Social Justice, Community Engagement, and Undergraduate STEM Education: Participatory Science as a Teaching Tool

Heather D. Vance-Chalcraft,[†*] Kalynda Chivon Smith,[‡] Jessica Allen,[§] Gillian Bowser,[‖] Caren B. Cooper,[¶] Na'Taki Osborne Jelks,[#] Colleen Karl,[@] Robin Kodner,[**] and Mara Laslo[††]

[†]Department of Biology, East Carolina University, Greenville, NC 27858; [‡]Department of Psychology, North Carolina Agricultural and Technical State University, Greensboro, NC 27411; [§]Department of Biological, Physical, and Health Sciences, Roosevelt University, Chicago, IL 60605; [‖]Ecosystem Science and Sustainability, Colorado State University, Fort Collins, CO 80523; [¶]Forestry and Environmental Resources, North Carolina State University, Raleigh, NC 27695; [#]Department of Environmental and Health Sciences, Spelman College, Atlanta, GA 30314; [@]Retired Community Member, Edenton, NC 27932; [**]Environmental Sciences, Western Washington University, Bellingham, WA 98225; [††]Biological Sciences, Wellesley College, Wellesley, MA 02481

ABSTRACT

Social justice is increasingly being seen as relevant to the science curriculum. We examine the intersection of participatory science, social justice, and higher education in the United States to investigate how instructors can teach about social justice and enhance collaborations to work toward enacting social justice. Participatory science approaches, like those that collect data over large geographic areas, can be particularly useful for teaching students about social justice. Conversely, local-scale approaches that integrate students into community efforts can create powerful collaborations to help facilitate social justice. We suggest a variety of large-scale databases, platforms, and portals that could be used as starting points to address a set of learning objectives about social justice. We also describe local-scale participatory science approaches with a social justice focus, developed through academic and community partnerships. Considerations for implementing participatory science with undergraduates are discussed, including cautions about the necessary time investment, cultural competence, and institutional support. These approaches are not always appropriate but can provide compelling learning experiences in the correct circumstances.

BACKGROUND

Projects that engage the public in scientific research have increased in recent decades both in informal science learning environments and formal learning environments where educators use such projects to bring authentic science experiences to students (Hitchcock *et al.*, 2021; Vance-Chalcraft *et al.*, 2022). This increased interest in participatory approaches has developed alongside the enhanced appreciation that social justice requires broader community engagement and is the responsibility of all disciplines and organizations (Rodriguez and Morrison, 2019; Sultana 2019; Parkes *et al.*, 2020). Institutions of higher education (i.e., colleges and universities at the postsecondary level) have great potential for affecting change by developing and maintaining social justice efforts within STEM fields. Our goal is to examine the intersection of participatory science, social justice, and higher education to suggest how the connections between these areas can facilitate both teaching about social justice in undergraduate STEM courses and collaborations between academia and local communities working toward social justice. We use the term participatory science as an umbrella term that includes a variety of approaches such

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*Address correspondence to: Heather D. Vance-Chalcraft (vancechalcrafth@ecu.edu).

TABLE 1. Potential social justice learning objectives using participatory science approaches

Goal	Learning objective
Evaluate the distribution of natural and built resources	1a) Synthesize multiple data sources to correlate resource/risk distributions with social vulnerability characteristics
	1b) Integrate historical data to uncover patterns of inequity and potential causal forces of current inequality in resource/risk distribution
Consider issues of equity, inclusivity and procedural injustice in research	2a) Describe from where, from whom, and what types of data are collected
	2b) Evaluate the social forces that influence what research is conducted (or not conducted) and what questions are asked (or not asked)
	2c) Explain mechanisms by which data analysis and presentation can be biased

as citizen science and community science (Cooper *et al.*, 2021; see "Clarifying definitions" below).

We assert that now is a particularly good time to discuss participatory science for social justice aims in education for a number of reasons. Recent disruptions caused by the COVID-19 pandemic have added urgency and provided novel opportunities for discussions of social justice and innovative teaching approaches. The pandemic exacerbated existing educational inequities among different demographics within higher education (Smith *et al.*, 2020; Muñiz, 2021) and coincided with renewed conversations about societal inequities regarding race and policing in the United States (Lewis and Usmani, 2022; Pickett *et al.*, 2022). Concurrently, the widespread shift to remote learning fueled greater changes in how and what we teach than any time in modern memory (Johnson *et al.*, 2020; Pokhrel and Chhetri, 2021). Higher education instructors are rethinking their course structure as they try to determine which teaching practices, content, and policies to keep after this transition. We suggest that instructors in higher education can leverage participatory science relevant to social justice to help meet current challenges.

Although we (the authors) try to consider a variety of settings and perspectives, we acknowledge that our lived experiences influence and may limit our views. The authors are part of a working group associated with a research coordination network in undergraduate biology education (RCN-UBE) called the USE Cit Sci Network (use-cit-sci-network.org). This Network brings together individuals across institutions to use the power of collaboration with diverse partners to study the use of participatory science in higher education. The members of this working group include faculty at a range of institution types and sizes, including historically Black colleges and universities (HBCUs) and minority serving institutions (MSIs), regional institutions, state universities, and elite private liberal arts colleges. We include individuals who are early-career to retired academics, members of underrepresented groups with different cultural perspectives, and varied scientific expertise in social science, health, and environmental fields.

