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Learning and Belonging in a Museum-School Environmental Stewardship Partnership

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ABSTRACT: Students in urban, low-income communities can lack access to environmental science outreach in natural settings. As a result, they may face barriers to applying course content to real-world contexts and developing an agentic, hopeful stance towards environmental stewardship. In this paper, we describe a partnership between a maritime museum and park, an urban school district, and ecology experts. The project aimed to increase students' knowledge of aquatic ecosystems, develop awareness of stewardship-related actions and career pathways, and support a sense of belonging to the museum. Activities included classroom visits by experts, field trips to plant classroom-grown grasses in the museum's lake, and teacher professional development. A single-group, pre-test/posttest design investigated changes in *N*=148 high school students' knowledge, along with post-program environmental stewardship attitudes and sense of belonging to the site. A paired t-test revealed a significant increase in knowledge scores. Changes were evident in students' ability to identify environmental problems and solutions. Post-program, environmental hope was significantly correlated with scientific knowledge and sense of belonging. Open-ended responses revealed elaborative processing of STEM content, students' sense of agency towards environmental action, and self-perceptions as an environmental steward. Implications for the conceptualization and design of field-based STEM outreach are discussed.

INTRODUCTION

To develop citizens with both the interest and the capacity to tackle environmental challenges, stewardship-oriented STEM outreach must move beyond increasing knowledge and help students to also develop personal investment in the issue and a sense of agency towards action (Calabrese Barton, 2002; Gruenewald, 2003; Kuwahara, 2013; Szczytko et al., 2019). Yet, students in urban, low-income communities are less likely to access environmental science outreach in authentic natural settings that provide action-oriented experiences that facilitate the transfer of content into real-world examples and the development of an agentic, hopeful stance towards environmental stewardship. In this paper, we describe an urban environmental stewardship project rooted in a partnership between a maritime museum and park, high school teachers and students, and ecology and sustainability experts from a university and a non-profit advocacy group. The *Mariners' Environmental Initiative* provided teacher professional development activities, classroom visits by Environmental STEM educators, collaborative school- and museum-based eelgrass (*Vallisneria americana*) cultivation and monitoring efforts, and field experiences in which students visited the museum's lake to plant eelgrass, conduct water quality testing, and learn more about regional aquatic ecosystems. In addition to striving to improve the water quality in the lake, the project had three main educational goals: first, to increase high school students' knowledge of aquatic ecosystems and the factors that impact key indicators of their ability to support life; second, to develop students' awareness that they could take related near and long-term actions including following a career path that involves STEM and environmental stewardship; and third, to support students' sense of belonging to the project site, because most were from urban, low income neighborhoods and were otherwise unlikely to visit the museum and lake. The project, in its third year at the time of writing, serves as a case study that can inform understandings of how, over the course of one school year, a relatively small number of experiences can have a meaningful effect on students' content knowledge, their ability to see the world in new ways because of their knowledge and experiences, and their sense of self in current and future roles that are germane to restoring and protecting the natural environment.

Background. Museums and parks often employ staff to tackle local ecology management issues such as monitoring and improving water quality, minimizing or mitigating pollution, preventing and managing erosion, and responding to natural and manmade impacts from the onsite activities of visitors and wildlife. However, educational outreach programming by individuals in these managed spaces often focuses on presenting demonstration products of ongoing restoration efforts or single-touch programs that provide real world examples of ecology concepts that students encounter in the classroom (Newton, 2001). Outside of intensive service-learning models, it is less common for students to join and participate in ongoing restoration efforts, even though these can provide connections among students and STEM professionals and potentially influence students' sense of belonging to a location.

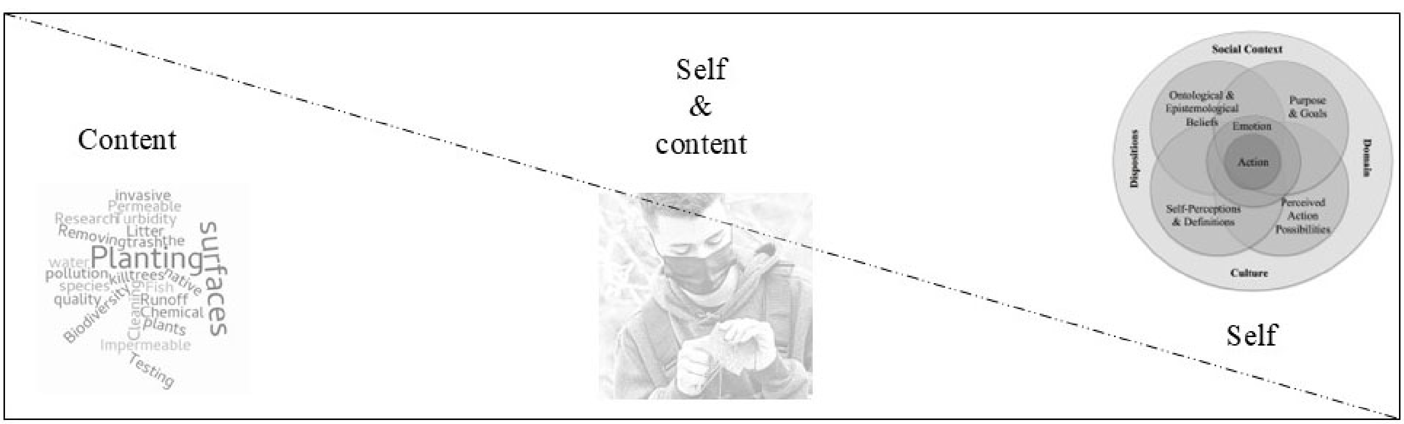
Field Experiences for Urban Students. Because urban and low-income students are less likely to have access to nature programs and experiences than more affluent students or students in suburban or rural settings, they may have difficulty transferring what is encountered in the school curriculum into real-world examples where environmental and biological science concepts apply (Hoover, 2020; White et al., 2018). Not only does this put them at a disadvantage for being able to recall or recognize examples of key concepts (Kuwahara, 2013), but it may also impact the development of attitudes towards the environment and beliefs about the role individuals can play in local environmental stewardship efforts (Gaston and Soga, 2016). In addition, without exposure to environmental STEM career role models, urban, minority and low-income students may never consider this career pathway (Lent et al., 1994).

