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Place-Based Environmental Civic Science: Urban Students Using STEM for Public Good

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In the United States, Black and Latinx students are underrepresented in STEM courses and careers due to a dearth of culturally relevant opportunities, which in turn are connected to broader issues of social justice. Place-based environmental civic science offers potential for addressing these issues by enabling students to apply their STEM learning to mitigate local environmental problems. By civic science we refer to science in which all citizens, not just experts, engage for the public good. In this paper, we report on a study in which we followed middle-and high-school science and math classes in urban schools serving racial/ethnic minoritized students as they engaged in an innovative contextualized curriculum—a place-based civic science model in which students work with STEM community partners to address an environmental issue in their community. We draw from students' open-ended reflections on what they learned from participating in place-based environmental civic science projects that could help their communities. Thematic analyses of reflections collected from 291 students point to beliefs in the usefulness of science to effect community change. Students articulated the science they learned or used in the project and how it could affect their community; they made references to real world applications of science in their project work and made links between STEM and civic contributions. In their own words, the majority of students noted ways that STEM was relevant to their communities now or in the future; in addition, a subset of students expressed changes in their thinking about how they personally could apply science to positively impact their communities and the ties between STEM and social justice. Analyses also point to a sense of confidence and purpose students gained from using STEM learning for their goals of community contribution. Results of this study suggest that focusing on local place as a foundation for students' STEM learning and linking that learning to the civic contributions they can make, cultivates students' perceptions of how they can use science to benefit their communities. Findings also suggest that engaging students in place-based civic science work provides effective foundations for nurturing STEM interest and addressing the underrepresentation of youth of color in STEM.

Keywords: civic science, urban education, minoritized children and youth, environmental education, STEM education and learning, underrepresentation in science, place based education

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INTRODUCTION

In the United States, people of color and people from poor and working class backgrounds are underrepresented in STEM education programs and professions (Conners-Kellgren, et al., 2016; National Center for Science and Engineering Statistics, 2021). And although minoritized groups endorse higher environmental concerns than White people (Leiserowitz et al., 2019), "green" STEM fields (e.g., environmental, conservation, atmospheric, and geosciences) remain among the least diverse (Pearson and Schuldt, 2014; Taylor, 2014) even relative to other science and engineering fields. This underrepresentation of marginalized students in STEM is linked not to a lack of talent but to imbalances in formal and informal STEM learning opportunities (National Academy of Sciences, 2019; Pinkard, et al., 2017) which in turn are connected to broader issues of social justice (Lachney and Green, 2021). To address this issue, we need to change the priorities and culture of STEM, moving away from the dominant narratives in STEM education (e.g., expanding STEM pipelines) which ignore the STEM knowledge of non-dominant groups and contribute to the practices that perpetuate the very social issues at the root of these inequities. Equity scholars of curricular practice argue that rather than trying to fit young people into the STEM mold, we should focus on changing the way that STEM is taught and applied (Vakil and Ayers, 2019; Lachney and Green, 2021). Especially relevant to this special issue, these scholars advocate for place-based, contextualized STEM curricula as a way to broaden concepts of how STEM is done and what knowledge is relevant, as well as to question the purpose of STEM education (Lachney, et al., 2021; Vakil and Ayers, 2019).

In this paper, we argue for the potential of place-based environmental civic science for addressing the underrepresentation of youth from marginalized communities in STEM and in civic environmental action. We report results from a National Science Foundation funded study of urban, racial/ethnic minoritized students in middle-and high-school science and math classes who worked with STEM community partners to mitigate environmental problems in their "back yards". The overall goal of this work was to understand how participating in place-based environmental civic science projects in collaboration with STEM community partners impacts students' beliefs, dispositions and interest in STEM. In this program, taught in STEM classes (mainly science and some math) in middle and high schools is Southeast Michigan, students work collaboratively as a class, with their teachers, and with what we are calling STEM professionals, i.e., community members in government, non-government organizations, and the private sector who use STEM in their work. In doing so, students integrate STEM knowledge with civic practice on public problems, connect the utility of STEM learning to community contribution, and see how they can apply STEM in future careers to affect their communities for the better.

