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INVITED PAPER

Authentic Science with Dissemination Increases Self-Efficacy of Middle School Students

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Synopsis Ethnically and gender diverse groups are more efficient, creative, and productive than homogeneous groups, yet women and minorities are underrepresented in the science, technology, engineering, and mathematics (STEM) workforce. One contributor is unequal access to high-quality STEM education based on socioeconomic status and race, which we may be able to address through inquiry-based out-of-school time programs. Here we describe a 6-month after-school program that allows an underrepresented community of middle school students to conduct original scientific research that they present at a conference each year. Through qualitative assessments and interviews, we found a trend for increased interest in STEM careers and self-efficacy in participants. Self-efficacy, or belief in one's ability to succeed, predicts performance and persistence in STEM. Both self-efficacy and interest in STEM careers increased after students presented their research at a conference, highlighting the unexplored importance of dissemination for shaping self-efficacy in K-12 students. Small after-school programs like ours can be easily accomplished as broader impacts by scientists, and well-designed programs have the potential to positively affect change by increasing access and participation in STEM for diverse students.

Introduction

The global competitiveness and economic advantage of the USA relies heavily on ideas and productivity from the science, technology, engineering, and mathematics (STEM) workforce (National Academies 2010). Yet, the majority of the US population is underrepresented in STEM education (Hira 2010). For example, women and minorities are underrepresented in certain STEM majors in college, are less-likely to pursue jobs in STEM fields, and are thus underrepresented in these fields (Oakes 1990; Hanson 1996; Beede et al. 2011; NSF 2013; Dasgupta and Stout 2014). Lack of diversity has both economic (Oakes 1990) and intellectual consequences. Diverse groups are more effective, more creative, have better communication, and have higher performance than homogeneous groups (McLeod et al. 1996; Milliken and Martins 1996, Hong and Page 2004), and this is true for academia where publications with diverse authors have a higher impact (Freeman and Huang 2015). Beyond these economic and intellectual reasons, it has also been argued that we have a moral obligation to provide equal access to education for all people, particularly groups of people that have been historically underserved (National Research Council 2012; Philip and Azevedo 2017).

Lack of access to quality STEM education due to socioeconomic status and race can lead to underrepresentation of minorities and women in the STEM workforce (May and Chubin 2003; Karen 2005). For example, K-12 schools that primarily serve minority students have smaller budgets, employ more underqualified teachers, and offer fewer advanced courses than primarily white institutions (Museus et al. 2011). The combination of school funding disparity, underqualified teachers, lack of advanced courses, and other challenges like stereotype threat results in inadequate academic preparation for K-12 racial and ethnic minority students, and this is linked to

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lack of success in STEM (reviewed in Museus et al. 2011).

While large-scale education reform is needed to address inequality in STEM education (May and Chubin 2003), out-of-school time programs (programs scheduled when school-aged children are not in school, such as after-school programs; Lauer et al. 2006) can provide access to quality STEM experiences in communities with a large proportion of racial and ethnic minority students (National Research Council 2009). Such programs can provide opportunities for engaging in STEM without fear of failure, offering a community of peers and mentors, and allowing families to become involved (Froschl and Sprung 2014). Out-of-school time programs can also directly shape interest in STEM careers by increasing (1) academic preparation and achievement (Lauer et al. 2006; Hayden et al. 2011; Michel and Neumann 2016), (2) motivation and interest in STEM (Gibson and Chase 2002; Hayden et al. 2011; Krishnamurthi et al. 2013; Kong et al. 2014), (3) identification with STEM careers (Froschl and Sprung 2014), and (4) self-efficacy (Pollock et al. 2004), defined as belief in one's ability to complete a task (Bandura and Locke 2003; reviewed in Dorsen et al. 2006). Further, out-of-school time programs can be designed to include factors shown to promote the success of minority students in STEM such as parental involvement, culturally relevant teaching, early exposure to STEM careers, and boosting STEM self-efficacy (Museus et al. 2011).

