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ARTICLE

Leaving the laboratory: Using Field Science to Disrupt and Expand Historically Enduring Narratives of Science Teaching and Learning

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Abstract

Despite efforts to help youth form better connections to the natural world, many recent science initiatives (such as the *Next Generation Science Standards*) privilege laboratory science over field science, thus reinforcing an image of science that is placeless and individual. To better understand the impact of field science on youth, we examined youths' experiences and participation in field science across two separate research projects, one of which was associated with a school (the "moth project") and one of which occurred in an informal setting (the "herpetology project"). We argue that field science, which is not given the same attention in NGSS as science derived from laboratory work, might disrupt and *expand* science teaching and learning. By expand, we mean that field science offers novel opportunities for youth and educators to develop and engage in practices that disrupt persistent sociohistorical narratives of how science work is accomplished, and that emphasize the cultural production of knowledge in a setting by making public the meaning making that is negotiated in a community. Such expanded moments differ from many experiences in which youth and educators expand typical ways of knowing and participating valued across many formal and informal settings.

Keywords Field science · Science practices · School science · Informal science

> I'm gonna bring in the biggest haul tomorrow. I got this perfect spot in my backyard with a bunch of trees, and I bet there are a ton of moths hiding. Tomorrow, when you see me, I'ma have this box [a tupperware container] stuffed with moths. (Crystal, moth project participant)

> I wanna go home and do some studying and look at some more detailed maps than what you might see in a beginner's field guide and see if I can find which species are in my home town that maybe nobody's ever found before because, you know, it's not a big scientific county. If I can find something that nobody has

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ever found before, that would be really cool to add to county records. (Jason, herpetology project participant)

Crystal and Jason, participants in two separate field science projects, describe their experiences doing field science in ways that evoke their wonder, discovery, and ability to add to official knowledge bases about biodiversity in their local areas. In essence, they are both describing an aspirational "good day in the field," a colloquial phrase used by field scientists to describe their work at the end of a successful day in nature. When doing field science, what counts as a "good day in the field"? Is there good science to be learned from a day in the field? These questions prompted initial musings between the two authors who conducted separate research projects centered on youths' participation in field science—that is, science work occurring in nature and beyond the walls of formal laboratory settings. Stroupe and colleagues' project was taught during a sixth grade school ecology unit in which youth designed and conducted research about local moths (order *Lepidoptera*), while Carlone and colleagues' project engaged high school youth in field ecology studies of reptiles and amphibians (herpetofauna or "herps") during summer enrichment programs and out-of-school weekend excursions.

Despite pronounced differences in our projects—different youth populations, settings, species, and study designs—we discovered a foundational goal for youth was to experience "a good day in the field," and this goal was reflected in common and compelling shared meanings. Youth in both projects expressed enthusiasm for finding animals in their natural habitats, described feelings of accomplishment and elation when they produced a "good find" for the group, shifted from disgust to curiosity about animals they initially found loathsome and/or scary, surprised themselves by trying out novel scientific practices, got recognized by others as smart and successful in ways that are absent in many science classes, and expressed strong motivation to learn more about and protect the species they studied in the field. In short, a good day in the field seemed to both of us to be *different* than a good day in the school science classroom or lab, and yet *surprisingly similar* across our two projects.

Surprisingly, research about field science in relation to youth's learning opportunities is underexplored in science education. Therefore, we wondered if field science practices provided youth with more expansive meanings of and experiences with science than they might typically encounter in typical school science classrooms. In particular, we are concerned with boundary guarding practices in typical science learning settings that unnecessarily perpetuate narrow definitions of science, scientific knowledge production, and science expertise (Bang et al., 2012). Even school science in the USA that is enacted in light of the *Next Generation Science Standards* (NGSS) (Achieve, Inc., 2013) privileges knowledge and practices derived from laboratory science (Carsten-Conner et al., 2018; Wyner & Doherty, 2017). Furthermore, historically enduring ways of enacting school science positions students as "technicians" by completing activities with pre-determined outcomes and by deferring to those positioned by society as experts to make and verify knowledge (Addelson, 1983; Stroupe, 2014; Dillon et al., 2016; Medin & Bang, 2014). School science too often shortchanges youths' experiences (Carlone et al., 2014), marginalizes their contributions and ways of participating (Warren et al., 2001), promotes competition over collaboration (Carlone et al., 2014) and compliance over curiosity (Archer et al., 2017), and undervalues the importance of emotion in scientific knowledge production and learning (Gilbert & Byers, 2017).

1 Problem Framing

We propose that field science, which is not given the same attention in NGSS as science derived from laboratory work, potentially offers three opportunities to disrupt and expand boundaries of science teaching and learning. First, youth, educators, and researchers can co-develop science practice communities in which definitions of expertise are expanded. By expanded, we mean that youth are engaged in epistemic responsibilities, such as knowledge production and practices, from which they are purposefully restricted in many other science settings (Stroupe, 2014). Second, field science allows youth to experience science as a collective and community endeavor, rather than an individual enterprise. Third, field science offers youth opportunities to feel the awe and wonder of scientific work that is often devalued in other science settings (Carlone et al., 2016). This paper represents our efforts to systematically examine these initial insights about the potential affordances of field science learning settings across our separate projects. To do so, we ask the following:

- How did scientific expertise come to be defined in each setting? How did youths' participation in knowledge production expand definitions of scientific expertise?
- How did scientific knowledge production come to be framed as a community endeavor in each setting?
- How did youth experience the awe and wonder of scientific work while engaged in field science?

2 Background and Framing

In this section, we first describe NGSS. Next, we differentiate between field science and laboratory science, and situate the importance of field science in larger conversations about science standards and the disciplinary work privileged in classrooms. Second, we consider how field science might be used as a site for teaching and learning. We conclude by considering how engagement in field science might expand the practices and roles of youth and educators across learning settings.

2.1 The Next Generation Science Standards

Beginning in 2007, multiple policy initiatives in the USA aimed to provide consensus around science learning expectations in science classrooms. The NGSS emerged from meetings convened by the National Research Council in which researchers and practitioners discussed how children think about the natural world, the knowledge production practices of disciplinary work in science and engineering, and how classrooms might serve as a site of new forms of science learning (Achieve, Inc, 2013). Such conversations stand in contrast to the science learning that is typical of many American classrooms that stress vocabulary acquisition, the development of procedural skills, the use of labs that have known outcomes, and the reproduction of textbook explanations (Abrahams & Reiss, 2012; Berland & Reiser, 2009; Jimenez-Aleixandre et al., 2000; Weiss et al., 2003).

2.2 Practices of Field Science

To understand how field science is situated within larger conversations about science standards and the disciplinary work privileged in classrooms, we offer a definition: field science is science that occurs anywhere in the natural world outside a laboratory setting (Vetter, 2011). For some, the distinction between field science and laboratory science may seem arbitrary. After all, field scientists and laboratory scientists both pursue knowledge-building endeavors, publish in journals, and are awarded the same degrees based on their professional training experiences. However, field science and laboratory science have histories and practices that differ. Historians of science and field scientists note that laboratory science achieved a "high" epistemic status in society, whereas field science was thought of as messy and uncontrollable, and thus was positioned with low epistemic status (de Bont, 2015; Ríos-Saldaña et al., 2018; Vetter, 2011). Therefore, field scientists had to simultaneously invent their practices while working to convince society that their version of science could produce knowledge as valuable as laboratory science.

Field scientists achieved their goal through two main avenues: embracing the "places" in which science occurs, and by developing unique practices to engage in the place-based work. First, laboratories achieved high epistemic status by aiming to produce universal placeless knowledge (Kohler, 2007; Vetter, 2011). The purpose of dissociating place from practice was to bound the focus of science to the knowledge under construction, rather than "confound" research by noting the idiosyncratic features of individual laboratories. Thus, laboratory science aimed to conduct controlled experiments in sterile settings to make claims about how the natural world operates under conditions that humans prescribe and maintain. Field science, however, is inherently linked to the specific geographical place in which science is conducted. Thus, the environmental and physical features of a place are explicitly part of the knowledge produced, rather than remaining unmentioned and devalued (Vetter, 2016). Field scientists, then, note that their knowledge claims have equal authority to those made in laboratories because they acknowledge *where* the science was conducted, and embrace that they examine phenomena in the natural world under conditions that nature itself sets and maintains.

