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ARTICLE

Child Development Perspectives

Civic science: Addressing racial inequalities in environmental and science, technology, engineering, and math education

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Abstract

Civic science (CS) is an approach to science learning and action in which youth determine issues of concern in their communities and use science, technology, engineering, and math (STEM) knowledge and methods to address them. In this article, we focus on CS as it is applied to environmental concerns and enacted by children and youth in urban communities. Core CS practices include relevance of local place and culturally responsive principles for youth's learning and community contributions, egalitarian intergenerational partnerships with adults from community-based organizations, teamwork and collective action, and public regard for youth's community environmental contributions. We discuss CS's potential to address the marginalization of youth from minoritized backgrounds in traditional STEM and environmental education. We also argue that the way CS frames science for the public good will prepare younger generations to meet 21st-century environmental challenges.

KEYWORDS
civic science, minoritized populations, urban environmental science

Communities of color shoulder disproportionate health burdens from environmental pollution and climate change, regardless of their location or social class (Bullard et al., 2011). Examples include air pollution from particulate matter, proximity to hazardous waste storage, and heat islands as a result of few green spaces in the built environment. Yet historically, environmental justice has not been prominent in environmental education (Kushmerick et al., 2007). However, in recent decades, attention to justice in environmental education has grown (Calabrese Barton & Tan, 2010; Davis & Schaeffer, 2019; Gallay et al., 2021), the theme is central to some graduate student training (Miller et al., 2021), and leading organizations such as the North American Association of Environmental Education have prioritized issues of justice.

Racial inequities persist in learning opportunities related to science, technology, engineering, and math, or STEM (Penuel, 2017) and contribute to the underrepresentation of ethnic minorities in STEM careers. The green energy workforce is among the least diverse: Fewer than 10% of workers in clean energy production and efficiency are Black (Muro et al., 2021). STEM pipeline models, the dominant paradigm to address divides in learning opportunities, have been criticized for ignoring the scientific relevance of minoritized students' cultural and community knowledge (Bang & Vossoughi, 2016). Instead, place-based models where students and educators use STEM to address issues affecting their community are recommended (Vakil & Ayers, 2019), approaches that position students to use science as a catalyst for change (Morales-Doyle, 2017).

Abbreviations: CS, civic science; NGSS, Next Generation Science Standards; STEM, science, technology, engineering, and math.

Addressing opportunity divides in environmental and STEM learning is an issue of economic equity, and also important to combat climate change and prepare younger generations for careers in the clean energy sector. In that sector, employees (with or without college degrees) earn higher wages than peers in other industries, but their jobs, especially in energy production and efficiency, require more scientific knowledge and technical skills (Muro et al., 2021). Thus, opportunities to learn and use STEM would give high school graduates and those with career and technical education a competitive edge in obtaining clean energy jobs.

In this article, we describe civic science (CS) as a pedagogical approach that holds promise for addressing these inequities. Our claims are based on studies we have conducted over the past 8 years in collaboration with a regional coalition of formal and nonformal educators dedicated to place-based education. The coalition facilitates partnerships between adults from community-based organizations and students in K-12 classes who work together as community scientists. In the projects we have studied, students (predominantly from African-American, Latinx, and low- to middle-income backgrounds) collect and analyze data on local environmental problems, take actions to mitigate them, and educate other members of the public about the problems and how they addressed them.[1]

WHAT IS CS?

We refer to these projects as civic science (CS), by which we mean science for the public good, co-owned and conducted by community members on issues that affect the well-being of their community and its residents.[2] The term alludes to CS's democratic quality, which sets it apart from citizen science approaches where "experts" determine questions and crowd source data collection to the public. Not only does the word *citizen* exclude some immigrants, but the practice can maintain power asymmetries between formally educated scientists who analyze and interpret data and citizens who collect it. By contrast, in CS, community members (including children and adolescents) determine issues, collect data, and interpret and act based on the results (Dillon et al., 2016; English et al., 2018; Levy et al., 2021).[3] Thus, CS expands the meaning and purpose of science, how and where it is conducted, whose insights are relevant, and who can do it. Such inclusive approaches also increase the relevance of questions, the transparency and credibility of the process, and the potential to translate findings into policy. Community-led science projects have raised issues of environmental, housing, and health justice, and many have led to policy changes (English et al., 2018).