Out-of-school programs generally focus on academic support like tutoring, but the most effective and advocated format for a STEM program allows students to participate in the scientific process as practicing scientists (National Research Council 2012; NGSS Lead States 2013; Furtak and Penuel 2019). While "scientific inquiry" involves participating in the scientific process (examining what is known about a topic, asking a question, gathering and analyzing data, interpreting and communicating results; National Research Council 1996; Furtak and Penuel 2019), "authentic science" goes even further. Authentic science experiences allow students to tackle unknown questions, experience uncertainty and problem solve with trial-and-error learning, and participate in a community of inquiry informed by sociocultural traditions where students may learn from peers and advisors (Chinn and Malhotra 2002; Buxton 2006; Roth 2012; Furtak and Penuel 2019). Authentic science should be effective at increasing scientific self-efficacy, which is a key predictor of student performance, motivation to pursue goals, and interest and persistence in STEM (Lent et al. 1986; Lent et al. 1994; Bandura and Locke 2003; Rittmayer and Beier 2008). Authentic science includes several features shown to increase self-efficacy: mastering tasks (through research, proximal goals, and encouraging feedback), vicarious experience (achieved through group work and role models), and social persuasion (through positive feedback and exposure to the STEM community through conference participation) (Britner and Pajares 2006; Rittmayer and Beier 2008).

Authentic science experiences should include dissemination of original research. Scientists regularly disseminate their findings at conferences through talks and posters, but the value of this experience for K-12 students is largely unexplored. Freudenberg et al. (2008) found that undergraduate finance students presenting at a conference had increased self-efficacy. Research at the undergraduate and graduate levels finds that science dissemination improves communication with diverse audiences, student self-confidence, and oral presentation skills (Hill and Walkington 2012). The organization required for writing and speaking about one's research enables deeper understanding of the material (Boyer 1998) and fuels the generation of new questions for future research. A program that guides undergraduate students through independent research experiences, including the dissemination step, can be a powerful equalizer, increasing the number of students on STEM career track for historically underrepresented participants (Carpi et al. 2017). Finally, interacting with the scientific community can facilitate the formation of a science identity, which is critical for persistence in STEM (Froschl and Sprung 2014). An ideal out-of-school program, then, would allow us to explore the importance of disseminating science findings for scientific self-efficacy and interest in STEM careers.

In this study, we designed a 6-month authentic science after-school program for middle-school students in a predominantly Latinx (gender-neutral inclusive label used to replace Latino/a; Salinas and Lozano 2017) community, which we ran for 8 years. Our goal was to increase scientific self-efficacy and interest in careers in STEM for the participants as well as to assess the importance of disseminating research findings. Despite extensive work on after-school programs and achievement (Lauer et al. 2006), we are not aware of other studies that investigate self-efficacy in an authentic science after-school program. Further, the importance of dissemination appears to be unexplored in K-12 students. We chose to work with middle school students because they are in the process of developing their science identity (Reynolds 1991; Guerra et al. 2012) and choosing their careers paths (Singh et al. 2002). Students who express interest in STEM fields in middle school are more likely to earn a college degree in a STEM-related field (Tai et al. 2006), but the middle school period is also associated with the largest reduction in interest in STEM (Thomson and Brooks 1996; Singh et al. 2002). We used Trinidadian guppies, *Poecilia reticulata*, as a research subject since live animals can increase student engagement (Allen 2004), and guppies have been used effectively as a teaching tool for core life science concepts (e.g., natural selection and adaptations, NGSS 2012; Broder et al. 2018; Kane et al. 2018). We had groups of students work together on one research project each year because group work can improve student achievement (Johnson et al. 1998) via peer interaction and cooperative learning (Satterthwait 2010). We assessed the 8-year program in the last 3 years. We had two main research questions. First, we asked if the authentic science program increased self-efficacy and if it increased interest in STEM careers. Second, we asked if participating in a scientific conference to disseminate research increased either self-efficacy or interest in STEM careers.

Materials and methods

Program description

We developed an after-school program called "Science Club" at a K-8 public school in northern Colorado. According to 2016–2017 demographic data, the student community at the school is comprised of 89% minority students; of this group, most are Hispanic and Somali refugees. A majority (87%) of students are eligible for free or reduced lunch programming and 54% of the student population is comprised of English language learners (Colorado Department of Education 2019).

Two of the authors (E.D.B. and K.E.G.) led the Science Club after-school program for 8 years (2010–2018) and administered assessments to participants in the last 3 years of the program. The Science Club was a free after-school program offered to any interested 8th grade students. K.E.G. made multiple announcements to all 8th-grade students for approximately 1 month before the Science Club began each year, making it clear that all students were welcome to participate free of charge. To generate interest in the Science Club, posters of final projects from previous years were displayed at the school (see below).