We expected that when students from minoritized backgrounds apply science learning to fix a local community issue alongside the STEM professionals, it would demystify the aura of science as something only experts do and increase students' beliefs in their own capacities to do science. Working alongside these professionals should also expand students' notions of the relevance of STEM to public and community issues.

Place-based Civic Science: Learning from and contributing to the community

We refer to the projects as place-based civic science to emphasize that the environmental issues of the local community motivate the work, and that local residents (including youth) are addressing those issues by observing, analyzing, and acting to mitigate the problem or impact policy. We use the term civic science to emphasize science as a public good that should benefit communities. Civic science is a type of citizen science but does not rely on the expertise of highly trained scientists to determine the questions or interpret the data collected by lay people. By emphasizing community members' capacities to engage in scientific work and make decisions for their communities, civic science also raises fundamental questions about whose knowledge and insights are relevant and reframes how we think about science and its goals.

The horizontal or egalitarian style of these projects is important: rather than the top-down, expert to novice model that is typical in science education, in these projects students work *alongside* teachers and STEM community partners. Students are seen from an asset-based perspective, bringing their personal and cultural STEM relevant knowledge, expertise and skills to the projects. This framing of students contrasts with the deficit savior narratives of some STEM education (STEM "for all") (Vakil and Ayers, 2019) that conceive of students from Black, Brown and Indigenous communities as recipients rather than producers of knowledge (Lachney, et al., 2021). In the projects we have been documenting students use the same technology and equipment as the STEM professionals; they generate hypotheses, collect and analyze data, take local stewardship actions, and communicate project results in public forums. Youth learn about the interdependence of human well-being with healthy natural systems in their urban ecology and reflect throughout the projects on ways that they are contributing to their community by applying what they are learning in STEM classes. Thus, STEM learning is linked with students' civic contribution.

We argue that place-based pedagogies that integrate local knowledge into STEM education are the best means to accomplish civic science goals. In order to prepare younger generations to grapple with 21st century challenges, scientific understanding should be an essential part of the civic capacities younger generations gain if they are to make informed judgments for their communities. Further, insofar as science is iterative and experts don't have all the answers, "top down" approaches in which citizens are passive consumers of science will not invigorate science for the public good and can even contribute to anti-science sentiments (Bäckstrand, 2003; Garlick and Levine, 2017). As an alternative, in place-based civic science pedagogies, students can develop scientific literacy, a vocabulary relevant to their concerns, and the capacities to translate findings into civic action. In this sense, science knowledge and practice become resources for civic engagement, democratic action, and political change. In summary, the emphasis is on doing science–not alone in a lab but in collaboration with fellow citizens, with the shared goal of contributing to the betterment or common good of one's community. By engaging in such practice, students' ideas about the purposes of science and about their capacities to engage in it should change.

Linking STEM learning with civic purpose in students' own communities holds particular promise for minoritized students who often feel excluded from mainstream STEM models. Place-based science teaching in particular has been endorsed as a way to improve the engagement and retention of students underrepresented in science (Semken and Freeman, 2008). Scholars of equity in STEM hold up place-based pedagogies as a means for transforming the learning possibilities in STEM for marginalized students. In their special issue on the racial politics of STEM, Vakil and Ayers advocate for practices in which "educators work with students and communities to identify local place-based problems to explore and address using STEM knowledge and tools" (Vakil and Ayers, 2019, *p*. 455). Likewise, Bang and Medin (2010) call for changing the way STEM is taught and applied, to focus "on authentic problems, placed-based issues, and the integral inclusion of . . . other community members" (*p*.1024).

In place-based civic science, students' knowledge of the community is considered equal in importance to classroom knowledge of STEM. In this sense it is similar to the core practices in *culturally responsive pedagogies* (CRP) which are associated with students' academic motivation and feelings of competence (Aronson and Laughter, 2016) and with their interest in science (Bouillion and Gomez, 2001; Brown and Crippen, 2017). Not only are students more motivated to learn when they feel they can use their learning to contribute to the community, but the products they produce with STEM learning are also more likely to meet real community needs. For example, Calabrese Barton and Tan (2019) observed that students used STEM learning to create making products that met community needs *because* the students relied on their knowledge of the local challenges that made life risky for residents. By recognizing that knowledge does not need to come from outside the community, but is already embedded within students' experiences and understanding of their community, these pedagogies push back against deficit mentalities and narratives of white saviors in STEM and instead present students with an opportunity to see their own STEM expertise (Lachney and Green, 2021).

