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Growing Plants and Scientists: Fostering Positive Attitudes toward Science among All Participants in an Afterschool Hydroponics Program

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Abstract This study examines an out-of-school time program targeting elementary-aged youth from populations that are typically underrepresented in science fields (primarily African-American, Hispanic, and/or English Language Learner participants). The program aimed to foster positive attitudes toward science among youth by engaging them in growing plants hydroponically (in water without soil). Participants' attitudes toward science, including anxiety, desire, and self-concept, were examined through pre-post survey data (n = 234) over the course of an afterschool program at three separate sites. Data showed that participants' anxiety decreased and desire increased for both male and female participants over the program. Self-concept increased for female participants at all three sites but did not change significantly for male participants. Participants' first language (English or Spanish) was not a factor in attitude outcomes. The primarily positive outcomes suggest that hydroponics can be a useful educational platform for engaging participants in garden-based programming year round, particularly for settings that do not have the physical space or climate to conduct outdoor gardening. Similarities in positive attitude outcomes at the three sites despite differences in format, implementation, and instructor background experience suggest that the program is resilient to variation in context. Understanding which aspects of the program facilitated positive outcomes in the varied contexts could be useful for the design of future programs.

Keywords Informal science education · Afterschool · Elementary · Attitudes toward science · Hydroponics

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Introduction

The disparity in achievement in academic science and representation in science careers in the USA is well documented. Analysis of national data has shown that individuals who are African-American, Hispanic, or Native American are consistently outperformed academically (National Research Council 2011) and underrepresented in most science, technology, engineering, and mathematics (STEM) majors and careers (National Science Foundation 2013) compared to their white or Asian peers. Additionally, although representation of women in STEM careers has improved in the last several decades, particularly in biological fields, women continue to be underrepresented in most STEM fields (National Science Foundation 2013). The necessity of increasing access to quality science education and the diversity in the STEM professions has been effectively argued in terms of both increasing democratic and economic justice for individuals and communities (Lee 2001; Tate 2001) and expanding the knowledge base and workforce for STEM fields (National Research Council 2011). Interest in science, and the intertwined concept of attitudes toward science, have been identified as major factors in individuals' decisions to pursue and ability to persist in careers in science (Cleaves 2005, Gibson and Chase 2002; Tai et al. 2006). Consequently, promoting "favourable attitudes towards science, scientists and learning science, which has always been a component of science education, is increasingly a matter of concern” (Osborne et al. 2003, p. 1049).

Extensive research has found that programmatic and personal factors influence students’ attitudes toward science (Osborne et al. 2003) and that the elementary years are an important time in attitude formation (Tai et al. 2006). While school science certainly plays a large role in science learning, children spend most of their time outside of formal schooling (Falk and Dierking 2010; National Research Council 2015). Studies on learning outside of formal schooling have shown that informal learning environments are well suited to fostering positive attitudes toward science (Bell et al. 2009) and that organized out-of-school programming, such as afterschool programs, are an important and influential piece of the STEM learning ecosystem for many young people (National Research Council 2015). Building on that work, we are focusing on fostering positive attitudes toward science in the critical elementary-age years among participants who are typically underrepresented in science through informal afterschool programming. In the current study, we examined changes in participants’ attitudes toward science over the course of an afterschool hydroponics (growing plants indoors in water systems) program at three different locations, considering both participants’ gender and language, which are often associated with differences in participant outcomes related to science learning.

Literature Review

Significant work has been conducted around how to foster positive attitudes toward science among youths. This work has examined multiple constructs and has been conducted across a number of different contexts. To frame our project and research study, we drew on aspects of the literature base that were most closely related to the contexts of the current work. Specifically, we examined research that has explored designing learning environments that support participants from populations that are underrepresented in science, particularly female and English Language Learning (ELL) participants and research that was conducted in out-of-school programs. This literature base guided the design of the afterschool program and framed the research questions around changes and variations in participants’ attitudes toward science.

Attitudes and Interest in Science

Non-cognitive factors, including interest in and attitudes toward science, have a long history as a focus of research in science education (Osborne et al. 2003), and interventions intended to increase participation in science have targeted improving attitudes and interest. Development of interest in science careers has been found to manifest early in individuals. An analysis of national longitudinal data found that students reporting an interest in science in the eigth grade were three times more likely to obtain a college degree in a science field than other students (Tai et al. 2006). Follow-up work (Maltese and Tai 2010) determined that interest in pursuing a science career had developed before middle school among 116 individuals who were completing PhDs in science fields. This suggests that elementary years are a critical time in the development of interest in science.

To understand how interest in science may develop, we turned to Hidi and Renninger’s (2006) model of general interest development. In this model, individuals progress through four sequential phases to move from short-term, externally supported, situational interest to enduring, internally supported interest in a topic. Hidi and Renninger suggest that progressing through the phases requires positive experiences that motivate the individual to seek reengagement with the topic over time. They suggested that programs can foster positive feelings in the early phases of interest development by offering participants’ choices in activities, helping participants develop the knowledge necessary to complete tasks, creating contexts focused on collaborative problem solving, and promoting feelings of autonomy and competency within activities. Additionally, they suggest that teachers can help participants move from external support to internal interest by providing participants’ with opportunities to ask their own questions about the content, thereby catalyzing them to connect their current understanding to alternative perspectives and building internal motivation to seek additional information. The critical importance of positive feelings to the development of long-term interest led Hidi and Renninger to propose that affective, or emotional, outcomes such as feelings and attitudes should be the focus of early phases of interest development.

Research on participants’ attitudes toward science has focused on identifying factors and designing programs that influence attitudes. In a review of the literature on attitudes toward science, Osborne et al. (2003) describe attitudes as “the feelings, beliefs, and values” (p. 1053) held by individuals about science broadly defined. They identified 11 different components that have been incorporated in various studies of participants’ attitudes toward science, three of which—anxiety toward science, desire to do science, and self-concept in science, described later—were examined in the current study. Although specific factors vary across contexts and topic, the research literature suggests that quality of teaching, curricula, cultural factors, gender, peer interactions, and personal factors including self-confidence and motivation influence participants’ attitudes toward science (Osborne et al. 2003; Zacharia and Barton 2004). In the next sections, we examine research that has explored fostering positive attitudes toward science in the multiple contexts that are relevant to and informed the design of the program in this study.

Fostering Positive Attitudes toward Science in Afterschool Programs

Out-of-school time science learning has been increasingly recognized as an important contributor to science learning (Falk and Dierking 2010). While out-of-school learning includes a wide variety of experiences, contexts, and formats, afterschool programs are a common means through which school-aged children, particularly elementary-aged children, engage in out-of-school science learning (Bell et al. 2009). A recent review of programs (Krishnamurthi et al. 2014) and evaluation of programs (Krishnamurthi et al. 2013) in the USA found that participants in STEM afterschool programs experienced improved attitudes toward STEM careers and fields; a higher likelihood of graduating from formal school and pursuing a STEM career; improved self-perception related to STEM; and increased interest, excitement, and engagement with STEM fields, among other outcomes.

Afterschool programs at the elementary level are often designed to be dissimilar to school (National Research Council 2015). While there is a wide variation in program focus, format, length, and resources (Krishnamurthi et al. 2013), afterschool program goals tend to focus on nurturing interest, engagement, curiosity, self-efficacy, and identity in STEM over specific content or academic goals (Krishnamurthi et al. 2014). This aligns to the goals described in the recent National Research Council report on informal science learning (Bell et al. 2009) that put forth increasing interest in science and value of science in society and personal life as important outcomes well suited to the domain of informal science learning. In order to maintain the informal and welcoming nature of the settings, programs often lack formal assessments in which participants are required to demonstrate their learning (Nasir et al. 2006), and research and evaluation may rely on methods that do not disrupt the informal nature of the activities (National Research Council 2015).

