

# Becoming a naturalist: Interest development across the learning ecology

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## Abstract

Engagement with and study of nature is increasingly important for science literacy and civic engagement. Spurred on by challenges of the Anthropocene, many informal learning institutions are exploring how their collections, programs, and scientific expertise can be mobilized to create new naturalist learning pathways for children and youth. In this paper, we explore retrospective life histories of 18 adult naturalists to examine experiences that they recall supporting their interest development in the natural world. Drawing on interest and informal learning literature, our analysis reveals how elements across the learning ecology, including school, family, and out-of-school learning, work together to support the development of naturalist practices and identities. We found that interest development in nature occurred across the learning ecology and that expression of situational or individual interest depended on the participants' age and the type of learning experience. A closer examination of three individual cases—a serious amateur naturalist, an environmental educator, and an ecologist—reveals some of the nuanced ways that interest in nature arises, is maintained, and can eventually develop into a deep, lifelong naturalist identity. We consider implications for how one might conceptualize and support informal learning pathways that involve deep engagement with and connections to nature.

## KEYWORDS

informal learning, interest development, learning ecology, naturalist, out-of-school learning

## 1 | INTRODUCTION

Over the last 40 years, a declining emphasis on natural history in the sciences has resulted in calls for the biological sciences to re-embrace a naturalist approach through direct engagement with the natural world (Dayton, 2003; Noss, 1996; Ricklefs, 2012). At their core, naturalists get into the field—out into the natural world—to apply the traditional skills of observing, recording, and interpreting species and natural processes (Grant, 2000; Noss, 1996). The study of the details of nature also demands an understanding of how organisms coexist and interact; and this kind of systems thinking can be applied to a variety of topics, from human health to land conservation and management (Charles, 2009). We suggest that the study of nature matters today more than ever in science education. The complex environmental challenges we face—from local water quality to global climate change—require an understanding both of the processes that drive natural systems and most importantly the role that humans have played in influencing changes to the natural phenomena (Tewksbury et al., 2014). Spurred on by these challenges of the Anthropocene, many natural history museums are actively exploring how their collections and expertise can be mobilized in the long-term community and educational engagement to create new naturalist learning pathways for children and youth (Dillon et al., 2016; Watson & Werb, 2013).

With this larger movement in mind, the Carnegie Museum of Natural History and the University of Pittsburgh created a research practice partnership to explore how the museum might conceptualize and support the development of a 21st century naturalist, which we broadly defined as the kind of scientifically and environmentally literate citizens who are prepared to think critically about some of today's most pressing environmental challenges. More important, our notion of a contemporary naturalist is of someone who embraces urban environments as part of the natural world and who will utilize these spaces as places to engage and inspire others (Tewksbury et al., 2014). We envision that 21st century naturalists are able to understand global interdependencies, have the skills to make local-to-global connections, and are ecologically minded civic actors at the local scale (Fleischer, 2011; Sobel, Gentile, & Bocko, 2014). By engaging youth in nature and the environment as part of science education, we hoped to broaden participation in science and deepen scientific literacy (Charles, 2009; Tewksbury et al., 2014; Wals, Brody, Dillon, & Stevenson, 2014), while also exploring how informal science education can support general 21st century thinking skills, such as creativity, critical thinking, and synthesis of ideas across interdisciplinary fields (NewKnowledge, 2013; Sobel et al., 2014).

To identify the kinds of informal and formal educational experiences that might be important in developing 21st century naturalists, our research practice partnership decided to conduct retrospective life histories with adults whose vocations or avocations embody deep connections to nature and naturalist practices. As our partnership was focused on creating programs for children and youth, we decided to focus the retrospective interviews particularly upon the question of how these adults initially became interested in nature when they were children and how that interest developed over time.

### 1.1 | Interest development

The question of how interest is initiated, sustained, and eventually developed into fully formed individual interest and identity is an important one for education (Ainley & Ainley, 2015; Bathgate, Schunn, & Correnti, 2014; Hidi & Renninger, 2006; Krapp, 2002). Interest is a concept and word used in daily vernacular to describe a feeling of attraction or excitement for something outside of ourselves. It contains an implicit nod to learning—interest embodies the desire to get to know more about something or someone. Interest throughout the course of one's life is central to learning in both in and out-of-school settings, especially for students from low-income, minority backgrounds who have historically been underrepresented in the sciences (Bang & Marin, 2015).

Interest in science has been attributed to both school experiences and self-initiated experiences (Maltese & Tai, 2010). Contextualization, personalization, and choice have all been shown to have strong effects on elementary school students' depth of engagement in learning (Cordova & Lepper, 1996). Topic interest has also been shown to

increase positive affect, which, in turn, increases the student's persistence to learn (Ainley, Hidi, & Berndorff, 2002). This topical relevance has been shown to be especially helpful for increasing both interest and performance in science for high school students with low expectations of success (Hulleman & Harackiewicz, 2009). Connecting science information to students own experiences (Basu & Barton, 2007) and community values (Bang & Marin, 2015) also support sustained interest in science.

