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Abstract

Youth development programs often provide young people with science learning experiences. We argue for reframing youth science learning from a focus on individual scientific literacy to an emphasis on collective scientific literacy—*community science*—to support young people in using science to address issues in their lives and communities. We provide examples from youth participatory action research (YPAR), one community science pedagogical approach. The YPAR model supports youth in deciding upon an environmental, economic, or social issue; designing and implementing research; and using their research findings to improve their community. We implemented YPAR with eight cohorts of youth over three years at five schools in Northern California. Using data generated from educator interviews and youth focus groups and analyzed with inductive thematic analysis, we explored what youth and educators reported about science engagement and learning. While YPAR projects offered opportunities for youth to strengthen scientific literacy, youth did not join a YPAR program because it was science education. Instead, as youth selected a personally meaningful topic, they began to see how they might affect community change. Engaging learners in relevant educational experiences situated in authentic community issues may improve motivation for deeper and sustained participation in science learning. Our YPAR example demonstrated an approach to learning STEM in youth development programs by ensuring relevancy and connection to community.

Keywords: youth participatory action research, science learning, culturally relevant science education

Introduction

Advancing scientific literacy is an important goal for society and individuals (DeBoer, 2000; Dewey, 1938; The National Academies of Science [NAS], 2007). Young people are living in a world challenged with complex environmental, economic, and social issues, such as climate change, water quality and availability, food access, poverty, individual and community health, and disproportionate impacts on communities of color. To address such issues requires groups who are civically engaged and collectively possess scientific literacy to collaboratively contribute to their communities (e.g., National Research Council [NRC], 2012; Rudolph & Horibe, 2015). Additionally, scientific literacy influences the nation's economic prosperity and the functioning of democracy (NAS, 2007); and for individuals, their workforce readiness, their participation in public discourse, and their everyday lives (DeBoer, 2000).

Multiple definitions of scientific literacy have been advanced (e.g., American Association for the Advancement of Science, 1990; Bybee, 1995; Hurd, 1998; Laugksch, 2000; Roberts, 2007). Many definitions are narrow in scope, primarily focusing on content knowledge and process skills from science disciplines, and ignore "the social aspects of science and the needs of citizenship" (Lang et al., 2006, p. 179). Through an analytical literature review, Smith et al. (2015) proposed a definition of scientific literacy using Roberts's (2007) focus-on-situations approach, which is applicable to out-of-school time youth programs. The definition outlined four dimensions (referring to them as anchor points): science content knowledge; scientific reasoning skills (e.g., scientific and engineering practices; NGSS Lead States, 2013); interest and attitude toward science (including motivation for science learning); and contribution through applied participation. The fourth anchor point—applied participation—was a novel and salient component, wherein Smith et al. (2015) recognized that strengthening scientific literacy involves engaging youth in authentic, community-based opportunities related to the science that interests them.

As assessed by standardized testing, scientific literacy for most youth in the United States is low and has been stagnant for decades (National Center for Education Statistics [NCES], 2016). Scores on standardized tests have shown that youth at all grade levels—elementary, middle, and high school—need to improve (NCES, 2016). Furthermore, disparities within grade levels exist nationally; the 2015 Nation's Report Card eighth-grade science assessment revealed that in California, a significant gap exists, with Whites (mean score =164) outperforming their Latino (mean score =129) eighth-grade counterparts by 34 points (NCES, 2016). Since standardized tests privilege certain types of knowledge and do not measure other important learning outcomes (e.g., youth development indicators, social-emotional learning; Claro & Loeb, 2017), these measures of individual scientific literacy should be interpreted carefully, particularly when comparing across racial and ethnic groups (Mormann-Peraza, 2018).

Responsibility for science education has focused principally on classroom science teaching; however, as many note, there are challenges such as limited instructional time devoted to teaching science (Blank, 2013), proliferation of didactic teaching methods (Bottie et al., 2021), and lack of educator preparedness (Banilower, 2019). Additionally, school-based science does not provide sufficient opportunities for youth to engage with authentic, science-related public issues (Roth & Calabrese Barton, 2004). For youth of color in particular, school-based science has not served them well, nor has it provided sufficient opportunities for these youth to engage with science-related public issues (Roth & Calabrese Barton, 2004). Youth of color often find that science education minimizes diverse cultural experiences; deemphasizes knowledge of, and sensitivity to, cultural diversity; and seldom brings awareness to structural inequity of science-related issues that may resonate with youth of color (Aikenhead, 2006).