Research on developing effective programs has examined factors that are present in successful programs. Building on Noam's (2008) quality triangle framework for creating high-quality, out-of-school time programing (across content areas), Freeman et al. (2009) suggested that high-quality, out-of-school science programing depends on three interconnected pieces: content, included hands-on inquiry learning opportunities; staff, included staff capacity, training, and knowledge around STEM content and pedagogy; and program features, included support structures and leadership to provide access to materials and STEM expertise. However, despite extensive interest in including science programing, having access to sufficient resources and high-quality program materials, as well as STEM content or pedagogy expertise and training for program staff, are challenges for many programs (Chi et al. 2008). Staff training and expertise, in particular, remains a substantial challenge (Chi et al. 2008; National Research Council 2015). Although programs vary in terms of formal or informal training for staff in both STEM content and pedagogy (Krishnamurthi et al. 2013), they tend toward less training and expertise in both than among staff in formal science education (Afterschool Alliance 2013). While professional development has been found to increase afterschool staff's confidence and effectiveness in delivering STEM programing (Junge and Manglallan 2011), there is limited guidance in the published literature on designing effective professional development programs for afterschool staff who may not have formal training in either science or pedagogy (Freeman et al. 2009; Junge and Manglallan 2011). Developing materials that can be effectively used by staff with varied background experience is an important consideration in designing scalable afterschool science programs.

Fostering Positive Attitudes toward Science for All Participants

There is a growing body of literature on fostering engagement with participants who have historically been excluded from science. In multiple projects with racially diverse children from low-income backgrounds, Barton and colleagues (Barton 2003; Basu and Barton 2007; Tan and Barton 2008) have found that situating science learning in contexts and problems relevant to the participants, and positioning participants as central creators of knowledge that could be used to solve problems encouraged participants to engage with science and see themselves as scientists. Rather than focusing on teaching specific science content, this approach connected to the science in participants' daily lives to reconceptualize science as a context in which the participants were already experts (Barton 2003). Additional research has suggested that legitimizing participants home and background knowledge or practices of knowledge building, giving participants ownership over what counts as science and science practices and helping participants navigate conflict between home practices and those valued in science can improve experience and access for participants who have typically been excluded from science (Bang and Medin 2010; Lee and Fradd 1998; Lee 2005; Lynch 2001; O'Neill 2005).

Participants' gender has also historically served as a predictor for engagement with and attitudes toward STEM (Osborne et al. 2003). Extensive research has been conducted around girls' attitudes toward science, development of STEM identities, and interest and persistence in pursuing STEM careers. Similar to the literature from cultural studies of science education, situating science learning in personally relevant topics and positioning girls as co-constructors of knowledge has been suggested as a way to foster engagement with science (Barton and Brickhouse 2006). Additionally, research has repeatedly shown that when girls are supported and encouraged to study STEM subjects actively, such as by parents or peers (Leaper et al. 2012; Stake and Nickens 2005), or passively, such as by female role models (Marx and Roman 2002), their motivation in those subjects increases. This suggests that programs based on relevant topics in which girls are encouraged to take an active and central role may foster positive attitudes toward science among female participants.

Finally, language also plays a role in science learning, and participants whose home language is different than the language of instruction face additional barriers to engagement and success (Lee 2005). Research suggests that, not surprisingly, higher proficiency in English facilitates science learning (Torres and Zeidler 2002) and demonstration of learning (Turkan and Liu 2012) when instruction and assessment are in English. However, studies from multiple contexts have found that allowing participants to discuss, reason, and write about science content using their home languages in English-language classrooms enhanced science learning and enabled participants to understand and engage with the science content in ways they would not have been able to using only English (Goldberg et al. 2009; Reyes 2008; Stevenson 2013; Tobin and McRobbie 1996). Informal science learning settings, without the requirements and assessments common in formal schooling, offer good opportunities to engage in science content in multiple languages. This is additionally in line with extensive work in multicultural education that rightly holds that student engagement, learning, and both affective and academic outcomes are improved when students' home language and cultural practices are valued and legitimized in the classroom (e.g., Brown-Jeffy and Cooper 2011; Ladson-Billings 1995; Lee and Fradd 1998).

In summary, the multiple research foci highlight the presence of hands-on inquiry activities rooted in topics or problems that are personally relevant to participants, where participants are positioned as central and active players, with instructors who are knowledgeable in the relevant content and pedagogical practices, as critical to creating programs that foster engagement and positive attitudes toward science among participants. The integration and interaction of these factors in the current project will be discussed below.

Hydroponics Afterschool Programs

The current study examines changes in participants' attitudes over the course of an afterschool hydroponics program. Hydroponics is a method of growing plants without using soil, where nutrients that plants typically extract from the soil are added to the water. Systems generally include a structure for holding the plants, a reservoir of water-containing nutrients, a method for getting the water to the plants, and lights. We recognize that science programming based around gardening and agriculture is not a new concept. There are many outstanding programs that exist that have proven to be successful in improving the attitudes, knowledge, and skills of urban youth (who typically have less direct and easy access to nature than their non-urban peers) in regards to science and their relationships with nature or food systems (i.e., Blair 2009; Rahm 2002; Williams and Dixon 2013). Recent reviews of garden-based programs have found that participants were excited to engage in gardening, proud of their work caring for the garden and the vegetables it produced, and had more positive attitudes toward school after participating (Blair 2009), and that social development and academic outcomes among diverse participant populations were consistently positive across various program formats (Williams and Dixon 2013). Additional work on participant outcomes has shown that gardening programs increased participants' understanding of the food system (Rahm 2002), improved attitudes toward the environment (Skelly and Zajicek 1998; Waliczek and Zajicek 1999), increased higher-order thinking skills (Mabie and Baker 2010; Waliczek et al. 2003), and increased in-school science achievement (Klemmer et al. 2005; Smith and Motsenbocker 2005). While these outcomes are certainly not universal or uniform across programs, there is sufficient evidence to suggest that well-designed and sufficiently resourced afterschool science and garden-based programs have the potential to foster positive attitudes toward science among participants.

Many of these programs focus on outdoor urban agriculture which requires outdoor space and climate suitable for farming. Hydroponics offers a gardening alternative that is not tied to external space and the growing season and can be conducted year round indoors. Systems can be set up inside classrooms or program spaces, facilitating integration with other activities. In terms of curriculum and programming, hydroponics effectively integrates the strands of science, technology, engineering, mathematics (STEM), the goal of a recent push in science education (Honey et al. 2014). Participants engage in engineering design and problem solving through building the systems, learn chemistry and biology content to maintain the nutrient and pH levels that sustain plant growth, and use math skills and scientific practices to design, conduct, analyze, and share experiments involving their plants. The relative ease of controlling and manipulating multiple variables that impact plant growth (lights, nutrients, pH, water flow) make hydroponics an excellent context for learning about and conducting experiments. Additionally, plants grow faster in hydroponics systems than in traditional agriculture, allowing more cycles of experiments and harvests to occur over the course of a hydroponics program than a traditional gardening program, particularly during the winter months.

Although hydroponics has a long history of sporadic use in education (see, for example, Ernest 1990; McCormack 1973), only a handful of studies have examined the potential of hydroponics as an educational medium either in or out of school. While several articles described the potential of hydroponics for education (Emberger 1991; Hart et al. 2013; Sell 1997), for integrating technology education in the science curriculum (Ernst and Busby 2009; Johanson 2009) or specific classroom activities (Hershey 1990; Lopez 1981), only one (Carver and Wasserman 2012) included data on student outcomes from participation in hydroponics-based curriculum. Carver and Wasserman (2012) described a multiple-week unit on hydroponics in a high school biology class, where students built hydroponics systems and then designed and conducted experiments on variables that influence plant growth. Students showed statistically significant gains on pre-post content tests. The authors also reported that students improved on the concept maps and attitude surveys, but neither statistics nor instrument descriptions were provided for either instrument. More research is needed to understand the potential impact of a hydroponics-based program on participants' attitudes, particularly among elementary age youths from culturally and linguistically diverse backgrounds.

Research Questions

The research questions focused on changes in participants' attitudes over the course of the program and any impact location, gender, or language may have had on participant outcomes. The specific research questions guiding the study were as follows:

1. In what ways did participants' attitudes toward science (anxiety, desire, self-concept) change over the course of the program?
2. Did participants' attitudes change differently at different sites, for different genders, or for participants who spoke different first languages, and were there any interactions between these factors?