Second, given the "placelessness" of laboratory science, the valued practices should look similar (though not always exactly the same) across sites, regardless of physical location. Field scientists, however, negotiate practices within the limits that natural settings permit. Several historians of science (de Bont, 2015; Kohler, 2007; Vetter, 2016) provide examples of field science practices that are inherently bound to the natural world, such as the following:

- Data collection techniques—field scientists engage in extended ventures into the world to collect data, such as surveys, expeditions, and excursions. The purpose is to revisit the same place to first know about the unknown, and then to track the known over time to see if/how/why it changed.
- Using localness—field science leverages localness (including people) to make knowledge claims. In addition, the purpose of research is to make knowledge claims at increasingly large scales based on local knowledge—scaling up by looking at data across sites.
- The materials and tools—the equipment used by field scientists is often "low tech" compared to laboratory science. Such equipment is often adapted based on the needs

and allowances of the local setting and the specific quirks of collecting data in that setting.

- Daily journals—field scientists, working in specific places, keep detailed and lengthy accounts of local conditions, such as weather, and number of specimens captured and catalogued.

Note that for each large set of practices, field scientists are intimately involved with the local setting, and rely heavily on local experts, with knowledge about the land and flora/fauna, to engage in the work.

2.3 The Importance of Field Science

Given the definition and features of field science practices, we argue that field science offers two important features that broaden the scope and purpose of science work beyond research that occurs solely in laboratory settings.

First, field science requires a different epistemic stance about knowledge production than laboratory science (Mogk & Goodwin, 2012; Vetter, 2016). As Kohler (2002) argues, the embrace of place by field science marks a purposeful effort to push back against the privileged view of laboratory science as placeless (Latour, 2018). A field scientist's persistence at a place over time enables a science that prioritizes commitment to a location, to observing change, and to becoming knowledgeable about features that may be invisible to others. Field scientists also argue that physically engaging with a place—traveling to sites where flora and fauna exist, rather than bringing them back to a human-created artificial setting—enables a deeper understanding of how and why the organisms function in a larger ecosystem. Field science, then, places epistemic value on data and claims that originate in, and describe, natural places.

Second, success in field science can defy historical definitions of epistemic status—i.e., whose knowledge and expertise get positioned as legitimate. For example, field scientists do not always carry traditional university credentials. Joseph T. Collins was a herpetologist at the Natural History Museum at the University of Kansas for 30 years; he had an Associate Degree in Arts with a major in zoology from the University of Kansas. As a nationally known, well-published herpetologist, Collins was among the founding group of the Ohio Herpetological Society, comprised of serious amateur herpetologists. The group began publishing a journal and newsletter and, in 1967, became one of the primary international professional organizations in the field—the Society for the Study of Amphibians and Reptiles (Willhite, 1999). That the efforts of amateurs (some of whom were teenagers at the time) became formalized into a well-recognized professional organization is a powerful example of broadening of historical notions of scientific expertise.

Field science also hinges on scientists partnering with local experts. By local experts, we mean those without extensive formal training in professional science practices through a university that might confer an advanced degree (Vetter, 2016). Since field scientists cannot be everywhere at once, they have to recruit, train, and rely on local experts to help them engage in rigorous research. While local experts are not often recognized by *society* as full scientists (though Collins, and other herpetologists, such as John Groves and Jeffrey Beane are important contributors to that specific field), field scientists can position local experts as invaluable to their work by supporting them to collect data, make methodological recommendations, and have the trust to identify and classify samples from the field (Vetter, 2016). Given that scientists rely heavily on local experts to engage in and shape their distinct epistemic practices, field science offers an intriguing perspective on enabling those who are typically excluded from science to have a stronger voice in shaping science practices and in contributing to the field's collective expertise. Across our studies, we wondered about youths' role in field science given that they are typically excluded from knowledge practices and expertise in science.

2.4 Field Science Opportunities for Educators and Youth

Given that credentialed scientists work with local experts on work that is complex, technical, and often invisible to outsiders, field science offers a unique opportunity for teaching and learning. For example, many university-based scientists used field work as a primary site of instruction for graduate students. For example, French zoologist Alfred Giard worked alongside students to study tide pools. Giard often placed his work station in the same room as students so that they could observe him work, and so that the students could feel as though they had an important role to play in the knowledge generation process. Giard also disrupted the notion that field work was for the junior and inexperienced students—field science was not a low status operation; rather field work allowed people to see animals in their natural habitat (de Bont, 2015).

In addition to a focus on student training, prominent field scientists advocated for K-12 teachers to visit field stations as a form of professional development—Vetter (2011) calls this the symbiosis of research and pedagogy. For example, Louis Agassiz, the Harvard biologist, wanted teachers to visit his field courses as early as 1872 so that they could introduce such science to their students (Bensen, 1988). Otto Zacharias, a German zoologist, encouraged teachers to visit a field station in Plön so they could learn about research and natural history, thus allowing teachers to engage in similar work with students (de Bont, 2015). In another example from 1909, the Mountain Lab, associated with the University of Colorado, hosted teachers for 3 weeks as they were in town for the National Education Association meeting in Denver (Vetter, 2011). In each example, field scientists attempted to show K-12 teachers that field science offered science knowledge and experiences that textbooks could not capture. While such efforts can be found in history, missing from historical analyses is the research about how youth and educators participated in field science, and how such participation impacted their understanding of science practices and expertise.

2.5 Conceptual Framing

We argue that science educators do not fully understand what field science might offer K-12 youth in terms of reimagining learning opportunities despite multiple reforms efforts aimed at engaging youth in science practices (Carsten-Conner et al., 2018). Given the expansive view of expertise, the practices, and the opportunities of field science for educators and youth described above, we propose that engagement in field science might *expand*, rather than constrain, the practices and roles that youth and educators shape and take up across learning settings.

This notion of expanding learning opportunities emerged as we considered potentially novel meanings of scientific knowledge, practices, and legitimate participants that are valued in field science. Schooling's remarkably intractable history of participation, or the "persistent grammar of schooling" (Tyack & Cuban, 1995), coupled with cultural meanings of science that position it as a body of knowledge and/or a constellation of practices makes likely that the goal of school science is often cultural reproduction of someone else's science. This is often true even in out-of-school science learning settings (NRC, 2009).

Since status quo science nearly always wins out, and those of us who care about a science education with more expansive learning outcomes seek fissures where moments of agency are possible (Carlone et al., 2016). While difficult to enact given K-12 constraints, labeling the practices of field science as potentially expansive science is a way to recognize that histories of practice prohibit a complete remaking or transformation of science education, but that reconfigured material, disciplinary, and social practices might desettle existing norms (Bang et al., 2012). For example, data collection, created on the spot, in the field with materials at hand counters the story of data collection at the bench, where every technique has to be done with precision and to minimize human impact. A debrief of the day's data collection might mean recounting the embodied experience of balancing across silt-slippery rocks on the banks of a chilly mountain stream looking for, and then finding, a satiny, slimy, Eastern hellbender (also known as a "snot otter"), an outstanding bioindicator that is also physically imposing at almost 2 ft long (Rowe, 2008). We acknowledge that there is often joy, wonder, and discovery in laboratory science; however, we argue that the culture of field science offers up different ways of knowing and producing knowledge that is worth serious investigation for its potential as an expansive science learning context. Expansion is not only about reconsidering science content and the culture of participation, but also about the epistemic roles of scientists, youth, educators, and researchers (Gutiérrez & Jurow, 2016).

For this study, we examined three overlapping features of science teaching and learning that, through their expansion, became catalysts for youth's shifting participation. First, youth engaged in field science might better understand invisible epistemic particularities and practices more deeply than reading about such practices or by passively observing scientists engaged in the work through various forms of media (e.g., documentary films and interviews). We agree with Jaber and Hammer (2015) who argue that participation in science provides youth with opportunities to develop a "feeling" for the discipline, rather than serve as observers of someone else's work. As Jaber and Hammer (2015) found in the case of their research participant, Sandra, students' interest in science often emerges as they engage in sophisticated epistemic practices and thus peek behind the curtain of science. In this study, then, such participation illustrated an expansive view of expertise in which youth and educators could develop science knowledge alongside field scientists.

Second, a key feature of field science is the building and sustaining of a community of colleagues that is necessary to conduct the complex work. This work disrupts an image of the solitary scientist in the laboratory. Such a community, often composed of scientists and local experts, encompasses a group of colleagues who negotiate norms for participation and action. One example of community-building for field science in K-12 settings is provided by Carsten-Conner et al. (2018), who conducted the Girls on Ice (GOI) program. The GOI program brought nine girls from diverse backgrounds to participate in glacial research alongside scientists on two glaciers in Washington State and Alaska. Framed from a Community of Practice (COP) perspective, Carsten-Conner et al. (2018) found that the girls in the program redefined science away from an individual pursuit, and towards a more "democratic and participatory, rather than directive or top-down" process (p. 171). In addition, the girls noted that a team of colleagues was much more productive than an individual attempting to conduct research in the field. Therefore, field science may help youth expand their role and their image of science as community work rather than a solitary endeavor.