Scholars have shown that informal science learning is a valuable complement to school-based science, and may afford more flexibility in providing opportunities to engage young people in personally meaningful science, technology, engineering, and mathematics (STEM) learning (Faulk & Dierking, 2010; NRC, 2009); likely due to the voluntary nature of out-of-school time spaces. Note that informal spaces have not always been accessible or welcoming to "nondominant" or marginalized communities (Russell & Van Campen, 2011).

Culturally relevant approaches to science education are appropriate to reach culturally diverse populations, particularly youth of color and youth from historically marginalized racial and ethnic groups (Mansour & Wegerif, 2013). These approaches need to engage youth in science such that they may learn about and apply their science learning in purposeful ways, particularly in addressing meaningful issues identified by and in their communities (Roth & Calabrese Barton, 2004). Approaching science from a community perspective may engage youth of color in culturally relevant science education, offering balance between becoming part of the dominant culture and retaining cultural pride, and giving voice to and expanding access to science-related civic engagement (e.g., advocacy, public engagement, informed decision-making) (Aronson & Laughter, 2016).

Rethinking Scientific Literacy as and for Community Participation

Science education—in both classrooms and informal programs—has traditionally focused on knowledge, skills, and dispositions of *individuals* (Bybee, 1995; DeBoer, 2000; Laugksch, 2000). However, some scholars have advocated for "rethinking science education as and for participation in community" (Roth & Lee, 2004, p. 263) whereby scientific literacy is viewed collectively rather than individually. This idea was advanced in a National Academies of Sciences, Engineering, and Medicine report (2016, p. 73) that asserted:

> *Science literacy in a community does not require each individual to attain a particular threshold of knowledge, skills, and abilities; rather, it is a matter of a community having sufficient shared resources that are distributed and organized in such a way that the varying abilities of community members work in concert.*

We argue that there is merit to integrating participatory scientific research with an emphasis on collective scientific literacy—*community science*—to support young people in using science to address issues in their lives and communities. Helping young people use scientific tools to engage in meaningful issues through authentic participation can strengthen collective scientific literacy while also helping youth advance their own science knowledge, skills, and science dispositions. We believe that youth development programs are an ideal place to introduce science programs tailored to youth of color. Youth development programs can do this by taking a community science approach in their STEM education programming.

Youth Participatory Action Research

A promising program model for community science is youth participatory action research (YPAR), an approach to youth and community development where youth conduct research and then act to improve their lives and communities (Cammarota & Fine, 2008). In the YPAR process, youth decide upon a research topic; design and implement the research (i.e., choosing methods, collecting and analyzing data, and interpreting and sharing results); and then plan an action project based on their research findings (e.g., sharing results with decision-making bodies, conducting a community service activity). A key factor in the success of YPAR is the presence of supportive, caring adults, who are willing to share power and establish productive youth-adult partnerships (Zeldin et al., 2013).

While much of the YPAR literature focuses on elevating nondominant youth voices, promoting civic engagement, and raising critical consciousness (Ayala et al., 2018; Cammarota & Fine, 2008; Mirra et al., 2016), there is some empirical work suggesting that YPAR can strengthen scientific literacy. For example, Birmingham et al. (2017) reported on a YPAR program wherein girls engaged with/in science with a commitment to their community and strengthened interest and attitudes (positioned by the girls as "science that matters"). Morales-Doyle (2017) found that using YPAR in a high school chemistry class helped students of color learn concepts and skills (NGSS performance expectations). Concurrently, it allowed students to "position themselves as transformative intellectuals" (p. 1054), cultivate a commitment to community, and develop credibility within their community. Despite these examples, the knowledge base of YPAR's merit in strengthening scientific literacy is still in its nascency.

Investigating Youth Science Learning

To test our assertion about the benefits of taking a community science approach to advance youth science learning, we embarked on a research project to explore the question: *In what ways do young people and educators reflect on their science engagement and learning? In what ways to young people and educators observe opportunities to strengthen scientific literacy?* We defined scientific literacy using Smith et al.'s (2015) definition of scientific literacy.