Methods

Project and Research Frame

This work is part of a larger initiative in which we are exploring the efficacy of a hydroponics-based science program in out-of-school settings to impact affective outcomes regarding science. In the larger project, we are partnering with local community centers and non-profits that provide afterschool science programming to elementary-aged youths in low-income areas with high ethnic diversity of a northeastern urban center and surrounding areas. The project involves development of activities, resources, and materials by the research team in collaboration with the staff at a pilot location (site 1 in this study) and dissemination and implementation at additional sites in collaboration with area non-profit afterschool programs (sites 2 and 3 in this study). The larger project goals include developing a sustainable program that can be easily implemented by different afterschool providers and that engages participants in hydroponics-based activities to foster positive affective outcomes related to science.

We are utilizing a design-based implementation research (DBIR; Penuel et al. 2011) framework to inform the iterative and collaborative development of materials, staff training, and resources necessary for successful implementation of the program across sites. DBIR recognizes that programs that work well in one context may encounter substantial challenges when implemented at scale and aims to address the challenges of developing effective, sustainable, and scalable programs by connecting research to iterations in design and implementation. The objects of design and research frequently extend beyond the aspects of a program intended for the learners (activities, content, materials), and focus also on the supports needed to effectively implement the program, including resources, staff knowledge and training, support materials, or contextual features of the program sites (Fishman et al. 2013). In our larger project, the varied potential and challenges of afterschool settings found in the research literature and experienced in the pilot year of this project led us to focus on both designing program materials to support development of sustained interest among youths who are typically underrepresented in science and on designing support materials and professional development for staff to enable effective implementation in diverse and dissimilar out-of-school settings. For the purposes of this paper, we will focus on the youth outcomes from the initial implementation in multiple sites beyond the pilot location. This study presents a first iteration of addressing the common DBIR research focus of "what works when, for whom, and under what conditions?" (Fishman et al. 2013, p. 146) for this project.

Sites and Participants

The data in this study come from three separate sites in the northeastern USA. All three sites were afterschool programs where the staff had the goal, in common with the research program, of increasing their youth participants' excitement about science. The curriculum used at each site was the same, but the sites varied in format, implementation, and instructor background experience. The site contexts are described below and summarized in Table 1.

Site 1, the pilot location, was an afterschool program in a large community center located in a low-income area of a large urban center. The program was free for low-income residents. The hydroponics program was included as a weekly activity in the afterschool program. It was run for 2 h once a week for 13 weeks, for a total of roughly 26 h of contact time with the participants. During the year, the data were collected the afterschool staff chose to run the program separately for

Table 1 Site contexts

Location	Format	Contact hours	Staff background
Site 1	2-h sessions once per week, 13 weeks	~26	Limited pedagogy, limited science
Site 2	2-h sessions once per week, 13 weeks	~26	Limited pedagogy, extensive science
Site 3	2-h sessions 4 days per week, 4 weeks	~32	Extensive pedagogy, limited science

boys and girls, with girls participating in the fall and boys in the spring. English was the primary first language of participants at site 1 (27 participants). Five participants selected Spanish as their first language, two selected Creole, and one selected Other. The instructors spoke English with the participants, and the hydroponics program was run in English. The instructors at site 1 were recruited from the neighborhood around the community center that ran the afterschool program. Part of the mission of the community center was to focus on hiring residents from the neighborhood. As a result, they had a more limited pool of individuals than the other locations and focused their efforts on finding individuals who (1) had an interest in teaching in an afterschool setting with children and (2) ideally had some previous experience in working with youth as a summer camp instructor, teacher, or other type of educational position. At the time of the implementation, the instructors at site 1 had no science background and very limited experience with any kind of formal or informal teaching. During the pilot year, the instructors were quite nervous about running the program. Extensive support and professional development workshops were provided by the research team during the first year, and a member of the curriculum development and research team co-taught the program with members of the afterschool staff. The data in this study were collected over the second year the instructors were involved in the program. During the second year, background support was provided but the afterschool instructors were primarily responsible for running the program.

Site 2 was also an afterschool program run by a community organization. It was located in a low-income city with a large recent immigrant population. The structure of the program was the same as site 1, with 2 h of program once a week for 13 weeks, for a total of 26 contact hours. The program was run simultaneously at multiple locations of the afterschool program with smaller groups of participants. The program was run by afterschool staff alongside science specialists. The first languages of participants in site 2 were mixed between Spanish ($n = 55$) and English ($n = 82$). Many of the afterschool staff spoke both English and Spanish, and both of the languages were used by staff during the program, though the science specialists conducted the activities in English. Participants were invited to use either language during the activities. The program staff at site 2 were science specialists with considerable experience running urban agriculture programs and urban gardens, though they had not done hydroponics before the program and had little experience working directly with youth. Consequently, the instructors at site 2 were confident and experienced in terms of the science content related to growing plants, but had limited background experience in pedagogy or education.

In site 3, the hydroponics program was included in a summer school program primarily for recent immigrant children in a large urban school district. The hydroponics program ran for 2 h a day, 4 days a week, for 4 weeks, for a total of 32 contact hours. However, the entire first week at site 3 was spent constructing the hydroponics systems (this was not as large a part of the program at the other sites), so the participants spent roughly 24 h engaged with the curriculum. The first language of participants in site 3 was primarily Spanish ($n = 60$), with two participants identifying English as their first language. The teachers of the hydroponics program at site 3 did not speak Spanish, but there were other staff at the site (though not involved in hydroponics) who did. The hydroponics program was conducted in English, but participants were invited to discuss the content and activities in Spanish. At site 3, the program was run by two elementary teachers with more than 5 years of experience in the classroom (though primarily with first grade whereas the participants at that location were mostly fifth grade). One of the teachers was an English as a Second Language classroom teacher. The instructors had, therefore, extensive experience working with youth but they had very limited experience with science or teaching science. Program staff at both sites 2 and 3 were given instruction and support related to maintaining the hydroponics systems, and a brief overview (one 2-h session) of the curriculum and activities. They implemented the curriculum independently but did ask questions of the research team as they needed or if a problem arose regarding the hydroponics systems (i.e., the plants were not growing).

A survey (described later) was administered at the beginning (immediately before implementation) and end (on the last day) of the program at each site. A total of 234 participants completed both the pre and post survey. The demographics of participants who completed the survey at each site are shown in Table 2. Three of the participants who completed the survey chose a language other than English or Spanish. Due to the small group sizes for languages other than English or Spanish, these three participants were removed from the final analysis.

Curriculum Context

Building from the literature base on engaging participants and fostering positive attitudes (Osborne et al. 2003; Zacharia and

Table 2 Participant demographics by site

	Total	Site 1	Site 2	Site 3
Number of participants	234 (100 %)	35 (15.0 %)	137 (58.5 %)	62 (26.5 %)
Gender				
Male	95 (40.6 %)	18 (51.4 %)	49 (35.8 %)	28 (45.2 %)
Female	139 (59.4 %)	17 (48.6 %)	88 (64.2 %)	34 (54.8 %)
First language				
English	111 (47.4 %)	27 (77.1 %)	82 (59.9 %)	2 (3.2 %)
Spanish	120 (51.3 %)	5 (14.3 %)	55 (40.1 %)	60 (96.8 %)
Creole	2 (0.9 %)	2 (5.7 %)	–	–
Other	1 (0.4 %)	1 (2.9 %)	–	–
Ethnicity				
African-American	68 (29.1 %)	14 (40.0 %)	54 (39.4 %)	–
Hispanic/Latino	134 (57.3 %)	2 (5.7 %)	70 (51.1 %)	62 (100 %)
Caucasian	1 (0.4 %)	1 (2.9 %)	–	–
Multi Racial	17 (7.3 %)	4 (11.4 %)	13 (9.5 %)	–
Other	14 (6.0 %)	14 (40.0 %)	–	–
Age				
8	12 (5.1 %)	12 (34.3 %)	–	–
9	101 (43.2 %)	14 (40.0 %)	87 (63.5 %)	–
10	49 (20.9 %)	1 (2.9 %)	32 (23.4 %)	16 (25.8 %)
11	61 (26.1 %)	6 (17.1 %)	17 (12.4 %)	38 (61.3 %)
12	11 (4.7 %)	2 (5.7 %)	1 (0.7 %)	8 (12.9 %)

Barton 2004), the curriculum aimed to engage participants in practical, hands-on, inquiry projects around a personally relevant topic, and position participants as knowledgeable experts, decision-makers, and co-creators of experiments and understanding. Although implementation varied somewhat by site, the general format involved participants first building hydroponics systems in small groups, and then maintaining the systems while conducting research on variables that impacted plant growth. Building the systems allowed participants to become familiar with the pieces of the systems and their functions, as well as practice engineering and problem-solving skills through connecting the pieces to get the systems working. Additionally, working on one system with a small group of other participants fostered a sense of ownership (Blair 2009; O'Neill 2005) over the system, which was reinforced throughout the program as participants cared for and conducted research on "their" system and plants.