Prior research suggests that even a small amount of exposure to environmental stewardship concepts and activities can have a beneficial effect. For example, in an evaluation of the Chesapeake Bay Foundation's programming aimed at middle and high school students, Zint and colleagues (2002) found that one-day field trips were associated with increases in students' perceptions of their knowledge of environmental issues and actions they could take, as well as intentions to take action to improve the environment. Similarly, in a small study of the impact of a wetlands field trip on middle school students, Hoover (2020) noted that a one-day experience that included scientific observation and water quality testing improved students' perceived connection to nature and their environmental knowledge, although this study did not find an impact on environmental attitudes. Others have suggested that more intensive exposure to the natural world can influence students' knowledge and beliefs about environmental matters. Nieman and Ades (2014) reported changes in environmental knowledge, values, and attitudes for college students who experienced a three-day program of visiting natural sites compared to a control group who did not. Meanwhile, Barnett et al. (2006) reported that a year-long initiative to involve underserved youth in scientific research while emphasizing knowledge of urban ecosystems produced significant changes in their science skills and ecological mindset (a measure of attitudes towards environmental stewardship), over and above a comparison group who only experienced in-class instruction.

Place-based Learning and Belonging. Place-based inquiry, which simultaneously exposes students to local heritage sites, landscapes, and cultures (Promise of Place, n.d.), can help to contextualize the curriculum, thereby making it feel more relevant to students' day-to-day lives (Kuwahara, 2013). However, for many urban students, a "lived" (Hurd, 2002) curriculum that "reaches out to the lives, communities, and experiences of students" (Price and McNeil, 2013, p.501) must include deliberate steps to overcome sociocultural boundaries and barriers to experiencing and participating in the natural world (Anderson, 2009; Calabrese Barton, 2002). One positive consequence of place-based experiences may be a decreased perception of separation between "home and school identities" (Kuwahara, 2013), and, in the case of an environmental stewardship project, the potential for students to explore alignments between their self-perceptions as a community member with agency to effect environmental stewardship or protection, and their purposes and goals for taking environmentally protective action, beliefs about the importance of the natural world for human survival and the need for environmental stewardship, and environmental stewardship actions at sites in their everyday home and school contexts. Alignment of self-perceptions, beliefs, goals, and action possibilities may co-occur with a sense of belonging to the place in which their environmental stewardship activities occur (Lim and Calabrese Barton, 2010; Price and McNeil, 2013; Pugh et al., 2023), and the opportunity to consider their own current and future self in relation to those activities. In other words, place-based learning may serve as a context in which students can engage in identity exploration—the act of deliberately processing information in relation to, and about, the self (Kaplan et al., 2014). Identity exploration may happen through environmental stewardship activities that build self-efficacy and agency for conservation efforts while exposing students to role models and prompting reflection on students' sense of who they are now and who they might become (Gruenewald, 2003).

A Conceptual Framework for Evaluating Students' Experiences. Because the educational goals of the *Mariners' Environmental Initiative* were to increase participants' understanding of watersheds *and* encourage students to internalize ideas about how human actions can positively and negatively impact the health and sustainability of bodies of water, evaluation of the students' learning and engagement was guided by a framework designed specifically for multifaceted STEM exposure in informal learning environments. The *Visitor Identification and Engagement with STEM* framework (VINES; Garner, Kaplan and Pugh, 2016) was developed to expand existing perspectives on museum and science center learning that prioritize visitors' acquisition of content knowledge. Recognizing that museums, natural sites, and other informal learning environments offer opportunities for visitors to explore relations between content and the world around them and reflect on their own positionality and identity, the VINES model conceptualizes a continuum that ranges from a focus on learning content to a focus on learning about the self. The continuum, and statements relating to students' learning and engagement in the context of the *Mariners' Environmental Initiative* project, are shown in Figure 1.

VINES includes a left-side emphasis on content, where the goal of an activity might be to build comprehension of scientific topics, principles, or ideas. Moving to the mid-way point, the continuum reflects a balance between learning about content while in a particular setting and learning to recognize instances of this content in one's everyday life. This includes *transformative experiences*, where STEM content is used to re-see the individual's world in new ways and increases the subjective value of the concept thereafter (Pugh et al. 2023). On the right-side, the primary focus is visitors' learning about themselves, using content as a trigger for identity exploration. The far-right area applies the concept of *role identity* using *Dynamic Systems Model of Role Identity* (DSMRI; Kaplan and Garner, 2017), which proposes that individuals' motivated decision making and action emerge from the social role that they construct and inhabit in a particular setting. Individuals possess multiple role identities that correspond to formal and informal social roles (e.g. educator, daughter, neighbor). They include dynamically and reciprocally interacting constructs of self-perceptions and self-definitions (e.g. "I am a student who achieves in science), purposes and goals (e.g. "I want to make a difference to the wellbeing of the organisms in the lake"), ontological and epistemological beliefs (e.g. "Our environmental problems are too big for individuals to solve") and action possibilities (e.g. "I would like to clean up our school yard to prevent water pollution"), as well as the emotions associated with each of these components. These components can be in alignment with one another, such as when a student feels confident that their knowledge can be useful to help them achieve a goal, or in tension, such as when a student values stewardship but feels that they lack the skills to take action. Importantly, role identity components and alignments or tensions, as well as the salience of a role identity, can be influenced by the social context (i.e., planting eelgrass at the lake with one's peers, walking in one's neighborhood, taking a standardized test at school). Further, since action can be either the impetus for or the product of changes in the individual's identity system,



Students' understanding of problems and solutions for maintaining the lake

Students' learning about the environment and environmental stewardship

Students' learning about themselves in relation to environmental stewardship

Figure 1. A modified Visitor Identification and Engagement in STEM (VINES) framework that references objectives associated with the Mariners' Environmental Initiative.

this approach embraces the idea that experiential learning can promote identity change.