Much of the work examining interest is done in studies conducted in school or school-like settings (Ainley et al., 2002). However, informal learning settings, such as science museums and science clubs, have also been shown to trigger interest (Azevedo, 2011, 2013; Dohn, 2011) and increase engagement in science material and knowledge acquisition (Martin, Durksen, Williamson, Kiss, & Ginns, 2016). Field-based, informal environmental education and nature exploration have also been shown to support science interest development (Zoldosova & Prokop, 2006).

Models of interest development in science have been empirically tested in different timescales—from a short-term structured learning activity (Dohn, 2011) to a semester-long intervention (Hulleman & Harackiewicz, 2009) to an analysis of 3 years of interest development (Alexander, Johnson, & Kelley, 2012). However, short-term learning experiences do not reflect the complexity of lifelong learning (Krapp, 2002). Interest develops as a result of numerous experiences that occur over a lifetime (Ainley & Ainley, 2015; Barron, 2006; Crowley, Barron, Knutson, & Martin, 2015) and learning is often experienced outside of school settings (Crowley et al., 2015). Learning happens across a variety of sectors and includes structured learning opportunities, such as school-based learning, and semi- and unstructured learning that occurs through out-of-school time experiences with family, friends, and at informal learning institutions. This broader set of temporal and structural experiences, which reflect the complexity of learning throughout an individual's lifetime, has been called a "learning ecology" (Barron, 2006; Crowley et al., 2015). Given the evidence for interest development in both in and out-of-school settings, we consider here how experiences across the learning ecology contribute to longer-term interest development.

In the context of this broader learning ecology, Barron (2006) has proposed three conjectures on learning and interest development: (a) that there are a variety of things that can spark and maintain interest, including media, conversations, and experiences; (b) that individuals make choices about the learning opportunities they experience based on their developing interests, provided that the opportunities for these experiences are afforded to them; and (c) that interest-driven learning naturally crosses boundaries between types of learning environments. She argues that formal and informal out-of-school learning should not be sharply compared and contrasted. Rather, they both form important components of the overall learning ecology. She stresses that adolescents, in particular, are involved in learning across many settings and that this is a developmental time when individuals begin to create their own learning opportunities. Barron also asserts that being engaged in many activities, along with the interactions between these activities, is key for identity formation. Studies that have examined longer-term interest development also support the importance of elements throughout the learning ecology, in particular, the role of family (Bricker & Bell, 2014) and informal engagement (Azevedo, 2011, 2013) with science content.

To deepen understanding of the complex and layered interest that develops over the course of an individual's entire childhood, we explore how Hidi and Renninger's (2006) four-phase model of interest development can be applied at this longer timescale. Given the length of time that we are examining, and the recollected nature of life history interviews, we suggest that looking at the two higher order categories of situational and individual interest, rather than also including the subcategories, are most useful at this grain size. Situational interest is described as including "focused attention and positive feelings" and is fostered and maintained primarily through environmental factors. It is often described as a momentary spike in interest, but can also lead to interest development over time (Azevedo, 2018). Individual interest, which includes positive feelings, but now also includes value and knowledge, reflects a predisposition to want to engage with domain-specific content. This individual interest does persist over time and has been shown to arise from regular situational interest experiences (Palmer, Dixon, & Archer, 2017). According to the model, each phase of interest development is sequential; for example, triggered situational interest could lead to maintained situational interest. This could then lead to emerging individual interest, which might culminate into well-developed individual interest.

## 1.2 | Project overview

This study examines the retrospective life histories of professional and serious amateur naturalists. We trace how our participants remember their interest growing over time and identify elements of the learning ecology that supported situational and individual interest. We also examine transitions between these two phases of interest and trace overall progressions from initial interest to a fully formed naturalist identity. Although life history data are necessarily shaped by the subjective recollections of participants, the data can provide a unique perspective on long-term learning pathways that are otherwise quite difficult to study, both in terms of engagement with the environment (James, Bixler, & Vadala, 2010; Stevenson et al., 2014; Williams & Chawla, 2016) and in terms of engagement with science (Bricker & Bell, 2014; Crowley et al., 2015; Jones, Corin, Andre, Childers, & Stevens, 2016).

We analyzed life history interview data to attend to the ways in which individuals perceive their own interest development and when they believed their interest transitioned from relying on external supports to embracing an internal and abiding naturalist identity. Thus, our analysis focused on identifying episodes of situational and individual interest in the life history and charting the larger trajectory of how the two interact during the development of a lifelong connection to nature. We recognize the limitations of relying on individual memory and interpretation of events but pursued this approach because of the potential benefits of exploring an extended look at interest development. Our study is guided by three research questions:

1. How might elements across the learning ecology support and maintain interest in nature?
2. Can we identify moments of situational and individual interest in these retrospective accounts, and is there evidence of how long-term connections to nature developed from these situational and individual episodes?
3. How do adult naturalists perceive and describe the genesis of their lifelong connection to nature?