After the systems were built, the curriculum was divided into units based on the major variables that could be altered in the hydroponics systems. These included units on the type and amount of nutrients in the water (electrical conductivity, EC), the pH of the water, the type and amount of light, and the type of substrate used to support the plant. The units followed a common structure in which participants were briefly introduced to the topic and its role in hydroponics, and then set up an experiment examining the impact of changes in that variable on plant growth. In the middle of the units, while the plants were growing, participants were engaged in shorter activities related to research skills or the target variable. Several different varieties of hydroponics systems (described later) were used during the program, and the specific research questions that could be asked depended in part on the type of hydroponics system used (e.g., not all systems used a substrate, etc.). At sites 1 and 2, several units and cycles of experiments focusing on different variables were conducted over the course of the semester. The instructors at each site selected which units to do based on system type and student interest. At site 3, it was only possible to run one experiment cycle during the shorter 4-week summer session, due to the time needed for plant growth. At this site, participants spent longer building their systems (see "Sites and Participants" section) and became more familiar with the systems and how they worked. After an overview of the factors that could be manipulated, participants selected one variable to explore in their experiment. To accommodate the shorter growing time (3 weeks after the systems were built), the experiments were started using larger seedlings than at the other two sites. While the plants grew for the remaining 3 weeks of the program, participants engaged in mid-unit activities about the different target variables from multiple units. As the summer session met for more hours per week, participants at site 3 were engaged in a similar number of mid-unit activities as at sites 1 and 2.

Through the experiments, participants engaged in several of the science practices outlined in the Next Generation Science Standards (NGSS Lead States 2013). Participants asked questions about the impact the focus variable might have on the growth of their plants, selected a question to investigate, developed a hypothesis based on their question, and planned and conducted an experiment to test out their hypothesis. For example, in the unit on light, participants may have asked questions about how the amount of light impacted plant growth, hypothesized that plants would grow better if the lights were on all the time, and set up an experiment to test their hypothesis. At the start of each session, participants collected data on the system variables (pH, EC) plant growth (height or number of leaves) and plant health (color, appearance) in their systems over roughly 4 weeks while the plants grew. At the end of the unit, participants analyzed the data from their system and compared with other groups to understand how changes in the target variable may have impacted plant growth. Comparing across groups required sharing and communicating information, and often provided an opportunity to discuss variables, controls, multiple trials, replicability, and the potential reasons for dissimilar results. In addition to exploring the impact of different variables, the experiments gave participants a chance to practice science skills such as observation and the collection and organization of data. Guidance in designing the experiments was provided by staff and through activities, but the participants in each group decided how they wanted to manipulate the variables in their hydroponics system. Additionally, although the focus variables in the initial units were determined by the instructors, in the final unit, participants were given full control over how they wanted to set up their system. This enabled participants to explore multiple variables (e.g., set up what they thought was the 'best' combination) or ask additional questions about growing plants with hydroponics (one group, for example, explored the impact of using orange soda instead of nutrients). Throughout the program, participants were positioned as central co-constructors of science knowledge (Barton 2003; Barton and Brickhouse 2006) around growing plants hydroponically. The focus was not on finding a specific or "right" answer, but rather on caring for plants and exploring factors that influenced the plants' growth.

The mid-unit activities were hands on and participant-centered, and focused on introducing participants to the content and skills they would need to care for the plants in their systems. For example, these included activities around understanding pH and EC, what those terms meant and why they mattered for hydroponics, and how to change the levels of those variables in their systems. Staff led and supported participants through the activities, but participants were not tested on the content or required to complete or turn in any work (Nasir et al. 2006; National Research Council 2015) as it was very important to the afterschool instructors that the program be as "unlike school" as possible. With this in mind, the goal of the activities was not to impart a set body of content knowledge, but rather to engage participants in thinking and asking questions about factors that might influence plant growth, and to provide opportunities to explore participants' questions.

In the initial unit, participants were given either lettuce or basil to grow in their systems, though in later units, some groups opted for other leafy greens (Swiss chard, kale, etc.). These crops were selected because they grow quickly and are relatively easy to care for in hydroponics systems, but more importantly because they were familiar to most of the participants. Growing plants that the participants recognized and had eaten before helped build a connection to the participants' real lives (Barton 2003) and excitement about caring for the systems because the participants could imagine eating the plants when they were fully grown. At the end of each unit, the plants were harvested and shared among the program participants, with the community, or sent home with the participants. This particular piece of the program delighted many participants, who were excited to eat "their" lettuce and basil at dinner.

Hydroponics Systems

Several different types of hydroponics systems were used during the program, including single- and double-tier nutrient film technique (NFT) systems (Fig. 1), Windowfarms (Fig. 2), and wick systems (Fig. 3). For all the systems, seeds are first planted in an inert substrate (we used rockwool) that provides structure for the seeds as they sprout. After around 2 weeks, seedlings are transplanted into the larger systems. In the NFT systems, the plants sit in plastic trays and a thin stream of nutrient-enriched water is constantly pumped from the reservoir to run over the plant roots. The NFT systems hold 6 plants per straight tray, and can be customized to hold from 6 to 60 (in the double tier) plants. In the Windowfarm systems, the plants sit in stacked cups. Nutrient-enriched water is pumped from a reservoir to the top cup, and then drips through the lower cups back to the reservoir. Each system holds four

Fig. 1 Single-tier nutrient film technique (NFT) system

Fig. 2 Windowfarms (*right* and *left*) and an NFT system (*center*)

plants. In the wick systems, the plants sit in the inverted top of a plastic bottle and nutrient-enriched water is drawn from the reservoir in the bottom of the bottle through a 'wick' (string, twine, etc.). Each wick system holds one plant.

The NFT and Windowfarm systems are commercially available from hydroponics stores or other online sellers for around US$250 and US$100, respectively, or can be home-built from materials available at hardware (PVC pipes) or other stores (plastic storage bins for the reservoir, plastic bottles for the cups) for significantly less cost. The wick systems are constructed out of inexpensive and easily accessible materials including plastic 2-L bottles, string, and a substrate (to support the plant) such as aquarium pebbles. Lights are also required if natural light from windows is insufficient or if participants wish to use light as an experimental variable. We have used T5 florescent bulbs which cost about US$10 and last for multiple years. The NFT systems typically require the most lights, and use three to four bulbs per tier. At our program sites, the electrical operating costs have been similar to running a 100-W bulb for 18 h a day. Other recurring costs include seeds, nutrient solution (around US$5 per year with typical program use) and rockwool (around US$10 per 100 plants).

Fig. 3 Wick system

The NFT systems require the most initial set up and can typically be constructed by participants in the first few sessions of the program, while the smaller systems are easily completed within the first session. Building the systems helps participants become familiar with and interested in the systems, and if desired, can be set up as an engineering challenge, particularly with home-built systems. Once they are built, the NFT and Windowfarm systems need to be monitored once or twice weekly to ensure the water, pH, and EC remain at acceptable levels, but otherwise, only require maintenance when the plants are harvested or if something leaks. Both of these systems need to be plugged in, but do not require access to water after the initial set up for each crop. The wick systems do not require regular maintenance or electricity and generally grow happily untouched for several weeks. The systems do not require a separate room and can typically be kept in the corner or along the wall in the program space, in a hallway, or in any available space. Keeping the systems in the program space encourages participants to observe, monitor, and talk about the plants, and facilitates integrating the hydroponics project into other aspects of the programs. If the program does not have a dedicated room or the systems must be kept elsewhere, the smaller systems are easy to carry and the NFT can be constructed on wheels for easy movement.

The variety in systems facilitates tailoring the equipment to program size, interests, and available space. The larger NFT systems produce more plants and make it easier for participants to eat and share the produce they grow. However, sites often do not have space for multiple systems, meaning only one experiment can be conducted at a time and participants share the single system rather than having individual systems to care for. The smaller systems do not produce the same abundance of greens, but allow for more flexibility and individual control over systems and experiments. During the time data for this study were collected, at site 1, an NFT system was used by the whole group while smaller groups of participants were responsible for Windowfarms, at site 2, all three system types were used by different groups at the site, and at site 3m small groups of participants were responsible for double tier NFT systems.