CLARIFYING DEFINITIONS AND FRAMEWORK

Participatory Science, Citizen Science, and Community Science

In this paper, we focus on applying participatory science approaches for teaching about social justice in undergraduate education. *Participatory science* involves the public in advancing scientific knowledge through data collection, analysis, or some other means. There are many types of participatory science, including citizen science, community science, community-based participatory research, participatory action research, community-engaged research, and community-academic partnerships, among others (see Table 1 in Davis and Ramirez-Andreotta, 2021). Each approach requires a different level of commitment and serves differing objectives (see Davis and Ramirez-Andreotta, 2021).

We use participatory science as a general term, with a greater emphasis on two approaches that fall on differing parts of the continuum, large-scale and local scale. We use large-scale participatory science approaches to refer to projects that generally have data collection over broad geographic areas and require little or no community building (e.g., citizen science). The term citizen science refers to projects in which decentralized volunteers contribute to data collection with the goal of facilitating scientific research over which traditional scientific and academic institutions retain control (Bonney *et al.*, 2009; Cooper *et al.*, 2021). In contrast, local-scale participatory science approaches require relationships and collaborations between parties with the goal of enacting change (e.g., community science). Community science projects highlight local expertise over scientists from outside the community, address concerns of the community, and translate research results to social action. ***We describe how large-scale participatory science approaches (such as citizen science) can be used for teaching students about social justice while local-scale approaches (such as community science) can provide opportunities for collaboration between institutions of higher education and local communities to facilitate social change***.

Social Justice

There are many types of social justice approaches, including distributive, procedural, restorative, and retributive (Sabbagh and Schmitt, 2016). Understanding how the variations of social justice and related activities are defined and their place in academia is especially significant in a time when the importance of social justice and the merits of higher education are being questioned in the United States (Goldfarb and Kriner, 2017; Parker, 2019). Societal polarization in the United States is driven in part by differences in beliefs around the importance of the civil rights of marginalized groups, the usefulness of science, and how science is, and can be, used to increase the quality of life of all people. Although social justice has many definitions, we will use the term primarily to refer to the position that the oppression of marginalized groups and resulting disparities must be abolished, with an emphasis on preserving (creating) democracy (Murrell, 2006; Sabbagh and Schmitt, 2016; Bowser and Cid, 2021). The social sciences and humanities have been traditionally more likely to center social justice in their approaches

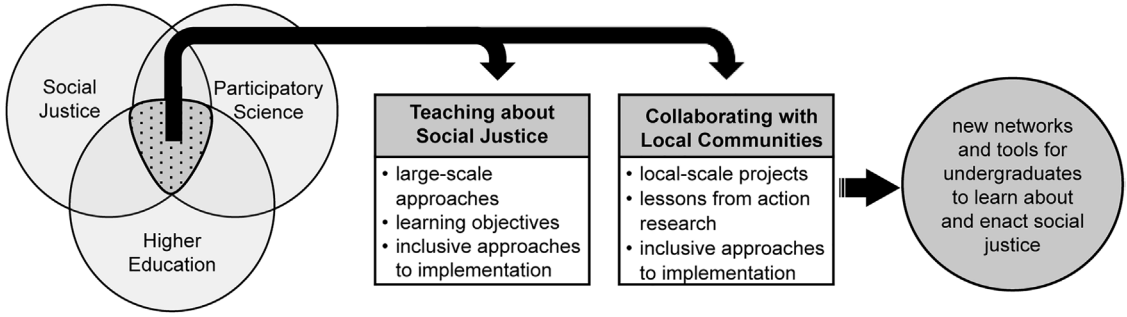

FIGURE 1. The intersection of participatory science, social justice, and higher education provides tools for teaching about social justice and collaborating with communities for social justice.

compared with STEM fields (Hytten and Bettez, 2011), however, it is becoming increasingly evident that the natural sciences must do the same.

Issues such as environmental injustice and health disparities are places where social justice most obviously intersects with STEM disciplines. Climate change has many social justice implications as the use and destruction of natural resources largely by industrialized nations has benefitted their populations while negatively impacting the health and well-being of all. Along with the issue of climate change, several highly publicized accounts of environmental pollution have demonstrated how racism and classism are deeply embedded in policy and regulatory enforcement in the protection and preservation of air, water, soil, and other aspects of the natural environment. Instances such as the Flint, Michigan water crisis (Butler *et al.*, 2016), the DuPont PFAS dumping scandal (O'Brien, 2020), and the Dakota Access Pipeline (Whyte, 2017) are just a few of many examples of environmental harm impacting public health. Similarly, there are racial and economic disparities in access to the benefits of healthy environments, such as green spaces in urban settings (Rowland-Shea *et al.*, 2020; Rigolon *et al.*, 2021) and access to nature writ large. The racial and economic disparities in exposure to environmental burdens and access to environmental benefits illustrate forms of distributive injustice (Lamont, 2017). Both social justice and science share the mission of improving individual's lives as well as advancing humanity and must work together to do so.

