Integrative and Comparative Biology
Integrative and Comparative Biology, pp. 1–11
doi:10.1093/icb/icab092
Society for Integrative and Comparative Biology

SYMPOSIUM

Perspectives on Community STEM: Learning from Partnerships between Scientists, Researchers, and Youth

Jasmine McBeath Nation [1,*] and Alexandria Killian Hansen [†]

*Department of Liberal Studies, California Polytechnic State University, San Luis Obispo, CA 93407, USA; †STEM Education Department of Biology, California State University, Fresno, Fresno, CA 93740, USA

From the symposium "SICB-Wide Symposium: Biology beyond the classroom: Experiential learning through authentic research, design, and community engagement" presented at the virtual annual meeting of the Society for Integrative and Comparative Biology, January 3–7, 2021.

[1]E-mail: jmnation@calpoly.edu

Synopsis Given our rapidly changing world and the pressing challenges of climate change and health care, it is more important than ever for youth and the broader public to learn scientific knowledge and skills. To reach the most people possible and increase diversity in Science, Technology, Engineering, and Mathematics (STEM) fields, we need compelling educational approaches that incorporate the lived experiences of students. Partnerships between researchers, scientists, educators, and community groups can enrich and extend scientists' research while providing authentic scientific learning experiences for undergraduate and K-12 students, especially from STEM-underrepresented groups. However, more research is needed on equitable long-term partnerships, including how these projects are organized and how partners align their interests and goals. In this article, we present recommendations from research–practice partnership projects that utilize a Community STEM model, an approach that draws from individual and collective strengths, contextualizes science learning, and positions youth as producers of content and artifacts. To situate this work, we review and highlight biology-related citizen and community science projects designed for youth. We characterize projects according to their goals and format, provide illustrative examples of three programs, and provide recommendations for other scientists and researchers. Overall, this article reviews research on all three approaches for partnerships (citizen science, community science, and community STEM) to provide recommendations for scientists who are interested in establishing partnerships within their communities. Limitations of each approach are described as well as areas for further research.

Introduction

Partnerships between researchers, scientists, educators, and community groups offer new approaches for broadening participation in the Science, Technology, Engineering, and Mathematics (STEM) fields. These partnerships can enrich and extend scientists' research, provide authentic scientific learning experiences for students, and enhance science within the community. One common approach for accomplishing this goal is through *citizen science* initiatives (Bonney et al. 2009; Parrish et al. 2018). Citizen science is a way for the public to contribute to scientists' ongoing research, often through collecting field observations or assisting in data analysis. However, this model of public engagement with science often prioritizes the scientist and can offer limited benefits to the citizen (Wilderman 2007). More recently, scholars have argued for community science as a more inclusive approach, particularly for youth.

Community science is sometimes considered a branch of citizen science but differs in that it focuses on issues embedded within local communities and often features partnerships with K-12 schools and informal science institutions, such as museums and youth-serving non-profits (Dickinson and Bonney 2012; Barton et al. 2017). Finally, as calls for interdisciplinary STEM learning increase (e.g., Brewer and Smith 2009; National Research Council [NRC] 2013), we propose community STEM initiatives as an effective model that maintains the focus on solving community problems, but allows for the integration of science and other relevant fields. This article reviews research on all three approaches for partnerships (citizen science, community science, and community STEM) and provides recommendations for scientists who are interested in establishing partnerships within their communities. Limitations of each approach are described as well as areas for further research.

Perspectives: beyond conventional citizen science

Citizen science is a way that youth and amateur scientists can assume agency in science and participate in authentic practices of professional scientists and engineers. Citizen science has a long history, especially when considering the broader version of public participation in science. In the late 1800s, lighthouse owners recorded information about "bird strikes," and amateur scientists started astronomical and weather observation groups. Everyday individuals mapped out bird patterns, found new stars, and monitored water quality (Bonney et al. 2009). More recently, public participation in science was envisioned to help scientists "amass data." Usually these projects are "contributory projects," where scientists set the research design and guide implementation analysis while the public contributes by collecting data (Bonney et al. 2009).

Wilderman (2007) describes this model as "community workers model," where scientists define the problem and design the study but the community collects data; for example, people counting reptiles or recording dates that trees first flower and sending this information to scientists to document climate change (Trautmann 2013). Researchers have documented learning gains for students who participate in citizen science data collection, such as mastering science content related to bird biology and nesting behavior, recognizing and understanding the impact of invasive species, and learning more about technology such as Global Positioning System (Bonney et al. 2016). Broader benefits include connecting with nature, meeting new people, and non-sport alternatives to physical activity and recreation (Trautmann 2013; Bonney et al. 2015). For undergraduates, participating in data collection and analysis can take on new meaning when included as part of their disciplinary training in STEM coursework (National Research Council 2003; Oberhauser and LeBuhn 2012). Citizen science projects are often housed in universities, providing undergraduates access to research mentors, novel datasets, and community partners. For example, in the Monarch Larva Monitoring Project, undergraduates constitute the minority of overall participants, however, they learn valuable skills through surveying monarchs and milkweed. Additionally, they analyze and publish a subset of the data during their summer independent research projects (Oberhauser and LeBuhn 2012). Recent calls in Biology education have proposed increased opportunities for students to engage in interdisciplinary learning that is relevant and supports the development of competencies in research and science communication (National Research Council 2003; Brewer and Smith 2009; American Association for the Advancement of Science 2018).