The Survey Instrument

Three components of participants' attitudes toward science were examined through the Modified Attitudes Toward

Science Inventory (MATSI) (Weinburgh and Steele 2000). These include participants' desire to engage in scientific activities, the anxiety they experience while engaged in or thinking about science, and their self-concept in science. Self-concept describes participants' perceptions of themselves in relation to a particular topic or activity (Pajares and Schunk 2001). With regards to science, self-concept addresses participants' underlying beliefs related to whether they perceive themselves as someone who can succeed in science. This construct is strongly related to self-efficacy and confidence, which focus on participants' perceptions of their abilities to succeed and solve problems in science. However, where self-efficacy tends to be experienced in relation to a specific skill or task ("I can solve this problem"), self-concept speaks to a deeper valuing of the self in relation to science ("I am good at science"). Drawing on Hidi and Renninger's (2006) model of interest development, individuals who have high anxiety and little desire related to doing science and low self-concept in science are unlikely to be intrinsically motivated and seek out extended participation in science activities.

This survey instrument was selected because it had been developed and validated for use with fifth grade urban African-American students, a population similar to the pilot year of this study, and was fairly short and quick to administer, as per the request of the afterschool staff. As the sample in this study included a more diverse population of participants, including many for whom English was a second language, we re-validated the instrument for use with our particular sample. Factor analysis with principal components method using a Direct Oblimin rotation was performed on the pre-survey data to examine suitability for the current sample. Three components were extracted that together explained 68 % of the variance and aligned well to the three subscales. Two items, one from the Anxiety subscale and one from the Desire subscale, did not load with the others. Removing these two items increased the Cronbach's alpha of the subscales from .705 to .880 for Anxiety and .835 to .982 for Desire. Additionally, one item in the Desire subscale showed insufficient variance in the post-test and was consequently removed from the analysis. The items from each scale included in the analysis and the reliabilities of the final subscales are shown in Table 3. Items were measured using a 5-point Likert scale.

Analysis of Survey Data—ANOVA

A repeated measures ANOVA design was used to analyze the survey data. The analysis included one within-subjects variable (time, pre and post), and three between-subjects variables (site, gender, first language). Separate analyses were run with each of the three subscale scores as outcome variables.

Results

In this section, we begin by presenting the results of the pre and post surveys measuring participants' anxiety toward science, desire to do science, and self-concept in science. We then present the analysis of each subscale separately, examining changes over time as well as variations related to location, gender, and language, with the goal of sharing how various interactions emerged across the project sites. The pre- and post-means for each subscale for each of the between-subjects variables are shown in Table 4.

Table 3 Final survey subscales

Final subscale items	Cronbach's alpha
Anxiety toward science	.880
When I hear the word science, I have a feeling of dislike	
I am not comfortable when someone talks to me about science	
It makes me nervous to think about doing science	
I have a good feeling toward science (reversed)	
Desire to do science	.982
Science is something that I enjoy very much	
I would like to read a book about science	
I like doing science homework	
It is important to me to understand science	
I really like to learn science	
Self-concept of science	.739
Science is easy for me	
I usually understand what we are talking about when we do science	
No matter how hard I try, I cannot understand science (reversed)	
I do not do very well in science (reversed)	

Table 4 Subscale scores over time: mean (standard deviation)

	Anxiety		Desire		Self-concept	
	Pre	Post	Pre	Post	Pre	Post
Total	3.04 (.65)	2.68 (.61)	2.00 (.69)	3.00 (.79)	2.16 (.51)	2.80 (.92)
Site						
Site 1 (*n* = 32)	3.55 (.46)	3.18 (.44)	2.51 (.69)	3.51 (.55)	2.28 (.69)	2.68 (.59)
Site 2 (*n* = 137)	2.89 (.64)	2.62 (.58)	1.96 (.66)	2.82 (.81)	2.21 (.49)	2.79 (.94)
Site 3 (*n* = 62)	3.09 (.63)	2.56 (.65)	1.84 (.66)	3.13 (.71)	2.00 (.43)	2.88 (1.0)
Gender						
Male (*n* = 93)	3.24 (.49)	2.86 (.57)	1.97 (.69)	2.93 (.81)	2.41 (.37)	2.8 (.93)
Female (*n* = 138)	2.90 (.71)	2.56 (.62)	2.02 (.69)	3.05 (.78)	2.00 (.52)	2.81 (.91)
First language						
English (*n* = 111)	2.98 (.62)	2.70 (.55)	2.11 (.74)	3.09 (.85)	2.18 (.48)	2.78 (.83)
Spanish (*n* = 120)	3.09 (.67)	2.66 (.67)	1.91 (.63)	2.92 (.73)	2.15 (.53)	2.82 (.99)

Anxiety toward Science

The anxiety toward science scale measured participants' feelings of anxiety while engaged in or thinking about science activities and topics. Lower values on this scale indicate more positive attitudes toward science. A repeated measures ANOVA showed significant main effects of time $F(1, 219) = 16.295$, $p < .01$, $\eta_p^2 = .069$ and location $F(2, 219) = 8.183$, $p < .01$, $\eta_p^2 = .07$. Gender, first language, and all interactions were non-significant ($p > .05$). This indicates that participants' anxiety toward science decreased over the course of the program. As seen in Fig. 4, participants' anxiety toward science decreased at all three sites. Post hoc testing showed that participants at site 1 started and ended significantly more anxious than participants at the other two sites (Tukey HSD, $p < .05$).

Desire to Do Science

The desire to do science scale measured participants' desire to engage in and learn more about science. Higher values on this scale indicate more positive attitudes toward science. The results for the desire to do science subscale were very similar to the Anxiety subscale. A repeated measures ANOVA showed significant main effects of time ($F(1, 219) = 44.764$, $p < .01$, $\eta_p^2 = .17$) and location ($F(2, 219) = 9.631$, $p < .01$, $\eta_p^2 = .081$). Gender, first language, and all interactions were non-significant ($p > .05$). This indicates that participants' desire to do science increased over the course of the program. As seen in Fig. 5, participants desire to do science increased at all three sites. However, post hoc testing showed that participants at site 1 started and ended significantly higher on the scale than participants at the other two sites (Tukey HSD, $p < .05$).

Self-Concept of Science

The self-concept of science scale measured participants' beliefs about whether they are someone who can succeed in science. Higher values on this scale indicate more positive attitudes toward science. For the self-concept subscale, a repeated measures ANOVA showed a significant main effect of time ($F(1, 219) = 14.145$, $p < .01$, $\eta_p^2 = .061$) and significant

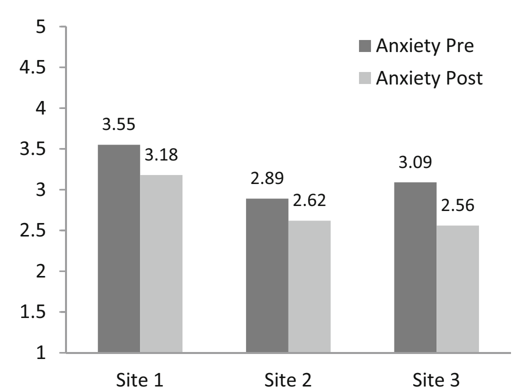

Fig. 4 Participants' anxiety toward science

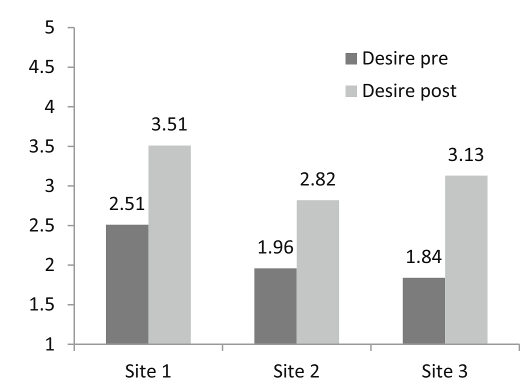

Fig. 5 Participants' desire to do science

time × gender ($F(1, 219) = 14.494$, $p < .01$, $\eta_p^2 = .062$) and time × gender × location ($F(2, 219) = 3.199$, $p < .05$, $\eta_p^2 = .028$) interactions. There were no main effects of gender, language, or location ($p > .05$). This indicates that overall, participants' self-concept of science increased over the course of the program, but that there were significant interactions between the other variables. Examining the girls and boys separately showed that girls' self-concept increased significantly over time ($F(1, 132) = 30.809$, $p < .001$, $\eta_p^2 = .189$), while boys' self-concept did not change significantly over time ($F(1, 87) = .001$, $p > .05$) (Fig. 6). Location, first language, and all interactions were not significant for both boys and girls ($p > .05$ for all tests).

