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Tacit knowledge and girls' notions about a field science community of practice

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ABSTRACT

The issue of girls' lack of connection to science has received much attention. Situated approaches such as research apprenticeships offer the chance to engage learners fully in science communities of practice and thus connect girls to science. However, such programs are often designed with lab settings, rather than field settings, in mind. This paper investigates a research apprenticeship program (Girls on Ice) that immerses girls in field science. In particular, the program makes explicit tacit elements needed for success in field science, such as a sense of adventure and physical and mental toughness. Using a qualitative approach, we explored how and in what ways girls connected to a field science community of practice. Emergent themes from the analysis illustrate that girls learned both explicit and tacit practices and ways of being that are associated with being a field scientist, such as team-oriented leadership and physical and mental perseverance. The results suggest that providing girls exposure to and practice with the tacit skills needed in science might constitute a new way to increase its perceived relevance and to counter gendered expectations of women in science.

KEYWORDS

Tacit knowledge; equity; gender; informal education

Introduction

Gender differences in science interest and participation are well documented in the literature. Science is stereotypically perceived by youth as a male domain (Finson, 2002; Newton & Newton, 1998; Stake & Mares, 2001), with many middle and high school girls reporting a perceived lack of relevance between 'school science' and their interests and daily lives (Archer et al., 2012; Baram-Tsabari & Yarden, 2011; Brotman & Moore, 2008). This disconnect from science is even more common among girls from non-dominant and socioeconomically disadvantaged backgrounds, due to enactments of science in the classroom that are at odds with their culture and concerns (e.g. Basu & Calabrese Barton, 2007; Carlone & Johnson, 2007). A situated approach to science learning (Lave & Wenger, 1991) has the potential make science 'come to life' in ways that classroom science does not. In the arena of out-of-school science learning, the research apprenticeship model has gained popularity as a situated approach in which participants work under the tutelage of genuine scientists and participate in authentic practices of the discipline (Barab & Hay, 2001; Charney et al., 2007; Feldman, Divoll, & Rogan-Klyve, 2013; Mogk & Goodwin, 2012). Research apprenticeship programs offer much promise for participants to learn both *who does* science, and *how* science is

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done, in ways that make the discipline more self-referential and relevant, particularly when attention is paid to using inclusive practices rather than those that reproduce patterns of marginalization. Past studies have shown that research apprenticeship programs for secondary-aged participants can increase self-confidence and self-efficacy towards science, increase understanding of the nature of science, and increase interest in science as a career (reviewed in Sadler, Burgin, McKinney, & Ponjuan, 2010).

Research apprenticeship programs clearly hold promise for impacting participants positively; however, the design of such programs is often based on immersion in laboratory rather than field settings, which differ from each other in significant ways. In field science, norms of behavior and practice go beyond those typically associated with science (e.g. Abd-El-Khalick, Bell, & Lederman, 1998; Driver, Newton, & Osborne, 2000). For instance, field scientists often possess a sense of adventure that compels them to explore new questions in the context of remote wilderness settings. They need to be mentally and physically tough to be able to collect data under challenging conditions, such as rain, blazing sun, or extreme cold. Field scientists often live and work together in close proximity for long periods of time, which requires them to have good teamwork and leadership skills. Such dispositions, habits, and skills, which can be thought of as cultural elements of 'science capital' (Archer, DeWitt, & Willis, 2014), are not often explicitly acknowledged as elements needed for success in science, yet they may connect to the 'non-science' identities of many young women. In this paper, we argue that explicitly making visible tacit knowledge (Collins, 1974, 2010) in research apprenticeship programs holds the potential to connect girls to science in new ways. We describe how girls connect with science while participating in a two-week summer research apprenticeship program, Girls on Ice, which was intentionally designed to build field science skills and dispositions among girls from diverse ethnic and socioeconomic backgrounds. The study adds to the knowledge base about what features of authentic, out-of-school science education experiences might be impactful in broadening participation in science.

Theoretical framework

We situate our work in Wenger's (1998) theory of social learning, which brings together theories of social practice with theories of identity. In particular, we rely on the concept of a 'community of practice' as an enterprise where people come together around three dimensions: (1) joint enterprise, (2) mutual engagement, and (3) shared repertoire. Joint enterprise can also be thought of as a domain around which participants coalesce. Members have a common purpose that motivates them to participate in the enterprise, as well as joint knowledge around the domain. The domain is, in a sense 'owned' by the members, who shape it in important ways. Members also have a sense of mutual accountability, which includes knowing about

> what matters and what does not, what is important and why it is important, what to do and what not to do, what to pay attention to and what to ignore, what to talk about and what to leave unsaid (Wenger, 1998, p. 81).