Though including undergraduates in citizen science projects appears very promising, more research is required to document the educational benefits (Oberhauser and LeBuhn 2012; Mitchell et al. 2017). Unfortunately, there is not much evidence that these projects shift attitudes toward science or aid in understanding the scientific process (Bonney et al. 2016). Additionally, diversity remains an issue. In citizen science, "participants in the majority of projects were highly educated, upper-middle class, middle-aged or older, and white" (Dickinson and Bonney 2012, 191). As the field begins to mature, scientists need to consider how to empower communities, engage in dialog with the public, and democratize science (Bonney et al. 2016; Roche et al. 2020). With intentional design and framing, citizen science can build from underrepresented groups' "funds of knowledge" situated in the home and community (Moll et al. 1992), thus broadening the definition and culture of science and engineering. We argue that community science is a better approach than citizen science to accomplish these goals. Moreover, community science efforts that integrate multiple disciplines of study are even more poised to broaden underrepresented students' conceptions of science and engineering; we call this model community STEM. Both community science and community STEM approaches are further described below.

Community science refers to "co-created projects" within citizen science, where the public and scientists work together (Bonney et al. 2009). Community science approaches often involve similar data collection and analysis as other models, but usually on a smaller scale and have goals related to environmental management and changing policy or local decision-making (Bonney et al. 2015, 2016; Ballard et al. 2017). Community science projects have also been framed as Participatory Action Research or "science by the people" since the community defines the problem, designs the study, collects, analyzes, and interprets the data (Wilderman 2007). Community science projects can also be powerful for marginalized groups since this approach "offers the opportunity for communities and people to participate in science, rather than simply to serve as recipients of outreach efforts" (Pandya 2012, 315). For example, community members of White Earth Nation in Minnesota collaborate with researchers from a local community college to collect data on wild rice and their crop harvest. The scientists are interested in climate change impacts and land use, while community members are motivated by issues such as economic security and conservation (Pandya 2012). Celebrate urban birds (CUBs) provide an example of youth-oriented community science, with a simple bird observation activity designed for integration into block parties, community gardening events, or faith-based educational programming (Purcell et al. 2012). For CUB, Cornell Lab of Ornithology researchers benefit from volunteers amassing data on how green spaces and city landscapes influence bird distributions. Partnering community groups satisfy their own goals, including connecting children with nature, investigating health issues, and improving habitat. CUB also hopes the public will gain new insights into scientific concepts and practices, while forming positive associations with science. Their approach empowers "participants to take action and become active contributors to their emerging 'science community'" (Purcell et al. 2012, 197).

Based on the work of a handful of innovators in education, we propose community STEM as a variant of community science. Specifically, community STEM involves projects and partnerships with the community, but provides opportunities to integrate science into other disciplines in meaningful ways. The community STEM model reconceptualizes citizen science as data collection, analysis, and dissemination in partnership with youth and community members, moving away from the "community workers model" and instead toward an equitable community partnership (see Fig. 1). Additionally, the projects feature integrated STEM learning, where students participate in scientific practices such as asking questions or carrying out investigations alongside engineering design practices such as defining problems and designing solutions. To fit within the community STEM model, community members must go beyond both "community science" where they investigate local phenomena and "participatory sensing" (Balestrini et al. 2016) where they use or build devices to collect and analyze data about natural or urban environments. Instead, the project should draw from multiple STEM disciplines, positioning youth to engage in research about their surroundings, and build their own devices or structures. Typically, participants create artifacts that demonstrate their understanding of science and engineering while improving their community. Projects should be authentic to ensure relevancy to participants' lives and include clear community connections. When conducting projects using the community STEM model, it is common for new questions to arise during the project that drive participants to engage in more advanced investigations, with the ultimate goal of learning more about and improving their local environment. Overall, the community STEM model contextualizes science learning within community and environmental issues, and positions youth and amateur scientists as active contributors, researching about problems and engineering solutions (Fusco 2001; Calabrese Barton et al. 2013; Birmingham and Calabrese Barton 2014; Balestrini et al. 2016). Community STEM can provide alternatives to what counts as science, engineering, and math in and out of classrooms, empowering youth, and promoting a deeper connection with science.