Implementation: Program, curriculum, and participants

We implemented YPAR with eight cohorts over three years at five schools in Northern California with youth of color (predominately Latinx & Asian youth). The specific context was 4-H youth development, a program administered by Cooperative Extension (a nationwide network of the United States Department of Agriculture, over 100 public land grant universities, and local county governments).

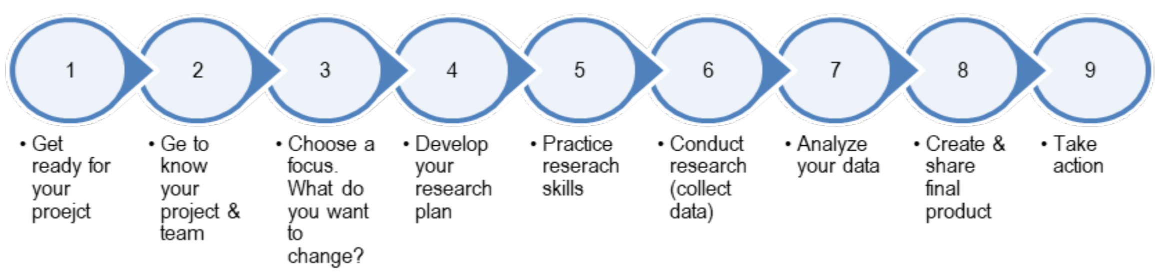
Sites. We selected high school and middle school sites from Northern California that had a group of low-income and/or non-White students interested in participating (see Table 1). These sites included:

- Site 1: A public high school where a third of the students were English-language learners, two-thirds were from lower socioeconomic status families, and the graduation rate was lower than the county average. Program participants were Latino youth, many of whom were recent immigrants. In year 1, the program took place during an English learning class during the school day; in year 2, the program was offered after school.
- Site 2: A public K–8 school where half of the students were from lower socioeconomic status families and one-fourth of the students identified as Latino. All program participants were Latino youth who participated during after-school hours during both years 1 and 2.
- Site 3: A public high school where just under half of the students were from lower socioeconomic status families, and less than 10% and 1% of youth identified as Latino or Black, respectively. During both years 1 and 2, the program was offered during the school day.
- Site 4: A small continuation high school, where two-thirds of the students were from lower socioeconomic status families and which had a low graduation rate. In year 2, the program was offered after school; in year 3, as a class elective during school hours.
- Site 5: A Buddhist high school in a rural county with a predominantly Asian student population, many of whom were not US citizens. The area in which the school was located had a predominantly White population and lower socioeconomic status, with a third of school-age children eligible for free and reduced lunches. The program was offered after school.

Curriculum. Educators used the *Community Futures, Community Lore* curriculum (University of California, Davis, 2021) when facilitating program sessions on a weekly basis during the school year for 60–90 minute sessions (see Table 1).

The *Community Futures, Community Lore* curriculum was designed to support youth participatory action research to build more socially just, resilient communities. The curriculum consisted of nine stages (referred to in the curriculum as stepping stones) that provide guidance to the educator in implementing the project (see Figure 1).

Figure 1
Community Futures, Community Lore curriculum stepping stones (program phases)



In practice, YPAR sessions were facilitated by the adult educator, with each session involving activities from the curriculum. Groups were facilitated in English, with the exception of Site 1, which was facilitated in Spanish by a bilingual Latino staff educator. Activities were experiential, with youth actively involved in large and small group discussions, simulation activities, and independent work. Youth cohorts spent time identifying their own research topic with no constraints; youth were encouraged to select any environmental, economic, or social topic. Educators emphasized verbally that youth would be engaging in science research on their topics to plan for an action/service project.

Youth identified topics relevant to them. These topics included creating an after-school club for learning and practicing English; reducing school cafeteria "fake food"; adding an ethnic studies class to school course options;

addressing community racism and bias; and raising awareness of Native American history and accomplishments (see Table 1).