Mutual engagement is characterized by social aspects of the community. It goes beyond simply knowing people in the community or alignment with organizational goals, but instead refers to engagement in an enterprise arising through doing things together and working in a way that maintains the coherence of the community. Shared repertoire refers to the set of resources, skills and values that a community of practice has developed through engaging together in the enterprise, and continues to use and shape. Domain-specific tools, ways of approaching problems, language, symbols, and processes are all part of the shared repertoire. The repertoire is dynamic, subject to interpretation and change as the community moves forward with its work.

While a community of practice is inherently a social construction, identity comes to the fore as an individual's experience within the COP. As Wenger (1998, p. 149) said, 'Inevitably, our practices deal with the profound issue of how to be a human being. In this sense, the formation of a community of practice is also the negotiation of identities.' In the apprenticeship model Lave and Wenger (1991) describe, a novice develops skills and ways of knowing about the COP through 'legitimate peripheral participation.' The novice is guided by an expert who provides context, meaning, and doable tasks, eventually gaining expertise (Streule & Craig, 2016). As individuals come to participate in the community of practice of science, they learn the ways in which individuals behave, adopt skills and dispositions, and engage in discourse consistent with the domain. They gain expertise and build social relationships within the community. As this work is accomplished, individuals may gain new ideas about who and what they want to become—in other words, new 'possible selves' (Markus & Nurius, 1986) open up as identification with the COP grows.

Our research explores how and in what ways girls connect to science as they participate in a program whose design includes both explicit and tacit elements of a field science COP. We begin by elaborating the features of a field science community of practice, then present an analysis around our research question: what do the girls learn about the COP of field science, in terms of knowledge, dispositions, behaviors, and practices? We also discuss the significance of making the normally tacit elements of a field science COP more visible to a novice.

Community of practice of field scientists

We argue that field science (across many areas, such as biology, geology, and others) has core values, ways of knowing and ways of being that are consistently associated with science 'outside the lab' that differentiate a COP in a field setting from one in a laboratory setting. In this paper, our conceptions of a field-science COP derive both from the literature and the personal experiences of two of the authors (Pettit, Carsten Conner) in conducting field science.

First, field scientists gain knowledge from direct perceptual experience and from *in situ* contexts, through two distinct approaches. One approach emphasizes making observations of nature, describing phenomenon, and noticing patterns (Kohler, 2002); the other is conducting experiments to collect specific data sets. With both approaches, field scientists generally develop scientific questions from observable phenomena *in context*. Thus, the practice of close observation of nature is highly valued by field scientists (Eberbach & Crowley, 2009; Norris, 1985). Although the latter style involves experimentation, it is different from a laboratory setting in that there is rarely a 'control' for a field experiment. The design of the experiment and interpretation of the data, therefore, requires allowing for multiple changing variables. Weather, logistics, and other complicating factors may lead to on-site modification of the experimental design. This continuous revision of the experimental design and data collection process, typically with limited time and resources, requires field scientists to be creative problem solvers.

With respect to dispositions, often what initially draws people to field work is a love of nature. A person growing up with a penchant for bird watching might later become an ornithologist based on experiences that deeply connect them with their study species. Similarly, a person who enjoys the challenge of hiking steep mountainsides, the thrill of fishing or hunting, or the fun of camping, might have experiences of awe and wonder that motivate a lifetime of connection to the landscape (Wells & Lekies, 2006). The emotional connection to the outdoors is an inherent part of doing fieldwork. As Mogk and Goodwin (2012, p. 140) put it: 'The joy of discovery in the field is frequently described as a transformative experience.' In many cases, this connection to nature goes hand-in-hand with a taught wilderness ethic and a learned or inherent desire to preserve or protect natural spaces.

Nonetheless, an exhilarating or awe-inspiring experience in nature is not always filled with pleasure. Often, science requires a dedication to data collection that can involve drudgery, discomfort, or personal risk. A wildlife biologist must go to where the study species lives, making observations and measurements at times of the day, and under weather conditions, that may be inconsistent with physical comfort. A glaciologist must traverse difficult, treacherous terrain using specialized climbing equipment. Sometimes field sites are only accessible through long, arduous hikes on foot, carrying gear and equipment by backpack. Field scientists may encounter bears, rattle snakes, scorching or freezing temperatures, or endure downpours that obscure vision and make paths slippery and muddy. A field scientist must have the physical stamina and mental toughness needed to cope with such conditions, and still be productive with respect to data collection. Thus, field scientists value hard work, stamina, and perseverance in the face of adversity. An adventurous spirit must be combined with a commitment to the science, leading to perseverance despite discomfort, which is a critical component of the enterprise. Field scientists tend to mark this dedication to the science, despite the hardships, with a sense of pride. This 'badge of honor' builds community among field scientists.

