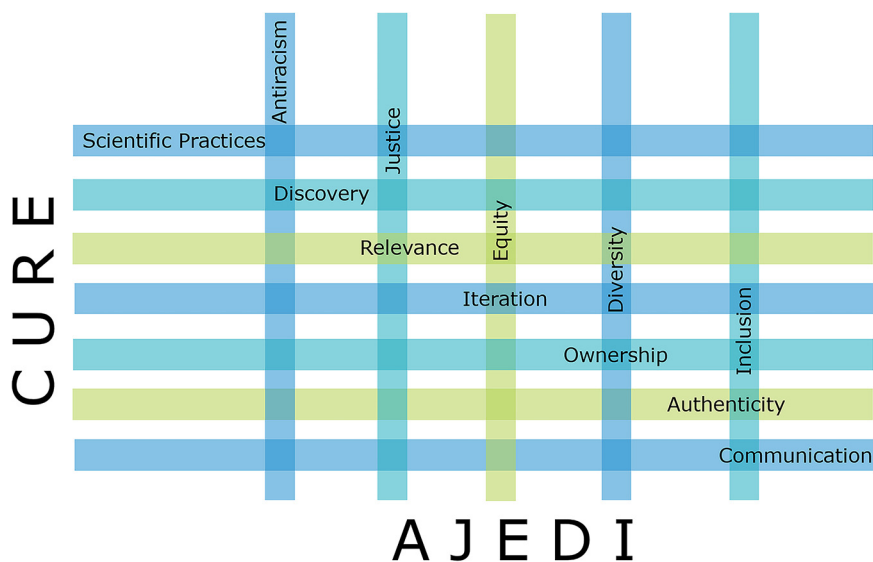


FIG 2. Tiny Earth weaves together the hallmarks of a course-based undergraduate research experience (CURE) with antiracism, justice, equity, diversity, and inclusion (AJEDI) principles.

resources. As classrooms move in and out of face-to-face, hybrid, and remote contexts (sometimes changing in real time), these materials continue to be adapted accordingly. Because the materials were created using a backward design approach that reinforces the importance of learning objectives, the adaptations between online, remote, hybrid, flipped, and face-to-face modalities are seamless.

A LEARNING COMMUNITY

Communities of practice offer the benefit of diverse backgrounds that create a collective intelligence and creativity that is unmatched by any individual. As they review materials, community members each apply their own lens of experience. When they test materials in the classroom, they return to their colleagues with feedback from students of even more diverse perspectives, thereby improving the content. This was amply demonstrated by the development of the land acknowledgment by the Tiny Earth community of practices. Initially it seemed to be a straightforward way to recognize the historical legacies of violence on the land where students collected their soil samples. In some classrooms it worked well, but some instructors found disturbing, unintended consequences, and in particular, the reawakening of past trauma among the very students whose histories were being honored (53). Other instructors found that simply reading a land acknowledgment was insufficient, and the community responded with a revised unit that provided more extensive background (e.g., 54) and guidance for successful classroom implementation.

The exploration of health disparities provides another example where the community evolved its approaches. A

typical approach to incorporating health disparities into the class involved discussing health outcomes between racial groups without clear context. Observations for why these differences exist were initially made by students and instructors and centered on things such as eating unhealthy foods, access to health care, and/or living in low-income households. While there are clear, demonstrated correlations between those factors (1, 54) that address the diversity, equity, and inclusion components, these activities fail to address antiracism and justice. Here, the iterative process led to the incorporation of additional inquiry and explanation to study why systemic racism leads to the social and economic differences that ultimately affect health outcomes (55, 56). Recommended activities were then realigned toward those antiracism and justice goals through something tangible: access to green spaces and how that correlates to health inequities (Table 2).

The process of engaging a community in developing curriculum—and in particular developing materials for a complicated topic like AJEDI in the context of an emergency pivot to online and remote learning—provided a few lessons learned. Most notably, the backward design approach proved to be the key to developing materials to endure beyond the pivot to online and remote and that can be used in flipped, face-to-face, and hybrid modalities. Because backward design insists on starting with learning objectives, it helps focus instructors on what is most important: student learning. Another benefit of a backward design approach is that learning objectives are often modality-agnostic, in contrast to activities and assessments, which are often tethered to one modality or another. The objectives provide a backbone on which activities and assessments hang. This flexible structure gives each instructor agency in deciding how the materials are taught, meaning the content is more accessible to use with a diversity of students at a variety of institution types—all of which increase the likelihood of uptake and sustainability.

Paradoxically, the backward design process is more effective when done iteratively; we learned that it is never too late to retrofit a long-standing curriculum with augmented objectives, and it is not a problem to let an activity or assessment inspire new objectives. What matters is that all the parts work together intentionally to reinforce learning toward the new goals.

AN AJEDI REVOLUTION THROUGH COMMUNITIES OF PRACTICE

Teaching science in the current system reinforces racial biases in the classroom. The resistance to change is enormous, but so is the insidious impact of maintaining the status quo. Structural racism confines the scientific enterprise with the same prejudices that shaped it historically (21). Changing the science education system to one that fosters belonging and accomplishment by diverse students will open science to new ideas and ways of knowing, leading to revolutions in scientific thought that would otherwise be prevented by the effects of exclusion (57).

Accomplishing sweeping change requires many individuals to act. But introducing antiracism into the curriculum is a deeply lonely endeavor for which few instructors receive support from their institutions (58, 59). Communities of practice can assist by providing the support instructors lack working alone. They may also learn strategies from one another for drawing their campus leadership into the revolution.

The Tiny Earth community of practice created materials to help instructors embark on building AJEDI classrooms. Issuing the challenge to do so is not sufficient; it must be accompanied by concrete materials and guidelines or many well-intentioned instructors will abandon the effort. Moreover, the community can provide the benefit of its experimentation and evolving philosophy of what it means for a classroom—whether online or face-to-face—to be actively antidiscriminatory, thereby further enriching the materials.

Communities of practice provide potent tools to induce long-overdue changes in science curricula. Using communities to create the content that takes a step toward counteracting structural racism in the sciences creates classrooms that enable underrepresented and excluded students to thrive. Experiencing even one classroom based on AJEDI principles may be enough to prevent a student from abandoning science, thereby shaping the future face of the scientific community.

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Apply to become a TEPI at <https://tinyearth.wisc.edu/join>.

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