Table 1

YPAR sites, participants, and youth-identified research topics

Site	Grades	During/ After School[1]	Year[2] & Number of Sessions	Educator	Youth	Youth-Identified Research Topic			
1	High School Y2: After Y2: 8 (75m)			Y1: During	Y1: 23 (75m)	Y1: Latino male		Y1: 16 (16 Latinx; 6 female/10 male)	Increasing after-school options for learning the English language
				Y2: Latino male		Y2: 10 (10 Latinx; 4 female/6 male)			
2	Middle School Y2: After Y2: 12 (60m)			Y1: After	Y1: 11 (90m)	Y1: Latina female		Y1: 4 students (4 Latinx; 4 male)	Reducing school cafeteria "fake food" and increasing healthy options
				Y2: Latina female		Y2: 7 students (5 Latinx, 2 African American; 5 female/2 male)			
3	High School			Y2: During	Y2: 13 (60m)	Y2: Latina female		Y2: 11 students (5 Latinx, 2 African American, 4 non-identified; 6 female/5 male)	Adding an ethnic studies class to school course options
4	High School Y3: During Y3: 21 (60m)			Y2: After	Y2: 12 (60m)	Y2: Latino males		Y2: 8 (5 Latinx, 1 African American, 2 White; 5 female/3 male)	Y2: Addressing community racism and bias.
				Y3: Latino males		Y3: 14 (8 Latinx, 1 African American, 3 White, 2 Asian; 10 female/4 male)	Y3: Strengthening how local businesses work with and serve teenagers.		
5	High School			Y3: After	Y3: 24 (60m)	Y3: Asian female		Y3: 12 (10 Asian, 2 Asian & White, all female)	Raising awareness on Native American history and accomplishments

[1] Y1 = Year 1 2018–2019; Y2 = Year 2 2019–2020; Y3 = Year 3 2020–2021

[2] Sites hosted during school hours used a "school enrichment" program model similar to informal learning environments.

Research approach, data collection, and analyses

Our research was exploratory, operating within a social constructivism epistemology (Creswell & Poth, 2018), and thus it was qualitative and employed a multisite, semistructured interview design to solicit adolescents' and educators' meanings and experiences (Krueger & Casey, 2015; Seidman, 2013). The research team were two women of color (Latina and Asian), a white woman, and two white men.

Data collection. During spring 2019, spring 2020, and spring 2021, the authors conducted educator interviews individually and youth focus groups in small groups. These small groups consisted of youth from their own cohort (with already established comfort and trust); the setting supported youth in sharing responses in their own words and manner. The Year 1 (Site 1) focus group was conducted in Spanish by a Latina Extension colleague. We developed semistructured interview protocols, with 16 educator prompts (see Appendix A) and 10 youth prompts (see Appendix B). Interviews were recorded and transcribed. In total, we conducted six educator interviews (Year 1: 1 interview, Year 2: 3 interviews, and Year 3: 2 interviews) and 15 youth focus groups (Year 1: 5 focus groups, Year 2: 7 focus groups, Year 3: 3 focus groups).

Data analyses. We applied thematic analysis to anchor our inquiry in the data (Braun & Clarke, 2006; 2022). Thematic analysis is a flexible analytical method for constructing themes in qualitative data (Terry & Hayfield, 2021); it has been applied in a wide range of disciplines, including social sciences (Braun et al., 2019). Four authors analyzed transcripts collaboratively using a consensus-based and systematic process designed to emphasize diverse perspectives.

First analytical step. We coded the 2019 educator transcript and development of independent codes. These codes were used as a sensitizing lens to develop codes for the 2019 youth transcripts. The researchers then discussed reasoning and evidence of code development and application. To analyze the 2020 and 2021 educator and youth transcripts, one author served as the primary coder, with the other authors as secondary reviewers. We then met to reach consensus on code application, a form of accountability to reach intercoder agreement. Additionally, when an analytical decision was made—for example, the conditions under a code were applied to text—the primary coder was responsible for returning to earlier transcripts to ensure appropriate code application.

Second analytical step. The second analytical step was to segment the data for deeper analysis across sites. Text excerpts for each code were combined from each transcript (denoted with youth/adult, site name, and year). One researcher was assigned to each code to identify patterns across sites, supported by evidence. Each researcher completed an analytical memo for their assigned codes (Merriam & Tisdell, 2016). These memos were presented to the team for discussion and reinterpretation; the memos went through several versions before the team reached consensus. See Table 2 for a final list of themes and codes.