## 2 | METHODS

### 2.1 | Participants

The university-based researchers began by closely collaborating with educators and scientists at the museum to identify broad categories of naturalists and potential participants for this study. To develop the categories, our team discussed the ways in which we have observed adults engaging deeply with nature both as professionals and amateurs. We included amateurs because there are naturalists who spend abundant time outside of work pursuing nature-based activities and gaining considerable naturalist skills, such as species identification. Although they may not be connected to nature professionally, these serious amateur naturalists also often share their knowledge with the broader community through activities, such as leading walks or writing blog posts about natural history.

We then refined this list of vocational and avocational engagements with nature until we agreed on seven categories to explore further: (a) applied scientist (e.g., ecologist working for parks organization); (b) research scientist (e.g., ornithologist working for research institution); (c) environmental artist (e.g., print-maker with emphasis on natural history); (d) environmental educator (e.g., education director for environmental nonprofit); (e) serious amateur naturalist (e.g., avid birder); (f) farmer/gardener (e.g., urban farm manager); (g) environmental community organizer (e.g., green jobs advocate). After the interviews were completed, we reevaluated the 21st century naturalist categories based on the interview data and added an eighth category—environmental designer (e.g., landscape architect)—to reflect an identity described by several of the participants in terms of how they interact with nature.

Our research practice partnership includes people who have worked extensively with naturalists in the region through both educational and scientific endeavors. Drawing on this knowledge, we purposively identified 48

potential interviewees spread across each of the seven naturalist categories. We continued to work as a team to prioritize potential interviewees that would provide diverse representation across the naturalist categories, genders, ages, and races. In particular, the team was looking to interview individuals that reflected what we defined as 21st century sensibility toward natural history—that is people who focused on urban areas, were from minoritized backgrounds, or included other disciplines in their work, such as art. This process led to a potential pool of 21 interviewees that reflected a diversity of age, gender, and race distributed across each of the seven naturalist categories. Of the 21 possible interviewees, three declined to participate in the project. After conducting interviews with the first 18 participants we found that we were hearing consistent themes and had reached data saturation. Thus, we decided to conclude the data collection rather than conduct additional interviews.

The final sample consisted of 18 adult naturalists, all living in the Pittsburgh region and all engaging regularly with nature either professionally or as serious amateur naturalists. The sample was fairly evenly split between women (10) and men (8). Participants were asked to identify their racial and ethnic background. Of the 18, 10 were identified as White, 5 as African American, 1 each as Latinx, Asian American/White, or Latinx/Black. The mean age of participants was 47; the minimum age was 24 and the maximum age was 68. The largest concentration of participants was between the ages of 35–44 (six total) and the remaining were fairly evenly distributed across other age brackets.

## 2.2 | Interviews

All naturalists participated in 60–90-min two-part semistructured life history interviews that were recorded and transcribed for analysis. The first part of the interviews, which are the focus on this paper, were life history interviews during which interviewees were asked to explore formative nature-related experiences from early childhood through college.<sup>1</sup> Life history interviews, derived from Crowley et al. (2015) earlier work examining life histories of scientists, began by asking interviewees to describe when their interest in nature first emerged (see the appendix). We then probed further for descriptions of the type of community they grew up in and asked them to consider how that may have influenced the type of outdoor play they engaged in, for example, “How did nature experiences figure in your experience of those places?”

To explore the influence of family on their interest development in nature, we asked questions such as, “How did your family support your interest in nature?,” “Are there specific memories that you have with family members that helped shape your attitude towards nature?,” “What kind of relationship do your parents have with nature?,” “Did your family do any activities with you that involved nature?” In particular, we probed for any examples of family initiated activities they may have participated in, such as gardening or hiking. We also asked them to reflect on any siblings’ adult orientation to nature to gain a sense of the parental influence on other members of the family.

The next section of the interview included a series of questions about other types of informal nature experiences, such as out-of-school programming like scouting; visits to informal educational institutions, such as museums or nature centers; and exposure to media that had a nature focus, such as magazines or television programming. We also asked them to systematically recount all school-based nature experiences. For this, we began by asking about elementary school experiences and then methodically moved through each level of schooling including middle school, high school, and any collegiate or postcollegiate experiences with nature they may have had in the classroom or through courses they took. We also explored any relationships with nonfamilial mentors that may have influenced the development of their interest in nature.

These retrospective accounts focused on key moments and experiences throughout each naturalists’ development that they recalled and identified as initiating or supporting their growing interest in the natural

<sup>1</sup>The second part of the interviews used a card sort task to elicit interviewees reflections on what it means to be a naturalist in the 21st century to inform museum planning. The card sort was completed with 65+ additional people, including regional K-12 educators and local and international natural history museums’ staff. We will be reporting elsewhere on the implications of these findings.

world. Questions probed deeply on when and where participants perceived their interest developing and, specifically, asked naturalists to consider those defining memorable experiences with nature that they believe led to their adult interest and identity as naturalists. For the three individual cases that are explored later in this paper, we invited each of the project participants to review these narrative accounts for accuracy and meaning; all names are pseudonyms.