Institutions of Higher Education

Societies can build on inclusive democratic ideals and enhance capacities of communities through institutions of higher education, specifically colleges and universities (Finkelstein, 2020). In this manner, institutions of higher education could be a powerful force for change through their roles in education and community engagement. But there are also inequities across institutions of higher education. For example, public predominantly White institutions (PWIs) regularly have higher overall capital spending compared with their HBCU counterparts, even after court mandated change (Brown and Burnette, 2014).

Institutions of higher education have diverse missions, histories, student bodies, and expectations of faculty. Some institutions prioritize research and innovation, while others, particularly HBCUs, Hispanic-serving, and other MSIs, may put a greater emphasis on community and service; some institutions emphasize both. Many universities in the United States include education of graduate students at the Master's and Doctoral levels, although here we will restrict our discussion to undergraduate education, the Associate's and Bachelor's degree levels. Institutional experiences and cultures impact the way participatory science tools in the undergraduate experience can be used to educate students about and promote social justice.

Using the aforementioned definitions of participatory science, social justice, and higher education as a starting point, we highlight how participatory science can be leveraged to both teach students about social justice and empower them to collaborate with community social justice movements through the application of science (Figure 1). We focus on large-scale participatory approaches (such as citizen science) for teaching students about social justice. Specifically, we review learning objectives relevant to social justice that can be met through participatory science, provide examples of participatory science tools that have or could be used for this purpose, and describe the role of context when considering using these tools to teach undergraduate students about social justice. Then we discuss how students can engage in local-scale participatory science (especially in the form of community science) efforts to collaborate with social justice change agents in their communities. Finally, we consider faculty skills and teaching considerations for implementing these ideas, as well as future directions for research.

USING LARGE-SCALE PARTICIPATORY SCIENCE TO TEACH ABOUT SOCIAL JUSTICE

Participatory science approaches, especially large-scale projects which are centrally organized but can be completed anywhere, can be particularly useful for teaching students about social justice. Participatory science has incredible potential to democratize science and to connect research to society more directly by allowing for the expansion of by whom, from whom, and where information is gathered (Parrish *et al.*, 2019). This is true even in projects where volunteer participation is limited to data collection (Hunter *et al.*, 2020). The very nature of the inquiry can also be adapted to address scientific needs, the needs of the community, and the needs of the volunteers themselves in projects codesigned with input from the community and focused on social issues (Shirk *et al.*, 2012). While not all participatory science projects have a social justice focus, the democratic potential of these projects make them uniquely fitted to help examine and understand social justice issues. Using large-scale participatory science approaches like citizen science to teach about

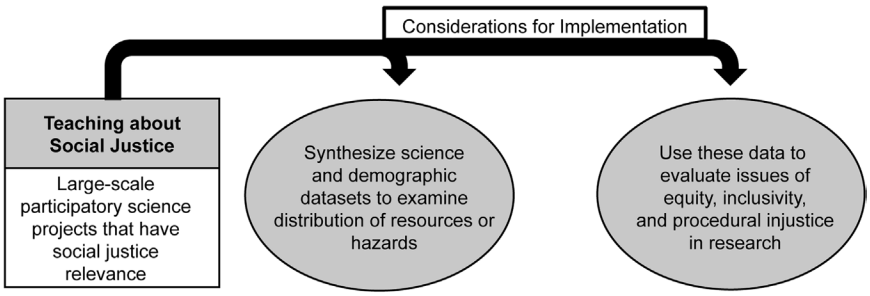

FIGURE 2. Large-scale participatory science projects can be used to teach undergraduate students about social justice.

social justice can be done in a single term (quarter or semester) or less and does not require an instructor to coordinate with other organizations.

There are many examples of large-scale participatory science projects being used to examine issues that have social justice components. These databases, platforms, and portals could be used as starting points in STEM classes to teach about social justice (Supplemental Table 1). This list is not meant to be exhaustive, but to provide examples of participatory data sources that can be used to teach students about social justice. Students can collect data and add it to these projects or use an existing database, depending on the instructor's objectives. While we suggest that sources such as these are well suited to teach undergraduates about social justice, we also recognize that their incorporation into lessons must be done mindfully (see "*Considerations for Implementing these Approaches*" below).

Potential Social Justice Learning Objectives

Expanding understanding of and access to scientific tools across society is a critical step to creating inclusivity and equity. Well-designed participatory science projects have great potential in this area (Hunter *et al.*, 2020; Cooper *et al.*, 2021). Here we propose a set of potential learning objectives about social justice that can be taught using participatory science (Figure 2, Table 1). The objectives below align with two major learning goals that can act as entry points: (1) large-scale participatory science datasets can be used to reveal inequities in community access to resources and burden of risk from potential hazards (e.g., distributive social injustice), and (2) participatory science projects can be used to start discussion about issues of equity in research. A discussion of scientific (as opposed to social justice) learning objectives that can be met through student participation in large-scale participatory science can be found elsewhere (Phillips *et al.*, 2018; Vance-Chalcraft *et al.*, 2022).