Third analytical step. We conducted deeper analysis for the excerpts marked with "science learning." We applied the four anchor points outlined in Smith et al.'s (2015) definition of scientific literacy, looking for evidence of youth reflecting on their experiences in relation to content knowledge, reasoning skills, attitudes about and interest in science, and authentic contributions. We report on these four codes in the findings. Additionally, we observed that two of the "YPAR Process and Element" codes were consistently co-coded with science learning, so we include them in responding to our research questions.

Table 2
*Emergent codes and themes**

Theme	Codes
Science Learning	Science-related content
	Reasoning skills, science practices
	Science-related interest, attitudes, and motivation
	Science contributions, applications, real-world connections
YPAR Process and Elements	Youth (psychological) ownership of YPAR
	Topic reflecting youths' lived experience (voiced connections between YPAR and youth lives)

Critical Consciousness (Civic Engagement)^
Youth Development^ (confidence, youth voice, sense of agency, empowerment)
Educator Roles and Learning^

* The table includes all themes identified during data analyses; however, we only include codes for those themes relevant to our research questions.

^ Themes/codes not reported in this manuscript.

Opportunities to Strengthen Youth Scientific Literacy

Youth cohorts identified distinct topics, undertook a research study, and took some type of action based on the results (although the action projects were impacted by COVID-19). Our analyses around science engagement and learning revealed four key findings: (1) the role of personally meaningful topic, (2) identification of cross-site science practices, (3) young people's motivation for joining and staying in the project, and (4) young people's perspectives about using science as a tool for community change. We report on these elements below. In the quotes, we replaced real names with pseudonyms.

Personally Meaningful Topics as an Entrée to Science

Our analyses revealed that youth entered scientific investigations through personally meaningful topics they believed might affect their own lives and community change. These topics were primarily social science issues and varied quite distinctly by site.

- At Site 1, youth were English-language learners. They identified the inadequacy of English-language instruction within the classroom. These students developed and implemented a peer survey to assess strategies used by their peers to learn English. They then created an after-school learning space for them to practice speaking English.
- At Site 2, youth were dissatisfied with school food options. They developed and conducted a peer survey and interviewed school personnel to learn how to improve school food options and move away from what they called "fake food."
- At Site 3, youth began the project with a desire to understand the issues surrounding homelessness and how to address the effects of poverty within their community. Mid-year, after a field trip where a student experienced racism from a white teacher (not part of the YPAR project), youth decided to change their topic. The new topic was to investigate how to create an ethnic studies class at their school.
- At Site 4, in year 1, youth had candid conversations about experiencing discrimination as children and teenagers in their town. They created a peer survey to understand their peers' experiences of racial bias. From this, they wanted to understand what causes racial bias and how to effect change. In year 2, youth observed that there were not many businesses welcoming of teenagers, so they designed a second survey study to ask local business owners their perceptions of teenagers.
- At Site 5, the female Asian students attending a residential Buddhist school (many of whom were international students) wanted to raise awareness of local Native American peoples and cultural practices. Many were international students themselves and expressed an interest in learning about and celebrating the cultures in their communities that, they thought, were not well understood or were "hidden."

The importance of topic selection to youth ownership and motivation were evident, and young people voiced displeasure when the group selected a topic in which they themselves were not interested:

> Zoom Chat Log
> *"Make sure everyone is engaged and finds the topic interesting to them, because they're not gonna care about the project and making something happen if they're not interested"* (Naomi, Site 4, 2021)
> *"^exactly"* (Joey, Site 4, 2021)

The young people's selected topics spanned social science disciplines and were deeply connected to the young people's lived experiences. The topics reflected an issue that (1) directly affected the young people's daily lives in a negative (or neutral) capacity (e.g., English-language learning, school lunches, racism) and/or (2) linked to the young people's lived experiences and cultures. Additionally, the topics reflected youth's experiences of marginality as youth of color, immigrants, and/or from other, nonmainstream US cultures.

Engaging in Science Practices

Youth engaged in science practices as they deepened their background knowledge of these topics and then began to plan and implement a research project. Our analyses showed various ways youth engaged with science practices, which varied by site; however, we identified three science practices common across all sites: exploring the existing literature, selecting appropriate methods, and analyzing and interpreting data.