Scholars conducting research on equity in STEM education such as Barton et al. have worked for years toward this aim. We intend to amplify their work with our framing of community STEM, reaching scientists who can create and enact these projects with the community. Research that reframes youth-oriented citizen science as community STEM can change citizen science in a way that "challenges traditional notions of scientific expertise because it values experiential knowledge, family concerns, and community history alongside scientific knowledge" (Calabrese Barton et al. 2013, 26). Students become "community science experts," using science to deepen their understanding of place, to both investigate and impact their communities. For example, students can engage in inquiry and data collection to build community play structures, host green energy fairs, or create artifacts that encourage discussion about access to clean water. Community STEM projects can broaden the definition of science, and can be particularly impactful in leveraging the expertise of youth from STEM-underrepresented groups such as girls and students of color (Birmingham and Calabrese Barton 2014). The partnership between university researchers and community members can also provide expanded roles for undergraduate students involved in these projects. In addition to being researchers, undergraduates can act as trainers,

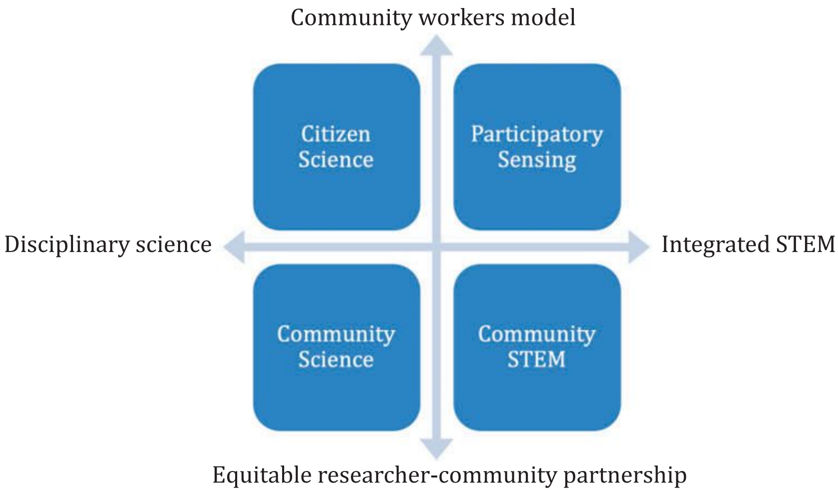

Fig. 1. Situating the community STEM model within citizen science and disciplinary science.

mentors, and even content "experts" in spaces such as community forums (Oberhauser and LeBuhn 2012).

The community STEM model is still not typical in universities, schools, or even in informal science programs, however, it is gaining popularity as digital and physical advances in technology are encouraging more people than ever to invent (Anderson 2014), as well as collaborate in collecting, processing, and sharing data (Dickinson and Bonney 2012). While there is great potential right now for the community STEM model in university settings, more research is needed to consider patterns of participation in these novel learning environments and how these programs support engagement with science at all levels for participants. Following, we provide examples of community STEM programs to further contextualize this model and provide inspiration for others who are interested in creating partnerships to enact the community STEM model in teaching and outreach efforts.

Illustrative examples of community STEM

Below we showcase three community STEM programs to illustrate the diversity of programs and aims, and provide recommendations for other scientists and researchers. The examples were selected from a comprehensive search of youth-oriented programs which included community science and engineering design. These programs do not necessarily refer to their work as "community STEM," but align with our operationalized definition introduced here.

Instead, these programs use diverse terms to describe their work, such as "bottom-up citizen action" (Balestrini et al. 2016), "educated action in science," "critical understanding of place" (Birmingham and Calabrese Barton 2014), "practicing culture of science learning" (Fusco 2001), and "community science expertise" (Calabrese Barton et al. 2013). However, we categorize them as aligning with our community STEM model due to their similar aims and orientations in partnering youth with community and empowering the public as scientists and engineers. We describe projects focused on middle and high school students as there are more examples of community STEM with youth, especially in informal settings. However, we present cross-cutting themes and suggest potential applications for university settings.

Community science experts—green energy technology city

Green Energy Technology City is an after school program in the Midwestern USA that introduced 10–14-year old to green energy issues and STEM practices through field trips and conducting their own investigations into electricity production, conversion, and use in their town (Calabrese Barton et al. 2013). Students learned about environmental impact by examining carbon footprints of their peers and families, and conducting "energy audits" at their homes, the after school club, and schools (Birmingham and Calabrese Barton 2014). Calabrese Barton et al. refer to this framing as "educated action in science," which helped students "leverage relevant and multiple areas of knowledge and practices to inform democratically responsible actions" (Birmingham and Calabrese Barton 2014, 2). Students built STEM expertise by engaging in authentic investigations and the corresponding science and engineering practices of developing research questions, testing models, collecting and analyzing data, and reporting their findings. They educated others through developing and presenting educational multimedia artifacts such as Public Service Announcements (PSAs), mini documentaries, podcasts, and blog posts. Students also hosted a Green Carnival for the community, which featured art and technology booths. Students encouraged visitors to compare the intensity and heat from different types of light bulbs and watch a video documentary they made to explain the light bulb audit at their school. Others displayed a digital and physical model of a proposed energy-efficient teen center that was Leadership in Energy and Environmental Design-certified with green features such as solar panels, rain collectors, and native plants to absorb water (Birmingham and Calabrese Barton 2014). Another exhibit featured a stationary bike attached to a generator so people could bike to power a light or control the music at the event (Birmingham and Calabrese Barton 2014). From their initial energy audit to their final community carnival, youth's "critical understanding of place and insider status" provided a unique perspective and access to broader community discussions about energy practices and technology (Birmingham and Calabrese Barton 2014, 23). This program aligns with our model of community STEM because it focuses on a community partnership with youth where they drove the scientific investigation and creation of artifacts based on local issues. Participants engaged in both science and engineering practices in ways that were consequential to their community.