For the 8 years that we offered Science Club, the number of participants ranged from approximately 15–30. In the 3 years that we administered quantitative assessments, the number of participants was 22, 15, and 15, and those groups were comprised of 59%, 80%, and 86% female students, respectively. However, as described below, we only included data from students that completed multiple pre- and post-assessments reducing the sample size in our quantitative analysis to 11, 12, and 9 for a total of 32 students over the 3 years. Because we did not collect identifying information, we do not have demographic data about those 32 students. For the interviews conducted at the end of the final year (2017–2018), we interviewed nine of the participants, all of whom were female (the same nine that were included in the quantitative analysis).

The club met once weekly during the school year from September through early March for 75 min at the end of the school day. This authentic science program allowed students to collaboratively work through the scientific inquiry process. Participating students generated novel research questions about Trinidadian guppies, made hypotheses, designed experimental methods, conducted experiments, analyzed data using statistics, interpreted results, and disseminated their findings during a full-day field trip to the Front Range Student Ecology Symposium at Colorado State University (CSU) (Fort Collins, CO). This regional conference is organized by graduate students in ecology and evolution and is attended by about 500 people. At the poster session there are approximately equal numbers of undergraduates, graduate students, and faculty with a small proportion of people from the general public.

Assessments

In order to measure changes in self-efficacy and interest in careers in STEM, we assessed our program using a sequential mixed-methods approach (Creswell 2003). We first administered a quantitative pre- and post-assessment in the most recent 3 years of the program (2015–2016, 2016–2017, and 2017–2018 school years) and added an exit interview in the most recent year of the program (2017–2018 school year) in order to explore the experiences of the participants in more depth. Both assessments were approved by internal review boards: CSU (15-6149H) and University of Denver (1170731-1).

The quantitative assessment included the 12 questions about scientific self-efficacy from Ketelhut (2011), which was designed to assess "motivational effects of a multi-user virtual environment on the science achievement" specifically in middle-school students. The assessment also included nine questions assessing interest in careers in STEM

(Friday Institute for Educational Innovation 2012; Supplementary Material S1). All questions were on a Likert scale ranging from 1 to 5 to indicate disagreement or agreement with each statement. In years 2015–2016, 2016–2017, and 2017–2018, we administered this written assessment before students participated in the program, after students completed the program, as well as after students participated in the conference. The post-conference assessment was approximately 2 weeks after the post-program assessment. We collected no identifiers and assigned a number to each student in order to link the two or three (depending on year) assessments. We excluded any students for which we did not have at least two of the three assessments resulting in a sample size of 32, approximately 10 per year. We averaged scores for each individual from the 12 self-efficacy questions and the 9 career questions to create two continuous variables that could range from 1 to 5. Higher scores on these variables indicated higher science self-efficacy and greater interest in STEM careers, respectively. To assess whether there was a change in either dependent variable after completing the program or participating in the conference, we performed separate mixed model ANOVAs for the self-efficacy and career scores with individual as a random effect to allow for repeated measures and assessment as a fixed effect (pre-program, post-program, and post-dissemination) using the program JMP (1989–2019; JMP®, Version 14). To test for the importance of participating in the conference, we ran *post hoc* contrasts for each of the ANOVAs where we pooled the first two assessments and compared them to the post-conference assessment scores. Because sample sizes were small, our power to test year as a factor was reduced leading us to drop year effects from our models.

In addition to the quantitative measures described above, we administered an interview at the end of the program in 2017–2018 that consisted of 10 open-ended questions related to self-efficacy, interest in pursuing STEM in the future, and their experience at the conference (Supplementary Material S2). EDB interviewed nine of the participants individually, by reading the questions aloud and recording responses as audio files using an iPhone. Students were not identified. EDB transcribed student responses and deleted the audio files. E.D.B. and K.E.G. summarized responses by identifying each as negative, neutral, or positive. Based on a common approach in qualitative pedagogic research (e.g., Dey 2003; Calabrese Barton et al. 2008; Varelas et al. 2012), we selected and descriptively interpreted representative quotes related to our three lines of questioning: self-efficacy, interest in pursuing STEM in the future, and experience at the conference.

Case study from 2017 to 2018

To illustrate how the authentic science process proceeded in our program, we present a case study from the Science Club participants from the 2017 to 2018 school year, and these steps are described in their poster (Fig. 1). Each year, EDB transported aquaria containing multiple Trinidadian guppies (*P. reticulata*) from the Ghalambor and Angeloni research labs at CSU to the K-8 school during week 1 of the program. Characteristics of the guppies varied each year depending on student questions and may have included, for example, guppies of different ages, guppies from streams with or without predators, domestic guppies that were obtained from local pet stores, as well as common guppy predators like cichlids. Fish transportation and basic behavioral experiments were approved by the CSU animal care committee (#15-5675A).