Evaluate the Distribution of Resources. Much scientific data is georeferenced, allowing for the possibility of connecting it with demographic data such as race and ethnicity, gender, income, education, age, primary language spoken, and the intersections of these variables (Objective 1a in Table 1). Georeferenced data collected on biodiversity, green spaces, water quality, the location of pollution and other environmental hazards, and the presence of antibiotic resistant microbes (among others) can be mapped geographically and assessed with demographic information relevant to equity and justice (Supplemental Table S2). For example, U.S. census data has been matched with tree cover data and land surface temperature in urban areas to determine that low-income blocks, on average, have 15.2% less tree cover and are 1.5°C hotter than high-income blocks (McDonald *et al.*, 2021).

While overlaying demographic data and georeferenced data can help reveal inequities in the distribution of resources, one must proceed carefully. Students should be cautioned against a deficit-based perspective in which they can be a "savior" (Bauer *et al.*, 2015). For example, a variable of race should not be conflated with racism as a systemic issue and root cause of these patterns. Instead of individual problems to be fixed, these issues represent opportunities to work with communities for social change (Kretzmann and McKnight, 1993). Also, instructors should acknowledge that identity and intersectionality are multifaceted issues that cannot be summarized as a single demographic variable.

Integrating historical data, and traditional sources of knowledge, in the evaluation of the distribution of resources (Objective 1b in Table 1) can uncover past patterns of inequity and potential causal forces of current inequality in resource/risk distribution. Studies focused only on the current state of a location, its ecosystems and people, may not capture the historical and political context that have shaped a community and impact current realities. Numerous natural history museums have started projects that connect modern data and public records, which together reveal long term ecological and social changes (Hill *et al.*, 2012; Heilmann-Clausen *et al.*, 2016; Sforzi *et al.*, 2018). Similarly, "digital humanities" projects are often focused on crowdsourcing of historical texts, artwork, and other collections to put modern findings into a deeply rooted context, allowing for possibilities to uncover historical patterns and evidence of inequities (Heinisch *et al.*, 2021).

Consider Issues of Equity, Inclusivity, and Procedural Injustice in Research. Participatory science also can be used to teach undergraduates about equity, inclusivity, and procedural injustice in research. Specifically, one can have students describe from where, from whom, and what types of data are collected (Objective 2a in Table 1). Examining patterns of volunteer engagement in large-scale participatory science projects can highlight social disparities in who is collecting data (Objective 2a in Table 1). Despite projects being "popular" and engaging thousands to sometimes millions of people (e.g., over one million in three months, Waldispühl *et al.*, 2020), these projects face a diversity crisis. Studies of demographic patterns within participatory science projects reveal that the overwhelming majority of participants in contributory, large-scale participatory science are White, highly educated, and wealthy (NASEM, 2018; Pateman *et al.*, 2021; Rutter *et al.*, 2021; Allf *et al.*, 2022). Other studies have examined the distribution of participant-generated data in relation to socio-demographic data to reveal social inequalities. For example, Mahmoudi and colleagues (2022) revealed racial, economic, and rural-urban disparities in rain monitoring; Blake *et al.* (2020) found racial

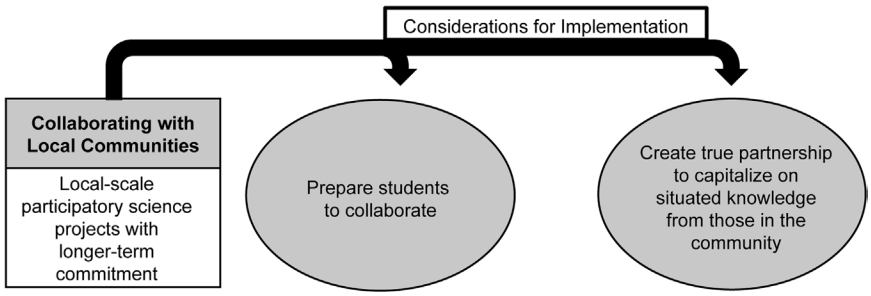

FIGURE 3. Instructors can prepare students and sustain community collaborations on local-scale participatory science projects to build capacity for social change.

and educational disparities in volunteer stream water monitoring; and the amount of low-cost air quality sensors per capita in a self-organized network in the Los Angeles areas are underrepresented in low-income and ethnic minority neighborhoods (Mullen *et al.*, 2022). Incorporating lessons on these types of patterns can help students understand and explore how these disparities arise, why they arise, and the consequences.

Biased collection of data is only one example of procedural injustice in science that can be highlighted using participatory science. Inequities in funding, development, and implementation of scientific research are also important in influencing who collects data and what research is conducted (Objectives 2a and b in Table 1). Much has been written on inequities in distribution of research funds from the National Institute of Health and the National Science Foundation based on the investigator's race and gender (Rissler *et al.*, 2020; Taffe and Gilpin, 2021; Lauer and Roychowdhury, 2021; Chen *et al.*, 2022). Attention has also been drawn to potential inequities in what is considered legitimate research, how different research methods are regarded across fields, and a lack of funding being provided for research questions that focus on resource disparities (Carnethon *et al.*, 2020; Odedina and Stern, 2021). Examining these topics may be impactful to students as they begin to think more critically about systemic factors and data practices in science.