Third, youth might become more curious about the natural world while engaged in field science (Kohler, 2002). Throughout the development of science, being labeled as "curious" has been a compliment, applied to those who choose to investigate the natural world (da Costa, 2002). Eamon (1994) argues that a primary feature of curiosity is the desire to "search" for truth in unexplored places and to find unexpected treasures. As far back as 1520s, people wrote about the need to put away books of known information, and to explore the unknown. As curious people engaged in searches, they realized that there were no ready-made rules for success, where agility, intuition, and quick judgment were more valuable intellectual traits than facility with logic. Importantly, science as a process of searching is purposefully different than science-as-logic in the laboratory because there are different epistemic values placed on the knowledge generated in each place. Since nature's hidden characteristics are beyond the reach of human's ordinary perception, they had to be sought by extraordinary means—new instruments, experiments, techniques, questions, and ideas and collaborative teams (Eamon, 1994). At the end of the search for curiosities, a person presents the results of the search (specimens, findings, and ideas) to a larger audience. If youth are to become curious searchers for natural treasures, then they must also look for unexpected things and then present the results.

In addition to curiosity, youth engaged in field science might develop a sense of wonder about the natural world. As noted by Gilbert and Byers (2017), wonder is important because it is the feeling of awe about the natural world that scientists identify at the heart of scientific practices. Given the complexity, failure, frustration, and time that science requires, wonder fuels the work and vision of scientists. In their work with preservice elementary teachers, Gilbert and Byers (2017) argue that instilling wonder in students and teachers may be crucial for the sustained work of science required in new standards.

Note that each of these invisible features of science—an expansive view of expertise, community, and curiosity and wonder—suggests that youth take on starkly different roles than those of passive recipients of other people's knowledge. Therefore, in this study, we wanted to better understand how field science provided opportunities for youth to engage in science that are not readily available in many science settings.

3 Methods

In this section, we provide a brief overview of the herpetology project and the moth study. We then describe how we looked across studies to examine expansive expertise, a community framing of science, and how students experienced the awe and wonder of scientific work.

3.1 The Herpetology Project

The herpetology project engaged over 200 diverse high school youth (all between the ages of 14–17) in a free, week-long residential herpetological research experiences (HREs) over 5 years (see Carlone et al., 2015, for a deeper overview of the project). The HRE's primary instructors were university biologists and science educators with decades of experience enacting youth-centered herpetology programs. Carlone's role was director of the educational research. Scientists and science educators led youth engaged on field excursions focused on snakes, box turtles, stream amphibians, aquatic turtles, lizards, and ephemeral pools. Youth set and emptied traps, marked and captured animals, collected data with field science tools, and learned how to safely capture, handle, track, and identify animals. Our team had a long-term aquatic turtle population database that youth contributed to through their data collection in the HREs. Evening activities included electives, where youth could delve into investigations or activities of interest that were facilitated by scientists and science educators; e.g., box turtle radio telemetry, dissecting snakes that were found dead on the side of the road, exploring nature photography. Primary data for this study include post-HRE semi-structured interviews with all youth participants ($n = 202$) across 5 years, fieldnotes and select video data from years 1 and 2 (the years we collected the best video data from the first-time participants). Interviews, conducted at the end of each year, focused on youths' meanings of the activities and celebrated practices, their descriptions of their engagement, interest, and participation during activities, and their stories about experiences that were most memorable, where they learned the most, where they felt "science-y," and where they felt proud of themselves. Youth were interviewed individually for about 30–45 min each. The research team also informally interviewed throughout each follow-up activity during the academic year to capture in situ reactions, questions, and sensemaking.

During years 1 and 2, one researcher was assigned to each small group of youth during morning field activities. Researchers' observation protocols were driven by two major questions: (1) what counts as "good science" in this setting? and (2) what does it mean to be a "good science person/participant" in this setting? To answer these questions, we focused on (1) scientific practices (regularly occurring scientific practices that youth were held accountable to enact to be considered a good science person in the setting); (2) social practices (peer-peer and peer-leader interactions that pointed to the meaning of good participant); (3) dispositions or "ways of being" that were celebrated in the setting (e.g., bravery, wonder, curiosity, persistence); (4) how "what counts" was tied to power, equity, and access. This set of observations was focused on shared meanings and the culture created in the groups. The team supplemented this lens with a focus on individuals' identity work, which is less relevant for the paper here. To supplement the team's memory and enhance the fieldnotes, we consulted video footage captured at each activity. Videos were taken in 2- to 5-min snippets to capture events we knew from prior work to be significant and representative of youths' experiences in the field (e.g., capturing a snake or lassoing a lizard, putting on waders for the first time, retrieving an aquatic turtle trap, sifting through leaf litter). After each morning of data collection, each researcher created full ethnographic fieldnote accounts, along with contact summary sheets for quick future reference. Contact summary sheets noted major parts of each activity, along with time intervals for quick reference of the expanded fieldnotes, summaries of key observations, and questions related to normative practices, social norms, dispositions, and participants' identity work.

Youths' roles in the HREs varied. Some first-time participants who had little prior experience in outdoor explorations, herpetofauna, and field science were positioned as newcomers to the community of practice. Other first-time participants had more experience with one or more aspect of fieldwork and/or with certain organisms. For example, a handful of first-time participants served as docents in the herpetology division of a local science museum; some youth had vast hunting experience; others had a pet snake at home. Their knowledge was leveraged in informal ways—e.g., helping their peers feel more at ease and less scared by volunteering to try new things first or by assisting peers with their first-time experiences. Each summer, a few students returned to the camp to serve as student research assistants (SRAs); they assisted a professor with teaching and caring for the animals before, during, and after a particular field study activity. First-time participants held SRAs in high regard; they took on important roles in the community of practice. For example, they served as role models for other teens, ensured daily data processing was complete and accurate, and cared for the health and wellbeing of the animals.

The HRE's curriculum was survey-like, an introduction to various field techniques in studying multiple kinds of organisms and species. Weekend excursions, electives for any HRE alumni, allowed youth to develop more expertise with the herpetofauna in another geographic area of the state (e.g., beach, mountains) and with the ways scientific knowledge was disseminated in herpetological communities (e.g., attend a professional meeting).

3.2 The Moth Project

The context for moth study was a 6th grade science classroom in a middle school (grades 6–8, with students spanning ages of 11–13) near a large Midwestern University (see Stroupe et al., 2018, for a deeper overview of the project). The research team—a science educator (Stroupe), a moth scientist (Dr. White) and his research team of 4 college students, and a teacher (Jake)—co-planned and co-taught an ecology unit to three 6th grade classes with the teacher each day for 22 instructional days, interacting with 90 students (30 per class). We wanted to understand how to help students take up epistemic agency—the power for individuals and groups to shape the knowledge production and practices in a setting (Miller et al., 2018; Stroupe, 2014). As a research team, we asked the following:

- How did adults in this study plan and enact opportunities for students to be positioned with, to perceive that they could act, and to act with epistemic agency?
- How does students' shifting epistemic agency shape their learning opportunities as the research team and students co-configured Lepidoptera research?

For the moth project, we collected and analyzed multiple forms of data from three different types of episodes: planning sessions and communication, classroom observations, and artifact collection.

Planning Sessions and Communication This category of data involved requested or informal planning (such as email communication). When engaged in planning conversations with Jake, we paid attention to his pedagogical reasoning, how he framed problems of practice, and his vision of teaching. As researchers, we recognized our influence on the Jake's thoughts and actions, just as we valued and used his insights in our collective planning. Each conversation was video or audio recorded.

While most conversations occurred in person prior to the unit's first day, we collected multiple emails about planning throughout the unit. Jake's emails often requested help in preparing or reviewing upcoming lessons, assessments, or activities. In addition, Jake wrote to us with ideas, critiques, and questions about potential features of the unit. We saved each email and coded them as part of data analysis.

Classroom Observations The second set of data we used for this study was classroom observations, which we video recorded. Using two video cameras at different angles in the classroom, we video recorded each lesson during the entire unit for a total of 66 observations (3 classes per day for 22 days). The purpose of the daily video recording was to document the events and classroom talk that developed over time.