In the projects we have been documenting, students' knowledge of their community and its culture are relevant input in environmental decisions in their local place, which has been shown to be positively related to students' interest and motivation to learn (Chun and Dickson, 2011; Aronson and Laughter, 2016; Garcia and Chun, 2016). The focus on local place also means that students work on projects that affect their daily lives, and are able to directly observe the impact of their efforts. As research has shown, Black and Latinx students are more engaged with STEM curricular activities that they felt enabled them to serve or help others (Gray, et al., 2020). The fact that students in this study are making a palpable contribution to their community by using STEM is likely to increase their interest in the subject matter.

Enhancing interest in STEM among minoritized youth: utility and relevance to issues of justice

Morales-Doyle (2017) posits that justice-centered science pedagogy in which educators work with students to identify local place-based problems and tackle them using STEM knowledge and tools, can address racial and class inequities in science education. In a similar vein, Lachney and Green (2021) argue for STEM motivation to be tied to issues of social justice. Empirical work provides support insofar as the motivation of young women of color is higher when STEM education is tied to social justice goals (Scott and Elliott, 2019; McGee, 2020). Finally, Vakil and Ayers (2019) challenge educators to embrace justice-centered STEM pedagogies by imagining a "STEM person" with a worldview and culture that mirrors the values and ethics of freedom fighters, so that "one can be a scientist or engineer and a community activist without irony or pause" (*p*. 444). The young people in the projects we have been documenting all live in urban areas and have experienced threats to their personal and communities' health due to environmental issues and systemic failures, such as poisoning of water systems and air pollution from nearby incinerators. In these communities the intersections of environmental and social justice are clear, since most often it is the communities where lower-income families and people of color live that bear the largest burden of environmental pollution and climate change impacts. Ecosystem health and human health—and the health of our communities—are inseparable.

The interdependence of humans with the natural environment in the local community and students' lived experiences with environmental issues are at the center of this model, and consistent with place-based education, the local community is understood as a place from which students learn and to which they contribute (Theobald, 2006; Smith and Sobel, 2010). The model of place-based civic science discussed in this paper builds on the place-based education (PBE) work developed by the Southeast Michigan Stewardship Coalition (SEMIS). For more than a decade SEMIS has been building a learning community of educators (teachers in formal education, community partner organizations from SE Michigan) who work with classes of students in PBE projects. Professional Development (PD) in-services in this project underscore the fact that many problems communities face, including urban heat islands or polluted water, are rooted in social inequities. Consequently, educators in the SEMIS coalition are grounded in culturally responsive and relevant education (CRRE) which encourages educators to take a critical stance toward the status quo and validate students' knowledge and capacities to apply their learning to make change (Gay, 2013; Ladson-Billings, 2014; Kumar et al., 2018).

Based on our analyses of surveys from students in this same study, we know that when these urban-residing students are reminded that they are using STEM learning to contribute to their communities, they become more interested in STEM and see the utility of it for their everyday lives. In the current paper we expand on these survey results by drawing from these same students' open-ended reflections on what they learned from participating in the place-based environmental civic science projects. Longitudinal research has shown that changes in students' attitudes toward their science classes are positively related to changes in their attitudes about how useful science is in everyday life and for future careers (George, 2006). For this reason, we analyze students' post experience reflective essays, paying particular attention to how they articulate the utility or relevance of STEM learning in their civic science projects for their communities and for people residing in those communities.

MATERIALS AND METHODS

In this article, we summarize the reflections of 291 students in 6–12th grade math and science classes (ages 11–18) from ethnically and socioeconomically non-dominant urban communities in the United States who worked in teams to mitigate environmental problems in their communities. We collected short reflective essays from students at the end of their place-based civic science projects.

Based on several years of our research-practice partnership with the SEMIS Coalition, we invited teachers of 6th through 12th grade math and science classes who taught in urban schools serving low-income communities, to engage their classes in a study of this civic-science model. Each of the participating classes was connected with one of three STEM community partners all of whom had participated in SEMIS PD. The STEM partners represented different sectors of the economy: 1. a low social impact for-profit business which focuses on ecosystem services; 2. an NGO that specializes in community development, greening, sustainability and energy efficiency; and 3. a local government agency monitoring natural resources and providing public education. Participating teachers and STEM community partners attended SEMIS PBE PD, including sessions led by our team in which they learned about the design of the study.