Exploring the literature. Youth reported extensively on how they explored the existing literature, including conducting background research to see what others had done before, looking up previous empirical research, data collection tools, and findings. One youth shared the following interesting aspect of YPAR:

> *Learning about [previous] scientific studies, because I didn't know about the methods used to learn more about a certain subject. So I think the [YPAR leader] gave us the methods and guided us in our ideas, because we clearly had ideas, but he helped guide us.* (Damiãn, Site 1, 2019).

Here, the youth was describing their experience of learning how to conduct a literature review (although the youth did not use the term itself). Guided by the program leader, the literature review became a way for the youth to further understand and articulate their research topic. Their comment that they "clearly had ideas" and the literature review "guided" them in developing these ideas suggested that the literature review gave credence to the youth's ideas.

Youth also shared that exploring the literature or finding reliable sources was often challenging. When asked about the most difficult part of YPAR, one youth responded:

> *The hardest part of the project was the research, because a lot of tribes don't have official websites or they have barely anything on their websites, so it's really hard to confirm the data as well as to get a reliable source, and that was the hard part for me.* (Jasmine, Site 5, 2021).

Another youth responded, *"Yeah, it was like really hard to find information, and we had to look super hard to find it out because we didn't have enough information about sandwich bars"* (Mike, Site 2, 2019). Both young people reflect on their growing understanding of the importance of obtaining "reliable sources" to guide their research projects.

Methodology. Youth spoke about engaging with sampling methodology; specifically, which sample methodology could provide the information to best address their research question. For example, one young person shared advice they would give: *"[G]et the best information possible, since we are not the only ones trying to learn English.… It is better to do this survey with people who have learned than with those who have not"* (Barrett, Site 1, 2019). Youth also recognized that methods would vary based on the research question: *"It would just be a different procedure [for another topic] compared to, like, the food [topic]"* (Eurico, Site 2, 2019). From there, youth learned various research methodologies and how those methodologies vary based on the research question and context. Youth used this knowledge to design and implement a research instrument that fit their context. One educator described this process: *"It was, like I said, it took a whole month just going over all the research methods. Pros and cons, why they're good, why they're bad. After we had the surveys—and they collected about 170 surveys."* (Derek, Site 1, 2019)

Data analyses and interpretations. Youth analyzed and then interpreted data, resulting in their conclusions. An educator described this process:

> *When they started doing data entry, since they were at that point, they would be asking questions about, like, "Well, what else can we graph? What else can we use Google Sheets for?" and I was like, "You can use Google Sheets for anything." And they started asking questions more about that, and it was just nice to see how these students are doing high school, college level—like, it's basic, but it's at that level where it's like, we're doing data analysis and you don't even fully understand yet, but you know that this is gonna create an image to show your school* (Alina, Sites 2 & 3, 2020).

Here, the youth were deeply engrossed in the data analysis process, reflecting an intrinsic motivation to engage in scientific practices.

For example, at Site 1, when asked what they learned from their English learning project, a young person replied, "to get the best information possible, since we are not the only ones trying to learn English and there are people who have already been through this, and they have achieved it with effort, and because of that is the survey" (Barrett, Site 1, 2019).

In this instance, the youth doing YPAR were all struggling to learn English, a necessity for their cultural survival. They used the peer survey to investigate how their peers had learned English. Through the surveys, the youth learned that the formal instruction they were receiving was often not particularly helpful for their peers, and that their peers preferred more informal settings, like talking with friends or listening to music in English. Through their data analysis, these youth were able to validate their own experiences of learning English. This helped them understand that the frustrations they had while trying to learn English were not their own failings but were a failure of the school system to meet their needs. They then used this new understanding to create an afterschool club to practice English. Their data analysis thus became a way of better understanding and eventually changing an issue impacting their daily lives.

Deepening Science Motivation

While youth recognized that they were engaged in science practices, the science itself was not the primary aspect that excited or motivated youth to join or stay in the program. Youth were passionate about creating change in their community around their identified topic. Science was one tool to help achieve that change. When youth were asked "what was interesting", almost all youth spoke about science in relation to their research topic; e.g., "*[T]he project we did was interesting because we collected information from people to be able to understand … the best methods to learn English*" (Barrett, Site 1, 2019); or *"I really enjoyed seeing all our efforts coming to fruition [raising awareness of Native Americans]"* (Takara, Site 5, 2021). Some youth did, however, speak about the science methods; for example, *"My favorite part was the focus groups, like making up the questions and all that, talking about what we want"* (Erik, Site 4, 2021).