Conducting scientific investigations in the local environment helped students contextualize science learning and valued students' rich understandings of their environment. Simultaneously, partnering student learners with professional scientists and researchers provided youth opportunities to put their knowledge into action (Calabrese Barton et al. 2013). Youth participation and engagement with community members around STEM redefined what it meant to do science and who could participate. Birmingham and Calabrese Barton report, "They suspended normative and prescribed ways of interacting and being, barriers that often keep people out of science" (p. 25). Although this project involved younger learners, students of any age could benefit from partnering with professional scientists, accessing broader science-relevant community discussions, and redefining participation in science. When considering how to scale this for a university class, undergraduates could survey community members about local concerns, conduct an energy audit of their homes and school, and investigate projects to address environmental issues in their communities. Undergraduate students could also create artifacts, such as PSAs, documentaries, or blog posts as a final assessment of course content, in line with project-based learning approaches.

Practicing culture of science—realizing environmental architecture league

The Realizing Environmental Architecture League (REAL) project also redefined youth participation in science and community life.

Adolescent participants researched social and physical issues in their environment before cultivating a community garden in an abandoned lot (Fusco 2001). After creating a collage of their concerns for themselves and other teens, they learned about action research, youth development projects, and how adults perceive youth more positively when they participate in community service. They researched political and economic conditions of their community, and discovered the history of the nearby lot which used to serve as a community garden. Student teams engaged in science as they tested soil quality, surveyed the land, researched sun patterns, plant types, and outdoor spaces before creating their garden. They engaged in math and engineering design as they experimented with different ways of measuring the space and evaluated materials, then modeled and revised designs of flower beds, sheds, and picnic tables.

They hosted a community celebration to showcase the plot and share their results: 3D models, art, and videos students made with information on the social and psychological benefits of gardening.

Fusco (2001) attributes the program's success to their focus on people and social interactions rather than staying "task oriented." She argues that educators should draw from individual and community strengths, diversity and "compassion for local action and change" (p. 873). A focus on improving the community through STEM transformed science from abstract knowledge into a tangible product that students were proud of for improving and beautifying their community. Science was relevant because the project was responsive to their interests and concerns. Researching and then constructing the garden structures also positioned children of both producers of science content and engineers of community artifacts. Fusco (2001) explains, "As producers, relevancy is inherent in science learning because the environment for learning science is part of what is created" (p. 862). Production was key to creating what Fusco defined as the "practicing culture of science learning" where "children draw on as well as define science, its activities, and its uses within a particular context for specific purposes" (p. 862). The REAL project aligns with our proposed community STEM model because youth investigated a local problem and designed solutions in the form of their community garden. Questions and new ideas surfaced throughout the project and drove more advanced investigation, with students developing STEM expertise, learning more about their environment, and transforming their community.

Further, for those considering adaptation at the undergraduate level, interdisciplinary courses at the intersection of people and the environment could help students simultaneously build new scientific understandings while valuing community knowledge and practices. Courses such as Science, Technology, and Society reveal how scientists and engineers influence the world and integrate ideas about the environment, medicine, education, democracy, and global security. Similarly, courses like *Applied Ethnobotany* have been found to help undergraduates make connections between diverse disciplines such as forestry, anthropology, and medicine while tackling real life problems and valuing community and indigenous knowledge (Hamilton et al. 2003).

People make sense of their environment—making sense Barcelona and the sound project

Making Sense was a 2-year project spanning nine sites throughout Europe that sought to examine how open-source tools combined with digital and engineering design practices could be "effectively used by local communities to fabricate their own sensing tools, make sense of their environments and address pressing environmental problems in air, water, soil and sound pollution" (Making Sense 2016, 1). At Fab Lab Barcelona, makers created the Smart Citizen open-source sensing platform to measure environmental conditions such as humidity, temperature, carbon monoxide, and sound (Balestrini et al. 2016). Next, youth and adult community members and makers from Fab Lab Barcelona worked with the neighborhood association of Plaça del Sol to investigate local noise levels. Plaça del Sol suffered from noise pollution due to crowds and evening revelry, and residents were curious about how local noise levels compared with other neighborhoods (Making Sense 2017). First, Making Sense makers and community members met at a Fab Lab Barcelona workshop to discuss noise pollution in the city. They discussed how to record sound levels and draw attention to the problem in a campaign referred to as "the neighborhood versus the noise" (Making Sense 2017). They designed strategies to set up sensors and measure data, and taught other residents how to assemble and maintain their environmental sensors and analyze the data. College aged students identified "noise pollution hot-spots" and determined that the Plaça del Sol neighborhood was "seriously affected by noise pollution" (Making Sense 2017, 4). After, they created an installation called *Noisebox*, with a microprocessor, sensor, and light emitting diodes to display noise levels in real time. The installation was featured at a community event to recruit more community scientists, and encouraged people to share their perspectives on sounds (Making Sense 2017). This project aligns with our community STEM model because community members investigated a relevant issue in their environment and engaged in engineering projects to design solutions. This type of project could be adapted to a university setting, where students in engineering and natural sciences form interdisciplinary teams to create and monitor sensors, investigate their local environment, and build artifacts that draw attention to and prompt discussion about local problems.