Further, social interactions between science team members are, by necessity, more frequent and of longer duration than they are in the lab. Fieldwork often involves camping or staying in rough accommodations with other group members, sometimes for extended periods of time. It can mean needing a high tolerance for infrequent bathing, when showers are far away and rivers are inaccessible. Down-time is time spent with the same people as during work hours, with little time alone and little time to connect with friends and family back home. Field scientists must have a high tolerance for this close and prolonged social contact and must be able to manage relationships in a way that promotes good will and teamwork under stressful conditions.

In the following section, we discuss the context of the present study, paying special attention to how the program includes design components to manifest the normally tacit elements of a field science COP.

Context of study: the Girls on Ice program

The present study was conducted in the context of the Girls on Ice (GOI) program, developed by author Pettit. GOI brings a group of nine girls on a mountaineering expedition to environments dominated by glaciers with the specific goal of integrating wilderness experiences with field science. GOI started in Washington State, where girls study the Easton Glacier on Mt. Baker. In 2012, the program expanded to a second location, Gulkana Glacier in the central Alaska Range. Both program locations focus on recruiting girls from diverse backgrounds from across the United States (and in some cases internationally), and there is no cost to participate. The program focuses on the following features: (1) offering an immersive, authentic science learning experience; (2) providing mental and physical challenges; (3) providing leadership experiences; (4) building respect for the environment; and (5) leveraging an all-female environment.

Immersive, authentic learning experience

During the program, participants learn field science through authentic field practices, under the guidance of scientists. The scientific goals for these field expeditions are specifically designed to give the girls ownership of the scientific process. The girls design their own research investigation, including deciding on a question, designing an experiment, collecting data, processing and interpreting the data, and presenting their results to a public audience.

To prepare girls for this endeavor, instructors scaffold experiences over the first few days to model all aspects of the research process. Instructors begin with skills related to observation in context because it is such a vital skill for field science. Instructors teach those skills through art exercises such as gesture and contour drawing, which transfer to scientific observation of the colors and shapes of landscape features. Such exercises, combined with explicit discussion, detach the girls from preconceived understanding of landscape features, and are key to both asking new questions and to identifying misconceptions.

Next, the instructors build the girls' experimental design skills by guiding them through one to two hour-long 'instructor-inspired' experiments such as digging a snowpit and analyzing the characteristics of the different layers of snow or identifying and comparing abundance of various plant species in different locations. During these experiments, instructors solicit girls' ideas for each step of the experimental design. This process models the larger experimental design, data collection, and analysis the girls use during their own research investigation.

After the team returns from the field expedition and the girls are ready to communicate their research results, instructors guide them through the process of synthesizing their results into specific conclusions supported by evidence and designing a presentation that will communicate their ideas to a public audience.

Physical and mental challenges

The science in the program is conducted in the context of a challenging climb to a basecamp on or next to a glacier, then spending the next seven days camping and exploring. Just as the instructors scaffold research techniques and approaches, they also scaffold skill building towards a goal of climbing high on the mountain at the end of the week (on Mount Baker, for example, this goal is to climb up a glacier to about 3,000 m to the rim of the active volcanic crater). The girls are taught technical skills such as walking up and down steep snow slopes, self- arrest to stop a fall, roping together for safety, and navigating around crevasses. The instructors also teach the girls self-care techniques required to maintain the physical and mental stamina to spend up to 10 or 12 h climbing a mountain on the 'summit day.' In order to make visible the importance of mental stamina in conducting field work, instructors explicitly discuss that mental stamina is more consequential than physical strength in reaching goals.

Leadership experiences

In a field research team, many activities may be happening simultaneously; for example, data collection, equipment repair, scouting for new sites, cooking or camp management, or communicating with support people back in the nearest town. In addition, important decisions may need to be made at unexpected moments with only a subset of team members present. Further, different team members have different skills, and injuries or problems with equipment can affect the progress of the research. Because of this, successful field teams use a leadership and teamwork style in which each team member may take on different responsibilities each day and the job of the primary leader is to distribute effort, leadership responsibilities, and decision making among the team based on each persons' skill and experience level. Often, then, the leader may train an inexperienced person so that they can step into a needed role. A 'top down' or 'micromanagement' leadership style, on the other hand, results in ineffective science and inefficient data collection. During the GOI program, the instructors model this distributed style of leadership both within the instructor team and among the entire field team.

The instructors emphasize, through modeling and open discussions, that leadership is not about telling others what to do or about being the most experienced or most knowledgeable in a group. Leadership is taught as akin to a facilitator position that requires putting the goals of the group ahead of personal goals and requires paying attention to everyone else's needs as well as one's own. The girls are given an opportunity to observe good leadership, understand the role of team members, and practice both through a rotation of responsibilities throughout the expedition. Each day, every girl is given a responsibility (e.g. team leader, team navigator, cook, water collector, journalist). Instructors give guidance, support, and encouragement so each girl can be successful with each responsibility. Each girl has to step up to one of the 'leader' positions during the expedition; likewise, each girl has to be a contributing team member on other days. The intent of this sharing of responsibility and practicing teamwork and leadership is to help the girls understand and immerse themselves directly into the *culture* of field science.