Jake and the university personnel informally debriefed after each lesson. During these 10-to 15-min conversations, we scripted notes as everyone described the successes and challenges of the lesson. In addition, we discussed particular actions (for example, why Power Point lecture was used) and actions that appeared unplanned or spontaneous (for example, why a teaching episode was skipped even though it appeared on the daily agenda).

Artifact Collection During each classroom observation, we recorded any learning objectives, warm-ups, and closing statements written on the board. In addition, we collected teacher and student-created documents related to planning, instruction, and reasoning for each lesson and all work associated with the classroom context, including lesson plans, assessments, instructions for activities or tasks, Jake's analysis of student work, and tools (created, modified, or adapted by participants to solve problems). We gathered the artifacts at the end of each lesson, or if they were in temporary spaces (such as a dry erase board), we took photographs and saved them to an external hard drive.

Here, we provide an outline of the trajectory of the 3-week unit, noting the negotiated decisions and events that unfolded over time. During week 1, five primary events occurred. First, the research team brought in samples of moths (pinned in boxes) for students to observe. Students recorded their observations, some of which became foundational for designing research projects (such as moth color and camouflage possibilities on trees). Second, students learned how to pin moths using specimens caught by the undergraduate students. Third, students built moth traps with the help of the research team. Fourth, students attempted an initial night of trapping, and brought back any specimens to class the following day. Fifth, Jake and the students engaged in the first whole class discussion about the moths while recording information about the captured moths in notebooks.

During week 2, five primary events occurred. First, students continued to compile data about moths from initial trapping opportunities, and they, along with Jake, noticed fewer moths appearing in traps. Second, each period engaged in a whole class conversation about observations they noticed when engaged in initial trapping efforts. Third, based on the observations, students selected a topic group for their research projects. Fourth, students in each class co-developed research questions with the research team. Fifth, each student-led research team planned the logistics of research, such as trap placement, a system for reminding each other to collect the moths, and the nights when the traps should be set out to capture moths.

During week 3, four primary events occurred. First, students continued to compile data about moths from initial trapping opportunities, and they, along with Jake, noticed more moths appearing in traps given warmer temperatures. Second, students set out traps and collected moths, which they brought back to class each day. Third, students and the research team established a daily routine for each class—identify moths, pin moths, record data on class sheets, and discuss data and procedures with the research team. Fourth, students began to answer their research questions with their team.

3.3 Data Analysis Across Research Projects

Given that many students had not participated in field science prior to each of the two studies described in this article, we wanted to understand if the experiences of field science provided students with expansive opportunities not normally found in school science. Using a priori coding from science studies literature about field science and previous research about students' experiences participating in field science, we each coded a sample of data using the final coding scheme that emerged from literature, identified areas of disagreement, and refined the coding process over time by examining each other's data and claims (Merriam, 2009). Here, we describe the three categories of codes that emerged from literature about field science that we applied to our analysis across research projects.

Expansive Definition of Expert Field science has the potential to disrupt hierarchies between "expert" and "amateur" in a way few other sciences allow. Thus, we looked for patterns across the two studies where an expanded definition of expert emerged from the field science practices. A crucial component of expanding the definition of expert included developing a deep understanding of tacit epistemic particularities and practices through participation rather than passive viewing. Markers of expansive definitions of expert included, for example, youth co-developing epistemic practices, such as designing and adapting equipment, asking and answering research questions the adults did not think to ask, gathering and analyzing data, and taking on leadership roles in the community of learners.

Community One feature of field science—building and sustaining a community of colleagues—is not always valued in school science, in which science is framed as an individual endeavor (Stroupe, 2014). Across studies, we looked for both moments in which youths' participation troubled the notion of science as an individual endeavor, highlighted their shifting understanding of science as a community effort, and how the community work of youth, teachers, and scientists shaped the disciplinary work that occurred over time.

Curiosity, Wonder, and Awe via Searching for Natural Treasures As noted, curiosity and wonder about the natural world are hallmarks of science work. We looked for instances in which students identified instances of their curiosity and wonder and acted on their emerging interest in producing new ideas and techniques. Specifically, we looked for student talk and actions when they name and describe what they are curious about, and why they were curious about a particular object or practice. Taken together, these coding categories illuminated how students began to see and understand nature and their role in science differently than they had in the past.

3.4 Member Checks

Across studies, we had many opportunities to conduct member checks with the participants during the initial research, and with each other as we analyzed the data. We asked participants, and ourselves, to respond to our interpretation of the data, with the freedom to clarify, expand, or refute our interpretations during class time, over email, and during conversations (Merriam, 2009).

3.5 Triangulating Data

The final stage of analysis involved examining the codes across studies to look for patterns in our data. After coding each data source, we triangulated our data by looking across data sources to find supporting evidence across data sources to enhance the credibility of the codes and subsequent claims (Merriam, 2009). When triangulating data, we created a shared document to input pieces of evidence from data sources, and we reviewed each other's claims about data through video conference meetings.

4 Findings

We make three primary assertions in this paper. First, field science enabled a more expansive and fluid definition of expert that positioned youth as co-developers of the epistemic practices of the local field work with scientists and educators. Second, the process of building a science community disrupted youth's images of science as an individual enterprise, and provided scientists with opportunities to see youth as important contributors to field science. Third, youth experienced the awe of wonder of science through the exploration of new entry points into the "invisible world" of hidden nature, in particular by framing field science as a search for natural treasures. The process of specimen collection helped youth overcome fears about fauna, and subsequently, the youth became more curious about the natural world.

4.1 Expansive Definition of Expert

Our first assertion is that though the learning experiences were organized differently in both projects, field science enabled a more expansive and fluid definition of expert that positioned youth as co-developers of the epistemic practices of the local scientific work with scientists and educators. Both projects provided youth with opportunities to participate in similar epistemic practices as socially recognized science experts—for example, finding and identifying species, co-developing methodological practices (such as capture techniques), and taking on roles that positioned them as knowledgeable among peers, family, and scientists. For each project, we describe how the implicit norms and practices of each setting's knowledge-generating activities shifted, subsequently producing expanded meanings of expert in field science.

4.2 Herpetology Project

Expansive Youth Roles While youth often looked to the scientists to answer questions, learn field techniques, and check their emerging understandings, youth also positioned themselves and were positioned by others as knowledgeable participants. One way this happened was through the student research assistant (SRA) roles. SRAs were project alumni returning for a second or third summer to assist project staff. New campers and project staff relied heavily on these teens to assist with all aspects of the projects in which they were assigned. Since SRAs helped with one project all week, they became experts on the animal studies they assisted to the point that, by the end of the week, they began taking on more teaching responsibilities. The SRAs readily took up this challenge, helping new campers learn how to view and handle wildlife differently. Antonio, for example, noted that:

> Just showing people that like a snake, they shouldn't be afraid of a snake just because like it's just a snake, honestly. It's not gonna hurt them as long as they're not ... As long as they respect it it's gonna show them respect back. And then just teaching about all the different things about reptiles and amphibians.

The SRAs took on important roles as co-teachers, following models set forth by university scientists and educators who led the projects, as exemplified in two examples below:

> Jeremiah: [The instructor] was standing back and letting me actually teach us today. I was there with calipers and everything and I did the whole thing. I just had someone put the answer in the data. I was collecting it and I had someone else there beside me recording it and I was showing them through and then on the second time that we're having that same trap, I did some of the process and I let the other students finish through the process and so that way they could have the feel of how to do it. And then when we got to the third turtle, I let them go all hands on and I stood back and watched and I was pleased with how they caught on so fast.
> Fernando: But here I was focused on lizards, so I really enjoyed just having the one group to focus on and it really helped me – well, now I know a lot more about lizards, but also I think I'm better at the whole teaching method that they have here, the whole like not directly giving the information, but like asking questions and helping the camper to reach the conclusion on their own because I really think that like last year I noticed that that was a more effective way to learn things. I felt like it stuck around longer in my mind.

The SRAs made it safe for new campers to gradually ease into learning new field techniques, working through fear, and also set a tone that the work was "cool" (i.e., not "nerdy"), modeling how to do the work safely and accurately. As is evident from their quotes, they assisted in ways that also made room for new campers to take on roles as knowledgeable others.

All youth, no matter their roles, were positioned as knowledgeable contributors to the group, helping to contribute and shape the group's investigative practices and thus, knowledge produced in the community. As Elizabeth said,

> They don't make you feel like you're a child or a student. They treat you as if you're on the same level as them, which definitely makes it more memorable. Because what child wants to come and be condescendingly spoken to?