Civic science need not be limited to environmental issues, although the natural environment has been a major focus of participatory science. Nor is it unique to urban ecologies: Rural White middle school students attending school where 52% of students are eligible for free or reduced-price lunch who participated in CS projects increased in their environmental sensitivity, behavior, community attachment, and confidence for civic action (Gallay et al., 2016). In fact, CS's place-based focus is a core theme in rural studies, where the civic purpose of education (learning from and contributing to one's community) has long clashed with the pull of opportunities outside the community (Greenwood, 2019).

ENVIRONMENTAL CS IN URBAN SETTINGS

Our focus on environmental CS in urban ecologies provides a different lens on relations between people and nature than has been typical in environmental psychology. The latter has emphasized how emotional attachment to the nonhuman natural world (environmental identity; Clayton, 2003) is associated with pro-environmental behavior, tapped largely by individual acts of conservation with measures such as the Pro-Environmental Behavior Scale. This work has provided important developmental insights into how childhood experiences with nature foster environmental responsibility (including activism) and generative concern in young adulthood (Matsuba et al., 2012). However, in the past, environmental psychology paid limited attention to racial/ethnic-minoritized populations (Jia & Krettenauer, 2019), emphasized individual norms, and neglected cultural and economic influences on relations between people and nature (Medina et al., 2019).[4] The lack of attention to minoritized youth also can lead to false inferences that they do not care about nature (Nxumalo & Ross, 2019).

In urban CS, the connections between human and environmental health and the impacts of the built environment on the local ecology are front and center.[5] For example, in urban forestry projects, high school interns might learn about the dangers heat islands pose to the health of people and ecosystems, and the benefits of a canopy, to which they contribute by planting trees. In other projects, eighth to 12th graders (all of whom identified as people of color and lived in neighborhoods of low income in a large west coast city) learned that moss is a bio-indicator that stores particulate matter (associated with respiratory and cardiovascular problems); by collecting moss samples from urban trees and mapping their locations, students documented exposure levels in different neighborhoods (Derrien et al., 2020). Impacts of the built environment are part of many school-based CS projects. For example, after studying the effects of streets and sidewalks on soil erosion, pooling of water, and pollution of waterways, fourth to 12th graders installed rain gardens and bioswales as mitigation efforts (Flanagan et al., 2019). In other CS projects, middle schoolers measured daily particulate matter and warned neighbors about bad air quality days that could compromise their health (Flanagan et al., 2021).

CS PROJECTS

Civic science projects can be done during or outside school, and can be structured to afford optimal opportunities for any age group. Children can participate in school or outside-school programs organized by community groups; internships are available to adolescents and young adults through job training programs run by the government and nonprofits. Whereas out-of-school options may be biased toward youth already interested in science or the environment, school-based programs can reach students regardless of prior interests.

Evidence for developmental affordances in CS comes primarily from studies of children in upper elementary school through high school (roughly 9- to 19-year-olds) but, as noted, opportunities in childhood to form affective bonds with other living things can be the foundation for a lifetime of environmental activism (Matsuba et al., 2012). Yet more work may be needed to realize the participatory principles of CS with young children: In a comprehensive review of research on early childhood environmental education from 2004 to 2014, it was common practice for adults to collect, analyze, and interpret data, with scholars only beginning to incorporate children's perspectives (Green, 2015). Concerns about potential risks to mental health from teaching children about environmental harm have been addressed by scholars of elementary science education, who argue that for children from minoritized backgrounds where socioscientific injustices are a daily reality, efforts such as CS that are transparent, supportive, and truthful are critical (Davis & Schaeffer, 2019).

Civic science is a fledgling field, and the developmental evidence for it is slim, although its goal of preparing all students to engage in finding scientific solutions to issues affecting their communities is a top priority of U.S. national standards for K-12 science education (Next Generation Science Standards [NGSS]; National Research Council, 2013). However, for students' solutions to be fully informed, they must be allowed to explore how political decisions (the Flint water crisis is an iconic example) and legacies of environmental racism (e.g., brownfield leftovers from industrial pollution) affect their communities' environmental and public health. In this regard, NGSS fall short because they emphasize the benefits but not the harms of science (Davis & Schaeffer, 2019; Levy et al., 2021; Morales-Doyle et al., 2019).