Each year, students in the Science Club went through an exploratory process to generate the research question they would address as a group throughout the year. First, students made observations of *P. reticulata* to build a foundational understanding of guppy biology and behavior. Next, we used a brainstorming exercise to generate many possible questions. Students worked in teams, writing a variety of potential research questions on sticky notes, which we displayed on the classroom board. We then collaboratively grouped similar questions in categories like “cool question, but we probably already know the answer,” “not feasible,” “not scientific,” and “consider this further.” Next, we eliminated less feasible questions. For those questions in the “consider this further” category, we talked through what would be required to complete the project (populations required, supplies, space, etc.) and what the independent and dependent variables would be. Finally, students voted to decide on the final research question from a short list of potential questions that were feasible to answer. We then worked with students to generate hypotheses based on our observations and prior research about guppies.

In 2017–2018, students voted to ask the question “Can guppies learn to fear a novel object?” The novel object they elected to use was a plastic zombie toy and they decided to test both wild guppies collected in Trinidad and domestic guppies in their

Fig. 1 Final poster created and presented by Science Club participants in year 2017–2018. Student names and the school name have been removed.

experiment. Students hypothesized that (1) wild guppies would be better able to learn to fear the zombie because they evolved with predators and (2) that there would be no difference between sexes in learning ability because both sexes need to recognize predators in order to survive. Students then outlined the experimental design, including details about the specific guppy populations needed to complete the experiment, the number of guppies needed to ensure a large enough sample size, and how to collect and record the data (including designing data collection sheets). Next they designed, created, and modified experimental apparatuses. This process took several weeks each year and required creativity, persistence, and engineering problem-solving skills; engineering has recently been emphasized in STEM curriculum (National Research Council 2012; Furtak and Penuel 2019). For example in 2017–2018 the students had to design a mechanism to move a zombie toy in an identical way in three replicate tanks through a viewing blind that completely covered the observation tank. They eventually used a series of stationary loops and fishing line to move the toy vertically in each tank.

After EDB transported additional guppies from CSU to the K-8 school, students conducted experiments following their protocols. In 2017–2018, students first presented wild-caught and domestic (pet-store) male and female guppies with a zombie toy, which they moved vertically inside of a testing tank, and recorded guppy baseline responses to the zombie toy. They then trained the guppies to associate the zombie with danger using conspecific olfactory distress cues (extracted by EDB following Nordell 1998) over two training sessions. Then, they measured guppy responses to the zombie without the distress cue present. Students collected data on data sheets they designed and completed data entry using Microsoft Excel. Data collection ranged from 4 to 12 weeks depending on the year. Students then learned to make figures and to work through statistics that allowed them to test their hypothesis and develop conclusions on the basis of available evidence. In 2017–2018, the students found that all guppies learned to "fear the zombie toy" as measured by a change from the baseline test to the final test in avoidance behavior and exploratory behavior (Fig. 1).

Upon completion of the experiment, students created a scientific poster (Fig. 1) that they presented at the Front Range Student Ecology Symposium (FRSES) at CSU. They participated in the conference in every way. First, they wrote an abstract that was submitted to FRSES and approved for presentation. Next students crafted their poster, wrote the text for each section, designed the layout and color scheme, added the figures they designed in the data analysis stage, finalized their conclusions, and chose photos to accompany their written descriptions. When the poster was finished, students diligently practiced presenting the poster to each other as well as to E.D.B. and K.E.G. who roleplayed as judges asking probing questions about the research. As a capstone experience, students spent the day at CSU visiting various labs and meeting scientists before they presented the group poster in pairs. Each pair of students presented the poster for approximately 30 min to poster session participants, judges, and visitors that ranged from undergraduate students to faculty.

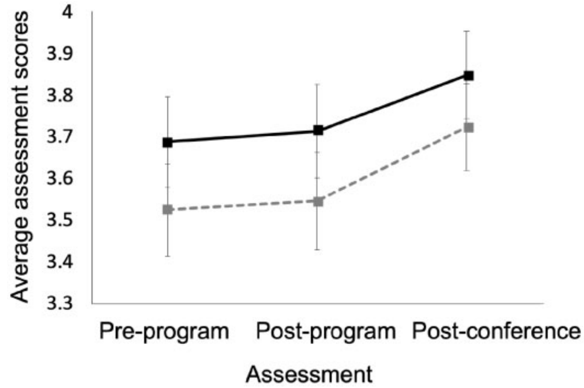

Fig. 2 Least squares means of Likert-scale scores for the self-efficacy assessment (black solid line) and the assessment measuring interest in careers in STEM (gray dashed line) over three time points. Error bars denote standard error. For both models the data show an increasing trend ($P = 0.1$), and *post hoc* contrasts reveal that "post-conference" differs from the two previous assessments (both $P < 0.05$).