### 2.3 | Survey

Following the interviews, all 18 interviewees were asked to complete a follow-up survey. The primary focus of the survey was to get inputs from these naturalists on the types of programming that the natural history museum should design to support the development of future naturalists. We elected to include these in a follow-up survey, rather than in the interviews, to allow the participants time to reflect and consider how their experiences might support future program strategies. In addition to programmatic questions, we asked the participants to self-identify some specific descriptive characteristics, such as demographics and employment. (We supplemented this employment information with basic information derived from organizational websites.) We also asked participants to select which of the naturalist identities best reflected their current work in the field. They were able to choose up to three categories and were given the option of creating their own category. All eight categories were selected by at least one of the interviewees and most interviewees self-identified as belonging to two or more of the naturalist categories (Table 1).

### 2.4 | Coding

Our coding of the data was iterative and involved several rounds of transcript review, code development and modification, and research team discussion about code application (Saldaña, 2016). To begin, we simultaneously read and listened to all 18 interviews to identify broad patterns in the data, which we derived both from answers to specific questions (e.g., "What were some experiences you had with nature through elementary school?") as well as emergent themes (e.g., type of independent outdoor time play). Given that these are life history interviews, we evaluated how participants described important moments in their pathway and considered the characteristics and patterns of these experiences. After careful review of these patterns, we then developed a preliminary coding scheme and imported the data into the computer-assisted qualitative data analysis software program Dedoose to code the transcripts. This first round of codes included the types of nature-based experiences, such as family led, school-based experiences, out-of-school time programming, or independent activities; along with reflections on relationships of influence, either positive or negative, with family or nonfamily members. Team review of these codes led to a tightening of code descriptions and applications.

Our final codes included three broad categories for engagement with nature: those that took place out-of-school with some structure via family or programs, those that occurred in school, and those that took place out of doors, but independently (Table 2). To better characterize out-of-school activities, we created secondary codes for four types of out-of-school experiences: family activities, institutions, media, and programs, which included certificates. Experiences with nature that were independent and not at all facilitated by an adult or program were coded as "independent outdoor time." For both of these sets of codes, estimated age period (e.g., early childhood, etc.) was coded when clear in the transcript. It was not possible to code for age for approximately one-third of these experiences because the nature of the experience was continuous over several stages or the age period was unclear. School-based experiences were coded separately and each educational period (e.g., elementary school, etc.) was identified. We also coded all participants' reflections on adults that they perceived as playing an important role in their interest development.

After reviewing the life history codes as a team and testing for interrater reliability (Cohen's  $\kappa = 0.75$ ), we began to layer in our interest development coding scheme, which also had several iterations. We developed robust criteria

**TABLE 1** Self-identified naturalist identities of each of the 18 participants (up to three total)

Current position	Naturalist identities									
	Applied scientist	Community organizer	Environmental artist	Environmental designer	Environmental educator	Community garden manager	Research scientist	Serious amateur naturalist		
Adjunct Professor of Art			✓		✓					
Artist			✓		✓			✓		
Associate Professor of Landscape Architecture			✓	✓						
Community Advocate		✓			✓					
Conservation Planning Manager	✓						✓			
Design Manager				✓						
Director, Conservation and Field Research	✓						✓			
Director of Education					✓					
Director of Information Technology <sup>a</sup>								✓		
Executive Director	✓	✓	✓					✓		
Facilities Coordinator						✓				
Naturalist Educator					✓			✓		
Program Associate for Educational Projects		✓			✓					
Research Assistant <sup>a</sup>							✓			
Senior Restoration Ecologist	✓			✓						
Senior Hydrologist		✓		✓	✓					
School Garden Coordinator			✓		✓	✓				
Teaching Artist, Environmental Artist			✓	✓						
Total for each identity	4	4	6	5	8	3	2	4		

<sup>a</sup>Most recent position if retired.