Respect for the environment

Instructors teach the 'Leave No Trace' ethic formally on the first day of the expedition, followed by regular reminders and discussions as the girls interact with the environment each day. Self care is a critical and overlapping concept with leave no trace, especially when it comes to human waste. Many participants have never had to relieve themselves outside and the outdoor community standards for human solid waste are typically not well understood even by active outdoors people. Because glaciers and the alpine environment have limited capacity to decompose material, the expedition team follows the highest standard for human solid waste and uses specially designed bags to collect waste, which the girls carry back down the mountain to a waste disposal site. Because of this high standard, the instructors spend additional time teaching proper use of these bags and encourage the girls to see this subject as open for discussion rather than a private matter. Frank discussion and openness is intended to make these and other aspects of living in a field environment *explicit* to participants.

All-female team

Girls on Ice maintains a team, including instructors and volunteers, of all female people (or who identify as female). The all-female composition is intended to highlight female role models in science and to relieve some of the social pressures that might constrain girls in fully participating in the experience if it were mixed gender (e.g. concern about clothing and other aspects of physical appearance). In particular, the role models are all practicing scientists (and some artists) who have experience and comfort with a wilderness environment.

Methodology

Participants

The GOI program recruited participants through an online application process. Girls were chosen based on diversity in ethnicity, background (e.g. a range of socioeconomic backgrounds; family situations such as foster care; home school, etc.) interests (science, art, etc.), personalities, and wilderness experience levels. Annually, eighteen girls were picked for participation in the two expeditions: nine for the Washington expedition and nine for the Alaska expedition. We offered enrollment in this study to all participating GOI girls over a three year period, encompassing six expeditions. All of the girls who participated in the expeditions opted in to the study; however, one girl later declined to be interviewed, for a total of 53 interviews in our final sample. Self-reported ethnicity was: 20% Alaska Native/American Indian; 2% Black/African American; 2% Native Hawaiian/Pacific Islander; 43% Caucasian; 18% Hispanic/Latina; 15% Mixed race. The mean age of participants was 16.3 years.

Data collection and analysis

To answer our research questions, we conducted semi-structured, post-only interviews that focused around what girls learned during the program, ideas about science and leadership, self-concept around physical abilities, career goals, and environmental attitudes. The interview protocol consisted of 10, multi-part, open-ended questions, including a number of retrospective questions that asked participants to compare and contrast their views from before and after their expedition. For example, we asked: ‘Describe how you feel about science.’ We then followed up within this multi-part question by asking: ‘Has Girls on Ice changed how you feel about science? If so, how?’ and ‘How did you feel about science before participating in Girls on Ice?’ We interviewed girls face-to-face on the last day of the program. On average, the interviews lasted 15 min, but duration ranged from 8 to more than 35 min. Each interview was audio recorded and transcribed. One interviewer conducted all the interviews. Three years of interviews provide triangulation across six expeditions, with 53 interviews.

With respect to data analysis, we used a directed qualitative content analysis approach (Hsieh & Shannon, 2005; Merriam, 2009), in which our initial coding scheme derived from theory and was refined through revisions that captured characteristics within the interviews; in this case, from the conceptions of a community of practice of field science. While recognizing that the three elements of a COP, joint enterprise, mutual engagement, and shared repertoire, overlap and interact, there are nonetheless ways in which these elements are distinct. We thus used these three areas as an initial coding scheme, with respect to a field science COP. Our codebook was developed by two of the authors (Carsten Conner and Perin) through extensive discussion and coding of sample text. A single code was applied exclusively to each excerpt; in the few instances when multiple codes could be applied, we discussed and redefined the code. Next, the same two authors independently applied these initial codes to transcripts; inter-rater reliability was calculated as pooled Kappa ($k = 0.84$; De Vries, Elliott, Kanouse, & Teleki, 2008). We provide a description of each code, and examples, in Table 1. We applied code to excerpted text segments using Dedoose. During subsequent rounds of analysis, we applied subcodes to the excerpts that more specifically reflected how the three COP elements were manifesting in the GOI context. These subcodes were derived from segments of the main codes' definitions. These subcodes included items such as wonder and awe; self-efficacy; views of scientists; new ideas about the enterprise of science; teamwork and bonding; and learning core practices of field science. We then looked for relationships between these subcodes and grouped them into the themes we describe in the findings, which relate specifically to the enactment of field science in this setting.