Projects

In these projects, students and teachers engage over a semester or year with one or more individuals from STEM professional community partner organizations with whom they learn about, conduct research and take collective action on a local environmental issue. Projects focus on the natural and built environment and in some cases, illustrate how issues of environmental and social justice intersect. Although the issues addressed by each partner (e.g., storm water runoff, energy savings from trees, etc.) and the STEM content and science classes vary, each partnership project contains core elements. The partner meets with classes of students at least five times during the project, explaining the science specific to their work via a curriculum they develop for the classes. In collaboration with the partner, students identify a local environmental issue to tackle and then work in groups to gather and analyze relevant data and discuss solutions. The class then applies what they've learned to mitigate the environmental issue and present their work publicly—in a formal program symposium and for some, to elected officials, school administrators, and to other community members.

The projects discussed here took place in urban working-class communities of color in Southeastern Michigan, part of the Industrial Heartland of the United States. Three of the projects focused on water related issues, one specifically on the issue of flooding on the school grounds which affected both student and public use of the area. Students in this project learned about and researched ecosystem services, biomimcry and green infrastructure. With their partner, they decided to install a demonstration area of permeable pavement to mitigate the flooding. A second project also focused on the flooding of the school grounds and green infrastructure. These students toured local rain gardens and worked with their community partner to design and install rain gardens on the property to address the flooding. All of these students presented their ideas and plans to local civil and environmental engineers, landscape architects and governmental officials, receiving feedback from these additional STEM professionals. The third water-focused project focused on water pollution. Students followed the flow of water down storm drains, tested the water quality of their local river, toured rain gardens in their community and designed and installed a rain garden on their school campus to help prevent pollution from reaching local waterways.

Two other projects focused on air quality in students' communities, one specifically on air pollution caused by a trash incinerator, the other on how local air quality was affected by a nearby oil refinery. Students in both projects learned about air pollution and particulate matter, made their own air filters, conducted air quality monitoring, graphed air pollution data over time, researched the effects of air pollution on human health and surveyed local residents. One group conducted advocacy efforts to shut down the local trash incinerator while the other led education efforts to inform residents of daily air quality status -raising flags to indicate good or poor air quality days.

Participants

From these projects we collected data from 291 students in 24 sixth through 12th grade math and science classes (ages 11–18), from ethnically and socioeconomically non-dominant urban communities. Based on students' self-reports, 55% identified as African American, 19% Latinx, 8% White, 1% Asian, 14% mixed race/ethnicity, and 3% other. Fifty percent of the sample identified as female, 41.9 as male, 2% identified with a different gender identity and the remaining chose not to answer.

Measures and Analysis

Reflective essays were administered after the completion of each civic-science project (typically several weeks before the end of the school year, approximately late May). We analyzed students' post-experience responses to the question, "Was there anything you learned in the project that you could use to help your community (or people in your community)?"

Thematic analyses of student reflections were conducted with a semantic approach and both deductive and inductive methods. Through an iterative process and starting with a randomized set of roughly 20% of the data collected, two of the papers' authors observed emerging themes including: references to the utility, value, or usefulness of the students' project work to the real world (i.e., to the community, their own home, or to a future vision of the world), an understanding of the positive or negative impacts people can have on the environment, indications of civic learning, and changes in their beliefs about STEM. With these emergent themes, and attending to themes central to STEM learning and community contribution, an initial codebook containing twelve categories was developed, which the study team consolidated into categories and refined through discussion and application to successive sets of student responses. The study team met regularly to discuss any disagreements in coding responses and modified the codebook based on inconsistencies. Coders had an agreement rate of 87%.