**TABLE 2** Code descriptions for nature engagement with example excerpts

Primary and secondary codes	Code description	Illustrative example excerpts
Out-of-school	Any type of out-of-school experience with nature that is mediated by some educational structure, such as family, program, or media	
Family outdoor activity	Family led semistructured outdoor experiences, such as hiking, camping, and gardening	"I guess it's state game land, but we could pull off and there's a lake there and we'd sometimes just stop there and fish on the way home for an hour or so"
Institutional visit	Visits to an institution that uses the built environment and is designed for learning, such as museum, nature center, science center; often family led	"We had an annual trip to the [natural history museum] and that was—that was a part of our growing up"
Media engagement	Indirect engagement with nature through media, such as magazines, television, books, etc.	"We had field guides. We had all those Peterson guides for birds and rocks and everything and such"
Program activity	Programs with informal education or youth institutions, such as scouting, summer camps, or museum programs	"I ended up off and on participating in earning badges through Girl Scouts. All of them, yeah, are like outdoors stuff. Either pitching tents or how to make proper fires...you know, like a warming campfire versus a cooking fire"
In school	Experiences with nature through formal schooling, such as lessons or projects done as part of classes that take place either indoors or outdoors	
Elementary school	Nature experiences through an elementary school class	"I had a third-grade teacher that had the most amazing collection of indoor plants in the classroom and she tended to them daily and I was lucky enough to sit kind of in that corner and to me, that was—that was the coolest thing in the world"
Middle school	Nature experiences through a middle school class	"Middle school had a pond on the property which was probably a storm water control pond or something. But it was natural and we'd go down there for science classes and do the typical sampling for amoebas and all that..."
High school	Nature experiences through a high school class	"I had a very eccentric art teacher and I guess he encouraged me to, you know, draw the—and paint the natural world, which was my inclination"
College	Nature experiences through a college course	"So, they had a field station as part of the university so we'd go to like [name] and do, you know—like capture small mice or like, you know, go on owl hikes or whatever else we—all the kinds of things you do as an undergrad in ecological science major"

(Continues)

**TABLE 2** (Continued)

Primary and secondary codes	Code description	Illustrative example excerpts
Postcollege	Nature experiences through graduate school	"I got a phone call from one of my faculty members in horticulture that said we have this graduate assistantship and do you want it? You need to start next week. So, I went back to school and got a master's degree in horticulture so then I had more of the hard sciences in it. But at the same time, that's when I was taking—always taking pottery and art classes and I realized I could merge the two...I got to do my first environmental art piece and it was adobe and branches. And so, you know, that—when I realized that, like oh my god, I could do art and landscape architecture and all this stuff like all together..."
Independent outdoor time	Outdoor time, that is, characterized by independent, self-directed activities without adult supervision, for example, free outdoor play, fort building, drawing, or bicycling with friends	"I was drawn towards a lot of like the little pockets of green. Be it like climbing that one tree that's on the block or digging around in the dirt with like figurine toys just because we didn't necessarily have like a doll house or something bought for us. So it was that sort of improvisation. Like okay, I need something to play with and this I'm drawn towards. I don't know why not like car, you know what I mean, or like blocks or something like that. But yeah, it was definitely green spaces to play on or with or add to whatever toys we had"

for identifying interest type and coded for either situational or individual interest for each excerpt (Table 3) where a nature-based experience, whether out-of-school, independent outdoor time, or school experience, was described by the interview participant. We defined situational interest as primarily being supported by an environment with structural support, while individual interest was primarily self-initiated as evidenced by such phrases as: "I did that on my own"; "I was drawn towards"; "I got really into"; "there was a curiosity"; "I had this big interest"; "I cofounded..."; and sometimes included activities with others, such as: "Then as I got older, we kind of pushed further into the woods." We completed some pilot coding of the finer scale of all four phases of interest development and confirmed the inappropriateness of using this approach at this grain size. Our interest development coding included excerpts from all 18 interviews. We thoroughly reviewed all of the interest development excerpts as a team, resolved differences in coding, and completed a test for interrater reliability (Cohen's  $\kappa = 0.93$ ).

Coding for examples of situational or individual interest allowed us to explore how participants' exposure to nature across multiple facets of their particular learning ecology may have supported their interest development. It also revealed the transitions between well supported situational interest and more focused, persistent individual interest. We coded for these recognizable transitions between phases and found 49 examples of these transitions distributed through 15 of the 18 interviews.

To more closely identify patterns in the data, we created three matrices that examined the frequency of code applications (Miles, Huberman, & Saldaña, 2014). The matrices included (a) the type of nature-based experiences

**TABLE 3** Code descriptions for situational and individual interest with example excerpts

Interest types	Code description	Illustrative example excerpts
Situational	Primarily supported by an environment that has structural support, including institutions, family, mentor, and so forth. May include independent activities when they rely on supports, such as independent outdoor time play, that is encouraged by parents.	"I remember a summer I did a week or two-week long art camp where there was a lot of interaction there with nature." "Well we were there with Boy Scouts, you know, so there were other fathers around, there were lots of other kids around. It was a group activity. It wasn't like the way I like to go camping now is, you know, get out in the woods and be alone and that wasn't what this was about. This was get out in the woods and sort of rough it." "We live right next to the woods and I went back there as an older person but it was—it's scrappy woods. You know, the teeny, tiny patch but it had grape vines all over the place because it was scrappy woods, and so we were able to play in that."
Individual	Primarily led by the individual; self-initiated; characterized by examples of actual or exhibited curiosity questions, experimentation, investigation, or other naturalist practices. Also, marked by persistent or repeated engagement, as with books or other content. May still have some environmental support, but individual choice is dominant.	"I got really into bats in high schools, and actually...I built a bunch of bat houses...I built like 30 of them or something like that." "I actually did a fair amount of fishing with the kid who lived on the street. (I) actually remember thinking why are these fish eating? Why is this area of the lake filled with weeds? All that. So, like there was a curiosity there." "I became fixated with trying to capture nature in certain aspects... make nature more visible or natural processes more visible. So that was something that, for certain, all of my work was within that conceptual kind of field. That became a real fixation for me for sure."