In summary, the data show that participants' attitudes toward science did improve over the course of the program at all three locations, regardless of their first language. In addition, female participants had greater improvement for self-concept than male participants.

Discussion

Our quantitative analysis suggests several findings that can be drawn from the study. First, hydroponics appeared to be an effective topic for engaging participants and fostering positive attitudes related to science in an afterschool context. Second, participant attitude outcomes did not seem to be dependent on a particular program format or staff background experience. Third, participant attitude outcomes did not seem to be influenced by participant first language. Finally, participant gender did appear to be associated with changes in self-concept, but not in anxiety or desire. These findings will be discussed separately below.

Finding 1: Attitudes Improved Across Multiple Contexts

The results show that, overall, participants' desire to do science increased and anxiety toward science decreased for all participants, and self-concept increased for female participants over the course of the program. Although the study does not support causal claims about the program, the general improvement in attitudes toward science across three separate sites suggests that participating in the program is associated with the development of positive attitudes toward science. This aligns to other work that found consistently positive outcomes in garden-based programing (Blair 2009; Williams and Dixon 2013) and other afterschool programs where participants were positioned as central players in solving hands-on, relevant problems (i.e., Honig and McDonald 2005). Further work, particularly observations and follow-up interviews with the instructors and participants at the respective sites, is necessary to understand what aspects of the program worked well, which facilitated student engagement and positive experiences, and which were challenging in different contexts. Understanding these aspects could inform both further iterations of design in this program, and provide guidance for other programs working in similar contexts. It is possible that the benefits found in connecting to the natural world (Blair 2009) may also be accessible through engaging with plants indoors through hydroponics systems, which can be done year round in any climate.

Fig. 6 Participants' Self-Concept in Science

Finding 2: Attitude Outcomes Independent of Program Format and Instructor Background Experience

The consistently positive change in attitudes is especially interesting given the differences in format and instructor training across the sites. Focusing first on format, participants at sites 1 and 2 experienced the program through short doses over the course of several months, while at site 3, the program was condensed into an intensive 4-week experience. The similarity in outcomes, particularly between sites 2 and 3, suggests that both the extended and intensive format provided positive experiences for participants. While this aligns with Williams and Dixon's (2013) review that found positive outcomes across program formats, the fact that this single program was associated with similar positive outcomes across sites suggest that the program is robust to changes in format. This may facilitate future use of the program and enable future sites to adapt it to their particular time and resource needs. However, while the format was different, participants at all three sites had similar contact hours in the program (roughly 26 to 32 h), and it is possible similar attitude outcomes would not be observed in shorter versions of the program. Further work is necessary to determine whether positive attitude outcomes could occur over shorter interactions with the program. Additionally, as the post tests at each site were administered immediately at the end of the program, follow-up work is necessary to determine whether participants' attitudes were maintained beyond the end of the program and whether the short or long program formats were associated with differences in sustained attitudes.

More interesting, perhaps, is the apparent lack of connection between participant outcomes and instructor background experience or training. The instructors' background knowledge and expertise varied substantially across the sites. At site 1, the instructors did not have a background in science or education; at site 2, instructors were science specialists without formal training in education; and at site 3, instructors were elementary teachers without backgrounds in science, but with a focus on ELL instruction. Although a range of pedagogical and content expertise and backgrounds, and a trend toward less formal training in either, is common among afterschool program staff (Afterschool Alliance 2013; Chi et al. 2008; Krishnamurthi et al. 2013), the literature on providing high-quality science programs and fostering positive attitudes also highlighted the importance of instructors who are knowledgeable in content and pedagogical practices (Freeman et al. 2009) who can help participants navigate learning science practices and concepts (Lee and Fradd 1998; Westby et al. 1999). However, despite the differences in instructors' backgrounds, student outcomes were fairly consistent across sites. At sites 2 and 3, where instructors had background training in either (but not both) science or elementary pedagogy, student change and outcomes on the anxiety and desire scales were statistically similar. Although site 1 was significantly different than sites 2 and 3 on both anxiety and desire, the difference was positive for desire (site 1 had higher desire) and negative for anxiety (site 1 had higher anxiety). Additionally, the effect size of the differences was small for both anxiety (η_p^2 = .07) and desire (η_p^2 = .081). This suggests that student attitude outcomes were not strongly or uniformly negatively impacted by the instructors at site 1 having limited background in both science and pedagogy.

Speculation on the reasons for this outcome suggests several potential contributing factors. First, while hydroponics offers a rich set of experimental, science practice, and content learning opportunities, the basic knowledge needed to construct and manage the systems is not very complicated. The initial activities in the curriculum focus on teaching participants to maintain their own systems, and then engage in inquiry and experiments related to manipulating the basic variables in the systems. It is possible that the relatively simple basic science content, combined with activities that build gradually from that basic content, provided staff without extensive backgrounds in science (sites 1 and 3) a manageable curve for learning both the content and feeling confident facilitating it. Second, the staff at site 1 were initially quite nervous about both the content and facilitating activities, and were provided with extensive support and professional development (PD) sessions over the first year of the program. In the second year, when these data were collected, the PD continued for the first weeks of the program but was quickly phased out, and the staff were solely responsible for running the program. The increase in staff independence facilitating the program and positive changes in participants' attitudes over the course of the program suggests that the PD may have helped the staff master the content and pedagogical practices, or increased their confidence, sufficiently to effectively conduct the program. An important piece of future work will be to examine the PD program to understand which pieces were particularly vital or effective for the staff. As guidance on designing PD for afterschool staff who may not have formal training in science or pedagogy is quite sparse in the literature (Freeman et al. 2009; Junge and Manglallan 2011), understanding if and how this PD program supported the staff could be useful for other programs.

Finding 3: Attitude Outcomes Not Influenced by Student' First Language

The third finding was that there were no significant differences in attitudes over the course of the program between participants whose first language was English versus participants whose first language was Spanish. This finding is interesting for two reasons: the lack of explicit language supports in the curriculum, and the varied background knowledge and expertise among instructors. The program was not specifically designed with ELL participants in mind. During the pilot year of the program at site 1, English was the first and primary language of both participants and staff, and program activities were initially developed to meet the needs of the participants at the pilot location. During the second year, when the current data were collected, the program expanded to sites with large percentages of participants whose first language was not English. As previously described, the background knowledge and expertise of the staff varied and, with the exception of the ELL teacher at site 3, the instructors were not explicitly trained in helping participants learn English or negotiate learning science across two languages while simultaneously learning one of the languages. Instructors reported that participants at each site were allowed and encouraged to discuss the content in whichever language they wanted, but explicit supports were not added to the activities and the primary instructors spoke English throughout the program.

The research literature offers several factors that may have contributed to the similarity in attitudes among English- and Spanish-speaking participants in this context. First, previous research has found that allowing and legitimizing use of participants' home language to discuss content when instruction is in English enhanced science learning (Goldberg et al. 2009; Lee 2005, Reyes 2008; Stevenson 2013). It is possible that encouraging and valuing participants' use of Spanish to discuss the content facilitated the development of positive attitudes during the program. Second, afterschool programs tend to be less structured than formal schooling, and tend to focus on hands-on, exciting, fun activities over reading, writing, or structured talk such as class discussions (Krishnamurthi et al. 2014). Without the pressure to use particular language and "talk science" (Lemke 1990), it is possible language presented less of a barrier (Wellington and Osborne 2001) to engagement and learning than it does in formal schooling. The focus on engaging and centering participants as constructors of knowledge over mastering specific content could allow participants to engage with the content using the language and discourse (Gee 1990) practices that make sense to them. This, in turn, could allow for positive experiences in science that foster the development of positive attitudes.