In a similar project in Southern California, the first author (J.M.N.) worked with a group of 15 teenagers to document noise pollution in their community. The specific neighborhood was situated next to a college campus and populated by many undergraduate students. The teens learned from their surveys that the majority of both undergraduates and families were upset with the loud parties. The teens worked with undergraduate and graduate students studying STEM education, Psychology, Biochemistry, and Computer Science to collect geotagged sound files, analyze data about noise patterns, and create graphs and interactive maps. STEM content was not foregrounded but instead presented when they needed it to reach the next step in the project, also referred to as "just-in-time-STEM" (Barton et al. 2017).

The project culminated with a community "Town Hall" meeting where the teens presented their findings on where and when it was loud, offered suggestions, and led a discussion about next steps. The meeting ended with the teens inviting community members to make artistic acoustic panels designed to decrease sound levels in their teen center study room (Nation et al. in press). Creating artifacts such as the maps or sound panels provided focal points which promoted reflection on the problem of noise pollution, solutions, and the role of the project and larger community. During discussions, survey creation, data analysis and presenting their findings, youth gained new skills while leveraging their insider knowledge about noise pollution in their neighborhood, and constructed identities as "community scientists." The science education researchers who led this project were interested in the process of artifact creation, STEM identity construction, and youth participatory research. Therefore, the team's research aims were aligned with the community's priorities of documenting and addressing noise pollution. Youth and community members were partners throughout the process, local STEM knowledge was valued, and science learning was contextualized.

The undergraduate students involved in this project also gained confidence in their technical and teaching abilities. Undergrads learned about new technologies embedded in the project and how to introduce these tools to the youth participants. Further, both the undergrads and youth gained skills in public speaking when preparing for and co-presenting at the community Town Hall meeting. This empowerment for undergraduates should not be minimized, as there is great value in undergraduates taking on roles as "experts" during question-and-answer sessions or when training other community members (Oberhauser and LeBuhn 2012). Other researchers conducting university–community partnership work have found that undergraduates benefit from youth seeing and referring to them as professionals in their fields (e.g., "she's an engineer"), even though, in their career trajectory, they are still novice scientists or engineers (McLean et al. 2019). Additionally, teaching others can solidify university-level content knowledge and validate out-of-school science experiences for undergraduates (see article in same special issue by Yep et al. 2021.

Community STEM programs draw from individual and collective strengths, contextualize science learning within community and environmental issues, and position youth as both the producers of science content and community artifacts (Fusco 2001; Calabrese Barton et al. 2013; Birmingham and Calabrese Barton 2014; Balestrini et al. 2016). Encouraging experimentation and drawing from youth and community knowledge can help redefine what it means to participate in both community decision-making and STEM disciplines (Fusco 2001; Birmingham and Calabrese Barton 2014). Below we synthesize recommendations from community STEM programs.

Recommendations for community STEM programs

Community STEM researchers emphasize the importance of multiple entry points, training to ensure rigor, goal alignment, and an equitable power structure. To allow for multiple entry points to STEM learning, projects should provide diverse opportunities to engage in authentic STEM practices. For example, students can choose to participate in a variety of scientific processes ranging from data collection to data analysis and public dissemination (Heggen et al. 2012; Purcell et al. 2012; Ballard et al. 2017; Roche et al. 2020). Long-term projects that are both authentic and collaborative encourage students to develop unique roles and expertise within the project. Educators can take advantage of the complexity of authentic scientific investigations to draw on diverse roles and practices for data collection, analysis, and communication. In particular, participating in data analysis and presentation appears compelling to students as they view themselves as authentic scientists and contributors (Heggen et al. 2012; Ballard et al. 2017). Projects might be able to increase ownership and engagement even more by enabling students to also design the technology they use to collect data (Heggen et al. 2012; Balestrini et al. 2016). Finally, multiple entry points allow educators to broaden the scope of science beyond conventional practices and potentially allow for interdisciplinary collaborations. Students can leverage other experiences and types of expertise or funds of knowledge, including art, gardening, conservation, and health (Purcell et al. 2012). Broadening and legitimizing the types of STEM-relevant content and practices can encourage students from historically marginalized groups to participate and support their rightful place in science. These community STEM activities can "desettle expectations" about what it means to be good at science and actively redefine what counts as STEM for both researchers and community members, a critical step toward addressing inequity (Bang et al. 2012, 302).