Results

Quantitative

The average Likert-scale responses related to self-efficacy tended to increase slightly with each of the three assessments from before students participated in the program to after students completed the program, as well as from after students completed the program to after students participated in the conference (Fig. 2; repeated measures ANOVA, $F_{2,49} = -2.2106$, $P = 0.1$). We detected a similar trend in the responses related to interest in careers in STEM (Fig. 2; repeated measures ANOVA, $F_{2,50} = 2.1998$, $P = 0.1$). *Post hoc* contrasts revealed a significant effect of participating in the conference. Compared to the first two assessments, the post-conference assessments were higher for both self-efficacy ($F_{1,49} = 4.2471$, $P = 0.04$) and for interest in careers in STEM ($F_{1,48} = 4.3011$, $P = 0.04$).

Summary of interviews

The interviews conducted after students completed the program in 2018 reinforce the trends we detected in the quantitative assessment; student quotes revealed positive impacts of the program on scientific self-efficacy, interest in pursuing STEM in the future, as well as the importance of dissemination in shaping their identity as a scientist (Fig. 3).

Questions 1 and 3 revealed high scientific self-efficacy after students completed the program (Fig. 3). When asked if they "know how to do science" (Fig. 3, question 1), students responded positively using phrases such as "yes definitely do." When students responded less enthusiastically, they acknowledged a positive change. For example, one student answered, "I'm not 100% confident, but I feel like I could do it better like I did before." Similarly, another student responded, "I'm not an expert, but I got more of an idea how to ... do things in science." A third responded, "A little bit more than I used to; ... we were all like helping each other and that helped me like get better at science than I used to be." Like the previous responses, this third response describes an increase in self confidence in the student's ability to do science, and it also points to the importance of a community of peers and group work in affecting this change. Responses to question 3 (How do you feel about your ability to do science?, Fig. 3) echoed the importance of group work. One student stated that she "got better at science" because she "got to work with more people" and now "know[s] more about science and how to do research and find answers." Another student stated: "Sometimes I am bad at science because I don't know what to do, but when someone helps me [...I] challenge myself more because I learn even more because of the people." This response indicates that support from peers working toward a common goal was an important motivator and driver of the increase in scientific self-efficacy for this student.

Responses to question 2 (Are you a scientist?) were split with half reflecting high scientific self-efficacy and half of responses expressing doubt (Fig. 3). Some responses were positive: "I think so, because everyone can be a scientist even though without knowing it." Other responses revealed that