Findings and discussion

During analysis, distinct themes emerged with respect to the theoretical dimensions of joint enterprise and mutual engagement. However, because the three elements of a COP interact by definition, some themes that we describe in the following sections are more integrated across dimensions. In particular, the two themes that emerged with respect to 'shared repertoire' were informed heavily by text coded as 'joint enterprise' and could more specifically relate to aspects of the domain of field science. We distinguished 'joint enterprise' and 'shared repertoire' when possible through the first-hand nature of a girl's experience, and as such, the knowledge became part of a repertoire of practice. We discuss the findings, with respect to what the girls learned about a field science COP, and the significance of this learning, below.

Table 1. Descriptions and examples of codes.

Code	Description	Examples
Joint enterprise	Participant expresses broad views related to ideas and dispositions about science (including *where* science takes place, and *what* science, particularly field science, is 'all about'); and behaviors appropriate to field scientists	*'I never really thought about field science as much. I was kind of thinking about people like in labs doing research and things and now I think scientists are that but then they're also I think they're more just like people that look at the natural world and are more interested in observing what they're seeing.'* *'… And so now when I think of a scientist I think of women generally now, and I think about them going out and exploring and asking questions, and like in school you learn like the methods, and then like okay, you got to do it this certain way. And doing this is like oh, it's field science like forget all those rules. So it's kind of like this new free form creative way of being a person.'*
Mutual engagement	Participant discusses development of bonds between student-student or student-instructor or practices that maintain the community of the expedition	*'We all had something to offer, and I know this is more of a team thing, but we all had like this leadership in us, we all took the lead of some aspect, and it was just so weird. I've never been in a team full of leaders, that's just crazy … it was like we all had something to give.'* *'… And it's just a fact that you have a strong support system and that we all had each other to lean one. When someone was down, we were immediately there to pick them up and show them that you can do this. And I feel like if all women did that in a sense in general it'd be crazy just to see around the world.'*
Shared repertoire	Participant discusses field science skills and physical ability (climbing, observing, etc.) in the context of a personal history of participation (seeing, donning gear, taking measurements, etc.)	*'My physical abilities, yes. Oh my goodness, I climbed a freaking mountain. Yeah, I mean I could never see myself climbing that or on Crampons.'* *'So I was carrying heavy packs and just like stuff I never thought I would do, and yeah it tested me physically, but I did it. I mean you can see like all over the place I fell. [referring to bruises] … But now it's, it was really good. I feel more comfortable on the mountains and on the ice, and in a way I never thought possible. Like the first day I didn't tell anybody. I was like panicking every time we went down a hill, because I thought I was going to fall off and die, but I didn't, and now it feels good. Now it feels like fun.'*

Joint enterprise

Theme: science is not just about the laboratory

The joint enterprise aspect of a field science COP involves developing ideas about what the COP is 'all about.' In the interviews, the girls explicitly discussed how taking part in a field experience opened up a new world of science for them. Many did not previously realize that field science existed, and had a very sketchy idea of what it entailed before participating. The girls overwhelmingly reported they thought science was done 'at a desk' or 'in a lab' before participating in the GOI experience, and reported that their views about both science and scientists broadened. Their new ideas about science were often consistent with a COP of field science, in that they learned that field science was about observing and the direct experience of nature and natural phenomena, and that actually being in a place to experience such phenomena was critical for developing domain-related knowledge. As one participant said:

> 'So it has been a big impact and actually like my main project with my group focused on the climate change on the Easton glacier and over 100 years the amount it receded it just blew my mind. And global warming I think one of the big like, I don't know, the big ways that people measure are through glaciers and **actually be on one** [Emphasis added] … '

Girls also reported surprise at how passionate the scientists in the program were about their work, that their job was inseparable from personalities and everyday behaviors, as illustrated by the following examples:

> 'When I think of a scientist now, I just think of somebody who is creative, somebody who is questioning all the time. Somebody who is really passionate about something that they want to learn.'

> 'It's not just an occupation, it's like a lifestyle that they have. That was new to me … . Being able to appreciate your work on such a big scale, like on a spiritual level because your work is so amazing being surrounded by nature and stuff.'

Participants also reported personal excitement about how field science affords the opportunity to work outdoors, and to travel. For instance, one girl talked about field science as 'the cool stuff' as opposed to studies in the lab, while another talked about how a career in field science would mean the chance to 'travel and not be stuck in a lab or an office.' Several other girls emphasized that travel would be an advantage of having a career in field science. These girls were noticing that aspects of science careers that were usually invisible in school-based science appealed to parts of their personalities that they did not usually associate as relevant to a science career.

Seeing firsthand what field scientists do, as well as interacting with field scientists who work in exciting outdoor settings appeared to resonate with the participants, many of whom self-identified as adventurous or athletic. Thus, views of what science is 'all about' became more aligned with how the girls view themselves. The importance of this point with respect to the girls' learning (from a sociocultural perspective) is particularly underscored when contrasted with common ideas about science documented in the literature, such as the idea that scientists engage in rote work, often alone, and have an unattractive lifestyle (e.g. Miller, Slawinski Blessing, & Schwartz, 2006). In contrast with these widely held views, the girls participating in the program were noticing exciting, adventurous aspects of field work that linked to elements of their own identities.