Youth were especially adept at noticing things adults may have missed. Jeremiah, a member of the Lumbee tribe and an avid hunter, noticed shot gun shells near the camp lake where we conducted aquatic turtle population studies. Quite concerned that the shot gun shells may have been from lead shot, he raised concerns with project staff and the camp director about the danger of lead getting into the water, affecting the aquatic turtle population. In another example, one of the aquatic turtle study groups raised questions about why traps were only positioned at the edges of the lake. They wanted to set a couple of traps in the middle of the lake to see if they would catch different kinds of turtles, but the adults were skeptical. In fact, a prominent herpetologist in the state was visiting the camp at the time and was convinced that they would not catch anything different. The youth helped problem-solve how to set traps and anchor them in the middle of the lake—a fairly complicated and creative task because we had never done so before. The youth were right—the middle-of-the-lake traps produced a river cooter, a species we had never found in that lake after years of aquatic turtle population studies.

Multiple Ways to Get Recognized as Expert In addition to their expanded roles as co-teachers and co-investigators, youth were uniquely positioned, sometimes better than adults, to help with fieldwork. For example, some youth developed a way to see natural spaces to become excellent spotters of wildlife. They were, in fact, developing an eye for herping:

> Judy: I even could spot all of them down, I spot one just after the other so I caught one after the other and that was just amazing that I could – I'm starting to get that eye for seeing these animals out in nature and like oh it's just a bunch of leaves and there's nothing there because that was me last year but I'm starting to get a look out on these animals that were just hiding there being quiet, being to themselves and I could actually see them.

One of the scientists noted youths' creativity in safely capturing animals, developing new techniques that adults had not tried previously. They were testing out their ideas and made suggestions while the group was in the process of trying to catch herps. Some youth developed a reputation as a good catcher and handler, which was a celebrated position in the community and also allowed them to get to know species in new ways.

> Fernando: I flipped my first spotted salamander with the [herpetology project], so that was pretty neat, and I held my first egg mass with you guys too. I remember thinking how charming ambystomids are, and now they're my favorite genus.
> Antonio: I remember I went for the picking the snake off the floor because I felt comfortable with snakes. I remember impressing people and inspiring the people after me to try it because I made it look easy.
> [One thing that made me feel like I belonged was] Catching running lizards and boasting of your mighty athletic abilities.

The youths' agility helped them readily catch the animals, and their young eyes allowed them to identify features that adults may have missed. For example, it was sometimes difficult to sex some of the animals, and youth were able to point out features, initially missed by adults, that aided in reaching agreement about the species identification.

Some youth who were more hesitant to catch and handle animals in their habitats became expert at using tools to measure and mark the wildlife. Their expertise at tool use became a source of pride for them, and a way to get recognized by adults and peers. For example, one youth noted:

> I was able to lead a group and mentor the people who hadn't like had experience with reptiles and amphibians. And help them learn about how to like measure salamanders, or like processing an Eastern box turtle. It was like – I was very more – much more of like – I felt like a leader, and it was very inspiring to me.

Youth who had more experience spending time in the natural world, like hunters, those from rural areas, and/or those who were returning from the year before became a source of comfort and knowledge to newcomers. In the field, if it were not for an age difference, it would have been difficult to identify the university instructor and the youth, as evidenced by Jeremiah's reflection:

> The [other kids] feel safer with me being in the water because I had more experience having on waders [from fishing experiences], and they wanted me to be there just in case they started to slip or they started to fall or anything like it. There's a snapping turtle in the trap then I [let the other youth let go of the trap], I go to the trap and turn it by myself so that way [the campers] wouldn't be endangered. I'm like more aware of the trap because when the students with less experience would wade on his own, when they're walking in and out of the water, they're worried about slipping and falling. They're not more worried about where the trap is like if it's beside him or right up against them or anything.

These examples point to the youth having the space to shape the knowledge-generating practices of the camp, but also to the unique ways field science leverages youths' dispositions as question-askers and problem-solvers, their "good eyes" to find and identify animals in the field, and their quest for adventure and "bragging rights" to try new things like holding snakes and teaching others to do so. In other words, the work of field science was uniquely youth-centered.

4.3 The Moth Project

Similar to the herpetology project, youth in the moth project provided opportunities for the definition of expertise to be expanded in the classroom setting given through the co-development of epistemic practices. In the moth project, youth contributed in two main ways: co-designing research projects, and co-designing data collection and analysis.

Co-designing Research Projects In the moth project, the university-based team purposefully structured the unit so that youth would co-design research about moths. By co-design, we mean that rather than the university team making all of the decisions about field science (such as moth trap placement, research questions, and trapping frequency), the youth in the class worked with the university team to make initial and ongoing research decisions.

Based on initial observations of moths and trapping, each class of youth selected a topic group for their research projects, and co-developed research questions with the research team. Listed here are the research topics from each class period:

- Class 1: (A) Does tree type matter for moth biodiversity (i.e., deciduous vs. coniferous)? (B) Will we catch more moths on properties with water features (e.g., ponds and streams) or on properties without water features? (C) Are moths attracted to traps placed near artificial lights (e.g., house lights and street lights) or traps placed far away from artificial lights?
- Class 2: (A) Do moths have a color preference for flowers? (B) Does proximity of water impact moth biodiversity (i.e., similar to 1B above; here the students wrote and distributed a survey to classmates and planned to triangulate this data with moth trap data)? (C) Does the brightness of the trap light impact moth abundance?
- Class 3: (A) What is the effect of tall grass or short grass have on moth biodiversity? (B) Do we catch more moths by tall or short trees? (C) Are moths attracted to traps with light or traps without light?

For each group of questions, youth and the researchers planned the logistics of research, such as trap placement, a system for reminding each other to collect the moths, and the nights when the traps should be set out to capture moths. Note that the university research team could have constructed the questions, created pre-determined roles for youth, and steered them towards certain field science. Instead, the youth worked in collaboration with the university researchers to design research that reflected their emerging interests and observations.

Co-designing Data Collection and Analysis After the initial design of the moth research, youth and the university team set up traps and began to capture moths. As noted, the research team could have established pre-determined field science practices around data collection and analysis. Instead, the youth and researchers are co-designing how to collect and analyze data, such as recording weather conditions; identifying moths, the structure, and purpose of data sheets; and cataloguing/displaying species.

Given the co-design process, the youth established two data collection and analysis practices that did not originate with the university researchers, nor did the university team anticipate might be necessary. First, the weather was cooler than expected, and thus, the moth capture rate depended on the temperature of the previous evening. Given the variability in the weather and the moth capture rate, the students' daily moth catch and emerging needs (such as trap repair) often necessitated immediate shifts in the instructional goals. By week 3, the first 5 min of class—the time in which Jake and the students recorded weather data—became the opportunity for the research team to hear from students and to make instructional decisions. For example, if the weather was cold on the previous night and students caught few moths, the research team and students agreed to repair traps and label any moths not yet identified. If students caught numerous moths, the day's goals focused on pinning the moths and recording the capture site and weather on class data sheets. Thus, the day's knowledge goals depend entirely on students' needs at the beginning of class.

Second, youth began to "specialize" in the epistemic practices as they found some data collection and analysis to be more interesting than other aspects of the work. For example, some students preferred moth identification, and often volunteered to examine unidentified moths. Other students had an interest in trap repair, and would help the undergraduate assistants with such work. Two students, Claire and Lily, developed an interest in pinning insects. While most student relished opportunities to pin moths, Claire and Lily became fascinated by pinning every insect caught in traps, including flies, ladybugs, dragonflies, and bees. Their interest caught the attention of an undergraduate assistant, Jenny, who worked with the students to become more proficient on pinning various insects. In addition, Jenny focused on questions the two students asked about insects during the pinning, such as body parts (Jenny named parts for the students, such as the thorax and abdomen) and behavior ("this yellow stuff on the bee's legs is pollen, which they were probably transporting back to the hive"). While the research team could have dismissed Claire and Lily's emergent interest, the students instead shifted their daily knowledge goals to learn about insects and to practice pinning. Note that in each example, youth helped to shape and advance the epistemic practices of field science.

4.4 Building a Community

Given the expansive definition of expertise, the process of building a science community disrupted youth's images of science as an individual enterprise, and provided scientists with opportunities to see youth as important contributors to field science. Simply put, youth and scientists learned that field science cannot occur rigorously or safely if attempted independently. Youth understood this quite early on in their experiences, and took up multiple kinds of helper roles which, in turn, created community norms that iteratively built a sense of belonging among the participants.

4.5 Herpetology Project

The norms and practices of the herpetology project created a "new normal" for youth which iteratively built community. For example, one participant noted:

> Outside of [the herpetology project], it is not necessarily considered normal to try to catch lizards or snakes you see outside. I think I felt like I belonged when everyone in the group would join in trying to catch a reptile or amphibian we saw scurry across our path, something I had never experienced before.