When applied to environmental stewardship outreach, the VINES model encourages practitioners and researchers to move fluidly along the continuum as they design for and investigate how participating students can not only learn concepts but also *see themselves as someone who* can take action to support and protect the environment. Notably, this perspective is aligned with contemporary approaches to environmental education, which recognize reciprocal relationships among changes in stakeholders' knowledge, attitudes, and behaviors (Brooks et al., 2013).

Prior studies using the VINES continuum to investigate content learning, seeing the world differently and seeing the self differently were conducted with adult participants rather than youth (Carver et al., 2021; Garner, 2019a, 2019b). However, younger participants may also experience STEM outreach programming in such a way that impacts their knowledge, expands their awareness of the world around them, *and* inspires them to think about action in various roles in the world beyond the program. If successful, this approach could inform others who are designing, implementing, and evaluating STEM outreach activities with goals of transcending cognitive, affective, and self-domains to motivate and prepare youth to become STEM-literate citizens and engage in STEM related career pathways (Ramlo, 2018; White, 2020).

The Present Study. The present study was conducted during the second year of a three-year STEM outreach project called the *Mariners' Environmental Initiative*, which included annual cycles of classroom and lake-based field experiences for ninth and some tenth-grade students. The initiative provided the school district with a local STEM outreach partner for supplemental instruction and increased access to the museum and lake for students of color and those from economically disadvantaged backgrounds. The project concretized the museum's values of servant leadership and regional participation in the community and has served as a testing ground from which additional lake-oriented environmental stewardship and STEM outreach programs have since been developed.

Research Questions. Three questions guided the research activities.

1. How does students' scientific knowledge of watershed pollution issues and potential solutions change from pre-program to post-program?
2. How can students' attitudes towards environmental stewardship be characterized in relation to their scientific knowledge and sense of belonging to the project site?
3. What do students report having learned about the environment and themselves after participating in the environmental stewardship activities?

METHODS

Participants. Program participants were high school students enrolled in biology and environmental science courses in a school district located close to the museum. During the pilot year, the project included two of the district's seven high schools. The remaining five high schools joined in a planned expansion ahead of the project's second year. Research participants were therefore high school students from across the schools whose parents provided consent to participate. The urban school district served by the project has a 76% minority enrollment including approximately 50% Black and 15% Hispanic/Latino enrollment, and more than 50% of students qualifying for free and reduced-price meals.

The analytical sample included N=174 students of whom n=148 completed pre- and post-program data collection. The sample was 53% female (n=92) and 44% male (n=76), with 3% (n=6) students preferring not to indicate gender. The sample was 41% Black or African American (n=72), 19% two or more races (n=32), 18% Caucasian (n=32), 11% Hispanic or Latinx (n=19), 5% Asian (n=8), 2% Middle Eastern or North African (n=4), 2% Native Hawaiian or Pacific Islander (n=3), 1% American Indian or Alaskan Native (n=2) and 1% other (n=1). The students' mean age was 14.53 years (SD=0.78 years) with a maximum age of 18 and a minimum age of 14 years.

Measures. The study involved the use of pre-existing and researcher-developed knowledge and attitude measures. Parental consent was sought prior to student participation. The concept sorting activity is included as supplemental material.

Scientific Concept Sorting Task. A sorting task was created in the form of a simple problem-and-solution format concept map (Novak and Canas, 2006; Garner et al., 2019a). Students completed the task prior to and then at the conclusion of the program. The task was completed in class and was presented in the online Qualtrics survey platform. It included the following prompt: "How can we change the health of Mariners' Lake?" Students were presented with opportunities to place 14 provided terms into a box to "List problems at Mariners' Lake" and "List solutions to help Mariners' Lake." In addition to the provided terms, students had the opportunity to create up to six added terms and place them in either the problems or solutions box. Items were generated by the scientists on the project's leadership team in consultation with the district's science administration leadership, and included grade- and course-appropriate concepts that were relevant to the project activities. The text used for the sorting task is included as supplemental material.

Environmental Stewardship Attitudes. Post-program, students were invited to respond to an eleven-item survey measuring attitudes and perceptions of environmental stewardship that was adapted from a measure created specifically for adolescents (Szczytko et al., 2019). These items were pilot tested in year one of the project and, using Cronbach's alpha (Cronbach, 1951), demonstrated acceptable internal consistency reliability (Year one, analytical sample of N=189; α = 0.87). Construct validity with principal axis factoring using ProMax rotation (Hendrickson and White, 1964) revealed two stewardship factors that were labeled *environmental hope* and *environmental despair.* The two subscales and the total scale score demonstrated adequate internal consistency reliability: the first subscale, environmental hope, had a maximum possible score of 35 and yielded a Cronbach's alpha (α) of 0.83; the second subscale, environmental despair, had a maximum possible score of 20 and yielded a Cronbach's α of 0.83. Internal consistency reliability for the total scale was adequate, Cronbach's α = 0.75. Examples of environmental hope items include "I believe people will be able to solve most environmental problems," "I believe scientists will be able to find ways to solve environmental problems," and "Because people can learn from our mistakes, we will influence the environment in a positive direction." Examples of environmental despair items include: "The actions I can take are too small to help solve most environmental problems" and "Environmental problems are out of my control."

Sense of Belonging. Due to school district preferences about data collection, at post-program only, students were invited to respond to a four-item survey measuring sense of belonging to the *Mariners' Environmental Initiative* project. These items were pilot tested in year one and demonstrated adequate internal consistency reliability (Year one, analytical sample of N=189; α = 0.93). The items also demonstrated adequate construct validity; items loaded onto a single factor that was uncorrelated with the environmental stewardship items. Example sense of belonging items are: "I feel like a real part of this program," "I am proud of belonging to this program," and "At the Mariners' Museum, I feel safe to be who I am." In this sample, the sense of belonging scale demonstrated adequate internal consistency reliability, Cronbach's α of 0.92. The maximum possible score was 20, and the mean score was 13.14 (SD=3.40).