Mutual engagement

Theme: leadership is about taking care of the whole team

With respect to mutual engagement, an emergent theme coalesced around what it means to lead people in the context of an expedition. When asked 'what does leadership mean to you,' after participating in the program, participants generally expressed a view of leadership that was much more democratic and participatory, rather than directive or top-down. A number of girls expressed that, prior to the program, they viewed a leader as 'the one who lead[s] the pack,' or 'a person we need to follow.' After the program, many girls expressed that 'anyone can be a leader' and that even soft-spoken or quiet individuals can have a role in leadership. Many of the girls talked about a good leader as a person who took into account the needs of the team and made others feel encouraged, safe and confident. Some quotes are illustrative:

> 'Leadership is being confident in what you have to share with other people, and at the same time, caring about their safety and pointing them in a better direction.'

> 'It's [GOI] made me realize I've grown more confident in being a leader. I found that I'm able to not necessarily suppress my emotions but be able to put the others like in the group's necessities before maybe my own. Not that mine aren't important but that something critical happens in the group and I can be there ... .'

At first glance, these ideas about leadership, particularly in the context of an all-female group, might be seen to underscore a traditional patriarchal idea that women are 'caretakers,' needing to subsume their needs and desires to others (e.g. Kaplan, 1994). However, these ideas are consistent with dominant paradigms of leadership such as the transformational approach (National Research Council, 2015) and with practices needed in a field science COP, as discussed above. Mutual engagement in a community of practice involves learning how to work together in ways that maintain the coherence of the community (Wenger, 1998). In the case of a field science COP, which involves physical challenge and extended, close social contact in challenging conditions, it is essential that COP members look beyond themselves and think about how actions impact the rest of the group. Safety is paramount, and learning to support others, physically and emotionally, can help maintain the community fabric, which leads to more effective and efficient research efforts. Thus, these views that GOI participants express are consistent with field science COP norms. It has been documented that girls prefer to work in ways that are more relational and social (rev. in Brotman & Moore, 2008); to the extent that the girls described here ascribe to that preference, these new ideas about leadership might serve to help make field science COP norms more self-referential.

In what ways did these changes in ideas about leadership come about? Several girls discussed the leadership roles that Girls on Ice set up as being important to formulating their enhanced ideas about leadership, along with being able to look to the instructors for cues about how to act. With respect to the leadership roles, several girls discussed how being in charge of one aspect of the camp's daily activities let them 'try out' leadership. This explicit acknowledgement of 'trying on' new roles to see if they fit, and developing new ideas about what it takes to be a leader, are consistent with the new possible selves theory (Markus & Nurius, 1986), illustrating a pathway to 'becoming scientists.' In addition, one participant talked about how the leadership roles made it less 'scary to step up and help someone,' a further indication that the leadership roles eased the pathway to trying on new ideas about leadership in the context of a field science COP.

With respect to looking to the instructors for cues about how to act, many participants talked about how specific instructors were role models to them with respect to how a leader should behave. Specifically, when characterizing the instructors as leaders of the expedition, words like 'supportive' and 'caring' often emerged. As one participant said:

> 'I was shocked to see all of these women who are already aware of what true empathy was and how to communicate in a healthy manner. Like, there's no hostility, there's no patronizing, no "I'm better than you." There's respect, but it's a kind of respect, it's not like authoritative respect, it's like, "you guys you're so cool, I respect you from the bottom of my heart." I think that's a better kind of respect. I think it's like earned, and it just means a lot more.'

In addition to these characterizations, the girls often expressed ideas about their instructors as strong, capable, and good role models in science. The quotes below are illustrative.

> It [GOI] introduced me to other women who are in the professional field who are scientists, like Megan and Casey, because sometimes you don't see a lot of women, and they're like professional ladies who actually do science for a living. So that was kind of inspiring because they're super down to earth and super nice and they're really smart.

> "I saw some really strong female leaders at Girls on Ice."

These ideas with respect to role models are consistent with the literature, which reports that youth often identify with scientist role models with whom they have personal connections and who have warm personalities, in addition to science expertise (Buck, Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008; Carsten Conner & Danielson, 2016).

Shared repertoire

The shared repertoire aspect of the field science COP involves developing a common resource based around domain-specific skills in the context of a personal history of participation (seeing, hiking, donning gear, taking measurements, etc.). The two themes that emerged under 'shared repertoire' (field science requires physical perseverance and field science builds a connection to nature) were closely intertwined with 'joint enterprise.' That is, in both of these themes, girls reported development of dispositions and ideas consistent with the *domain* of field science, and that these changes came about through their *personal history of participation*. We discuss each theme separately below.