Even youth who did not have prior experience with or great fears about herps were recognized, respected, and participated in the shared norms and values developed in the community.

> Tanisha: At home, like if you see a snake, in the country, you put mothballs around your house…we don't like snakes. We try to stray away from snakes, and if we do see a snake, we kill it. And like, it's different from when you're here because if you see a snake, you run towards it, and you try to catch it. You try to identify what type it is, and you take it to someone, even if that snake is roadkill. If you're at home, you just say, "Ew, that's nasty." If you're here, you bring it so you can dissect it, and then like pull its fat out, and its intestines, and like look at everything. And so, there's a big difference, and those are things that I've experienced that are like totally different because in one environment, you run away from snakes. You kill snakes. You're disgusted by snakes. But in another place, you love snakes. You admire them. They're your friends.

Youth did not feel like they had to get over their fears on their own; they had other peers and adults to help them through fears to allow them to engage more deeply and feel connected to the community.

> Ned: Earlier today, we were working with Armand who, at the beginning of the day, the kid was terrified of snakes. Like, he didn't even wanna go out in the field. But we finally convinced him to go out in the field and just – and he could sit back, and he didn't really do much in the field, but once we got to the classroom again, we started working with him. I think he started to understand and see how much we enjoyed snakes and how nice they were, and by the end of it, he actually – he volunteered to hold the corn snake. He actually held the snake and we – I was really impressed with him and I felt like we've – I was impressed with me and Christina and how we've really flipped his opinion on snakes.

The physicality of the fieldwork was challenging—e.g., hiking through difficult terrain with lots of mosquitos in the heat, putting on and taking off chest waders, measuring a wiggly snake or salamander, filing the scutes of a box turtle and weighing it with a spring scale, and trying not to fall on slippery, muddy hills. As one youth put it, "You've got to think about where you're going, where you are, and how you can physically protect yourself from like bugs, scratches, bruises, falling."

Individual groups developed different systems to help one another navigate the tricky physical terrain:

> Youth 1: I feel like with the ephemeral pools, because I and she seemed to be the only ones getting stuck in the mud. And our feet would get stuck, and we would have to pull each other out.
> Youth 2: Yeah, like [inaudible] because one of us would get stuck. The other one would be like, here, here. Okay, hold my shoulder here, and then give me your other hand. And we were just literally pulling each other out of the mud because we kept getting stuck.

Many youth mentioned the challenge of donning, navigating in, and taking off chest waders, and the systems they developed to help one another through these difficulties.

> Youth 1: Like when we were in the aquatic [inaudible], like every time we went down there, like someone always slipped and like almost fell. So we –
> Youth 2: Right. And so, so it's just like instinct to grab them.

In addition to the necessity of helping one another navigate the physical terrain, many youth mentioned the inextricable nature of data collection/analysis and teamwork:

> The group activities were always a good way to connect with other students and also practice group project dynamics. For example, it's difficult to conduct measurements by yourself so teamwork was required to obtain accurate data and was also a good practice in terms of who was particularly skilled in one area and learning from them about the areas I needed more practice in.

One youth noted the accomplishment she felt when helping others catch organisms:

> One thing I won't forget is today I helped Katrina catch – she never caught a frog with a net before and together we tag teamed it just catching it together and that was amazing. Then I also helped Christina (project leader), she had a strainer and she caught a green frog in it but she couldn't get it out because it's hard and stuff, you can't really reach in and grab it so I helped her with that and I guess it's that teamwork that both of us could actually catch something together. That just wowed me a little bit like catching a frog is one thing but doing it as a team all together, catching that one little thing together is just, 'Whoa I didn't know we could actually do that—like teamwork actually works.'

This quote captures the notion of science as a community endeavor as evidenced in the herp project.

4.6 Disrupting Ideas About Science Participation During the Moth Project

Similar to the herpetology project, a main goal of the moth project was to disrupt ideas—among the youth and researchers—about how youth can participate in science through the initial building of a community of co-researchers. Specifically in the moth project, a primary aim was to position youths' ideas as foundational for shaping the Lepidoptera research projects, rather than the scientists tell students "correct" answers or mandate how they participate in field science practices. However, youth often do not experience such opportunities, and in the moth project, expressed initial disbelief that they would work alongside scientists. For example, one such moment occurred at the beginning of the moth project as the classroom teacher introduced the research team. The teacher, Jake, noted that "the scientists need your [the students] help to answer questions about moths and ecology they don't know the answers to yet." This introduction led to immediate questions and comments from some students, such as "I thought scientists knew everything," "How can we help scientists when we're in 6th grade," and "Why do scientists need our help? Don't they have workers?" After the questions, White (the entomologist) noted that science (in particular, moth ecological research) does not often involve an investigation of processes occurring at small scales, within local communities. The data that they could therefore collect would present an interesting opportunity to examine ecological relationships at a unique scale. An undergraduate assistant, Paul, added that, with their help, we might be able to discover new things. After the introductory remarks in each class, White, as planned, initiated brief whole class conversations with students about his work as an entomologist, and gave an overview of the unit. He told students that "Right now, we're going to get you up to speed on moths. The next two weeks, you'll start to take over the class and do more of the science work." Jake added on to White's overview, noting that "it's rare to get a scientist in the classroom once, much less to have a team of researchers here for three weeks."

Note two features of the introductory conversation. First, many students wondered how they might engage in science if the scientists did not have answers. In other words, students indicated that they expected the scientists to tell them what to do rather than have a voice in conducting science. Second, given the students' skepticism, the research team—from the beginning of the unit—worked to position students with power to shape the science work of the community, rather than position success as an individual endeavor.

4.7 Youth as Contributors to the Moth Project

In addition to disrupting ideas about who can participate in science, the moth project served as a means for scientists to see youth as important contributors to field science work. For example, while White and his graduate students brought entomology knowledge into the 6th grade classroom, he had no understanding of youths' lived experiences with moths, little experience in youths' communities in which moths lived, and limited time and resources given his small team. For example, during a whole class discussion in which youth shared observations about moths in their homes, one student told a story about moths living close to a pond in his yard. He asked White: "Why would a moth live there?" Rather than provide a generic answer, White replied "I don't know, I've never been to your house, so you know more than me about that habitat. Let's think about some ecology ideas and help answer your question together as a class." Note that White worked to build a community while expanding definitions of expertise. Working with 90 sixth grade students immediately enhanced his data about moth abundance and diversity because there were more traps, more communities, and more participants involved in the research. In addition, White learned about community needs around moths, rather than solely propose questions from his perspective on the field science.

4.8 Curiosity, Wonder, and Awe

As the youth and educators built communities in which expansive definitions of expertise were developed, the youth began to investigate the natural world in ways that seemed inaccessible or restricted. Through such exploration, youth experienced the awe of wonder of science through the exploration of new entry points into the "invisible world" of hidden nature, in particular by framing field science as a search for natural treasures. By searching for and physically holding animals, many youth overcome fears about fauna, and subsequently, the youth became more curious about the natural world.

4.9 Herpetology Project

Each summer we offered the herpetology camps, in any of the camp settings and with any group of participants, searching for natural treasures was an accurate shared metaphor for fieldwork. A good day in the field was framed as either finding lots of animals and/or finding rare species. At the end of each morning in the field, youth circled up to share their morning's finds. Some had species that brought back to process and return to the field later; others shared tales of their rare find, along with interesting facts about that animal. In a follow-up survey conducted 1 to 4 years after they attended the camp, multiple youth mentioned this "circle time" as among the most memorable experiences.

We note a striking example of the importance of finding animals as a measure of the quality of their fieldwork experiences. One morning, a public television crew came out to film one of the groups conducting the Eastern Box Turtle study. One of our project leaders, someone who learned to herp as a hobby, trained his Boykin Spaniels (dogs) to help track and find the turtles because they were good hunters and had "soft mouths" to safely carry the turtles to the researchers. These finds were especially exciting because the tracking devices we were using as another way to find the turtles were not working especially well. The television crew, however, wanted to get the right shot, so they kept staging the dogs "finding" the same turtle and returning it to the youth. The youth were furious that their time at the box turtle study was disrupted by the television crew. This is just a snippet of DaVeon's (an SRA) rants about the television crew:

> The TV crew just screwed it for me. They screwed it up badly. They wouldn't let the dogs go out and find any more turtles. They didn't wanna be out in the sun and they were hot. They were complaining they were hot but they dressed in long sleeved shirts and pants and I mean I kind of just looked at them like, 'That's your fault for dressing like that, for one.' For two, I asked them nicely two times to stop using the turtles—let us catch another turtle and film that. Don't keep using the same turtle… because the dogs have been known to puncture holes in turtles. They can hurt and potentially kill the turtle, and they wouldn't listen. They just kept on trying to get a shot of the dog picking up the turtle and each time the dog got more and more excited. Nothing happed to the turtle, they didn't hurt it… [but] we only got to catch two turtles when the rest of the week we've been catching like five to eight turtles a day. [With four dogs out], I was thinking we were supposed to catch a whole gang of turtles but we only caught two which was kind of jacked up—like really, you just kind of killed the whole experience for everybody. Y'all could've gotten so much more if you would just let us do our thing.