However, limitations in the current data set prevent definitive conclusions about language from being drawn. The survey collected information on participants' reported first language, but did not include any measures of proficiency or current language use patterns as we needed to keep our research instrumentation as short as possible (per request of two of the sites to prevent the program from feeling like school). Additionally, no data were collected on the way participants actually used language while engaged in the program. Further work that gathered more nuanced data on participants' language proficiency and practices, and the way language was used by participants and staff during the program, would illuminate the results. This could also inform the design of activities and guidance for instructors in the curriculum to support both language and content learning and engagement with science for all participants.

Finding 4: Participant Gender Associated with Differences in Self-Concept

An interesting outcome in the survey data was that participant gender was not associated with differences in anxiety or desire scores, but was associated with differences in self-concept. For both anxiety and desire, girls and boys started the program at similar points on the scales and experienced similar positive change over the course of the program (see Table 4). For self-concept, girls at all three sites started lower and ended higher than boys at all three sites (see Fig. 3), and the change was significant for girls but not for boys. The differences in change over the course of the program between boys and girls on the self-concept subscale, but not the others, may be related to the nature of the attitudinal variables. Anxiety and desire both reflect emotional responses to doing science. The decrease in negative (anxiety) and increase in positive (desire) feelings related to doing science among all participants over the course of the program suggests that the program effectively fostered positive feelings about science among participants.

Self-concept, however, is a somewhat more introspective belief about the self in relation to science, and whether the individual believes they are someone who is or could be good at science. Gender-based differences in self-concept are not unexpected, as previous work on other self-belief constructs, such as self-efficacy, suggests that gender may play a role in the development of these constructs in children and adolescents (Usher and Pajares 2008). Drawing on Bandura's (1997) suggestions for sources of self-efficacy, Usher and Pajares (2006a, 2006b) found that the development of self-efficacy in a given domain among middle school participants was influenced more by mastery experiences (succeeding in the domain) for boys and social persuasion (positive messages or praise from important others) for girls. This is similar to Stake and Nickens (2005) finding that peer support influenced self-concept in science for girls. While these studies did not focus exclusively on the development of self-concept in science, the interconnectedness of the self-belief constructs (Bong and Skaalvik 2003; Pajares and Schunk 2001) suggest that aspects of the content or enactment of the program may have been experienced or manifest differently in relation to self-concept for girls than boys.

Speculation on why this may have occurred in this program include the possibility that the afterschool program context, which focused on positive interaction with and around the hydroponics content rather than producing a particular or evaluated product, offered more opportunities related to social persuasion than mastery experiences, and thus provided more support for self-belief development for girls than boys. Additionally, multiple studies have found that biology topics are more interesting to girls than boys (Baram-Tsabari and Yarden 2008; Prokop et al. 2007; Stark and Gray 1999), and it is possible that the plant-based hydroponics content was more effective at engaging the girls in the program. However, further work, including observations of the program in action and interviews with participants, is necessary to understand what aspects of the program contributed to the observed difference and supported the development of self-concept for girls but not boys.

Implications

The positive changes in attitudes across multiple sites suggest that the hydroponics program effectively fostered positive attitudes toward science among participants from populations that are typically underrepresented in science. The gender differences found on the self-concept scale suggest that the program may be especially effective for girls, and could contribute to increasing girls' interest and participation in science. Hydroponics could be a valuable option for programs that want to develop or extend garden-based learning experiences, but lack the appropriate space or climate to do so outdoors. This could be particularly beneficial for programs in northern climates where the growing season does not neatly align with the academic year.

The similarities and generally positive changes in participants' attitudes across the three sites are especially interesting in light of the differences in instructor background experience and implementation among the sites. Given the importance of staff training and experience in providing high-quality afterschool science programming (Freeman et al. 2009), the variations in instructor preparation common in afterschool settings (Afterschool Alliance 2013; National Research Council 2015), and the challenges associated with providing professional development for afterschool staff (Chi et al. 2008), developing programs that can work well and be expanded to multiple contexts, where instructor experience is not a constant, is challenging (National Research Council 2015). The fact that participant outcomes from this program were similar across sites suggests that something about the content, curriculum, or program enabled instructors with different background experiences to implement it effectively. This resilience across instructor background experience suggests the program has significant potential for out-of-school settings where instructor background is often an unknown, and that the program could serve as a model for other projects working in similar, variable, contexts. Understanding which aspects of the project (curriculum pieces, content, PD model) facilitated positive outcomes across sites could inform and improve the design of future afterschool science programs.

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References

Afterschool Alliance (2013) Defining youth outcomes for STEM learning in afterschool. Retrieved from http://www.afterschoolalliance.org/STEM_Outcomes_2013.pdf

Bandura A (1997) Self-efficacy: the exercise of control. Freeman, New York

Bang M, Medin D (2010) Cultural processes in science education: supporting the navigation of multiple epistemologies. Sci Educ 94(6):1008–1026

Baram-Tsabari A, Yarden A (2008) Girls' biology, boys' physics: evidence from free-choice science learning settings. Research in Science & Technological Education 26:75–92

Barton AC (2003) Teaching science for social justice. Teachers College Press, New York, NY

Barton AC, Brickhouse N (2006) Engaging girls in science. In: Skelton C, Francis B, Smulyan L (eds) The sage handbook of gender and education. Sage Publications, Thousand Oaks, CA, pp 221–235

Basu SJ, Barton AC (2007) Developing a sustained interest in science among urban minority youth. J Res Sci Teach 44(3):466–489

Bell P, Lewenstein B, Shouse AW, Feder MA (eds) (2009) Learning science in informal environments: people, places, and pursuits. The National Academies Press, Washington. D.C

Blair D (2009) The child in the garden: an evaluative review of the benefits of school gardening. J Environ Educ 40(2):15–38

Bong M, Skaalvik EM (2003) Academic self-concept and self-efficacy: how different are they really? Educ Psychol Rev 15:1–40

Brown-Jeffy S, Cooper JE (2011) Toward a conceptual framework of culturally relevant pedagogy: an overview of the conceptual and theoretical literature. Teach Educ Q 38(1):65–84

Carver J, Wasserman B (2012) Hands-on hydroponics. Science Teacher 79(4):44–48

Chi BS, Freeman J, Lee S (2008) Science in afterschool market research study. Lawrence Hall of Science, University of California, Berkeley, Berkeley, CA

Cleaves A (2005) The formation of science choices in secondary school. Int J Sci Educ 27(4):471–486

Emberger G (1991) A simplified integrated fish culture hydroponics system. Am Biol Teach 53(4):233–235

Ernest N (1990) How-to-do-it. Hydroponics and aquaculture in the high school classroom. Am Biol Teach 52(3):182–184

Ernst JV, Busby JR (2009) Hydroponics: content and rationale. Technology Teacher 68(6):20–24

Falk JD, Dierking LD (2010) The 95 percent solution. The American Scientist 98:486–493

Fishman BJ, Penuel WR, Allen A-R, Cheng BH, Sabelli N (2013) Design-based implementation research: an emerging model for transforming the relationship of research and practice. National Society for the Study of Education 112(2):136–156

Freeman J, Dorph R, Chi B (2009) Strengthening after-school STEM staff development. Lawrence Hall of Science, University of California, Berkeley, Berkeley, CA

Gee JP (1990) Social linguistics and literacies: ideology in discourses, 4th edition. Abingdon. Routledge, Oxon

Gibson HL, Chase C (2002) Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. Sci Educ 86:601–736

Goldberg J, Enyedy N, Welsh KM, Galiani K (2009) Legitimacy and language in a science classroom. English Teaching: Practice and Critique 8(2):6–24

Hart ER, Webb JB, Danylchuk AJ (2013) Implementation of Aquaponics in education: an assessment of challenges and solutions. Sci Educ Int 24(4):460–480

Hershey DR (1990) Pardon me, but your roots are showing. Science Teacher 57(2):42–45

Hidi S, Renninger KA (2006) The four-phase model of interest development. Educ Psychol 41:111–127

Honey M, Pearson G, Schweingruber H (eds) (2014) STEM integration in K-12 education: status, prospects, and an agenda for research. National Academy of Engineering, National Research Council, Washington, DC