Transferring Environmental STEM Knowledge. At the post-program time point only, students were invited to provide an open-ended response to the prompt: "What have you learned about the environment from completing the Mariners' Museum project?" This prompt was designed to reveal instances of expanded perception of the world where students connected curricular concepts to experiences in the project or in related activities or contexts in their everyday lives.

Identity Exploration. At posttest only, students were invited to provide an open-ended response to the prompt: "What have you learned about yourself from completing the Mariners' Museum project?" This prompt was designed to solicit written evidence of changes in students' self-perceptions, beliefs, goals, and/or action possibilities, along with the emotions associated with these.

Timeline and Procedure. The program involved teacher professional development, classroom outreach visits, and a field experience visit to Mariners' Lake, a 167-acre lake on the grounds of the 550-acre Mariners' Museum and Park.

Teacher Professional Development. The project involved three teacher professional development (PD) sessions designed to increase teachers' knowledge of the scientific merit of the project and familiarize them with the activities that would take place during the field trip. The first, two-day teacher PD was delivered ahead of the beginning of the school year. It introduced the teachers to the project's concept through demonstrations and guest speakers from partner organizations, as well as a visit to the field trip site. The curriculum standards that the program was intended to cover were also reviewed. A second, half-day follow-up teacher PD was provided in January of the school year. Museum educators and partners assisted teachers to transfer curriculum content into ideas for school-based environmental stewardship projects called action projects. An idea for such a project (a model storm drain) was demonstrated, an ecology presentation by a guest speaker, and teachers received a tour of the museum. A third, two-hour PD session was held to conclude the school year. It included a presentation of the year's activities and a feedback session.

Environmental Stewardship Classroom Instruction. Within the first two months of the school year, students were visited in their biology or Environmental Science course classroom by Mariners' Museum and Park educators, scientists, and program interns. The project was introduced, including the location, history, and significance of the Mariners' Lake. Educators additionally brought representative field trip equipment (e.g., waders, hydrometers, test strips) to give students a sense of what was expected during the field trip. Students completed the pre-program scientific terminology sorting task. Students then spent several weeks monitoring and caring for a tank of eelgrass in their classrooms and participated in the field trip (see below). At the end of the semester, students were invited to complete the post-program sorting activity and the survey items after a second classroom visit. During the visit, educators guided students through a graphing activity featuring dissolved oxygen and turbidity data from Mariner's Lake and encouraged students to develop student action projects based on their experiences. Students ended with a virtual reality experience of the *U.S.S. Monitor* shipwreck. Activities were intentionally chosen to encourage systems thinking, remind students of the community action and solutions they were part of during the semester, and provide real-life career exploration and examples of large-scale solutions for habitat issues.

Lake-Based Field Experiences. Each class of students participated in one field experience during either the fall or spring semester. The lake-based field experiences included four facilitated stations through which small groups of students rotated during a 90-minute period. One station, led by one of the partners in the project, involved a game of ecosystems-themed Jenga, with blocks that included watershed and ecology related text printed on them. The second station offered students the opportunity to create a hypothesis examining if Mariners' Lake was the best location for the eelgrass, and conduct water quality testing including taking pH, turbidity, salinity, dissolved oxygen, and temperature measurements. The third station involved a simulated fishing game, where students cast rods to connect with fish shapes on which information about whether the fish was an invasive or native species was printed. The fourth station involved students putting on waders and entering the lake to knee height to plant an eelgrass strand using a stake and coconut fiber square. The eelgrass was provided from the students' classroom tanks. Numerous partners of the *Mariners' Environmental Initiative* were present at each field experience to assist students, provide scientific expertise, and connect students to community organizations.

Pre- and Post-Program Data Collection. There was an interval of approximately ten weeks between pre- and post-program data collection. Students completed the sorting task activity using an online survey platform at the beginning and end of the semester in which they received classroom visits and participated in the field trip. At the post-program time point, students also responded to the environmental stewardship attitudes items, open-ended questions about what they had learned, and completed a brief demographic survey to capture gender, race-ethnicity, and age.

Data Analysis.

Sorting Task. Sorting task data were downloaded from Qualtrics and converted into Excel format for cleaning. Non-matched cases were removed from the analytical data file. Identifiers were removed from the remaining cases. The resulting spreadsheet was converted into SPSS format and text-based variables were recoded into numerical variables with labels as needed. Aggregate variables were calculated to reflect pre- and posttest total scores with one point given for each correctly placed term and one point removed for each incorrectly placed term (e.g., adding "research" to the list of problems). An additional aggregate variable was calculated to include 0.25 points added for each correctly specified term that the student wrote in themselves. Terms that were too vague were removed (e.g., "pH" without further elaboration). There were no statistically significant differences between the fall and spring cohorts, so the data were collapsed across the two groups.

To determine the magnitude of change in the use of the terms, a paired t-test was conducted using the aggregate problem and solution scores. To determine the magnitude and direction of changes in the use of each term as a problem or solution, pre-test frequency scores were subtracted from posttest frequency scores. The resulting index was then converted into a z-score and graphed (see Figures 2a and b).

Environmental Stewardship Beliefs. Not all students (n=118) chose to complete this portion of the protocol, which was presented after the concept sorting task. Subscale scores were calculated for *environmental hope* (maximum possible score of 35) and *environmental despair* (maximum possible score of 20) in accordance with the prior conceptualization of the scale by Szczytko et al. (2018) and a pilot phase factor analysis.

Sense of Belonging to the Project Site. Items were aggregated to create a total score which was subjected to internal consistency reliability analysis, correlation analysis, and exploratory analysis using independent t-tests to detect or rule out any gender-based differences in students' perceptions.