RESULTS

Overall, analyses point to students' beliefs in the usefulness of science to effect community change. Specific to this special issue, we report here on students' responses referencing how their projects drew on the context of the local environment and how they saw STEM as useful or relevant for their civic contributions. Responses fall along a continuum of utility or relevance, from a focus on the utility of the learning and project content (e.g., "Yes curb cuts, these help with managing waste water and street water, and this would help the community because there isn't any water after this on the street") to responses that also include a reference to what the student intends to actually do with their knowledge in the future (e.g. "If I see a bussiness (*sic*) with a big puddle or a neighbor I can suggest a rain garden and I can tell them what they need, where to put it and how to make it").

Applications of STEM in the context of place

The majority of respondents were able to articulate the science or math they learned or used in the project, and how what they learned was useful in the real world, with one student mentioning "I learned that rain gardens help the community by taking in all that water and helping the environment. The rain garden helps take in water and things like grass can't take in a lot of water and flat things like sidewalk cause flooding because the water can't go in the ground." Another replied that "I learned that rain gardens can be really useful with rain runoff. They're also a beautiful way to decorate your community and can help with wildlife." A third student specifically invoked the importance of human-nature interdependence for solving local environmental problems: "In some of the projects I learned that if you work with nature you can have a better outcome when its (*sic*) a flooding. For an example our soccer field flooded because it was built on a down slope so it had water left over after it rained. We used green infrastructure to fix it. We are using premable (*sic*) pavement." Such learning should positively impact students' attitudes toward STEM because they see learning science as relevant to their capacity to do the environmental project and thus to contribute to their community.

Some students invoked the future relevance of the STEM they were learning. For example, "I learned a lot, such as why rain gardens are important and how to make them. This could help in the future because I'd like to make one of my own one day and now I know how to set one up". Another student referenced plans for applying their learning in the future to organizing efforts, noting "I would like to have community clean ups and have reunions. Re-educate those who are in the streets can creat (*sic*) jobs for them. Job for example recycling and showing them that everything could be done with a good cause."

One group of students reflected specifically on how engaging in these civic science projects had changed their assessments of themselves and of their community. One noted how the project had changed what she noticed or paid attention to in the community: "When we learned the seven different types of infrastructure, I started to notice where we could use some of those everywhere I went." Another noted how their new knowledge would change their own behavior for the betterment of their community: "I learned that pollution can cause asthma and that we shouldn't be throwing trash on the streets, beaches, parks, etc. This helped me realize that whenever I see trash in my community or neighborhood, I should pick it up and that way it will reduce the chances of more pollution." Others referenced how they could apply what they had learned to a problem very close to home. For example, "I learned that you should place a rain garden were (*sic*) there are floods. I always have a flood in my backyard so that is an example of were (*sic*) a rain garden should and could be placed" and "Yes I can because I have standing water by my house. And before I learned about rain gardens I did not know what I was going to do about the problem but now I know. I can tell people about rain gardens to see if they want to build one." Some students are literally seeing environmental problems in their own or their neighbors' back yards but with a new sense of empowerment, or an added awareness that they can do something to fix the problem: "In certain spots in my neighborhood there is flooding. I can use the knowelege (*sic*) that I learned from rain gardens to maybe plant some around my community to help stop the flooding." The emphasis on action in these quotes alludes to the fact that students in these projects are *doing science*, not just studying it. They are making real contributions to their neighborhoods with STEM skills and knowledge and they are cognizant of other spaces and needs in their communities where they could apply what they have learned. The fact that they are able to see the utility and transferability of their STEM learning to other community problems aligns with scholarship indicating that in order to value STEM subject matter, students must view the content as useful, and applicable to other contexts (Berger, et al., 2020).

Relevance of STEM learning for community contribution

With respect to community contributions, students also articulated how learning from their PBE projects could specifically affect their community: "I have learned that making a rain garden can help my community in cases of bad rain storms and that having a rain garden can help the water go in back to the soil where it belongs and that it will also help the plants." Another linked the contribution they could make with STEM learning to the health and well-being of community members: "One thing I learned was that there are a lot of people who get sick because of the smell from the incinerator and it can cause trouble with breathing, cancer, birth problems, health risk. So we need to be aware of these things happening to people in our community. We need to protect the people with asthma because it is a very difficult time if they breathe in the smell."

Students also made links between STEM and civic contributions by referring to the direct impact of their efforts on the community: "We did learn some things like how if we replace some concrete with permable (*sic*) pavements it will help the flooding of the soccer field." Another referenced their work in collecting air quality data, "Like calling people when it smells. This could help people in the community because they could try to get rid of the smell which would help everybody and it would allow people to go outside and not smell a great stink."