Finally, biased data collection and analytical approaches can have an impact on how findings are interpreted (Objective 2c in Table 1). For example, opportunities to work with nonquantitative methods give STEM students experience with social science tools and allow them to develop skills and experience with uncovering deeper explanations for oppression, marginalization, and potential for bias in scientific research. Students can be encouraged to explore, compare, and contrast research approaches and learn to integrate diverse streams of knowledge, which broadens cultural perspectives and bolsters related social justice work.

USING LOCAL-SCALE PARTICIPATORY SCIENCE TO COLLABORATE WITH COMMUNITIES TO BUILD CAPACITY FOR SOCIAL CHANGE

While some approaches to teach students about social justice (e.g., encouraging students to collect data in a more inclusive and equitable manner) can also contribute to social justice action, preparing students to use local-scale participatory approaches to help facilitate community change efforts will require more investment than those used to solely teach about social justice. For example, sustained effort is required to provide students with the opportunity, and give them the skills necessary, to collaborate with communities to address social justice (Figure 3; see "*Considerations for Implementing these Approaches*" below). Under the appropriate circumstances, however, this collaboration can be a powerful experience for both the students and community with the potential to produce social change.

Many benefits of using a local-scale participatory approach with students have been identified. These efforts build a relationship between communities (often underserved) and academic institutions and can provide useful information to communities (Masterson *et al.*, 2019; Vadjunec *et al.*, 2022; Vance-Chalcraft and Jelks, 2023). Beyond building social capital for researchers, it can help nonscientists in the community better understand how science works (Vadjunec *et al.*, 2022). Students learn to work with diverse parties and how to ethically engage with their communities (Malotky *et al.*, 2020; Vadjunec *et al.*, 2022). They also can gain a deeper understanding of applied research methods and express an increased interest in future research and community activism (Malotky *et al.*, 2020). These approaches can be particularly impactful for minoritized students who value community engagement and collaboration more highly than students from majority backgrounds (Garibay, 2015; Estrada *et al.*, 2016; Puritty *et al.*, 2017; Malotky *et al.*, 2020).

Local-scale participatory science approaches can be used to connect undergraduates in STEM courses to new or established community partners. These connections between institutions of higher education and communities help students gain a greater understanding of local issues of concern and potential action-pathways to resolve them (Varelas *et al.*, 2018; Herman *et al.*, 2021). Incorporating affected communities and social movements into the dialogue from the beginning shifts power from academic institutions to the community while capitalizing on situated knowledge from people in the community with diverse identities and perspectives (Green, 2021). Students can then be taught to bring the power and resources of science and their institutions to help facilitate the change the community is creating.

These partnerships exist in many disciplines but are particularly prevalent in public health. For example, Malotky *et al.* (2020) describe an interinstitutional course (shared between a private PWI and a nearby HBCU) in which the research question that students asked each semester was dependent on the needs of their community partners. These local-scale participatory research projects focused on health disparities in underserved communities near the two institutions. The students reported gains in their understanding of how this type of research can make an impact on communities and help address real-world problems. In addition, students made gains in their interest in community activism and in working with diverse individuals. Beyond learning about these issues, community members, faculty, and students joined together to take actions (e.g., lead workshops) to address the health disparities, demonstrating community empowerment (Malotky *et al.*, 2020). In addition,

TABLE 2. Three dimensions of empowerment needed for students to be able to facilitate change (modified from Dimick [2012])

Dimension	Description
Social empowerment	Learning collaborative skills and building nondiscriminatory (well informed) relationships
Political empowerment	Practicing agency over their learning, connecting human behaviors and societal problems, and illustrating the ways people can influence political structures
Academic empowerment	Using scientific knowledge and skills to apply critical scientific thought to social problem solving

Jelks and colleagues (2018) paired residents with university students to design an app to collect data on watershed stressors and create a spatial narrative that combined local knowledge with Geographic Information Systems to examine these stressors and gain actionable data. Other examples of this approach include students addressing local research needs and capacity building identified by the community to develop meaningful deliverables related to drought resilience (Vadjunec *et al.*, 2022), and involving high school students in the collection of quantitative data about their neighborhoods to present park design ideas at their City Hall (Van Wart *et al.*, 2010).

These local-scale community collaborations involving students were likely successful because they incorporated evidence-based practices for creating effective participatory research partnerships (Hatch *et al.*, 1993; Furco, 2010; Sandmann and Kliewer, 2012; Hart *et al.*, 2013; Davis and Ramirez-Andreotta, 2021). For example, locally focused participatory research has been found to be more likely to produce structural change when community members are leaders in the project, decision makers and policy goals are included in the original design, and multiple sources of funding exist to support long-term partnerships (Davis and Ramirez-Andreotta, 2021). In addition, community engagement is strongest when this work is seen by an academic institution as a legitimate and valued way to educate students and conduct research, as well as a public service (Furco, 2010).