Applying Science as a Tool for Community Change

Youth reported that scientific methods may be used to help solve problems or provide answers. Youth recognized that they could apply science to issues that directly impacted and were relevant to them. The YPAR model, coupled with the participants' lived experiences, led to the selection of a topic and helped youth see how they might make change using science practices coupled with their own motivation to make change in their selected topic. For example, when asked what they learned from YPAR, one said, "*Definitely communication, and just figuring out ways where you could solve a problem on your own and use that for later in life, where—if you want to either work, [be at] home, [do] anything in life—[you would] look at the information you're given…* (Sadie, Site 3, 2020).

Other youth spoke about using science to understand their own experiences and about using that knowledge to begin to develop solutions. Additionally, youth demonstrated a growing ability to reflect critically upon social structures experienced by youth of color. When asked what kinds of problems can be addressed through science, a youth responded:

> *Well, I think teaching other people the same way we did, to analyze society; and I think that people would be a little less selfish if we would [say], "Think of that problem that you have, another person also has it." That is, the program helped us analyze the problems of society, and if we would teach*

it to someone else, I think they would be equally equitable with all people (Damiãn, Site 1, 2019).

For example, at Site 3, students originally identified homelessness as their topic. But then on a field trip outside of the program, one youth in the group had a racist experience with a White teacher. Upset by this, that youth's group decided to change their topic from homelessness to introducing ethnic studies at the school. They reached out to their leader, asking for an emergency meeting. They told the leader about the racist experience and said they wanted to change their topic. The leader was supportive, saying, *"[W]hat's the first step? ... [H]ow about first we do research? ... They were contacting each other, figuring out exactly what they wanted. And it ended up being this whole new project"* (Alina, Site 3, 2020). In this instance, youth viewed YPAR and thus science as a legitimate tool for making change in the world. After a disturbing experience, they turned to YPAR (and science) to address this issue.

Youth Participatory Action Research Positioned Science Learning as and for Community Participation

Our qualitative analyses of educator interviews and youth focus groups revealed that youth entered scientific investigations through a personally meaningful topic. Then, in the context of their chosen topic, youth engaged in various scientific practices and had opportunities to deepen their science motivation. However, science itself was not what compelled youth to join or remain; instead, they maintained participation because they saw YPAR's core science approach as a way to effect change on an issue that affected their lives. Science became a tool for youth to better understand and change the material conditions of their lives and communities.

Young people strengthened their scientific literacy collectively, no participant improving it in the same way or to the same degree. Youth had opportunities to improve their content knowledge (particularly drawing upon social sciences), their scientific reasoning skills (by engaging in science practices); their attitudes about, interest in, and motivation for science; and make contributions through applied participation.

Overall, the youth participation in these YPAR projects more closely resembled collective efforts to address socioscientific questions, where participation varies by interest, skills, and other factors. Youth appropriated scientific tools and scientific practices to better understand their world, which became a means for critical reflection and action. At all sites, we found an intertwining of young people's selection of a YPAR topic based on their own personal experiences; on a desire to change a situation, relying on their collective knowledge; and on the use of science tools and practices to begin to achieve this change.

Our work contributes to an emerging recognition that to better serve youth of color—and, really, all youth—science education should position science as a tool for social transformation, with entry through lived experience. In this paradigm, science practices become one of many resources (e.g., economics, politics, cultural values) youth can draw on when engaged in community change. Community science crosses disciplinary boundaries, centering human values at the core of educational practice. This builds the capacity of young people to identify questions, make evidence-based decisions, and effect change (Harlen, 2001). Our YPAR efforts reinforce the argument for involving young people in critically examining their communities, using science as a practical and useful tool to improve their lives and conditions.