Related to the connection of environmental quality to human health, many students referenced their ability to inform others about environmental conditions in their communities and the direct impacts on their health and well-being: "We can show the air quality data to the kids at our school that have asthma, and they can decide if it's safe to go outside or not." Another student took this one step further, specifying "I would tell them the days that the air is bad and good. And I would tell them that because some people would "A" like to know and "B" they might have kids with allergys (*sic*) to something in the air or they might want to have the info for their own."

Relevance of community knowledge: Expertise of students and community members

Some students referred to expertise gained in projects, showcasing how their knowledge of STEM and of their local place is not only useful to their communities, but makes them local experts on the issues: "I can do this around my community and I can do this more at school, I can also teach people because I already know how to do it." For other students, an awareness of their newfound expertise extended to their capacity to lead others in implementing environmental solutions: "Let's say they plan on doing a rain garden. I can actually say I have helped with a rain garden myself so they need someone to help, like plant spacing looking into stuff, I can definitely help them."

Some students saw the utility of their newly acquired expertise as similar to the role that public health and natural resource managers fill in their communities: "Informing people about bad air quality from the incinerator can help people stay inside on days that the air quality is bad. Informing farmers about the ash that can blow into their crops can help them make sure to protect their crops." The egalitarian structure of projects, of students and community partners doing science together, changed some students' beliefs about who can hold scientific expertise and what science is and who can do it: "I also saw how many varieties of scientists there are. I always thought all scientists were just some old white guys in a lab with goggles (Bill Nye). To see young black women teaching me science was cool and inspiring. Science is just a tad more exciting now."

Social Justice and STEM Relevance for the civic sphere

As noted in the introduction, communities of color shoulder a disproportionate environmental burden. So it is not surprising that some students framed their potential to lead with a social justice lens: "We can bring all the people in our community together and discuss what we can do to stop this pollution. We should be more organized (clean, and have clean air). Because all this pollution people breathe, they are getting cancer or asthma. We need to stop this." Another student referenced the importance of mobilizing fellow residents to effect change: "I learned how to be a leader and not care what others think and to start clubs or groups that can help our community."

Mirroring the idea of civic science as science for the public good, some students invoked the potential political relevance of their projects, as one expressed, "Fight for your rights because we/people wanted the incinerator shut down. So we did all this stuff like researched to make slides, tested air, and a lot more. And how this could help the community is since we did all this we know the ins and outs of the incinerator so then when we tell the people in charge there (*sic*) minds might change." This student directly references their use of STEM, through data collection and analysis, and how their work can affect community change. As already noted, the sense of collective agency that students gain through their civic contributions can be especially empowering for minoritized youth who reside in urban areas and whom are often marginalized from political decisions. For some students the projects were a means whereby they found their voice and spoke up for social justice: "Another thing I learned was how to be a leader. This helped me because I now know that my voice matters and I can use it in certain situations to let others know what I think is right. This will help me in the future and I'll be able to stand up for myself."

Other students connected the political voice they were claiming to the root causes of the environmental problem they were tackling, i.e., the industries that were responsible: "The air quality censors are a good way to help the people in the community understand what the air quality is like here and the problems it can cause. I think that part of the problem with companies getting away with releasing polutants (*sic*) into the air is people not knowing how this can affect them and what they can do about it." Another noted, "I learned that you should use your voice in order to do what's right. When a company is compromising the health of others, it becomes a problem. Use your voice. Pull up information to back up your claim and don't give up to do right. I learned that many companies like the (nearby oil refinery) plant really don't care about the quality of the air and we can stop that by letting them knowing (*sic*) that's not good." These responses point to a sense of confidence and purpose students gained from using STEM learning for their goals of community contribution and the lens of social justice that many are applying to environmental problems in their local place.

In summary, after participating in these civic science projects, students were aware of the connections between environmental and human health and were defining themselves as experts who wanted to use their new found expertise to inform, educate, and lead others. In addition, by using science for public good alongside STEM community partners, students began to see STEM as something that is not reserved only for the elite, but rather something all citizens can use to make decisions for the common good.