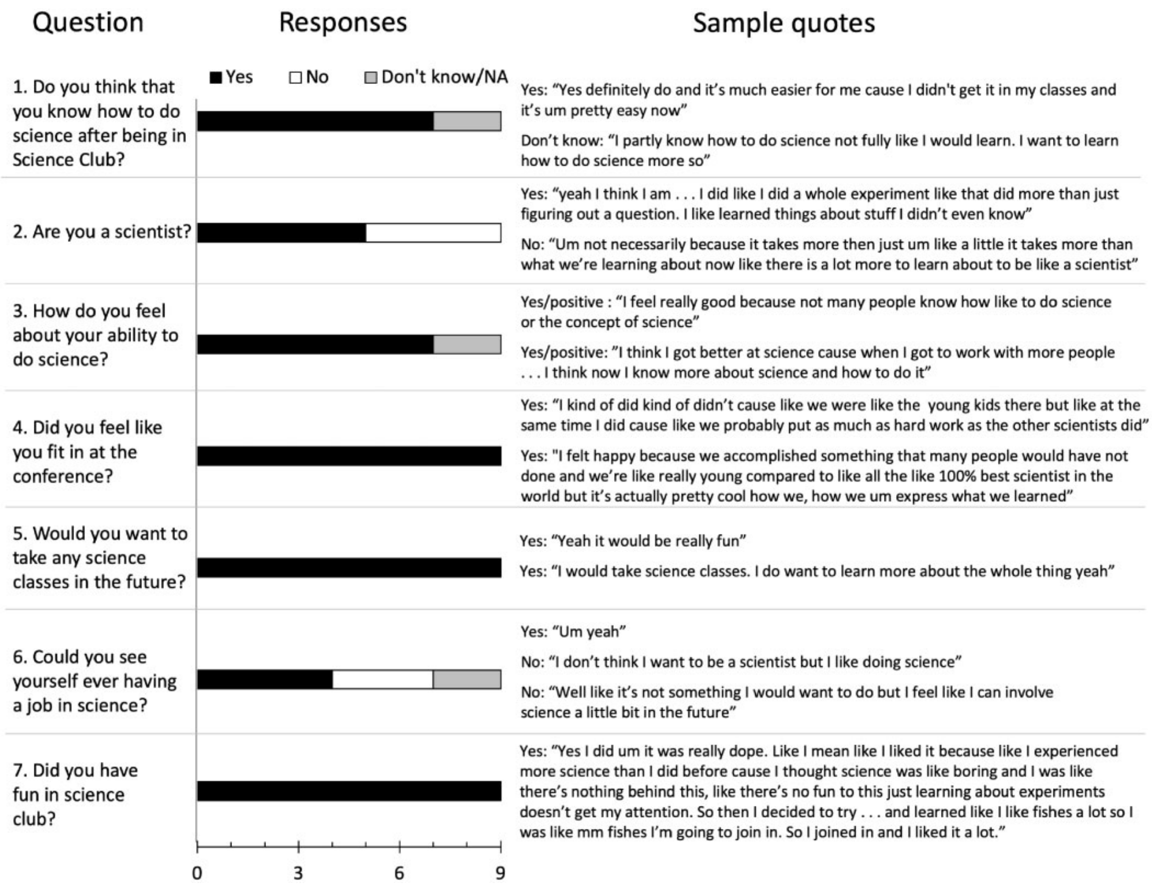

Fig. 3 Selected interview questions (left column) administered in 2018 after students completed the program and participated in the conference. The bars in the center of the figure are a stacked horizontal histogram showing the number of positive/yes (black), negative/no (white), and neutral/don't know (gray) responses to each question. Selected sample quotes appear in the right column.

the experience of conducting science and interacting with scientists opened students' eyes to how much more there is to learn. One student responded, "Um not necessarily, because it takes more than just um like a little. It takes more than what we're learning about now, like there is a lot more to learn about to be like a scientist and for a scientist, so I don't think I am." Similarly, another student responded, "Not that much. Cause like I'm not an expert; like I'm not a professional like the other, like I saw at school, like at CSU. I'm not that professional." Thus while some students felt they were scientists, others felt additional learning and experience were required before adopting that label, perhaps reflecting an increase in understanding of what it takes to be considered a professional scientist.

Questions 5 and 6 (Fig. 3) asked if participants planned to take science classes (question 5) and if they could see themselves having a job in science (question 6). Every participant responded overwhelmingly positively to question 5 whereas answers to question 6 were more variable with approximately equal distribution among "yes," "no," and "don't know" responses (Fig. 3). One student stated "Yeah, cause I want to learn like more" when asked about science classes but answered "Uh probably" when asked about a job in science. Similarly another student answered positively to the question about classes, "Yeah, in like high school and maybe in college, too, I would like to because it's pretty fun," but more neutrally about a job in science, "Kind of; a little bit." A third student also answered positively to question 5 about classes, "Yes, cause science, really, like science makes me happy" but more hesitantly to question 6 about jobs, "It depends on what the job is; … if it's a science teacher, no." Hopefully, this last response is not an insult to their teacher, KEG, but rather evidence that students have a narrow perception of what jobs are considered STEM. Perhaps because our program did not include an intentional description of possible careers in STEM, we found a difference in how our program shaped interest in science classes compared with science careers.

All participants responded positively when asked if they felt like they fit in at the conference (question 4, Fig. 3). One student's response highlights points made by several students: “I felt happy because we accomplished something that many people would have not done, and we’re like really young compared to like all the like 100% best scientist in the world, but it’s actually pretty cool how we how we um express what we learned and . . . how to teach it.” This student expressed pride at a big accomplishment and in sharing what she learned with the community. However, she also notes the age difference. This age difference was mentioned in about half of responses: “we were like the young kids there” and “it was like old like people; . . . we were smaller than the rest of them.” Despite some recognizing age as a reason they may not have fit in, many students compared their accomplishments positively to those of the undergraduate and graduate students presenting at the conference. One student answered, “I would say yes, because we did the like same concepts that other people were doing.” Another answered, “I did, cause like we probably put as much as hard work as the other scientists did there so.” Finally, several students also alluded to a sense of community in their responses. One student stated, “Yeah, when we were doing the presentation we helped each other a lot and yeah.” This response suggests that her peer group, Science Club, was important in making her feel comfortable at the conference. Another student stated, “I did. I liked, because I like to talk a lot, and I like l like to like meet new friends, and like talk to them about like how like science is, and like they understand me like.” This response also highlights the importance of community, but in this case participating in the larger scientific community at the conference. This emphasis on community appeared in responses to other questions. For example, when asked if she “had fun in science club,” one participant responded, “Yes, it was very fun, cause like we were all together as one and were just like having fun with all of us together.” Thus, the experience of participating in the program and the conference seemed to be an overall positive experience for most students.