Local-scale participatory science approaches are not appropriate for some courses or cocurricular experiences. Similarly, not all community needs will be amenable to work with undergraduates. For projects whose intended goals and logistical realities are appropriate for these partnerships, numerous paths for collaboration exist and no single formula will be appropriate or fruitful in all circumstances. Seeking out support and resources for such activities through the university, professional organizations, and nonprofits can help identify interested community partners. Once trusting relationships are built, they can be maintained through the participation of many students and courses over multiple academic terms to facilitate ongoing change efforts.

Relevant Theories to Cultivate Student Skills Necessary for Social Action

There is an extensive literature on social justice education as well as on science education and it is beyond the scope of this article to provide a comprehensive review. Here, we will focus on theories relevant to preparing students to engage with community change processes. For example, Sondel (2017) describe "justice-oriented STEM", in which faculty "cultivate the knowledge; interpretive frames; methods, strategies, and skills; and sense of advocacy necessary for a justice-oriented STEM practice (pg. 42)." In addition, Dimick (2012) argues that educators must pay attention to three dimensions of empowerment (social, political, and academic) simultaneously to teach students the skills needed to help facilitate change (Table 2). Separating these three dimensions analytically can help ensure that classroom structures are established and maintained to support each one. Participatory science approaches can incorporate all three of these dimensions of empowerment to produce students who are better prepared to help communities access science and facilitate community efforts to solve problems of interest.

Action research provides lessons relevant to preparing students to collaborate with local communities, inside (e.g., classes, cocurricular activities) and outside (e.g., community volunteering) of the academic experience, to address social justice issues. Three major themes from action research that may be relevant are: 1) existing change theory can provide a guide for collaborations, 2) community participants should determine the actions that need to be taken to achieve change, and 3) outcomes can be predetermined but emergent ones should be supported as well (Henderson and Stains, 2020).

Asset-Based Community Development (ABCD) change theory is one of many change models, change frameworks, or theories of change. ABCD has particular relevance to using local-scale participatory approaches to prepare students to work with communities for social change. This theory is based in social constructivist ideas and focuses on positive "assets" in the community (e.g., natural resources, local community knowledge and expertise of community residents and community-based organizations) instead of a need-based or deficit model where the community and its people are seen as powerless and deficient (Kretzmann and McKnight, 1996). In this ABCD model, instructors and students relinquish control and help facilitate change that is directed by the community, in a reversal of the typical top-down structure of academic directives. Processes must elicit participation from those often excluded from community decision-making to minimize the perpetuation of structural power and privilege inequities (Cunningham *et al.*, 2022). Positive change occurs when academics and students work with communities to identify assets, build relationships between interested parties, mobilize these assets, facilitate ongoing communication to develop a plan and share useful information, and leverage internal and external resources to support local initiatives (Biscotte and Mouchrek, 2020; Figure 4). Mechanisms for capturing and learning from the messiness of the process may facilitate unexpected outcomes, while keeping the change theory in mind can help maintain forward momentum and embrace the nonlinear and cyclical nature of the process of change.

CONSIDERATIONS FOR IMPLEMENTING THESE APPROACHES

We see many possible learning opportunities related to using participatory science data to evaluate the distribution of resources but recognize that the task of securing, formatting, organizing, and computing geospatial analysis on publicly available datasets is nontrivial. One challenge in using databases

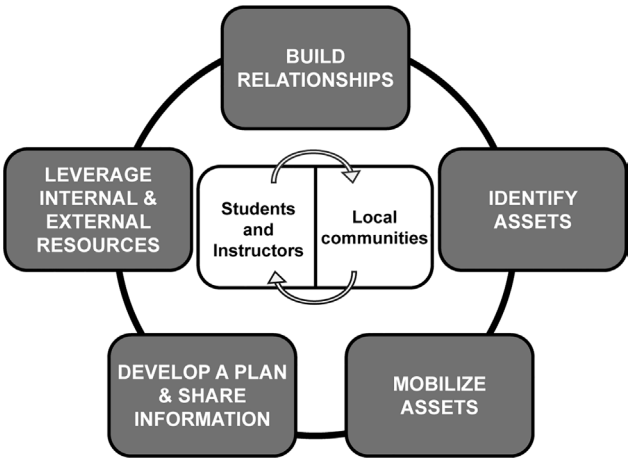

FIGURE 4. Graphic of conditions necessary to create positive change through academics and communities working together (modified from Biscotte and Mouchrek, 2020). This change requires long-term, sustained efforts and is cyclical in nature.

to evaluate the distribution of resources is selecting the data source of interest. We list a variety of potentially relevant databases (Supplemental Tables S1 and S2) but many others exist. Academic research librarians can be invaluable in locating sources of data and a variety of resources are available to help instructors get their students working with these data. For a range of publicly available, publicly-funded tools, instructors can access training webinars and resource documents that provide an introduction to the tools and guidance on how to utilize them (Supplemental Table S3). Therefore, faculty who do not have much prior experience in linking social justice issues to their course content may be able to identify some starting points for learning more about social justice issues and how to access relevant datasets.