DISCUSSION

Advocates of place-based education note that part of the dignity of a human life is in the positive impact one can have on the lives of others (Theobald, 2006). Results of this study suggest that focusing on place for students' STEM learning and linking that learning to the civic contributions they can make, can cultivate students' perceptions of the relevance of STEM for their community and how this can positively impact themselves and others. In their reflections on how they could use their learning to help their communities, students expressed multiple ways in which they could apply their STEM skills and knowledge to contribute to their communities. They referenced the direct impact of their efforts on their community, such as the decrease in flooding and pollution due to impermeable surfaces.

The link of STEM learning to their civic contribution was also evident when students connected their work with the health and well-being of their community and its members. Many wrote about their ability to educate and inform others about dangerous environmental conditions and the impacts of these conditions on people's health. Understanding such connections is particularly relevant for youth of color, who are motivated to work on environmental issues when they see the connections between the health of the environment and that of their community and culture (Gallay, et al., 2016; Quiroz-Martinez, et al., 2005).

Students' responses also revealed a sense of pride in their work and a desire to educate and lead fellow community members in using the science they had learned to mitigate environmental problems affecting their quality of life. The fact that students articulated a range of ways that they had used STEM learning to improve their community or help its residents suggests that a core goal of these civic science projects was realized, i.e., students understood that they were engaging in science for the public good.

Scholars of STEM education point to the utility value students place on science or math as important attitudes for continued engagement with STEM subject matter (Berger, et al., 2020). The value students place on STEM subjects reflects the extent to which they see that subject as "being useful, important, or having applications in other contexts" (Berger, et al., 2020, *p*. 414). Student responses in this study reflected an appreciation of the usefulness and applicability of what they had learned in projects to other contexts. For example, many identified specific instances of flooding in neighbors' houses that could benefit by applying the mitigation measures they had learned in projects. Likewise, because of their work on these projects, students began noticing where green infrastructure is needed in their community and how they could apply what they had learned to a problem very close to home.

Research has shown that for middle and high school students, positive attitudes toward science are associated with positive attitudes about the utility of science and that seeing the practical relevance of science increases interest in science (George 2006). Scholars of STEM education have therefore called on educators to emphasize the practical applications of science "so that students understand the importance of science as a major contributor to society" (George, 2006, *p*. 586) and to tailor pedagogical practice to foster the perceived value of STEM (Berger, et al., 2020). Our results point to the value of place-based civic science curricula for nurturing students' awareness of the usefulness or relevance of STEM for the contributions they can make to their community.

Besides articulating how their STEM project learning is useful in the real world, some students also connected their learning to future work and community needs. They referenced how they could prevent or mitigate environmental problems, or apply their learning to future collective action efforts. Some used language indicating that they intended to use what they learned, such as the student who expressed "Now, I can inform people of how bad our air is and why its so bad. Maybe if more people know, we can all help out our earth and make it better."

Concerning the potential of this place-based civic science model to address issues of groups who are underrepresented in STEM, several possibilities emerge. First is the potential of demystifying the aura of science as a domain of highly educated elites. Decades of research on young people's perceptions of scientists has shown that the image of scientists-as white men, working alone in labs-is remarkably persistent (see Chambers, 1983; Finson 2002). Yet, for some students, working with community partners to apply science to a community need altered these stereotypes, as was evident in the reflection of one student who shared that her conception of scientists had changed from that of Bill Nye the Science Guy, to the two young Black women leading her through their collaborative civic science project. In most projects, students had opportunities to meet multiple professionals from their community applying STEM in their real lived world. Students' responses suggest that they appreciate that science is not something that just takes place in a lab but happens through engaging with community members and that the work of science can benefit communities like theirs.

A second possibility of this civic science model for engaging minoritized groups is the emphasis on students' agency. Whereas many science curricula offer few opportunities for student agency (Olitsky, 2006), students in these projects gather and analyze data, devise plans, and take action. The fact that they are applying learning to address a local environmental problem should boost what others have called, students' *critical science agency,* i.e., beliefs in their capacities to analyze an issue and apply their scientific skills (Basu and Calabrese-Barton, 2007). Due to the non-hierarchical relationship of students working alongside STEM professionals, the focus on community contribution, and on students' agency in applying science, this model worked to demystify students' beliefs about what science is, what scientists do, and about their own capacities to do science (Bang and Medin, 2010).