Youth can benefit greatly from community partnerships with local experts that result in a sharing and blending of expertise (Calabrese Barton et al. 2013) as well as support from government, nonprofit, and industry partners (Balestrini et al. 2016). However, community members need training and technical skills, realistic expectations, and a variety of data collection tools and methods (Balestrini et al. 2016). There is the tension between broadening participation and ensuring rigor of data collection and analysis (Bonney et al. 2009; Parrish et al. 2018). Scientists and educators can hold conflicting goals of advancing scientific knowledge versus providing learning opportunities (Roche et al. 2020). Wilderman points out that with citizen science research there is a tradeoff between efficiency, democracy, and sustainability. In comparison to community-based approaches, the traditional citizen science "community workers model" produces results more quickly. However, the public usually lacks access to the findings, and when funding dissipates, scientists move on to other projects. Conversely, community-based research takes much longer and requires more volunteer training. In order to maintain quality control in data collection, community scientist volunteers need training and technical skills to install and maintain sensors (Balestrini et al. 2016; Parrish et al. 2018). The cheap, do-it-yourself sensors do not always live up to people's expectations for data collection (Balestrini et al. 2016). Despite the challenges, it is important to recognize that the process is more democratic since community members can use the data and make their own interpretations. This type of research is also more sustainable because it "builds community capacity to continue even after experts and monies are gone" (Wilderman 2007, 13). For a longer collaborative project to succeed, collaborators need to clarify goals and expectations from the beginning (Henrick et al. 2017; Merson et al. 2018). Combining more than one method could help with data quality, and working with a variety of organizational settings (Balestrini et al. 2016). It is also important to acknowledge the "motivations, value judgements and social norms coming from citizens and communities" (Balestrini et al. 2016, 16). Professional scientists are often wary of citizen science reports. They might not trust findings from projects where people appear biased, or are collecting and reporting data with the goals of an activist rather than scientist. Balestrini et al. (2016) propose that ideally, nonprofits, business, and government organizations would all partner to create "inclusive stakeholder networks" to bring together diverse groups and develop community capacity (p. 17). Universities and undergraduates, in particular, can act as intermediaries between scientists and community groups (Roche et al. 2020).

Overall, researchers and community groups benefit from shared goals and an equitable power structure to ensure consistency and sincerity in the partnership (Purcell et al. 2012).

Programs need a flexible design that meets local needs and supports strong community partnerships. These ideas are well aligned with recommendations for Research–Practice Partnerships (RPPs), where practitioners and researchers work together to address problems of practice over time (Henrick et al. 2017; Penuel 2017). Henrick's model of effectiveness for RPPs describes how successful partnerships are built on trust and long-term relationships. A long timeframe helps foster relationships between scientists and community groups (Purcell et al. 2012), and allows students to see the impact they are making (Ballard et al. 2017). Ultimately, researchers help the partner organization achieve their goals, and researchers benefit by developing and disseminating knowledge (Henrick et al. 2017). University researchers can partner with community groups, but also education specialists at non-profits such as museums, libraries, and makerspaces. To effectively enact community STEM projects, interdisciplinary teams are needed with expertise in the community, various STEM disciplines as well as education, teaching, and learning.

Part of developing shared goals includes managing funding and academic schedules for researchers at universities. While classes with new undergraduate students every semester or quarter can be challenging for establishing longer term projects, there are models of successful partnerships. One example is University–Community Links, a collaborative network that has leveraged the expertise of educational researchers and community leaders since 1996 (Underwood and Welsh Mahmood 2018). The network has a long history of "implementing effective strategies for building and sustaining youth-oriented learning across activities that reach across geographical, cultural, and institutional boundaries" (Underwood and Welsh Mahmood 2018, 209). Undergraduates engage in fieldwork at afterschool sites, mentoring and learning from youth from nondominant communities (Vasquez 2003; Cole 2006). The projects offer educational opportunities for youth to explore digital technologies while developing college-bound identities. University partners gain new contexts for research and teaching, while undergraduate and graduate students can connect theory from coursework with practice (Underwood and Welsh Mahmood 2018). Although undergraduates are often placed at sites as part of quarter-long education courses, many partnering organizations require a two-quarter commitment on a volunteer basis.

Additionally, the long-term partnership between community organizations and the university instructors working with graduate students helps provide continuity despite new cohorts of undergraduates. For example, the Southern California noise pollution project mentioned in this article included numerous undergraduates during the coordinator's 5-year graduate program and occurred within a 20-year overall partnership between university professors and the Teen Center director. Within long term partnerships, undergraduates can complete research or act as a mentor to fulfill requirements in the context of an individual class project, independent study experience, or internship.

Conclusion

The community STEM model offers interdisciplinary and personally-relevant opportunities to increase students' interest in STEM, whether at the K-12 or undergraduate level. Educators have successfully leveraged the inquiry-based practices of community STEM to learn about local concerns, collect data, define problems, and design solutions. These approaches to posing and solving problems encourage both individual expression and community action.

Participating in these programs affords opportunities for students to produce tangible results, working with peers and professionals to tackle real life issues. Additionally, these projects provide disciplinary knowledge and twenty-first century skills and learning dispositions such as critical thinking, patience, creativity, and self-confidence (Schusler and Krasny 2008; Trautmann 2013).