Theme: field science requires physical perseverance

A strong theme that emerged with respect to practices associated with a field science COP was related to the physical aspects of the expedition. Almost every participant discussed the experience of participating in a challenging mountain hike, specifically with reference to 'being nervous' before the hike, feeling unsure about whether or not they could do it, hitting emotional plateaus during the hike, pushing through and past boundaries such as feeling cold or tired (personal history of participation), and feeling rewarded by successfully pushing those boundaries (domain-related rewards). One participant said:

> 'Most memorable, probably after like the big hailstorm we had and everybody was soaking wet and freezing and cold and the next day CeCe wanted to go do our science projects and nobody wanted to go. We just wanted to stay in our tents where it was like the only warm place we had. But then like CeCe was my science leader so she was like, "oh, let's go climb the nunatak" [an isolated rocky peak] and I was like in my head I was like "I don't want to. I just want to go back down and go back to bed," but then I was like, "okay, let's do it." And then we got up to the nunatak and it was clear and it was beautiful. And it was warm and it was like one of the most beautiful things I've ever seen, seeing the whole valley. It was really awesome. I don't think I would change anything for that one moment. It was beautiful.'

In this passage, she is acknowledging that hard work and physical perseverance is sometimes necessary (shared repertoire) in order to have the types of unique and awe-inspiring experiences that often occur while carrying out field work (joint enterprise). In numerous cases, the girls discussed additional types of personal rewards, such as feeling tougher and more confident as a result of summiting the mountain, or realizing that they were 'stronger than I thought.'

The physical aspects of such an expedition, while certainly a core practice of field science, are not enough on their own to engender a connection to a field science COP; however, the experience of hiking in the context of 'doing science' appears to give the girls a good sense that such activities are a necessary part of field science. Climbing up to the nunatak, in the example above, meant emerging from the warm comfort of bed for the sake of data collection (with the added benefit of a majestic view).

In sum, while girls generally self-selected into the program with a strong sense of physical ability, the program afforded new challenges and the opportunity to work through emotional and physical barriers that are part of the *context* of field work. They 'become tough' by experiencing authentic, challenging conditions. This affordance *combined with science activities* helped them see new possible selves as a field scientist.

Theme: field science builds connection to nature

In a field science COP, it is tacitly recognized that significant, first-hand experiences with natural settings and phenomena in the context of research often lead to emotional connections to nature, as well as greater awareness about how human actions might affect those systems. The girls in the program appeared to develop some of these domain-related dispositions (joint enterprise) through having direct experiences with the glacier (shared repertoire). In many cases, the girls talked about how climbing the glacier and seeing the recession lines led them to think more deeply about climate change. One girl used a poetic approach to describing her connection to nature after experiencing the glacier:

> 'I wrote in my journal again, "Take your ice to our journey. Let it travel through the mountains, down a valley, swim through a river, and fly or hover over the sky, crawl to the ground and soak in the depth of your soul." So I feel like you can go high up and low down, or just in the surface to know what really needs attention and what's going to be the impact in the future generations.'

Another said:

> 'Before I wasn't really that interested in the environment and just like preserving the environment and the natural world. Like the way I thought of it before was just like recycling basically or not littering but now I feel like it's more than that because something I learned with Girls on Ice is how much the glaciers are receding even just like the past years you can see really big differences … . So now I think of it more just like on a lot bigger scale and how it affects us.'

Several girls also discussed the 'leave no trace' philosophy and how that raised their awareness of human impacts and the need to preserve the environment. They talked about how having to 'poo in a wag bag' or pick up litter in the campsite even if it was left behind by a previous visitor, led to these changes. As one participant put it:

> 'We did the thing where like leave no trace and so like I never realized how much I impacted the world if I didn't pick up a little piece of scrap trash. And now like that they like made it so big and I'm like I can really change the world just because I left a little piece of trash and I was too lazy to pick it up. And so yeah, like now I feel like I'm going to tell everybody pick up your trash.'

The connections between significant outdoor experiences and feelings of environmental stewardship are well documented in the environmental education literature (e.g. Chawla & Cushing, 2007; Farmer, Knapp, & Benton, 2007; Palmberg & Kuru, 2000). The emergence of this theme lends further credence to the importance of participating in significant nature experiences for developing an environmental ethic. Further, the design features of GOI, in emphasizing a leave no trace philosophy, combined with attention to engaging girls in a personal experience of field practices, specifically led to the dispositions developed here.