The other youth in that group shared DaVeon's sentiments. They were agnostic about appearing on public television; finding turtles was, by far, the more valued activity.

Discovering herps in their natural habitat and/or holding them allowed youth to see and understand the animals in ways that were previously inaccessible to them. Physically holding an animal helped them identify the animal, allowing them to see differences in scale arrangement, eye color, head shape, markings, scute shape, claw type, carapace shape, and more, as noted by Julia:

> Actually, it was a new level of hands-on for me as well, so that was a good way to do science. Actually get up in there and look at them. You get to admire it so much more than – I mean, I never got to do that before…I actually got to get up close, observe them closely, get to know some of their features, and it was interesting.

Processing animals for data collection for population studies demanded safe handling to mark, weigh, and measure without harming them. Learning to do so required creativity, soft and agile hands, bravery, and precision. In the field, youths' talk was peppered with questions about the animals' habitats and predictions about the species they would find in different locations. They became more adept at identifying species and using their field guides over time. This work would not be the same had it been completely located in a classroom setting, as noted by Charles:

> I can tell a Fowlers toad from an American toad now. I was really happy about that. Because last year, I was so tired of just looking at spots and warts and it was like American toad? Fowlers toad? American toad? Fowlers toad? But now I was just like able to identify them. And like I become more keen with my like skills at identifying other animals too.

While youth were certainly enthusiastic about finding and catching lots of species, they were just as excited about finding rare species, and/or finding wildlife in unexpected places. An excellent example of this, mentioned by many youth, was the state's herp monitoring program and bioblitz at Charles's house. After hearing from a prominent herpetologist talk about the lack of herp species recorded in their home county, the youth wanted to add to the state's official record. So, they conducted a systematic bioblitz—a survey of a specific area of land to identify as many species possible—of Charles's property. They found the bioblitz interesting, motivating, and memorable.

> Vern: I was like anticipating to catch like all different kinds of stuff… So I was just like interested and it stuck because I wanted to catch as much as I could, and I was like hoping for like catching some stuff that was like maybe not recorded in this region yet.
> Melissa: I think it was a cool way to try to find the herpetofauna. I feel fancy using that word! Just because they made it kind of official. Like, 'Okay, you're going to be in this quadrant, and you're going to be over here.' It was fun and cool… because looking for them was fun because like, 'Oh yeah, there's a log, let's move that over.'
> George: We looked for some lizards, but we couldn't find any and we went back and caught a Northern Cricket frog, which was cool because it was really small. And it was on our list [of species to look for]… so it was cool that we got to cross that off.

The fieldtrip to Charles's house made visible the teeming wildlife of a friend's backyard. A friend who lived "near Charles" but "deeper in the country" than him expressed surprised about the number of wildlife found "right next to his house… It was different than I thought it would be… I've lived in the country all my life. It was definitely a lot more herps there than I thought there would be."

Through these searching experiences, youth gained deeper respect for wildlife.

> Susan: I think going to camp helps me see not to disturb their habitat or not to or how to handle them so you don't hurt them. I think it would make me more careful with nature, but also more willing to explore it.

4.10 Youth Discover the Wonder of Moths

Similar to the herpetology project, the youth engaged in the moth project experienced wonder at encountering animals encountered. During the initial class sessions for the moth project, many youth readily admitted two moth-related wonderments. First, many youth were unsure that they had ever seen a moth because the animals are nocturnal and hide in dark places. Second, many youth had never examined moths up close. For example, one youth expressed surprise that "moths have eyes – I didn't know that!" Since youth interacted with moths almost daily, they had many opportunities to ask questions of the research team, examine moths, and record ideas about moths over the course of the unit.

One example of a youth expressing wonder about moths occurred during week of the unit. This youth, John, expressed initial trepidation about working with moths, and therefore was quiet during his group's initial research design. However, as the research progressed, John told his group that he had a woodlot behind his house, and that his group should place the traps in the trees to avoid light. They agreed, and John's woodlot became a primary location for "light-free" traps. At the end of week 3, when White was not present in class, John brought in the moths collected in the trap, and found a moth that none of the research team could identify. John and a graduate student research worked together to identify the moth, which White confirmed as an eight-spotted forester moth (*Alypia octomaculata*), and that to his knowledge, the entomology lab did not have a sample of the species. Students applauded, and some patted John on the back. White also asked John if he could keep the moth as a "voucher specimen" in his lab, and asked if he could include John's name as the person who captured the moth. A student said "you're famous now, John!" While unexpected, John's discovery illustrated that a single moth—a discovered treasure from a youth who was initially nervous about participation—prompted class-wide excitement.

5 Discussion

Given the findings across two studies focused on field science in which educators and youth expanded definitions of expertise, supported science as a community endeavor, and promoted the wonder of nature through searching for natural treasures, we return to our conceptual framing of expanding science teaching and learning, rather than reproducing typical ways of knowing and participating valued across many formal and informal settings. In this section, we describe how the field work conducted by youth and educators provided two opportunities for expanding science: positioning youth as field scientists and instilling a sense of wonder and an emerging environmental ethic by searching for natural treasures.

5.1 Positioning Youth as Field Scientists

The purposeful discourse and actions taken by scientists, educators, and youth to position youth as field scientists helped to expand science learning opportunities in two ways across our projects. First, positioning youth as field scientists enabled data collection and examination that would not be possible without the help of local experts. As Vetter (2011) argues, public participation in science is crucial in the field because they can provide valuable observations, photographs, specimens, weather data, and histories of their place. For example, local experts play important roles in the search for the ivory-billed woodpecker (Lux, 2019), and in the ongoing Cornell Project FeederWatch (2020). Across the herpetology project and the moth project, youth also contributed important ideas, data collection methods, and research questions to scientists and educators. In addition, the sheer number of youth participating in field science increased the quantity of data available for analysis by the community of learners.

Second, positioning youth as field scientists helped dismantle an epistemic hierarchy between people positioned by society as those who are solely allowed to make and verify knowledge claims (professional scientists) and local experts (Vetter, 2016). As noted by McCook (2011), an enduring myth of science is that local knowledge is less rigorous, and therefore less valuable, than globally "generalizable" knowledge. Yet, knowledge that is accepted as canonical in field science originates in, and utilizes, data gathered and analyzed from local places by local experts. Thus, field science can trouble the epistemic gulf between lay people and professional scientists because scientists could not make knowledge without local experts (Vetter, 2016).

Across the herpetology and moth projects, the scientists and educators worked to dismantle the epistemic hierarchy by purposefully supporting a community of field science in which all participants' ideas became important resources to shape and advance the community's work. Creating and maintaining a community that was shaped by youth helped them realize that their participation was desired and valuable, rather than marginal and unnecessary (i.e., de Bont, 2015). Such participation, encouraged and legitimized by scientists and educators, positioned youth as field scientists rather than "technicians" who are only permitted to conduct work that others deem important, a significant repurposing of such learning opportunities. As Dillon et al. (2016) caution, such positioning can perpetuate inequities in science as scientists receive acclaim and enhance their status by capitalizing on the labor of people with less power.

5.2 Wonder, Environmental Ethic, and the Search for Treasures

A second opportunity for repurposing science was to treat field sites as teaching sites in which youth, educators, and scientists began to see nature differently; rather than observing nature from outside perspective as those who simply inhabit a place, participants started becoming people who know about the flora and fauna of a place and wanted to see such a place thrive (Marin & Bang, 2018). An affiliation of place can potentially deepen a person's commitment to that place (Smith, 2007). Across both studies, youth exhibited a growing concern about the natural world. Prior to both projects, youth who would previously stomp through a walking path would carefully eye the path just in front of them to be aware of the ways their footsteps could damage flora and fauna along the way to their destination. Recall Jeremiah, an avid hunter, who raised questions about the lead shot along the pond's edge where they found numerous species of aquatic turtles, as well as John, who shifted from initial fear to capturing a novel moth. The careful study of these organisms, previously thought of as scary, gross, dangerous, and a nuisance, prompted affiliation, care, curiosity, and connection (Bixler et al., 1994; Simmons, 1994; Wals, 1994).