(e.g., independent outdoor time), (b) the correspondence of situational or individual interest with these types of experiences, and (c) the distribution of interest types across different stages of life (e.g., early childhood, middle childhood, adolescence, and young adulthood). We then used these frequency matrices to consider what types of experiences were associated with supporting situational or individual interest development at different ages for this group of naturalists.

### 3 | FINDINGS

#### 3.1 | Participant characteristics

All participants completed high school; 16 went to public high school and two attended private or parochial schools. All of the participants had some college exposure; 15 received a college degree and the remaining three attended some college. Of those with a college degree, six received a Bachelor of Science (Biology, Ecology, and Evolution, Engineering, and Computer Science), four received a Bachelor of Arts (Biology, Environmental Science, and Social Studies), and five received a Bachelor of Fine Arts (Art and Design).

Over half of the participants went on to graduate studies. Of those entering graduate school, six completed a Master's of Science (Conservation Biology, Forestry, Ecology, Horticulture, and Political Geography), three completed a Master's of Arts (Art, Art Business, and Landscape Architecture), and one did not complete the degree they began (Environmental Engineering). Of the total number of participants, three completed a Ph.D. (Genetics, Avian Ecology, Political Geography).

Fifteen of the participants are engaged in naturalist practices professionally. Professional scientists who either conduct research and/or are engaged in natural resource management account for six of those who use naturalist practices professionally. The remaining nine participants who are engaged in naturalist practices professionally are educators who bring the natural world into their work either through science (five) or art (four). The three participants that are not engaged in naturalist practices professionally are serious amateur naturalists who are consistently and deeply engaged in birding, botany, and/or environmental advocacy for natural systems. Fifteen of the participants were currently employed, two were retired, and one was unemployed at the time of the interview.

All of the participants currently live in the Pittsburgh region; however, they did not all grow up in the region. There was a fairly even distribution in the type of community they primarily grew up in: 6 are from rural communities, seven from urban communities, and five from suburban communities. The places they grew up in were broadly dispersed throughout the continental United States and included the urban core and suburbs of Pittsburgh, other large cities in the Midwest and West Coast, and rural communities in the Northeast and Southeast. However, several of the participants discussed moving from one type of community to another during childhood. There were also several participants who recalled spending memorable periods in rural areas with relatives even if their primary residence was suburban or urban.

### 3.2 | Interest in nature develops across the learning ecology

Participants nearly universally attributed their initiate interest in nature to independent outdoor time saying things such as, "I can remember having a lot of freedom to go and explore the neighborhood." The perception that early independent outdoor time was formative for their later interest in nature held for people in their 20s, in their 60s, and all ages in between; it was remarked on regardless of whether they grew up in inner cities, suburbs, or rural communities.

The kinds of independent outdoor experiences that participants recalled often involved nearby places they could easily access as young children, such as small woodlots, vacant lots, or back yards. Trees figured prominently in participants' recollections, with frequent mentions of playing and climbing in trees in yards, on the block, or in nearby woodlots. Some participants connected basic outdoor play, such as imaginative games, to their adult interest in nature, whereas others described strong, early connections with specific natural elements, such as water, insects, or birds, as in this recollection from a retired, serious amateur naturalist:

*There was an empty lot at that intersection and I lived a block away and a couple of things impressed me. I would go to that spot and sit in what I considered the woods. Now the traffic is all around, but I felt safe...I really felt very safe there and sat there and looked at things. I would look at leaves and, you know, the whole bit. I looked at everything...There were trees and probably brambles and whatever grows on an empty lot...in those days common nighthawks were common and there was an apartment building the next lot over on [street name], that had a gravel roof and every early May, the nighthawks would return and dive bomb over that roof. Lots of them! And I could sit on the front stoop of my house and watch them, and I thought they were awesome. They were like my signature bird.*

However, independent outdoor time was not the only place that participants perceived their connection to nature developing and being sustained. We found that all participants recollected nature-based experiences across

their learning ecologies, including in school experiences and out-of-school experiences, in addition to independent outdoor time. Still, school-based nature experiences, which were distributed throughout the elementary, middle, and high school accounted for less than one-quarter of all the recollected nature experiences. Although some participants had powerful school experiences with nature, many others could not recall a single school experience that connected to nature at all. In contrast, over three-quarters of all the nature-based experiences that participants perceived as significant happened during structured out-of-school activities or as unstructured independent outdoor time.

Many participants perceived out-of-school experiences as being important supports for their on-going interest development in nature; the most dominant recollection among these participants were family led experiences, such as hiking or fishing, followed closely by informal programs, such as scouting. Participants typically perceived the combination of these types of activities—across the learning ecology and throughout their childhood—as critical for their on-going and lasting interest development in nature. When asked to recall a specific moment that led to their interest development, most participants instead pushed back and expressed the idea that their interest was instead attributable to a host of interwoven experiences. They used phrases like “constant exposure” and “it’s just what we did,” and explained that they believed that experiences across multiple settings came together to help grow and maintain their interest in nature.