Summary and implications

In this paper, we set out to study what girls learned about a field science COP during participation in the GOI research apprenticeship program, particularly with respect to elements that are normally tacit rather than explicit. The emergent themes illustrate that girls learned both explicit and tacit practices and ways of being that are associated with being a field scientist. Members of a COP build and maintain social relationships (mutual engagement) through common experiences (shared repertoire) and events around a particular joint enterprise, or domain—in the case of the Girls on Ice program, the domain is expeditionary field science around glaciers. The shared repertoire of a COP includes shared tools, concepts, discourses, and ways of doing things that are learned through personal participation. In the case of GOI participants, girls learned a number of field science COP practices that would normally be considered explicit: observation *in context* and the development of research questions, for instance, are explicit practices of field science. Other outcomes associated with these more explicit aspects of field science included an increased sense of connection to the environment, which is in turn a more tacit disposition in a field science COP. Further, other dispositions and ways of being in the field, such as being physically tough and persevering in the face of emotional and physical challenges, being passionate about your work, and taking personal steps to ensure the success of the whole team, are also tacit, rather than explicit, but are vital to the success of a field endeavor. Learning about and experiencing these elements of a COP resulted in new ideas about leadership, self-confidence in the face of challenges, and new ideas about what scientists are like—that is, it provided the grist for new possible selves with respect to field science.

A few points come to the fore when thinking about the analysis as a whole. First, it is clear that the girls acquired new knowledge and attitudes about science and scientists, replacing stereotypical images with more accurate representations. Many girls reported that, prior to the program, they thought that science was done mostly at a desk and was fairly dry and clinical rather than creative. Participating fully in a field science experience under the tutelage of authentic scientists who love their work allowed them to see a whole new way that science is done, through direct observation and inference (science skills) related to phenomena and places outdoors. Further, they started to link traits such as passion and creativity with science and scientists. Such attitudinal markers are broadly thought to be important in pursuit of science pathways over time, and thus, are important indicators of the girls' science learning in the sociocultural sense of the word.

However, almost more important in terms of the girls' connection to field science was the ways in which the girls responded to normally tacit elements of the field science experience, such as leadership, teamwork, and adventurous and physically demanding experiences in a natural setting. While these elements are not unique to field science, they are a *critical and core part* of field science. Girls' feelings of wonder, awe, and self-efficacy were most often linked with these elements, illustrating their affective power. Further, the act of making these practices explicit and linking them to authentic science practices (e.g. observation, data collection) was important for the girls. In sociocultural models of learning such as the cultural learning pathways model (Bell, Tzou, Bricker, & Baines, 2012), the place where learning occurs, the positioning of the learners, and the discourses and other actions taken within the learning setting interact in inextricable ways to produce specific learning outcomes. Thus, while the we feel that the act of making explicit the normally tacit elements of a field science COP was powerful and important, it would not have the same impact with respect to attitudinal outcomes around science if not enacted within the context and place of a field science expedition.

Several design features of the program emerged as important for the girls' connection to the COP, and should be considered by others when designing research apprenticeship programs. First, the scientist instructors were knowledgeable, relatable, and personable—factors that have previously been documented as important to being perceived as a role model (Buck et al., 2008; Carsten Conner & Danielson, 2016). But beyond that, the scientists shared their enthusiasm and passion for their work, including painting a picture of field science as a way to travel and see the world. Second, the structured leadership roles, in which participants made navigation decisions, cooked meals, or wrote in the team journal showed how their individual actions impact the whole team. These roles appear to have been essential for the girls' understanding the importance of maintaining the community fabric in the context of a field expedition, and in developing new ideas about leadership that can carry over to other areas of their lives. Third, experiencing challenging physical conditions in the context of field data collection allowed girls to have an authentic field experience and build confidence in their abilities. Fourth, promoting the leave no trace philosophy, combined with having awe-inspiring nature experiences, was impactful in developing an emotional connection to nature and strengthening an environmental ethic among participants. Finally, the instructors make a conscious effort to explain to the girls how each of the activities and the design of the team structure contribute to making the expedition a success—that is, they consciously make these normally tacit elements explicit to the participants. Taken together, these features allowed field science to become more self-referential and relatable to the girls during the expedition. However, while many of the design features can be linked directly to an increased sense of connection to a COP, it is not clear how the single-gender format might be different for the girls' learning compared to a mixed-gender format. While several girls commented on the friendships they made with other girls in the program and expressed that the experience would have been different with boys present, it is not clear, for instance, how that played in to the development of their conceptions of a field science COP as a whole. Future studies should attempt to disentangle these factors.

The COP-related outcomes documented here come to the fore when we consider the negative ideas about science and scientists often held by girls (e.g. Archer et al., 2012; Baram-Tsabari & Yarden, 2011; Brotman & Moore, 2008). Providing girls an expansive understanding of the skills needed and types of people who can contribute to the scientific enterprise beyond a laboratory setting counters gendered expectations of women in science, perhaps ultimately broadening participation. In particular, working alongside 'tough' female scientists who are also relatable may open new ideas about 'appropriate' careers for girls.

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