For all survey data, since no gender-based differences were found, the data are presented for the entire sample.

Learning about the Environment. Not all students (n=73) provided a response to the question prompting them to state what they had learned about the environment, which was presented after the survey items. Responses were coded in two phases. In the first phase, simple positive, negative, or ambiguous responses were separated from the other responses. Two students said "yes" or "yea"; two students wrote "idk" (I don't know); one student provided an incomplete response "I've learned that" and one student indicated that they did not participate in the field trip. This left n=67 responses that could be coded thematically.

Pugh's definition of transformative experiences guided the generation of themes for learning about the environment. This definition encompasses how the student uses the subject matter "to more fully perceive some aspect of the world and finds meaning in doing so" (Pugh, 2011, p.111). Three main themes emerged: explicit mention of scientific concepts that were introduced during the program (*n*=32 or 43% of responses; not considered evidence of a transformative experience); an increased awareness or re-seeing of the world to recognize the fragile or non-optimal state of the environment that was described during the project's activities (*n*=27 or 37% of responses; considered to be indicative of transformative experience); and explicit mention of the environment in ways that also referred to either negative or positive human impact (*n*=27 or 37% of responses; considered to be indicative of transformative experience). Thirty-eight students provided responses that were coded as representing one theme; twenty-one students provided responses that were coded as representing two themes; two students provided responses that were coded as representing all three themes.

Identity Exploration: New Self-Knowledge. Slightly fewer (*n*=62) students responded to the question about what they had learned about themselves over the course of the project, which was the last prompt included in the protocol. A similar process to the one used to code responses relating to learning about the environment was used, including an initial review to identify ambiguous or simplistic responses, but the thematic framing that was used corresponded to the components of the DSMRI. As identity exploration was not explicitly scaffolded in the project, it was anticipated that there would be variability, with some students reporting that they did learn about themselves and some reporting that they did not. Two students wrote only "yes" and four students wrote "nothing" or "I have learned nothing." One student wrote "idk." The remaining *n*=55 responses were coded thematically to align statements with the role identity components of self-perceptions and self-definitions, ontological and epistemological beliefs, purposes and goals, and action possibilities, as well as recognizing responses that combined or otherwise revealed relations (e.g., alignments, tensions) among these constructs.

RESULTS

RQ1. How does students' learning about environmental science concepts change from pre-program to post-program?

A paired t-test revealed a statistically significant increase in pre- to post-program knowledge scores for the sorting tasks. The mean pre-program score was 7.80 (SD=2.62) and the mean post-program score was 10.83 (SD=3.33), $t_{(147)} = -10.14$, $p<0.01$. To gain additional insights into how students' responses changed from pre- to post-program, a concept level analysis was conducted. This revealed variation in the relative amount of change in the usage of a concept as either a problem or a solution. The mean shift from pre- to post-program for each science concept is represented as z-scores in Figures 2a and 2b below.

The most notable changes in how students perceived the terms can be seen by looking at the left- and right-most por-

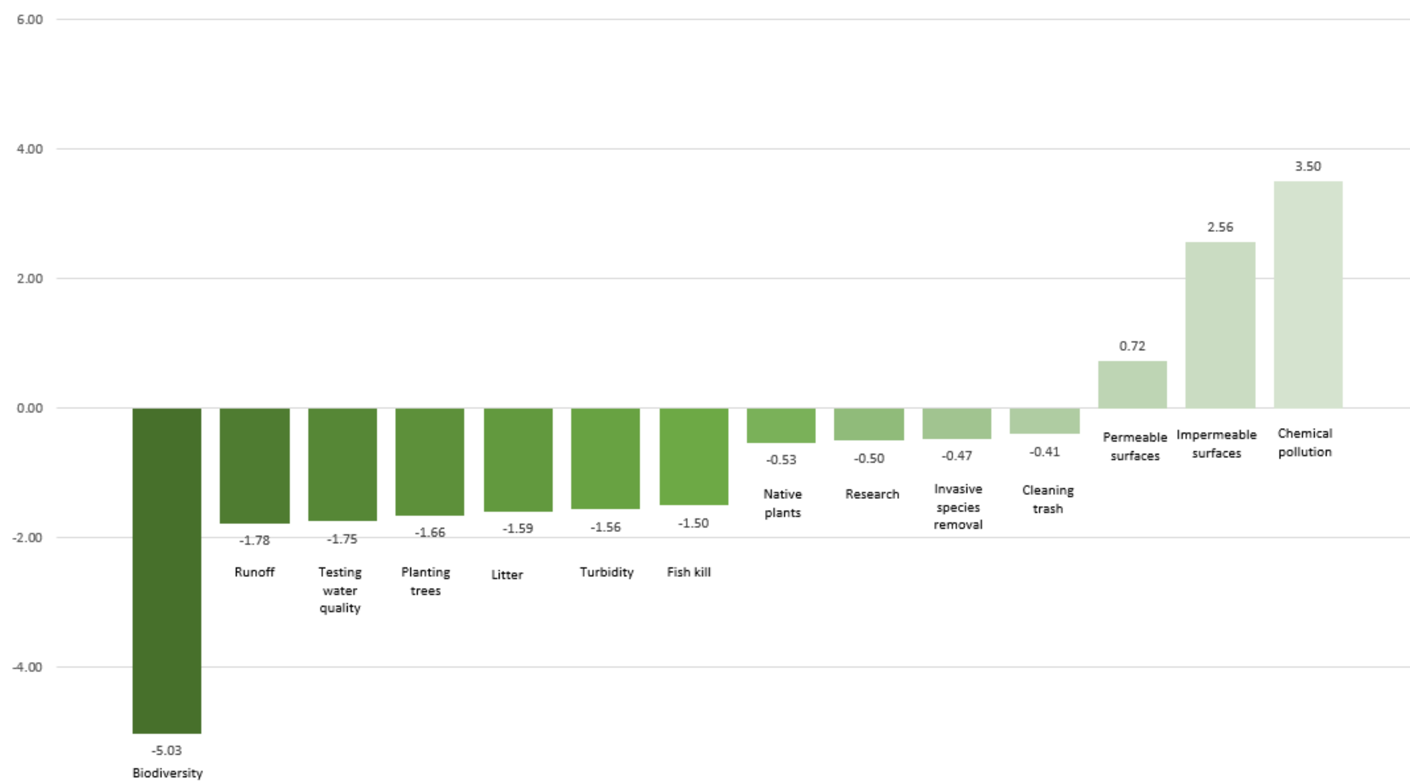


Figure 2a. Changes in pre-test to posttest usage of concepts as problems for the lake.