ELEMENTS OF CS IN PRACTICE

What does CS in K-12 schools look like? Next, we discuss core elements distilled from studies over the past 8 years of fourth through 12th graders (who were predominantly from African American, Latinx, and low- to middle-income backgrounds) engaged in CS projects (see Flanagan et al., 2019, 2021, Gallay et al., 2021 for details).

Place-based education and culturally responsive pedagogy

Civic science embraces principles of place-based and culturally responsive pedagogy. Consistent with the tenets of place-based education, the local community is both a respected source of knowledge and a society to which students belong and contribute (Greenwood, 2019). Students' community and cultural knowledge are relevant to identifying issues and solutions.

Civic science reflects core principles of culturally responsive pedagogy: Educators hold high expectations for all students (not only those who fit the STEM pipeline), support them in challenging the status quo, and incorporate students' experiences into classroom practice (Ladson-Billings, 2009). Experiencing such classroom climates is positively related to students' academic interest, motivation, competence, and sense of belonging at school (Aronson & Laughter, 2016). When high school students from minoritized backgrounds feel included in their STEM classes, they are more confident that they can use STEM to solve a community problem (Mulvey et al., 2022). Honoring cultural knowledge also matters to students in elementary school: One of the main reasons for the success of a fifth-grade urban environmental restoration project was that teachers emphasized to the students how relevant their Mexican parents' knowledge of plants was to understanding the natural environment (Bouillion & Gomez, 2001).

In CS, students apply learning to address a community problem. Youth from minoritized backgrounds hew strongly to such communal goals. For example, Black and Latinx middle school students reported more behavioral engagement (attending, listening, working hard, and participating in class discussions) for STEM activities they rated relevant for serving the community, one another, or other living things (Gray et al., 2020). Furthermore, Black and Latinx middle schoolers in STEM-maker projects (hands-on learning in which youth pursue projects from concept to product) chose ventures that would help people and redress injustices (Calabrese Barton & Tan, 2019). These studies suggest that it is possible to educate youth to become both STEM authorities and community activists (Vakil & Ayers, 2019).

Working for social change is a less important career goal for STEM college majors than for non-STEM majors. But students from minoritized backgrounds pursuing STEM majors are an exception: They rate working for social change as an essential or very important career goal (Garibay, 2015). Similarly, first-generation college students from underrepresented minority backgrounds who were enrolled in science classes overwhelmingly selected "helping others" as their motivation for attending college; when asked to reflect on the relevance of science course content for their lives, their grades improved (Harackiewicz et al., 2016). However, if science is to be inclusive and democratic, opportunities to use it for public good cannot wait until college; they must be part of K-12 education.

CS action in public spaces

The community contributions youth make in CS are visible to the public: They plant trees, build rain gardens, and advise neighbors about air quality. In some programs, youth present their work in public venues—community forums, environmental coalitions, local government meetings. The public context of the work may affect youth's science identities if they get feedback that others perceive them as science people or experts on environmental issues (Flanagan et al., 2019; Morales-Doyle, 2017). This could pique their interest in pursuing STEM learning opportunities, since that interest is correlated with minoritized students' confidence in their science identity (Vincent-Ruz & Schunn, 2018).

Yet given longstanding stereotypes about what qualifies as science, programs may need to focus students' attention on the ways they are *doing science* in their CS projects to influence their beliefs about how useful science is to them and their community (Flanagan et al., 2022). As an example, in one study with upper elementary students, emphasizing *doing* science was more effective in promoting students' engagement than was emphasizing *being* a scientist (Lei et al., 2019). In addition to expanding the definition of science, urban CS projects can expand the meaning of environmental identity to include the natural systems integral to one's community. For example, when fourth to 12th graders discussed how their CS projects had benefitted their community, many referred to the responsibility they felt for "our river," "our watershed," and "our future generations" (Flanagan et al., 2019).