Discussion

The effectiveness of inquiry-based after-school STEM programs on feelings of confidence and self-efficacy is limited despite several lines of educational research suggesting they could contribute to broadening participation. Here, we presented a case study of a successful after-school science program in which middle school students from a historically underrepresented community practiced science and presented their original research at a local conference. Quantitative assessments over the last 3 years of the program showed an increasing trend for both scientific self-efficacy and interest in careers in STEM. For both dependent variables, this trend was significant when we compared the first two assessments with the post-conference assessment in *post hoc* contrasts, revealing the importance of disseminating research at a scientific conference. Interviews administered after completing the program and the conference in year 2017–2018 provided additional support for the role of the program in boosting self-efficacy and interest in STEM coursework. These interviews also allowed us to explore student experiences in more detail.

Our quantitative assessments and interviews suggest that our program impacted scientific self-efficacy for program participants. This increase in self-efficacy is critical because self-efficacy predicts student achievement, motivation to pursue goals, and interest and persistence in STEM (Lent et al. 1986, 1994; Bandura and Locke 2003) and may be an especially important influence on success of K-12 racial and ethnic minority students (Museus et al. 2011). While there are examples of programs that have successfully increased scientific self-efficacy (e.g., Liu et al. 2006), few studies have investigated the effect of after-school programs on self-efficacy. In a year-long study with Latinx middle school students, researchers found no change in self-efficacy in an after-school tutoring program, though self-efficacy did predict achievement (Niehaus et al. 2012). Opposite this study, we did find an increasing trend in self-efficacy in predominantly Latinx middle school participants in our 6-month program. Unlike the tutoring program described by Niehaus et al. (2012), our program was inquiry-based and intentionally included features shown to bolster self-efficacy including experience mastery, vicarious experience, and social persuasion through conference participation (Britner and Pajares 2006; Rittmayer and Beier 2008). We did not attempt to identify which program features were most important in shaping self-efficacy in this study, and it is likely that all contributed; however, our interviews highlighted the importance of a peer community, teamwork, and participating in the larger scientific community (vicarious experience).

Self-efficacy predicts interest and persistence in STEM (Lent et al. 1986; Lent et al. 1994; Bandura and Locke 2003), and indeed we found an almost parallel increasing trend in interest in STEM careers in our study (Fig. 2). It is possible that the same attributes of our program that increased scientific self-efficacy also increased interest in careers in

STEM, and self-efficacy may also directly drive interest in careers in STEM (Betz and Hackett 1986). It has been suggested that project-based, community-focused programs can increase engagement and interest in STEM (Wallace et al. 2005), helping students link STEM activities to real life and future careers. Our program allowed students to integrate into a diverse scientific community while completing a project in which the questions were completely student-driven, as evidenced by the zombie apocalypse study (Fig. 1). One major weakness of our study was that due to the limited assessment options for middle school students at the time, we used subsets of previously published and validated assessments, which may decrease their validity. However, we supplemented those quantitative measures with interviews that revealed the same patterns. One notable difference that the interviews revealed was a distinction between interest in science classes (overwhelmingly positive) and interest in science careers (more hesitant). One possible explanation is that, for women in particular (all 2017–2018 interviewed participants were female), career decisions are based on confidence in abilities (self-efficacy) as well as a multitude of complex factors such as expectations for success, self-perception shaped by gendered socialization, and tradeoffs with other life choices like family (Eccles 1994). Additionally, while our program and study were relatively long, career aspirations may require years rather than months to shift. According to social science research, values and attitudes require years to shift (Gouveia et al. 2015), and it is possible that career choice behaves like a value. It would be interesting to determine if experiences similar to Science Club over several years further increases student interest in STEM careers.