Research that involves communities in every stage of the process is time intensive and requires a long-term commitment on the part of the research design team and institution; community trust and rapport may take time to earn and develop, respectively. To be successful, there must be a commitment for a long-term investment into building a partnership from individuals associated with the institution of higher education and those from a relevant community. If different students are involved each semester, a great deal of confidence needs to exist between the academic and community partners. Ideally there will be a positive historical relationship between the two entities and they will share common goals. The partnership must provide benefits to each side and both partners must feel ownership over the plans.

Unfortunately, many communities are familiar with examples of representatives from academia who have extracted information (e.g., local knowledge, opinions, community voices) or samples (e.g., human tissues, environmental monitoring samples) without sufficient discussion with the community about how these items will be used, how the community may be impacted by revealing the results, or whether the results will even be reported back to the participants (Johnson Butterfield and Soska, 2004; Wolinetz and Collins, 2020). Prior asymmetric relationships between university and community partners have been particularly prevalent in marginalized populations so additional work will be needed to build trust and cocreate expectations and guidelines for research with these communities (Wilson *et al.*, 2014; Karasik, 2020; Wolinetz and Collins, 2020). Asking potential partners about prior experiences they have had with university personnel may allow researchers to avoid collaboration pitfalls and clarify procedures so that communities can serve as full partners in the relationship (Darby *et al.*, 2016). Instructors can also seek guidance from resources such as the Data Ethics Toolkit (https://media.scistarter.org/curated/2023-01-02/Data_Ethics_Toolkit.pdf).

The characteristics of the participating college or university also can impact the nature and feasibility of these partnerships. Institutions that have service to their community as a long-standing emphasis in their mission may be more easily trusted by community partners and have positive relationships. These institutions may also provide more support for instructors who want to undertake such partnerships. This support could be financial (e.g., materials and transportation costs for these projects) or logistical (e.g., community engagement or extension offices that can facilitate connections with local organizations) or even psychosocial (e.g., encouraging and valuing these efforts).

A variety of logistical challenges exist for institutional-community partnerships. For example, community, academic, and student schedules often do not align well (Masterson *et al.*, 2019). Significant flexibility needs to be included in course design so that community input can help revise student project plans. Even getting students out to the community can be difficult due to transportation availability, costs, and travel time. While technology provides opportunities for virtual communication, digital access is still not universally available. Additionally, the structure of discipline-based undergraduate science courses may make community-driven interdisciplinary problems hard to fit into a single course and could require assessment methods aligned with the project experiences that may not be familiar to science faculty.

Cultural Competence and Cultural Humility

Participatory science approaches provide many avenues to pursue and teach social justice in STEM; however, it requires instructors to have cultural competence and cultural humility (Quigley 2016a,b). Cultural competence requires that an individual understands and acknowledges the differences between their culture and others, while cultural humility includes an awareness of how sociopolitical power structures shape implicit bias and ethnocentrism against minoritized cultures. Cultural humility also stresses that researchers educate themselves on the experiences of marginalized groups, instead of relying on members of these groups to teach them (Tervalon and Murray-Garcia, 1998; Mosher *et al.*, 2017; Bowser and Cid, 2021).

Awareness of critical theories designed to bring about social change may be useful to properly executing social justice curriculum in STEM classrooms (Sondel, 2017). Some examples of relevant theories are Critical Race Theory, Latina and Latino Critical Theory, Native American Critical Race Theory, and Feminist Theory (Stovall, 2006; Writer, 2008; Allegrini, 2014; Kokka, 2018; Delgado and Stefancic, 2023; Huber, 2023). Together, these theories lay the foundation for the historical underpinnings of implicit bias and the ongoing need for social

justice across disciplines. These theories offer a better understanding of the experiences of minoritized students as well as the needs of minoritized communities. Intersectionality, a theory also embedded in Critical Race Theory, further addresses that individuals with more than one minoritized social identity are likely to have multilayered experiences of discrimination with more severe outcomes than other minoritized groups. Examining how oppression shapes the experiences of particular groups of minoritized people differently in the U.S. enables educators and researchers to help address the unique needs of these communities (see Collins, 2019; Delgado and Stefancic, 2023). In addition, this examination provides avenues for instructors and students to recognize how their lived experience influences how they understand the world (Takacs, 2003). Being perfectly knowledgeable about each of these theories is not necessary, but instructors need to accept that we may make mistakes that we need to apologize for and learn from.

As instructors strive to model and discuss cultural humility, cultural competence, confronting biases, and promoting inclusion, there is a concurrent need to recognize, and not minimize, the systemic nature and root causes of oppression (Tatum, 2003; Kendi, 2019). Inequities the students discover will need to be taught in context and not as standalone issues. We must encourage students to critically examine current policies and practices within our society to determine if they perpetuate the exclusion of some people and work to increase structures that provide access to opportunity and allow all to thrive (Osta and Vasquez, n.d.). Structural change is often difficult but teaching students to embrace the ideas and concerns of local communities can help prepare them to look for creative and bold solutions in unconventional places. Participatory science approaches can be used to help democratize and decolonize the production of scientific knowledge while empowering individuals to address social justice concerns.