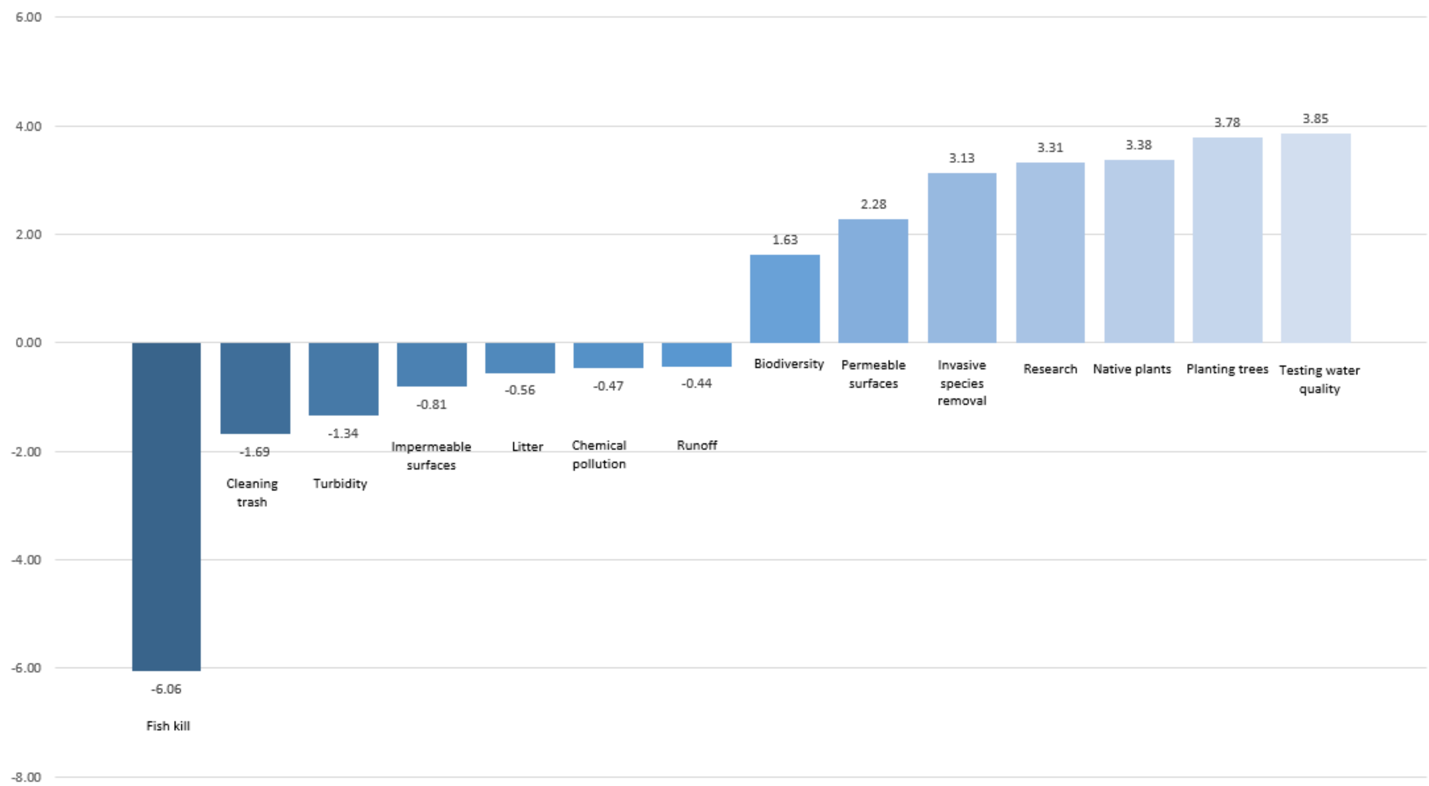


Figure 2b. Changes in pre-test to posttest usage of concepts as solutions for the lake

tions of Figure 2a and 2b. For example, as shown on the left-side of Figure 2a, at post-program the students were much less likely to identify biodiversity as a problem than at the pre-program time-point. The right-most portion of Figure 2a shows that they were also more likely to perceive impermeable surfaces and chemical pollution as problems at post-program compared to pre-program. As shown on the left-most side of Figure 2b, students were less likely to identify the issue of fish kill as a solution at post-program than at pre-program. The right-most side of Figure 2b shows that they were more likely to identify native plants, planting trees, and testing water quality as solutions at post-program than at pre-program. These findings suggest that over time, students improved their understanding of factors that help or harm the wellbeing of an urban aquatic ecosystem in ways that correspond with both the science content and its applications as students witnessed them during the program.

RQ2. How can students' beliefs about environmental stewardship be characterized in relation to their scientific knowledge and sense of belonging to the project site?

Environmental Stewardship. Table 1 presents the mean and standard deviation scores for each attitude subscale. Of interest is that the two subscales were uncorrelated with one another, r= -0.01, p>0.05, suggesting independence between students' responses to items measuring environmental hope and their responses to items measuring environmental despair. Because of this finding, our subsequent analyses maintained the integrity of the two subscales. Of the two subscales, environmental hope was more strongly related to knowledge and environmental stewardship than environmental despair.