### 3.3 | Episodes of situational and individual interest are nonlinear and mutually reinforcing

We found that all 18 participants described instances of both situational and individual interest occurring throughout their learning ecology and at all stages of their childhoods. They largely described a nonlinear, back and forth layering of situational and individual interest experiences, rather than a clear sequence of situational interest followed by individual interest. In many cases, individual interest was strengthened due to additional situational interest experiences that provided structural support in the way of programs and important adults. In all cases, the types of interest recalled by the participants were intertwined in both time (different stages of childhood) and space (different elements of the learning ecology).

Out-of-school nature experiences, both structured and semistructured, made up the majority of the examples of situational interest that were described by participants. This included activities, such as projects in afterschool environmental clubs, family visits to nature centers, and watching nature programs on television. Individual interest episodes were recollected as most often having occurred during independent outdoor time experiences. Although school-based experiences were overall less indicative of interest development than either out-of-school or independent outdoor time, these experiences were nonetheless described as important for participants in their recollection of experiences that supported the development of their individual interest. Several participants recalled teachers or classroom activities that anchored their burgeoning interest.

Participants recalled examples of situational interest as occurring most often between the ages of 6 and 12 years for both out-of-school and independent outdoor time. Examples of out-of-school time experiences where situational interest were recalled include such things as camping and hiking with the Boy or Girl Scouts, fishing with parents, and family visits to museums, especially natural history museums. Independent outdoor time experiences that participants recalled typically involved exploration of nearby woodlots and parks due to a parent’s encouragement or insistence to get out of the house to play. One participant remembered their experience this way: “They wanted to see me go outside. Whenever it gets dark, come inside.”

Participants recalled that middle childhood, between 6 and 12 years old, was also when the most examples of individual interest during independent outdoor time occurred. Some described the value of this independent outdoor time during adolescence for individual interest development. Independent outdoor experiences at this stage often included recollections of close examination of the natural world through activities, such as bird

watching, experimenting with building using natural materials, or insect collecting, as with this recollection, “We did a lot of collecting of insects too ... My brother and I used to chase butterflies all over the neighborhood.”

Individual interest during out-of-school activities was more broadly distributed throughout the developmental stages and included recollected instances where participants described their motivation to pursue a topic or experience on their own, such as requesting to participate in a program. School provided over a third of the individual interest according to our participants’ recollections and these experiences tended to happen in high school, college, and beyond. Participants often drew connections between their in- and out-of-school experiences as well as episodes of situational and individual interest connection across the learning ecology. Here, a participant recalls a high school horticulture class that led to an individual interest episode at home where she was able to continue her exploration of plant propagation.

*Horticulture was cool because it was hands on and I liked to learn hands on. That's what I connected to most. And it was fascinating to me to learn about something and then have a lab like plant propagation where we got to touch the plants and propagate them and I got to bring them home and take care of them.*

### 3.4 | Pathways may vary but structural supports and mentors are consistent

We now present three individual cases to explore more of the details of how individual and situational interest manifest and transition across the learning ecology, with an attention to who is involved and how structural supports, situational interest, and individual interest intersect. The three cases—an amateur naturalist, an environmental educator, and an ecologist—were chosen to reflect the diversity of our participants across age, gender, race, and naturalist identity. Their varied life paths toward becoming naturalists help to reflect the breadth of experiences that our 18 participants recollected and shared with us. The cases illustrate how interest in nature and a naturalist identity can develop in very different types of learning ecologies. For some, strong supports at both school and home have led to professional work with nature, for others negative experiences in school were overcome, thanks to family encouragement or, sometimes, there was support of a critical adult outside of the family. In each of these three cases, we see how participants perceive the importance of structural supports, such as mentors, for the development of their adult naturalist identities (Table 4).

#### 3.4.1 | The serious amateur naturalist

Eric, 66-years-old and African American, works as the facilities coordinator in the office of a large, multinational corporation. Eric is a serious and long-time amateur naturalist whose story illustrates how early and consistent family encouragement supported his situational interest in nature. His story also offers some cautionary examples of how a lack of support, and even discouragement, in formal school settings undermined his potential trajectory toward a more academic connection to science and nature. However, despite the lack of strong support in school, Eric’s story provides an example of how individual interest can develop through a long-term relationship with an out-of-school program that provided a strong platform for knowledge development and interest persistence. Although he does not engage in naturalist practices professionally, he is a serious amateur naturalist with an emphasis on botany and photography. He selected the categories of serious amateur naturalist, community garden manager, and environmental artist to describe himself.

Eric recalled that his desire to explore outdoors and seek out the beauty in nearby nature was strongly encouraged by his family from early childhood. Both of his parents and his grandmother played significant roles in helping to provide structure for situational interest to develop in science and nature. His family was of modest means—his father was a minister and his mother stayed home with the children when they were young and then went on to work in a department store when Eric was in junior high school. Although neither did something that professionally connected them with nature, Eric remembers that they both loved to be outdoors.