Student Positionality and Power Dynamics

Positionality describes how the social and political context in which people live helps shape their identities. Students from the dominant culture may not recognize that they, too, have a positionality. Intentional reflection may be required for them to begin to understand how their worldview was influenced by their membership in this dominant culture (Takacs, 2003). Instructors should be aware of the diverse positionality students within a class may have whether students are involved in large-scale or local-scale participatory science approaches.

A student's positionality can influence their views about particular issues or communities. Within a single class, students may identify strongly, or not at all, with a particular social justice topic (or community) based on their lived experiences. Students may need to be reminded that other students may view an issue very differently from them and they need to practice active listening and respectful communication with individuals in and outside of the class (Takacs, 2003).

Participatory science approaches also raise unique issues around power dynamics between university and community partners as well as between instructors and students. As these approaches bring more individuals into science, student voices and those from the community will need to be amplified and protected. Instructors and students need to be willing to share power and control with their community partners. Similarly, both academic expertise and situated knowledge of local individuals must be solicited and respected. Making participatory science a mandatory class assignment requires careful consideration of issues related to power dynamics and agency. Instructors hold power over students and must provide clear guidelines on what constitutes an acceptable level and quality of project participation. As students do not have the same level of agency as a project volunteer from the public would, reward (e.g., grading) structures must be aligned to course objectives and should not incentivize unethical behavior or historically overrepresented data. For example, counting the number of data points contributed to a project database could reward students for providing falsified data to a project, or collecting only the easiest to get data, unless appropriate quality checks are in place. Allowing students to choose which large-scale participatory science project they want to contribute data to may increase intrinsic motivation but may not align as well with course objectives. Within a local-scale project, providing students options for participation may not be possible, depending on the needs and capacities of the community partner.

Student Considerations

When using local-scale participatory approaches with students, participating students need to be trained and demonstrate competency at working with people who may be different from them. Incorporating all the prerequisite skills for undergraduate students to work effectively with a community partner (such as cultural competence) is difficult in a single semester. A sequence of courses may be needed to provide students with the time and practice to develop the competencies required for working most effectively with community partners.

Philosophical questions may make students uncomfortable as they are not accustomed to such discussions in most science courses. For example, discussions of social justice in a science class may raise questions about whether science is really neutral and objective or whether it has helped perpetuate and exaggerate disparities in opportunity and resource allocations (Green, 2021). This work may reveal questions about the role of science (or an academic institution) in a community as well as the dynamics between parts of the academic hierarchy.

Encouraging students to think critically about these issues requires an intentional approach to teaching about social justice in a science classroom while promoting participatory perspectives at the same time. Providing time for reflection can allow students to recognize the perspectives that underlie these issues and relevance to their own lived experiences ("situated knowledge" or "situated values") and develop new methods or structures addressing social justice (Green, 2021). In addition to using reflection in the classroom, other evidence-based practices like active learning, place-based pedagogies, and constructivist approaches can align well with social justice curricula (Dimick, 2012). Finally, fostering socially just interrelationships between students and teachers and between students and their peers may model principles of social justice efforts that one is trying to teach (Dimick, 2012).

CONCLUSION

Large-scale participatory science databases can be used to design curricula that can illustrate the relevance of science to social justice issues while these approaches at the local scale can

change students' perspectives on how to facilitate social change within communities by leveraging resources, knowledge, and tools available to them. The databases and training resources included here are examples of the vast number of accessible options. Lessons from justice-oriented STEM, action research, and theories of change are highlighted that can inform efforts to cultivate the student skills needed for social action. The need for cultural competence and cultural humility in instructors and students is critical. This constraint, along with various logistical, philosophical, and practical matters, indicate that participatory science and the incorporation of social justice perspectives may not be appropriate for all courses, instructors, or communities. In some circumstances, however, these approaches can be timely and of interest to students attending college in the era of upheavals due to pandemic disruptions and racial injustices. Participatory science provides options for making science more relevant and authentic to students while making the benefits of science more accessible to communities. These approaches also complement recent governmental efforts to create an excellent STEM ecosystem that is more equitable for all (White House, 2022a) and incorporates underrepresented voices and traditional knowledge systems (White House, 2022b).

Future research should examine ways to appropriately assess these participatory science approaches with undergraduates. The development of validated instruments and cataloging of existing instruments, along with recommendations for implementing embedded assessments (activities already completed as part of a project within class but can also be used to evaluate learning objectives) will be critical to establishing the value of these efforts in a variety of institutional, community, and social justice contexts. These tools will also help lower the implementation barrier for instructors considering trying a participatory science approach with the incorporation of social justice in their STEM curriculum.

As we examine the intersection of institutions of higher education, participatory science approaches, and social justice efforts, it may also be beneficial to consider ways that institutions, or representatives from institutions, can collaborate. Supporting research across diverse institutions can level opportunity and increase the generalizability of findings. Using a network approach, such as those facilitated by the National Science Foundation's Research Coordination Networks for Undergraduate Biology Education (RCN-UBE), can allow for the development of transportable research infrastructure, bring additional voices to the research enterprise, and share lessons learned. The Undergraduate Student Experiences with C* Sci Network (USE C*Sci; use-cit-sci-network.org) is one such example that focuses on the educational benefits of incorporating participatory science approaches in undergraduate courses.

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