Scholars have called for science education to address the particular needs of urban youth, especially those from marginalized communities (Calabrese Barton, 2002). Our findings suggest that to address the under-representation in STEM of youth from these communities, engaging them in place-based civic science work provides an effective foundation for nurturing their interest in STEM. The urban-residing students engaged in these place-based contextualized projects articulated how their STEM learning is relevant to their lives and transferable to their communities, signifying the value they see in STEM and STEM learning. In urban communities of color, place-specific environmental issues are also inherently social justice issues and several students in our study connected the work they did in the project to issues of social justice and political consequence. Project work helped some students develop a political voice and fight for connected issues of social and ecological justice in their communities. In summary, building on scholarship indicating that, for youth in marginalized communities, connecting the cultural practices of one's community to STEM enhances their attitudes toward STEM (Leonard, et al., 2016), expanding the lens on STEM learning and local place to incorporate social justice pedagogies is a logical extension of pathways that students from underrepresented groups might pursue (Tucker-Raymond, et al., 2016).

Limitations

There were several limitations of this study. First, insofar as the civic science model, the urban ecology, and the sample of students from groups underrepresented in STEM were all relatively unique, we relied on students' response to an open-ended question: "Was there anything you learned in the project that you could use to help your community (or people in your community)?" Although qualitative responses provide important insights into a phenomenon (such as civic science), quantitative studies with larger samples would help to answer the question of how representative these students' reflections are.

Students' verbatim responses point to a range of ways they interpreted the question. A minority summarized the science but did not mention helping the community (e.g., permeable surfaces, ecosystem services, particulate matter) and even fewer (less than 5%) responded that thy did not learn anything. A majority focused on the latter part of the prompt and made connections between environmental and human health (PM and asthma) or identified similar environmental problems in their community that they could address by applying what they had learned (e.g., using rain gardens to prevent basement flooding) or connected what they had learned to new roles they could play in their community (e.g., communicating, educating, leading fellow residents, engaging in science like the Black women who worked with them). Based on this range of responses, future studies could develop scales to assess the degree to which students feel that they can use environmental civic science to benefit their communities.

A second limitation of the current study is that the data were collected after students had engaged in projects. In future studies, changes in students' beliefs about the relevance of STEM content and methods for their ability to address community problems could be assessed if data were collected before and after students engaged in civic science projects. Finally, we sampled from a population of racial/ethnic minority students and projects focused on the natural environment in the urban ecology. Future studies in more privileged communities could determine the degree to which students' application of STEM learning to their local place would result in similar student learnings or whether students' insights about social justice would figure only in the reflections of youth from communities that have been marginalized from the mainstream.

CONCLUSION

Place-based civic science is a way to reimagine STEM learning by enabling students, especially those from minoritized backgrounds, to study, analyze, and act on environmental problems in their "back yards". Our results suggest that youth from non-dominant backgrounds, for whom inequalities in STEM education persist, get engaged when they have opportunities to apply learning to solve local community environmental issues. This place-based civic science model centers young people from backgrounds that have historically been excluded from STEM. The linking of learning with civic action, the emphasis on local place and what youth can accomplish through collective action, are all key to addressing inequality. Working collaboratively with teachers and STEM community partners, students saw the utility of science for contributing to their communities and developed an awareness of how science can be used by citizens (regardless of their profession) to foster community resiliency in the face of environmental crises.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, upon reasonable request and without undue reservation.

ETHICS STATEMENT

The study was reviewed by the University of Wisconsin Education and Social/Behavioral Science Institutional Review Board (IRB) and the IRB determined that the project is evaluation and does not constitute research as defined in 45 CFR 46.102(d). Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study due to the Institutional Review Board determination. We have followed ethical considerations in informing participants of the study, obtaining verbal assent, and maintaining the confidentiality of participants.

AUTHOR CONTRIBUTIONS

EG took the lead on the conceptualization and writing of the manuscript as well as data collection. CF was the PI on the project, and assisted in conceptualization of the manuscript and provided feedback. EG and BP coded and analyzed the data and BP provided feedback on the manuscript.

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