Across the herpetology and moth projects, a key reason for this emerging shift towards an environmental ethic was youths' emerging wonder about nature given their search for natural treasures. In practical terms, field science illuminated an invisible world that youth did not yet easily observe or recognize (i.e., turning over logs to find salamanders, or catching moths in traps in field at night). Searching for natural treasures was a shared, celebrated ethic across both projects.

Though it may be easy to brush aside searching for natural treasures as an "unsophisticated" and epistemologically nascent practice, such daily work proved to be an essential aspect of the youths' participation in both projects. Indeed, as noted in our framing, science-as-hunt disrupts the epistemological status of field practices when compared with science-as-logic associated with laboratory science (Eamon, 1994). For example, the practice of searching for natural treasures minimized typical academic hierarchies between youth and adults in both projects. Youth who were not necessarily recognized with good grades or test scores in typical school science became the best "finders," "pinners," and "trappers," which are essential disciplinary practices of field science. Searching for natural treasures can broaden what counts as science and who counts as being scientific. In our data, the searching process also built community, promoted empathy for living things, created a shared understanding of the interconnections of organisms and their habitats, prompted critical dialogue about ambiguous data, and allowed youth to problem-solve unique ways to contribute to classroom and state-wide scientific databases. Additionally, there is an innate excitement and identity-building pride entangled with finding a treasure, especially after battling heat, difficult terrain, and nocturnal fears, which brings in embodied ways of knowing so often diminished in school science.

Finally, in our projects, the youth began to express an ethic about the natural world that may have remained hidden without field science. Across the herpetology and moth projects, youth expressed a desire to know more about their field sites, to help their field sites thrive, and to educate their communities about the importance of the flora and fauna in the sites. Establishing such connections to the natural world is not trivial. As Haraway (1991), Latour (2018), Medin and Bang (2014) and many others have cautioned, youth must construct a sense of urgency, empathy, and morality about the natural world given prior generations' disconnected, disembodied, and conquering stance of their place in the universe. We argue that field science might provide youth with opportunities to reimagine their relationship with the natural world that is not available when engaged solely in laboratory science.

6 Conclusion

This study contributes to teaching and learning science in three ways that illuminate how science can be expanded in formal and informal places. Such contributions illustrate the impact that field science can have on youth across sites of learning, as well as the science that occurs during purposeful co-designed collaborations between scientists, youth, and teachers. First, youth and field scientists collaborated to design and conduct the research, which was necessary for the science work to advance. As noted by historians of science, local experts help scientists develop the daily practices, and serve as crucial collectors of data, roles that a solitary scientist could not accomplish alone. Second, field sites served dual purposes as places of science and external classrooms. As Vetter (2011) notes, field training and learning science have gone together since the early twentieth century as university courses moved into the field along with lectures. This is a reshaping of where and how youth see nature—from an outside and individual perspective as those who simply inhabit a place, to someone who knows something about the place and wants to see the natural world preserved through community-building work. Third, youth experienced a sense of wonder about science that is often missing from lectures and confirmatory activities. Rather than follow instructions with a known outcome, youth helped scientists engage in research that did not have prescribed procedures, practices, or answers. Participation in such work might help youth develop science-linked identities that may not be possible if science is framed exclusively as a laboratory activity. We conclude by considering how field science might push the boundaries of "what counts" as science in the NGSS era, by offering a caution for those interested in field science work with youth, and by posing lingering questions to drive future research and partnerships.

6.1 Finding a Place for Field Science in the NGSS Era

We argue that field science—given its different epistemic practices, community work, and reliance on local experts—provides a crucial, but undervalued image of science. As noted, laboratory science often holds a higher status in society and in sites of science learning than field science. Yet, field science has different epistemic ideals and standards than laboratory science—field scientists hope to create knowledge by comparing observations of multiple, shared, complex phenomena by embedding themselves in the natural world. Such experiential knowledge construction might help give youth an image and examples of science, equity, and social justice that laboratory science, and the NGSS, cannot.

Environmental educators have been arguing for decades that schooling's practices promote competition, individualism, anthropocentrism, and siloed, reductionist thinking that are fundamentally at odds with a place-conscious, ecological curriculum (Gruenewald & Manteaw, 2007; Stevenson, 1987). Gruenwald (2003), in arguing for a place-conscious education, explains that schooling is becoming increasingly placeless. As standardized and neoliberal approaches to pedagogy, assessment, and curriculum become more pronounced, possibilities for field science diminish. A number of recent critiques of NGSS in the literature, too, resonate with those we raise here. For instance, Feinstein and Kirchgasler (2015) argued that the NGSS stress global earth systems over local, rendering particularities of place invisible, privileging presumptive neutral, quantitative ways of knowing over other ways of knowing, and positioning natural sciences and engineering as the primary mechanisms by which we can understand and solve sustainability problems. Merritt and Bowers (in press) argued that observation-based ecology (OBE) is an essential, and currently anemic, part of a responsible and ethical science education. They found that, "Looking sequentially, students could spend many years in NGSS-oriented classrooms without conducting firsthand observations of the natural world" (p. 15). OBE is an essential aspect of ecological sciences, they argued, but also is an accessible, multi-epistemological, way of knowing that leverages youths' natural curiosity and affinity for living things and can provide a strong foundation for being curious about, understanding, and solving human and other-than-human ecological problems. As we found across projects, when given opportunities to reimagine science as inherently tied to place and as a community endeavor, they expressed interest and opportunities typically denied them by school, laboratory, NGSS-framed science.

6.2 A Word of Caution

While field science has the potential to help youth in multiple ways, we offer a caution to those interested in pursuing such work—as with any interactions between those with and without power, the potential exists for those with power to explicitly or implicitly maintain their power. In the herpetology and moth projects, the scientists, educators, and youth worked diligently and purposefully to disrupt participation structures in which youth acted solely as technicians. For example, the work of searching for natural treasures was framed as crucial for the work of field science, and was structured so that the youth used the data to help expand definitions of expertise and build a science community. Our caution is that important work such as searching for natural treasures could be used to reproduce divisions of power while operating under the guise of expanding science teaching and learning, even operating under the guise of work such as "citizen science." In other words, field practices that appear to help youth engage as field scientists on a superficial level could also result in the perpetuation of outcomes that limit youth's participation in actual science. If, for example, the main goal for youth engaged in searching for natural treasures is to capture specimens that scientists and educators take and use for their purposes, the potential of such searching disappears and youth are, once again, positioned as technicians for those in power (Dillon et al., 2016). We hope colleagues interested in such work with youth will consider, plan, and enact purposeful practices to position youth as field scientists rather than technicians.

7 Lingering Questions

We conclude with four lingering questions. First, field science might address calls for science to be "relevant," "community-based," and "local." But, we wonder what such buzzwords should mean for field science—who decides what is "local" or "relevant" in field science? What role can youth play in such decisions? Second, a potential exists for certain youth to be elevated over others as more closely aligned with scientists' and educators' views of who should engage in field science. How can those with power work to ensure that every student in a learning setting has opportunities to shape the practices of the community rather than perpetuate unjust epistemic hierarchies? Third, we wonder about the roles of scientists in such communities. Clearly, there is a need for some form of recognized expertise guiding field science—otherwise, youth and educators can quickly become stuck, lost, and frozen in metaphorical place. Without help, field science efforts become disingenuous to youth because they are not engaged in science that might help advance knowledge, practices, or solve community problems. Thus, we wonder when or why scientists and educators might retain authority, and still learn with youth as they co-develop the community and research. In addition, we wonder about the reaction of scientific communities to such collaborations with youth. How might local scientists and youth produce texts and media that help scientific communities reimagine their roles with schools and see the value in the science produced by such partnerships? These questions help push our thinking and work forward, and outdoors, as we venture back into nature with youth, scientists, and educators. Finally, while both of our projects helped youth experience local science, we missed opportunities to ask questions and take actions towards environmental justice. We propose that collaborations between youth, educators, and scientists, especially in their local communities, have the potential to help create a future through the expansion of science teaching and learning opportunities, which can better promote an environmental ethic and wonder of the natural world.

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Declarations

Ethics Approval The studies reported on in this paper both received IRB approval, and participants are protected from identification.

Conflict of Interest The authors declare no competing interests.

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