Pre-test knowledge scores were not statistically significantly correlated with environmental stewardship attitudes. At posttest, environmental hope scores, but not environmental despair scores, were significantly correlated with posttest knowledge scores, (r=0.38, p<0.01). Although no causal relationship can be determined, students who scored high on environmental hope were also likely to score high on the posttest sorting task. In other words, knowledge and personal agency towards environmental matters tended to trend in parallel.

Sense of belonging to the project site. Sense of belonging to the project site was uncorrelated with both pre-test and posttest knowledge scores, and it was also uncorrelated with environmental despair. However, it was strongly correlated with environmental hope (r= -0.55, p<0.01). Students who

Table 1. *Students' post-program environmental stewardship attitudes (n=118).*

	Descriptive Statistics	
	Mean	**Std. Dev.**
Environmental hope	25.84	5.20
Environmental despair	13.09	3.38
Total score	**38.38**	**7.41**

felt a strong sense of belonging to the project site were also likely to score highly on environmental hope.

RQ3. What do students report having learned about the environment and themselves after participating in the environmental stewardship activities?

Learning about the Environment. Students' open-ended responses to the question of what they had learned about the environment were coded thematically and non-exclusively. Table 2 provides examples of responses that fall under each of the themes.

Many students' responses represented more than one theme. For example, a 15-year-old female African American student responded that they had learned about the fragility of the environment and that humans are a cause of its degradation. She wrote:

> *The environment isn't as healthy as we think it is. Our fish, plants and even people are dying due to problems that I'm 100% sure are our fault. A lot of us are aware of this too, but despite that we aren't doing enough to change it.*

A 14-year-old female multiracial student connected the idea of specific scientific activities and humans' approach to improving the environment, writing:

> *I have learned what terms mean like turbidity and permeable surfaces. I have also learned that in order to better the environment you need to work together and you need to analyze all of the factors that go into an area before experimenting.*

A 15-year-old Asian male emphasized that collective action is needed, writing:

> *I learned that our actions can affect the ocean and environment negatively. Researchers and scientists always try to help the environment with tests and reseaches* [sic]. *They also need us to help them because improving the environment needs the whole planet to cooperate*.

A fourth example, written by a 14-year-old female African American student, connected awareness of the environment's non-optimal condition to specific scientific terms. She relayed:

> *What I've learned is how fragile ecosystems really are. Adding or removing one thing from it can change practically everything. I've learned how our water isn't as healthy as I thought it was, and I figured the reasons for why that might be the case. Runoff trails a lot of sediment into the river, so adding plants help block and ground it. The plants will also help to add more oxygen to the water through photosynthesis.*

Table 2. *Thematic examples of students' reflections on what they learned about the environment.*

Theme	Example Responses
Statements relaying project-specific scientific phenomena	"I learned about how bad invasive species can be I learned how to plant eelgrass and how to test the water for dissolved oxygen and turbidity." "I learned that no dissolved oxygen can kill the life in the water. I learned that high turbidity can cause a cloud over the water, therefore killing the species in the water. I learned that planting eelgrass can stop erosion in the water."
Awareness of the non-optimal state of the environment	"What I have learned about the environment from completing the Mariners' Project is that it is not as good as we hope it could be." "The environment is fragile."
Awareness of the positive or negative impact of humans on the environment	"The environment is in need of help from scientists and people. Even though humans create many of the worlds [sic] problems humans can also be the solution. If people work together most problems can be solved." "I learned there are many ways to save the environment. Also, humans are not the only cause of envirnment [*sic*] pollution."

Identity Exploration: New Self-Knowledge. Just less than half (*n*=55) of the students responded to the prompt asking them to state what they had learned about themselves. The prompt was designed to reveal impacts of the program on components of their identity, including their self-perceptions, beliefs about the world, purposes and goals, and possibilities for action in the future. Examples of the ways in which students' responses were coded into the various iden-

Table 3. *Coding of identity components in students' responses.*

Identity Component	Example[1]
Self-perceptions	I enjoy talking about environmental issues more than I thought I did. I like the feeling of the water while wearing waders. I really do enjoy things like this when I listen and participate. That I cooperate and [am] helpful. I don't really care about the lakes. I don't really like the water.
Beliefs	Earth needs to bind together. My voice matters in the environment. I can make a difference in the world. I am part of a species that needs to change how we view the world.
Action Possibilities	I am considering joining the program. I should consider this as a major. I can help by cleaning up the environment and convincing other people to help.
Purposes and Goals	I need to step up my game. I want to help the environment more in the future as much as I can.

[1]The examples are excerpts from students' complete responses to illustrate the various components of the identity system separately. Additional examples of responses that demonstrate the interconnections among components are provided in the narrative.

tity components are included in Table 3.

In many cases, students' responses revealed connections between the four identity components. For example, one female, 15-year-old African American student revealed *self-perceptions* of loving the environment and *beliefs* about being able to make a difference. This was connected to perceived *action possibilities* for future environmental stewardship action. She wrote, "Even though I am just one person—I can still make a difference in our world. I genuinely love the environment and I hate to watch it fall apart. I am considering joining the program."

Another female, 14-year-old African American student relayed new *self-perceptions* and connected this to *action possibilities* of helping at the museum, stating:

> *I have learned that I can really be helpful when planting eel grass. I have also learned about myself that I will be able* [sic] *to help the people at the Mariners' museum and help there* [sic] *lake or just help them in general at the museum.*

An additional female 15-year-old African American student wrote about a new *belief* that they can make a difference in environmental wellbeing, and new *self-perceptions* about sharing their interest in environmental issues:

> *I have learned that there are many different environmental issues that I didn't recognize before because I didn't think any of it was in my control. Now, I know that my actions (even small ones) can have great impacts on the environment. I also learned that I enjoy talking about environmental issues more than I thought I did.*

Exposure to the scientific activities raised new, career-related *action possibilities* for some students. One female, 14-year-old Caucasian student commented, "I learned about myself from planting grass in the water that I don't like walking in rocky water. I also take interest in marine life. I realize that I should consider this as a major."