Intergenerational community partnerships

In many places, adults from community organizations coordinate environmental programs during out-of-school time and partner with school-based projects. Like other youth-serving organizations, these programs provide opportunities for positive youth development (Schusler et al., 2017). For example, Black and Latinx 15- to 18-year-olds from Brooklyn, NY, interning with a food justice organization described their experience as somewhere to belong, be pushed, grapple with complexity, practice leadership, and become yourself (Delia & Krasny, 2017). Typically, adults who volunteer with such projects are committed to nurturing environmental awareness, and they resist age-related hierarchies by working *alongside* youth as fellow community scientists (Schusler et al., 2017). Such intergenerational conservation partnerships are more likely to succeed if they respond to real-world challenges, use open communication, proactively seek youth's input, respond to both adults' and youth's interests, and share their work with the public (Cisneros et al., 2021).

Collective learning and action in groups

A common stereotype about science is that it is conducted in laboratories by smart people who make discoveries on their own. This contributes to a mystique about science as settled truth rather than as a process of inquiry that benefits from different ways of knowing (Bang & Vossoughi, 2016). The lack of transparency and the communication failures when science is practiced this way also have contributed to an erosion of public trust in science.

In contrast, a basic tenet of CS is that it is carried out in communities by residents who co-own and co-create the science. To learn and ultimately believe that principle, youth should work on projects with others so they can practice skills that develop their CS dispositions (i.e., the ability to consider diverse perspectives, modify plans, trust in the group process, and find common ground). Doing science this way reveals it as an iterative process that is transparent and trustworthy.

In one study, when fourth- to 12th-grade students (predominantly from African American, Latinx, and low- to middle-income backgrounds) reflected on what they learned from engaging in CS projects, many referred to the dynamics and outcomes of working in their group, that is, learning to listen to and be patient with peers with whom they disagreed, and realizing that they shared a goal with others in their group that transcended their differences (Flanagan et al., 2019). Working in groups may also benefit mental health. For example, the climate crisis can feel overwhelming if faced alone, but tackling problems with others can build resilience and a sense of community (Sanson et al., 2019).

Stewarding the environmental commons

The core elements observed in CS projects parallel characteristics identified by the political economist and Nobel prize winner Elinor Ostrom (2010), as features of groups that are effective in stewarding *common pool resources*—that is, pastures, fishing waters, and forests—that provide benefits to everyone but can be depleted if abused or overused. Ostrom contested the fatalism as well as the passive role for citizens implied in the so-called *tragedy of the commons*, the premise that natural resources that are collectively used will inevitably be overexploited by the people who use them. Through empirical studies conducted across the world, Ostrom and her colleagues demonstrated how ordinary people create rules and institutions whereby they sustainably manage such resources. They identified several characteristics of effective groups, including: (1) proximity to and knowledge of the natural resource; (2) strength of members' identification with the group and its goal of preserving the resource; and (3) group dynamics, including mutual respect, responsibility, and communication, that enable members to know one another and build trust.

These features of groups map onto the CS practices we have outlined. Place-based and culturally responsive learning emphasizes proximity, local knowledge, and attention to the diverse people, life forms, and natural systems that are part of one's community. Partnerships with adults are bases for connecting youth's goals to those of other members of the public committed to stewardship of the community and its natural resources. In the relationships forged through teamwork, youth explore what it means to co-own CS work. They develop skills in respecting and grappling with diverse perspectives, trusting one another, and finding common ground.

For the past 8 years, we have analyzed K-12 students' reflections on what they learn in CS projects. Based on their comments and informed by Ostrom's work, we have adopted the concept of an *environmental commons* to capture both people's rights to the natural resources that support life (water, land, air) and their responsibilities to steward those resources by engaging in public spaces (schools, community organizations, libraries, public meetings of local government, the Internet) where people can determine together how to care for those resources and for the communities they inhabit (Bowers, 2006; Flanagan et al., 2019).

We do not suggest that local actions are sufficient to combat environmental degradation or climate change, but that they should be part of what Ostrom (2010) referred to as a *polycentric approach*. While global efforts must be part of the solution to climate change, focusing on them alone is myopic, especially since global goals have thus far proven elusive and difficult to enforce. According to Ostrom, polycentric approaches facilitate achieving benefits at multiple scales, as well as experimenting and learning from diverse experiences and policies.