Scholars and educators studying community STEM programs advocate for valuing community knowledge and partnerships, contextualizing science learning within community and environmental issues, allowing for multiple entry points and diverse student participation, and broadening the definition of science and scientist. With intentional framing, community STEM projects can meet both community and scientists' need for data collection and local action, while simultaneously addressing collective problems and promoting expertise sharing (Cavallo et al. 2004; Purcell et al. 2012; Calabrese Barton et al. 2013).

The community STEM model can provide insight into local history and help frame what is possible or recommended for STEM projects (Fusco 2001). Additionally, it can inspire or motivate youth makers, lending authentic purpose to construct artifacts. This grounding in collective issues can help students persist when they reach challenges, and to understand and relate more deeply to the project and science behind it (Barton et al. 2017). Whether published in a journal, uploaded to a blog, or presented at a community festival, these artifacts encourage more discussion about science in local contexts.

While lower-tech community STEM projects have been around for over a decade (Fusco 2001), new advances in technology make it difficult to predict the future for community STEM. However, even in its current form, the community STEM model could push citizen science in new, positive directions. A grounding in community STEM could help combat surface-level participation in citizen science projects, with longer-term framing, and projects grounded in students' lives, values, and communities. One of the key issues with the data collection format of citizen science is that scientists control the project and data. Scholars advocating for community STEM instead argue that co-created projects provide more equitable access to data. With community STEM, community members have the option to not only access their own data, but also fabricate their own tools to collect, analyze, and share their data with others. Longer-term, integrated projects could help participants see the impact of their work, and reflect more deeply on the tensions between science and activism. Ultimately, the community STEM model could "truly foster the more democratic, social justice outcomes many hope for" (Ballard et al. 2017, 66).

Data availability statement

No new data were generated or analyzed in support of this research.

References

Anderson C. 2014. Makers: the new industrial revolution. New York (NY): Crown Business.

Balestrini M, Ladera T, Polvora A, Nascimento S. 2016. Mapping participatory sensing and community-led environmental monitoring initiatives: making sense H2020 CAPS project [Internet]. [Cited 1 March 2021] (https://op.europa.eu/en/publication-detail/-/publication/21a45749-316b-11e8-b5fe-01aa75ed71a1).

Ballard HL, Dixon CGH, Harris EM. 2017. Youth-focused citizen science: examining the role of environmental science learning and agency for conservation. Biol Conserv 208:65–75.

Bang M, Warren B, Rosebery AS, Medin D. 2012. Desettling expectations in science education. Hum Dev 55:302–18.

Barton AC, Tan E, Greenberg D. 2017. The makerspace movement: sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. Teach Coll Rec 119:44. https://eric.ed.gov/?id=EJ1260677.

Birmingham D, Calabrese Barton A. 2014. Putting on a green carnival: youth taking educated action on socioscientific issues. J Res Sci Teach 51:286–314.

Bonney R, Ballard H, Jordan R, McCallie E, Phillips T, Shirk J, Wildman C. 2009. Public participation in scientific research: defining the field and assessing its potential for informal science education. A CAISE Inquiry Group Report. Center for Advancement of Informal Science. (https://www.informalscience.org/sites/default/files/PublicParticipationinScientificResearch.pdf).

Bonney R, Phillips T, Enck J, Shirk J, Trautmann N. 2015. Citizen science and youth education. (http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_089993.pdf).

Bonney R, Phillips TB, Ballard HL, Enck JW. 2016. Can citizen science enhance public understanding of science. Public Understand Sci 25:2–16.

Brewer C, Smith D, (eds.). 2009. Vision and change in undergraduate biology education: a call to action. (https://live-visionandchange.pantheonsite.io/wp-content/uploads/2011/03/Revised-Vision-and-Change-Final-Report.pdf).

Calabrese Barton A, Birmingham D, Sato T, Tan E, Calabrese Barton S. 2013. Youth as community science experts in green energy technology. Afterschool Matters. [Internet]. (https://eric.ed.gov/?id=EJ1016811).

Cavallo D, Blikstein P, Sipitakiat A, Basu A, Camargo A, de Deus Lopes R, Cavallo A. 2004. The city that we want: generative themes, constructionist technologies and school/social change. In: IEEE International Conference on Advanced Learning Technologies 2004Proceedings, 2004 Aug 30–Sept 1; Joensuu, Finland. p. 1034–8.

Cole M; Distributed Literacy Consortium. 2006. The fifth dimension: an after-school program built on diversity. New York (NY): Russell Sage.

Dickinson J, Bonney R. 2012. Citizen science: public participation in environmental research. New York (NY): Cornell University Press.

Fusco D. 2001. Creating relevant science through urban planning and gardening. J Res Sci Teach 38:860–77.

Hamilton A, Shengji P, Kessy J, Khan A, Lagos-Witte S, Shinwari Z. 2003. The purposes and teaching of applied ethnobotany. People and Plants. (https://www.researchgate.net/profile/Alan-Hamilton-3/publication/250070192_The_purposes_and_The_purposes_and_teaching_of_Applied_teaching_of_Applied_Ethnobotany_Ethnobotany/links/55f67f3b08ae6a34f6633eea/The-purposes-and-The-purposes-and-teaching-of-Applied-teaching-of-Applied-Ethnobotany-Ethnobotany.pdf).