Recommendations for youth development professionals

Many youth development programs emphasize service through civic engagement (Lerner, 2004; Michelsen et al., 2002). Civic engagement may take many forms, including learning about issues, addressing collective problems through joint action, mobilizing political pressure, and engaging in both formalized participation (attending public meetings, protesting, voting) and new forms of public participation (such as forming online affinity groups) (Bennett, 2008; Rogers, Mediratta, & Shah, 2012). However, while existing PYD frameworks often include civic engagement, they tend to minimize the role of activism or of changing the status quo. Engaging young people in meaningful community participation may involve reflection on "the history of policies and practices that have inflicted symbolic and material violence on groups of people" (The Politics of Learning Writing Collective, 2017, p. 93). In our YPAR work, we found youth motivated to gather and analyze scientific data to question the "status quo" on a personally meaningful topic, like school lunch, learning English, or raising awareness of Native American culture. Taking a community science approach may help advance the field of youth development to better support young people in raising their critical consciousness of injustices and in preparing them to advocate for consequential change.

Concluding Thoughts

Scholars have argued that science education should empower young people to contribute to, critique, and partake in a just society (Calabrese Barton, 2003); in other words, science education and civic engagement must go together (Roth & Calabrese Barton, 2004). Lang et al. (2006) advocates for socially oriented science learning that reflects the real-world needs of students, crosses disciplinary boundaries, and places human values at the center of educational practice. Based on our experience with YPAR, we argue that informal science education programs must go beyond *practice fields* (a term from Barab & Duffy, 2012)— where youth learn and practice science in an artificial environment segregated from real life (as seen in most published youth development curricula)—to *communities of practice,* where youth become legitimate participants in real-world communities by addressing socioscientific issues (Barab & Duffy, 2012). Viewing learning from a participatory perspective instead of the traditional acquisition viewpoint opens possibilities to engage learners in authentic and relevant experiences. Such experiences provide youth with opportunities to contribute, influence, and/or contest the practices, norms, and power structures in communities (Worker et al., 2017). Engaging learners in relevant educational experiences situated in authentic community activities may improve motivation for deeper and sustained participation in science learning experience, while also preparing them for the real world. Science education should ensure relevance, value youth expertise, involve partnerships with local experts, and empower youth to act, where youth are positioned as community science experts (Calabrese Barton et al., 2013). Furthermore, public value is created when an educational program benefits society as a whole, thus improving the program's importance and benefit beyond a limited number of participants. In other words, focusing on community impact, rather than individual outcomes, is better for both the individual and the community.

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Appendix A: Educator Interview Protocol

1. What is your name and which site did you work with?
2. Tell me about the projects you were involved with. Where did you end the projects?

3. Tell me about your overall experience with YPAR this year.

4. I'm going to ask you about how you saw youth changed from beginning to end in a few different domains: (a) social-emotional development, like social skills, relationships, and interactions (b) personal growth (c) scientific practices and the science process (d) other life skills like teamwork, leadership, and communication

I am going to move to asking about your observations and experience as you supported youth in figuring out a research question, collecting and analyzing data, and sharing findings.

5. How do you reflect on your role balancing a more traditional teacher role versus guiding and empowering?

6. How do you think the young people's values and personal experience shaped their choice of a research question?

7. In what ways did youth talk about how the project related to their own lives?

8. What experiences or training helped you prepare to facilitate YPAR? What additional resources did you use to prepare and facilitate YPAR?

9. Which components of the fall educator training were helpful?

10. What additional support would have been helpful? *Follow-up:* What advice would you give to other YPAR educators? What essential skills or qualities do YPAR educators need?

11. What do you feel you learned, if anything?

12. What was your most important contribution to the YPAR program?

13. What, if anything, was challenging for you in the program?

14. If you went back in time and started over again, what advice would you give yourself?

15. What, if anything, would you change about this program?

16. Any other thoughts, comments, observations, or feedback?

Appendix B: Youth Focus Group Interview Protocol

1. What is your name and age?

There were many things you did in this project like talking about your ideal versus real community, figuring out a research question, collecting and analyzing data, and sharing findings.

2. Tell me about your project. What was the topic and what were you hoping to do or learn? *Follow-up: What tools did you use? What did you learn from the data you collected?*
3. What was your favorite part of the project?
4. What was the hardest part of the project?
5. What do you think you learned in the project?
6. If you went back in time and started the project over, what advice would you give yourself?
7. Imagine sitting with your best friend. If they asked you about the project, what would you tell them?
8. If you were going to do a project on a different issue, what might you do the same? What might you do differently?

9. In what ways can we make the project better when we do it at another school?
10. Anything else to add?