LOOKING AHEAD

Civic science is but one example of participatory, community-driven science (Ballard et al., 2021), and the dearth of published work on CS does not imply a lack of practice. Indeed, to our peril, the history of land-based indigenous science practice and education has been ignored by mainstream science. Going forward, developmentalists can contribute to the evolving cross-disciplinary discourse on transforming to more inclusive community-driven science learning and highlight work being done by minoritized communities. We recommend the following four steps:

First, although we have learned much from youth engagement in out-of-school environmental programs, school-based programs are the only way all students can have opportunities to participate in CS. Thus, studies are needed on how to integrate CS into schools and simultaneously deal with science-related testing mandates. Developmental studies could compare the implementation of CS practices in different grade levels or assess outcomes for students who engage in CS over several years. Longer-term impacts on youth who participate in CS also should be studied, for example: Do they pursue careers in which they use STEM? Do they maintain beliefs in the potential of science to contribute to their community? Researchers could also conduct experiments with cross-disciplinary CS, especially since some learning objectives for social studies (e.g., the C3 framework, which emphasizes the acquisition and application of knowledge to prepare students for college, career, and civic life; National Council for the Social Studies, 2013) and science (NGSS) are aligned (e.g., formulating questions, planning inquiries, evaluating evidence, interpreting data)—although the NGSS neglect the more active civic roles of students, such as communicating their findings to others and influencing policy (Levy et al., 2021).

Second, whether in or out of school, the developmental affordances of various community partnerships should be explored. For example, as youth interact with fellow community scientists, how do their ideas about using STEM—whether to solve local problems or imagine what they might do in the future—change? The benefits of partnerships with Black, Asian, Latinx, and Indigenous role models should be the highest priority in such research to address issues of underrepresentation in STEM and environmental work.

Third, since local government policies and infrastructure directly affect a community's environmental quality (e.g., through land use, development, zoning, idling ordinances), incorporating engagement with local governments in crafting solutions to environmental problems would build on the place-based and public actions that are core CS practices. Researchers could examine how engaging with elected officials and staff might demystify the abstract concept of government in youth's minds or how youth's input might influence local policies.

Finally, in this article, we have focused on the United States, but as many young activists have warned, the climate crisis threatens the future of life on earth. Through their failures to address climate change, governments across the globe are abandoning their obligations to protect the rights of children as outlined in the

United Nations Convention on the Rights of the Child. Grassroots organizations in many countries have been educating children about their rights under this treaty and the climate crisis should be a priority.

CONCLUSION

In this article, we have focused on the value of CS for minoritized youth whose voices have been muted in conventional environmental education and in pipeline models of STEM learning. However, the integration of science with civic action that is captured in CS is the kind of preparation that all young people need if they are to address 21st-century challenges (Hart & Youniss, 2018). Transforming to a zero-carbon economy requires fundamental changes in agriculture, industry, transportation, and shifting production of goods and services from global to local economies (Sanson et al., 2019). Incorporating CS practices into K-12 education could expand concepts of STEM from a domain reserved for highly trained experts to one in which community members apply STEM knowledge, methods, and tools to make informed decisions for their community's well-being. Finally, adopting CS practices would be a smart way to prepare younger generations for careers in a green economy. If a truly representative democracy is the ultimate goal of education, addressing opportunity gaps in the K-12 years should be the highest priority.

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ENDNOTES

[1] The coalition serves students from any schools in the southeast region of a Great Lakes state. Our studies have focused on minoritized students in schools in urban areas of the region.

[2] Terms for similar approaches include community-driven science, community-based participatory research, and eco-citizen science (Ballard et al., 2021; English et al., 2018; Makuch & Aczel, 2020).

[3] In promoting CS, we do not deny the value of bench science, but contend that expert-driven approaches will not revitalize science for the public good and that a broader science framework is needed to prepare younger generations to meet 21st-century challenges.

[4] An expanded framing of environmental behavior is captured in the Environmental Action Scale, which focuses on collective actions to achieve system-level change (Alisat & Riemer, 2015).

[5] Connections are made to physical health, but as the nascent literature on climate change indicates, mental health also is affected. Impacts of extreme weather or climate-related disasters include increases in posttraumatic stress disorder, depression, anxiety, feelings of helplessness, aggression, and learning problems (Sanson et al., 2019).

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