Heggen S, Omokaro O, Payton J. 2012. MAD science: Increasing engagement in STEM education through participatory sensing [Internet]. (https://www.semanticscholar.org/paper/MAD-Science%3A-Increasing-Engagement-in-STEM-through-Heggen-Omokaro/e31dc6a484cfb0fbe64c9c0dfba78cfaffff6780).

Henrick EC, Cobb P, Penuel WR, Jackson K, Clark T. 2017. Assessing research-practice partnerships: Five dimensions of effectiveness. William T. Foundation [cited 2021 May 31] (https://eric.ed.gov/?id=ED610463).

Making Sense. 2016. A new approach to citizen science: co-creating technology for change with concerned communities. Making Sense. (http://making-sense.eu/about/).

Making Sense. 2017. Making sense of noise pollution in plaça del sol. Making Sense [Internet]. (http://making-sense.eu/making-sense-noise-pollution-placa-del-sol/).

McLean M, Nation J, Susko T, Harlow D, Bianchini J. 2019. University-elementary school partnerships: analyzing the impact of a service-learning freshman engineering course on students' engineering values and competence beliefs. Int J Eng Educ 35:1415–24.

Merson M, Allen LC, Hristov NI. 2018. Science in the public eye: leveraging partnerships—an introduction. Integr Comp Biol 58:52–7.

Mitchell N, Triska M, Liberatore A, Ashcroft L, Weatherill R, Longnecker N. 2017. Benefits and challenges of incorporating citizen science into university education. PLoS One 12:e0186285

Moll LC, Amanti C, Neff D, Gonzalez N. 1992. Funds of knowledge for teaching: using a qualitative approach to connect homes and classrooms. Theory Pract 31:132–41.

Nation J, Sañosa D, Duncan J, Durán R. Forthcoming 2021. Make some noise: teens respond to sound pollution in community science + maker project. In: Wilson-Lopez W, Esquinca A, Mejia Alejandro Joel, Tucker-Raymond E, editors. Literacies of design: studies of equity and imagination in engineering and Making. West Lafayette (IN): Purdue University Press.

National Research Council. 2003. BIO2010: transforming undergraduate education for future research biologists. Washington (DC): National Academies Press. [Internet]. (https://www.nap.edu/catalog/10497/bio2010-transforming-undergraduate-education-for-future-research-biologists).

National Research Council. 2013. Next generation science standards: for states, by states. The National Academies Press. [cited 20201 May 31]. (https://www.nap.edu/catalog/18290/nextgeneration-science-standards-for-states-by-states).

Oberhauser K, LeBuhn G. 2012. Insects and plants: engaging undergraduates in authentic research through citizen science. Front Ecol Environ 10:318–20.

Pandya RE. 2012. A framework for engaging diverse communities in citizen science in the US. Front Ecol Environ 10:314–7.

Parrish JK, Burgess H, Weltzin JF, Fortson L, Wiggins A, Simmons B. 2018. Exposing the science in citizen science: fitness to purpose and intentional design. Integr Comp Biol 58:150–60.

Penuel WR. 2017. Research-practice partnerships as a strategy for promoting equitable science teaching and learning through leveraging everyday science. Sci Educ 101:520–5.

Purcell K, Garibay C, Dickinson J. 2012. A gateway to science for all: celebrate urban birds. In: Dickinson J, Bonney R, editors. Citizen science: public participation in environmental research. Ithaca (NY): Cornell University Press. p. 191–200.

Roche J, Bell L, Galvão C, Golumbic YN, Kloetzer L, Knoben N, Laakso M, Lorke J, Mannion G, Massetti L, et al. 2020. Citizen science, education, and learning: challenges and opportunities. Front Sociol 5:613814.

Schusler T, Krasny M. 2008. Youth participation in local governance. In: Reid V, Jensen A, Nikel B, Simovska J, editors. Participation and learning: perspectives on education and the environment, health, and sustainability. New York (NY): Springer. p. 268–84.

Trautmann NM. 2013. Citizen science: 15 lessons that bring biology to life. Arlington (VI): NSTA Press, National Science Teachers Association. p. 6–12.

Underwood C, Welsh Mahmood M. 2018. University-community links: a collaborative strategy for supporting extended education. Int J Res Extended Educ 5:207–10.

Vasquez OA. 2003. La clase mágica: imagining optimal possibilities in a bilingual community of learners. Mahwah (NJ): Lawrence Erlbaum Associates, Publishers.

Wilderman C. 2007. Models of community science: design lessons from the field. In: Citizen Science Toolkit Conference. Ithaca (NY). p. 1–13.

Yep A, Nation JM, Moreno R, Reyes H, Torres A, De Smet C. 2021. Nuestra Ciencia: transforming microbiology for Spanish-speaking elementary and college students. Integr Comp Biol (doi: 10.1093/icb/icab117).