Honig MI, McDonald MA (2005) From promise to participation: afterschool programs through the lens of socio-cultural learning theory. Afterschool Matters Occasional Paper Fall 2005. Retrieved from http://www.niost.org/pdf/afterschoolmatters/asm_2005_op5_fall/asm_2005_op5_fall-1.pdf

Johanson EK (2009) Aquaponics and hydroponics on a budget. Tech Directions 69(2):21–23

Junge SK, Manglallan SS (2011) Professional development increases afterschool staff's confidence and competence in delivering science, engineering, and technology. In A. Subramaniam, K. Heck, R. Carlos, & S. Junge (Eds.), Advances in youth development: Research and evaluation from the University of California Cooperative Extension 2001–2010 (pp. 70–78). Davis, CA: University of California Agriculture and Natural Resources. Retrieved from http://4h.ucanr.edu/files/130754.pdf

Klemmer CD, Waliczek TM, Zajicek JM (2005) Growing minds: the effect of a school gardening program on the science achievement of elementary students. HortTechnology 15:448–452

Krishnamurthi A, Bevan B, Rinehart J, Coulon VR (2013) What afterschool STEM does best: how stakeholders describe youth learning outcomes. Afterschool Matters, Fall 2013:42–49

Krishnamurthi A, Ballard M, Noam G (2014) Examining the impact of afterschool STEM programs: a paper commissioned by the Noyce Foundation. Retrieved from http://www.afterschoolalliance.org/ExaminingtheImpactofAfterschoolSTEMPrograms.pdf

Ladson-Billings G (1995) But that's just good teaching! The case for culturally relevant pedagogy. Theory Pract 34(3):159–165

Leaper C, Farkas T, Brown CS (2012) Adolescent girls' experiences and gender-related beliefs in relation to their motivation in math/science and English. Journal of Youth and Adolescence 41(3):268–282

Lee O (2001) Preface: culture and language in science education: what do We know and what do We need to know? J Res Sci Teach 38:499–501

Lee O (2005) Science education with English language learners: synthesis and research agenda. Rev Educ Res 75:491–521

Lee O, Fradd SH (1998) Science for all, including students from non-English language backgrounds. Educ Res 27(3):12–21

Lemke JL (1990) Talking science: language, learning, and values. Ablex Pub. Corp, Norwood, N.J

Lopez LM (1981) Hydroponics—studies in plant culture with historical roots. Science Teacher 48(6):47–49

Lynch S (2001) Science for all: is not equal to "one size fits all": linguistic and cultural diversity and science education reform. J Res Sci Teach 38(5):622–627

Mabie R, Baker M (2010) A comparison of experiential instructional strategies upon the science process skills of urban elementary students. J Agric Educ 37(2):1–7

Maltese AV, Tai RH (2010) Eyeballs in the fridge: sources of early interest in science. Int J Sci Educ 32:669–685

Marx DM, Roman JS (2002) Female role models: protecting women's math test performance. Personal Soc Psychol Bull 28(9):1183–1193

McCormack AJ (1973) Space-Age Plant Culture. Science Activities 10(3):20–24

Nasir NS, Rosebery AS, Warren B, Lee CD (2006) Learning as a cultural process: achieving equity through diversity. In: *The Cambridge Handbook of the Learning Sciences*, chapter 29. Cambridge University Press, Cambridge, pp 489–504

National Research Council (2011) Expanding underrepresented minority participation: America's science and technology talent at the crossroads. The National Academies Press, Washington, DC

National Research Council (2015) Identifying and supporting productive programs in out-of-school settings. In: Committee on successful out-of-school STEM learning, board on science education, division of behavioral and social science and education. The National Academies Press, Washington, DC

National Science Foundation, National Center for Science and Engineering Statistics (2013) Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013. Special Report NSF 13–304. Arlington, VA. Available at http://www.nsf.gov/statistics/wmpd/

NGSS Lead States (2013) *Next Generation Science Standards: For States, By States*. The National Academies Press, Washington, DC

Noam G (2008) A new day for youth: creating sustainable quality in out-of-school time. A white paper commissioned by The Wallace Foundation. Harvard University, Cambridge, Massachusetts

O'Neill T (2005) Uncovering student ownership in science learning: the making of a student created mini-documentary. Sch Sci Math 105: 292–301

Osborne J, Simon S, Collins S (2003) Attitudes towards science: a review of the literature and its implications. Int J Sci Educ 25:1049–1079

Pajares F, Schunk DH (2001) Self-beliefs and school success: self efficacy, self concept and school achievement. In: Riding R, Rayner S (eds) Perception. Ablex Publishing, London, pp 239–266

Penuel WR, Fishman BJ, Cheng BH, Sabelli N (2011) Organizing research and development at the intersection of learning, implementation, and design. Educ Res 40:331–337

Prokop P, Prokop M, Tunnicliffe SD (2007) Is biology boring? Student attitudes toward biology. J Biol Educ 42:36–39

Rahm J (2002) Emergent learning opportunities in an inner-city youth gardening program. J Res Sci Teach 39:164–184

Reyes I (2008) English language learners' discourse strategies in science instruction. Bilingual Research Journal: The Journal of the National Association for Bilingual Education 31:95–114

Sell M (1997) Hydroponics in the classroom. Sch Sci Rev 78:73–78

Skelly SM, Zajicek JM (1998) The effect of an interdisciplinary garden program on the environmental attitudes of elementary school students. HortTechnology 8:579–583

Smith LL, Motsenbocker CE (2005) Impact of hands-on science through school gardening in Louisiana public elementary schools. HortTechnology 15:439–443

Stake J, Nickens S (2005) Adolescent girls' and boys' science peer relationships and perceptions of the possible self as scientist. Sex Roles 52:1–2

Stark R, Gray D (1999) Gender preferences in learning science. Int J Sci Educ 21:633–643

Stevenson AR (2013) How fifth grade Latino/a bilingual students use their linguistic resources in the classroom and laboratory during science instruction. Cult Stud Sci Educ 8:973–989

Tai RH, Liu CQ, Maltese AV, Fan X (2006) Planning early for careers in science. Science 312:1143–1144

Tan E, Barton A (2008) From peripheral to central, the story of Melanie's metamorphosis in an urban middle school science class. Sci Educ 92:567–590

Tate WF (2001) Science education as a civil right: urban schools and opportunity-to-learn considerations. J Res Sci Teach 38:1015–1028

Tobin K, McRobbie CJ (1996) Significance of limited English proficiency and cultural capital to the performance in science of Chinese-Australians. J Res Sci Teach 33(3):265–282

Torres HN, Zeidler DL (2002) The effects of English language proficiency and scientific reasoning skills on the acquisition of science content knowledge by Hispanic English language learners and native English language speaking students. Electronic Journal of Science Education, 6(3)

Turkan S, Liu OL (2012) Differential performance by English language learners on an inquiry-based science assessment. Int J Sci Educ 34(15):2343–2369

Usher EL, Pajares F (2006a) Inviting confidence in school: invitations as a critical source of the academic self-efficacy beliefs of entering middle school students. Journal of Invitational Theory and Practice 12:7–16

Usher EL, Pajares F (2006b) Sources of academic and self-regulatory efficacy beliefs of entering middle school students. Contemp Educ Psychol 31:125–141

Usher EL, Pajares F (2008) Sources of self-efficacy in school: critical review of the literature and future directions. Rev Educ Res 78(4): 751–796

Waliczek TM, Logan P, Zajicek JM (2003) Exploring the impact of outdoor environmental activities on children using a qualitative text data analysis system. HortTechnology 13:684–688

Waliczek TM, Zajicek JM (1999) School gardening: improving environmental attitudes of children through hands-on learning. J Environ Hortic 17:180–184

Weinburgh ME, Steele D (2000) The modified attitudes toward science inventory: developing an instrument to be used with fifth grade urban students. J Women Minorities Sci Eng 6(1):87–94

Wellington JJ, Osborne J (2001) Language and literacy in science education. Open University., Buckingham

Westby C, Dezale J, Fradd SH, Lee O (1999) Learning to do science: influences of language and culture. Commun Disord Q 21(1):50–64

Williams DR, Dixon PS (2013) Impact of garden-based learning on academic outcomes in schools: synthesis of research between 1990 and 2010. Rev Educ Res 83(2):211–235

Zacharia Z, Barton AC (2004) Urban middle-school students' attitudes toward a defined science. Sci Educ 88:197–222