Finally, the program seemed to provide an uplifting emotional experience for some students. One 14-year-old Caucasian student who did not provide their gender stated, "I learned that I like to help the environment. It helps me feel like I have a place for the earth and helping. It helps me so much to feel that."

DISCUSSION

Partnerships among museums, natural sites, and schools can provide opportunities for teachers and students to experience scientific concepts far beyond the classroom walls and make small but meaningful contributions to environmental stewardship projects. The findings from this study of the *Mariners Environmental Initiative* revealed that supplemental classroom outreach visits and one field experience was associated with a small but statistically significant increase in students' scientific knowledge about factors that either support or harm a lake ecosystem. Post-program, students were much less likely to misidentify supportive factors as negative ones, and less likely to misidentify harmful factors as supportive ones. Moreover, relations among knowledge and attitudes were also found—at the conclusion of the program, students who held more optimistic environmental beliefs were more likely to have high content knowledge, and optimistic beliefs and content knowledge were also associated with post-program feelings of belonging to the museum and lake project site. Feelings of environmental despair were not absent but did not correlate with either knowledge or feelings of hope that individual and collective action could overcome environmental problems.

Many of the participating students were able to articulate ideas they had learned about the environment and, notably, their own interest and agency towards environmental stewardship. The qualitative data revealed insights into the impact of the program on students' content knowledge, ability to consider concepts as ideas that can shape their understanding of the world (Pugh, 2011), and their identities as scientifically literate and agentic citizens. Students' responses to prompts about environment-related learning led to the articulation of specific knowledge of scientific terms associated with aquatic ecosystems and community water sources, but also many examples of using the terms to express increased awareness of the connection between human activity and ecosystem wellbeing. This suggests that the activities did support students' recognition of how concepts can be used to see the world in a new way (Pugh, 2011), which falls at the mid-point between a focus on content and a focus on the self within the VINES continuum that we used to frame this research. Further, while many of the students chose not to respond to the prompt about identity-related learning, those who did respond seemed to have considered the relevance of their activities within the project to their lives outside of the project and some had considered the project's relevance to their future activities and career plans. In other words, the activities also seemed to prompt psychological processes that are consistent with identity exploration (Kaplan et al., 2014) and resulted in changes to students' beliefs, goals, self-perceptions, and possibilities for action.

This study supports the idea that STEM outreach programming that blends classroom with field experiences can help students develop what Basu, Calabrese Barton and colleagues (e.g., Basu et al., 2009) and others have termed "critical science agency," a combination of an understanding of science content, a sense of agency, and motivation for action. As such, we propose that partnership-oriented programs such as the *Mariners' Environmental Initiative* can benefit urban students so that they not only learn science concepts but that they also see themselves as a critical part of society's efforts to promote citizens' protective and restorative environmental actions (Ardoin et al., 2020; Price and McNeill, 2013).

Implications for Design. The *Mariners' Environmental Initiative* incorporated the needs of its main partners by ensuring that students' (and teachers') experiences were closely aligned with the required curriculum. The design of the program required a significant narrowing down from the many potential opportunities for exploring the natural world, and even from the broader topic of environmental stewardship that was afforded by the lake and park. In addition to prioritizing scientific concepts present in the high school curriculum, however, the program's designers also leveraged an authentic need that existed for the natural site: the lake's water quality, including its dissolved oxygen, turbidity, and ability to sustain life, could be improved by the addition of eelgrasses in specific areas. The success that emerged from intertwining the congruent priorities of each partner organization can be taken as a key lesson when considering how to create stewardship programs in the future.

A second implication for design comes from our finding of positive relations among students' knowledge, attitudes, and transfer of the experiences to other contexts and to the self. Post-program, a portion of the students were able to articulate how their experiences had broadened their perceptions of their local environment and *their role within it*. Other, classroom-based research on transformative experiences and identity exploration has suggested that explicit teacher modeling and lesson-based prompts are needed to promote such reflections (Pugh et al., 2023; Kaplan et al., 2014); in this case, experiential learning and being positioned in the role of steward may have supported students to engage in transformative experiences and identity exploration. However, future programs might incorporate explicit modeling of the value of the concepts and specific strategies for using the context of the learning experience to help students articulate how they can use these skills and values towards stewardship in their lives and in their future actions.

Implications for Theory and Practice. As others have pointed out, interrelationships among knowledge, attitudes, and readiness for action can emerge from environmental and experiential programs (Brooks et al., 2013). Our findings support others' calls for exposing students to the scientific study of local environmental issues, opportunities to learn from and form relationships with scientists, and co-curricular experiences that connect broad societal issues with individual behavior and decision making (Ardoin et al., 2020; Toomey et al. 2017). However, the limitations of this study's single-group design that, due to data collection protocols in place within the school district, only captured relations among the various types of learning at the post-program time point, invites further exploration of the ways in which content can be leveraged to support both transformative experiences and identity exploration, and the degree to which these can feed back on one another in a supportive way. However, currently, knowledge on how this happens is quite limited. Researcher-practitioner partnerships and collaborative action research may therefore yield insights into specific pedagogical strategies that can promote students' ability to see the world, and themselves, in new ways. One approach might be to bring educational researchers and ecology and stewardship staff together to co-design and iteratively gather data about how the public is experiencing their programming.

CONCLUSION

Co-curricular experiences can facilitate "re-seeing" the world and the self in new ways (Garner et al., 2016; Carver et al., 2021), but students in urban and low-income communities may have less access such experiences. Exposure to scientific concepts through classroom resources alone may reduce perceptions of relevance (Pugh, 2011), and do little to enhance students' perceptions of agency to effect change using STEM knowledge and skills (Calabrese Barton, 2002). The creation of partnerships between schools and local museums, natural sites, and environmental advocacy groups can provide opportunities for students to join meaningful stewardship projects and create connections between the classroom and the outside world. Moreover, such projects may provide contexts in which students can explore who they are in relation to the environment, and who they might wish to become.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this manuscript.

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ABBREVIATION

PD: Professional Development

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