Our quantitative assessment highlighted the important role of conference participation and research dissemination for both self-efficacy and interest in STEM careers. This matches work at the undergraduate and graduate level suggesting that science dissemination increases self-confidence and self-efficacy (Freudenberg et al. 2008; Hill and Walkington 2012) and can be particularly powerful for historically underrepresented students (Carpi et al. 2017). One reason that the conference attendance may have been particularly important for increasing self-efficacy and interest in STEM careers is that it allowed students to engage with the larger scientific community. Vicarious experience (achieved through group work, role models, and encouragement) and social persuasion (positive feedback and integration into the lager STEM community through conference participation) are important drivers of self-efficacy (Britner and Pajares 2006; Rittmayer and Beier 2008). Role models at the conference and during Science Club may have been an important factor affecting student self-efficacy. All authors of this work identify as female and/or minority, and students who attended the conference interacted with additional diverse role models, which has been shown to increase self-efficacy (Stout et al. 2011) and lead to increased participation in STEM (Drury et al. 2011). However, it is important to note that the conference may have been intimidating for some students. When asked if she was a scientist, one student said no because she was not an "expert" like those she met at the conference. Additionally several students commented on being the youngest or smallest people at the conference. In the future it would be interesting to compare conference experiences with mostly peers, like a middle school science fair, to conference experiences with college-level scientists.

Interview responses suggested an important role for a peer support network, group work, and participating in the larger scientific community. Social networks are critical for promoting student engagement for Latinx communities in particular (Rodríguez and Conchas 2009). Other key factors for Latinx communities are incentives and a space that promotes peer relationships (Rodríguez and Conchas 2009). Science Club offered the funded field trip to the CSU conference at the end of the program as an incentive and provided a collective space through the Science Club classroom. Safe spaces in the community and in schools that allow students to interact with peers and caring adults are one of the most important factors keeping Latinx students enrolled in school (Harris and Kiyama 2015). While our program's emphasis on community would likely promote student engagement for any student, this work highlights the importance of understanding the cultural values of the participants.

While we are encouraged by the outcome of this program, we also recognize the limitations of this work. First, although the school has a high proportion of minority, free, and reduced lunch, and English as a second language students, we did not collect identifying information about race or socioeconomic status; thus, we are assuming that our participants roughly match the demographics of the school. In addition to this underlying assumption, we also cannot account for selection bias in this study. Notably, to help avoid selection bias we made the program free and advertised it widely within the school so that all students were invited to participate. Nevertheless, participants self-selected and may have represented students with greater social capital and/or students with fewer conflicts. Conflicts between Science Club and other extracurricular activities at the K-8 school likely explain the overrepresentation of females in Science Club; specifically, coaches of male after-school sports were less flexible than coaches of female sports in allowing students to participate in multiple extracurricular activities. However, we cannot detangle scheduling conflicts from interest. It is also possible that girls were more interested in Science Club because both leaders (K.E.G. and E.D.B.) were women. This study was also limited by the assessments used. Due to limited self-efficacy assessments for middle school students available to us at the time, the quantitative assessment included an instrument that was validated for use with virtual environments and may not translate to our study. We added an interview to supplement the quantitative assessment, but we only presented a summary of our interview responses whereas a thematic analysis (Braun and Clarke 2006) would have been more informative. Additionally we did not explore the effect of year in our models. While we believe that our program positively impacted the community that we worked with, the small sample size and limitations of the work require readers to extrapolate the outcomes with caution. Finally, it is important to recognize that our conceptualization of equity is ever changing (Philip and Azevedo 2017). While this program was designed to address inequality in STEM education and certainly impacted students, it is naïve to believe that one positive STEM experience is enough to overcome the political, social, and cultural hurdles that women and people of color must overcome to pursue a career in STEM. It would be interesting and challenging to design an inquiry-based after-school-program that begins with a social movement and then uses science to solve a community problem (Philip and Azevedo 2017).

In conclusion, we showed an increase in scientific self-efficacy and interest in careers in STEM as a result of participating in a scientific conference in an authentic science after-school program. We also highlighted the importance of a community of peers working toward a tangible goal as well as participating in the scientific community, which may be especially important for Latinx communities. Because middle school is associated with the largest reduction in interest in STEM (Thomson and Brooks 1996; Singh et al. 2002) and students are developing their science identity during this period (Reynolds 1991; Guerra et al 2012), authentic science out-of-school programs that include dissemination may be critical for increasing self-efficacy and interest in STEM careers. We hope that our work encourages educators and researchers to prioritize programs like ours in communities of historically underrepresented students with the larger goal of creating a STEM workforce that reflects the socioeconomic, gender, and racial diversity of the USA.

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Supplementary data

Supplementary data are available at *ICB* online.

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