**TABLE 4** Examples of situational and individual interest development in nature drawn from participants' recollections and descriptions in each of three focal life histories

	<b>Eric: The serious amateur naturalist</b>	<b>Ada: The environmental educator</b>	<b>David: The ecologist</b>
Participant characteristics	65-Year-old African American man  Facilities coordinator for a large corporate office  2 Years of college, biology, no degree	33-Year-old Latinx woman  School garden coordinator for urban community non-profit  BA in Biology and Fine Art; MS in Ecology	41-Year-old white man  Conservation planner at a statewide environmental organization  BS in Ecology and Evolution; MS in Conservation Biology
Perceived structural support for situational interest	Parental support through gardening, enrollment in out-of-school programs, and exposure to books, such as field guides  Frequent activities with and encouragement from grandmother  Museum educator recognized interest and supported additional learning opportunities	Regular outdoor activities with mother, such as fishing  Positive experience with scouting and scout leader  Pivotal support from high school teacher as mentor and advocate	Regular outdoor activities with both parents, such as fishing and visits to nature centers  Strong school-based experiences throughout K-16 including field studies and leaf-collection  Out-of-school experiences, such as clubs and nature-themed media (e.g., books and videos)
Recollected examples of individual interest	Insect and spider collections  Nature drawings and photography  Exploration of city parks and green spaces	Riding horses in middle school and beyond  Self-advocacy for advanced science studies in high school  Powerful experience living off-grid as a young adult	Fishing and camping without adults  Building bat boxes in high school  Creating an environmental film company
Articulated challenges for interest development	Discouraging high school experience  Inability to complete higher education	Negative feedback from some school officials  Contrasting parental attitudes toward nature	Nothing acute

Eric recalled his interest developing through such experiences as roaming the woods, gardening and picnicking with the family throughout childhood. Eric attributed his parents' affinity with nature to their having grown up together in a small, rural community that was near the Mid-Atlantic city they moved to before his birth. After the move, the family continued to regularly visit his grandmother in this nearby rural community and he reflected, "a lot of my interest was really spurred by her and by where she lived." He attributed a lot of his interest development to his grandmother and recalled spending extended periods with her during the summers and hours spent in her garden, which is the site of his earliest memory. He also recalled his grandmother taking him foraging for wild edibles, including mushrooms. These examples of situational interest were formative in his perception of his own interest development.

His father had an interest in photography, which Eric took up as well. He recalled bringing an old box camera to his grandmother's house and roaming the fields looking for things to photograph, an early example of Eric's

individual interest beginning to emerge. These linked interests—nature and photography—persisted throughout Eric's adult life and he continues to photograph plants and insects regularly.

When at home in the city, Eric recalled that his parents gave him a lot of freedom to be outdoors without adult supervision. He described how he played outdoors in green spaces near his home and the small garden in their yard that his father maintained. Eric also credits his parents in helping to maintain his growing interest by buying books and bringing Eric to the local museum of natural history. Eric perceived that he had a strong interest in nature as early as 10 or 11 years, which he remembers expressing through individual interest activities, such as collecting insects and spiders, which his mother would let him bring inside in jars.

Eric cited his father as having recognized his growing interest and enrolled Eric in a “junior naturalist” program at the local natural history museum as a pre-teen. Eric remembers attending the program, which was free at the time, every Saturday for several years. He convinced a couple of neighborhood friends to attend with him and together they studied at the museum and went on field trips to a nearby university field research station and to state parks. He recalled with pride winning second place in a diorama contest where he constructed a diorama of preserved insects and plants at the age of 12; the first place winner was 16 years old. One of the program instructors recognized Eric's interest in insects and recommended that he study more closely with the museum's entomology department, where he ended up taking additional classes to learn more specifically about insects. This provides an example of structural support from the museum staff in providing a platform for Eric's individual interest to grow.

However, Eric did not recall finding support for his interest in nature in school. In fact, when asked to consider examples of school experiences with nature, he could only recall a negative experience that took place in 11th grade. He recalled going to live with his grandmother for a year and a half and attending school in the rural community she lived in.

*I remember I wanted to do a biodiversity study and I still have the papers with me— my own drawings. I was doing a study of the mud dauber wasp and its influence on its immediate ecosystem. The mud dauber was a wasp that preys on spiders and literally entombs them in these mud sills and I was attempting to do a biodiversity study and I showed this to one of my teachers but it didn't have the impact that I wanted it to. I didn't get much feedback from that teacher. It was a little disappointing because at the time, I thought it was certainly worthwhile and wanted some pointers on how to improve this study as best as possible...I think if I had gotten a bit more help, a bit more direction, it would've had a better influence on my track after that.*

This project, and the attending lack of support, clearly held some significance for Eric based on his tone when telling this story and the fact that he maintained papers from the project for approximately 50 years. Despite the lack of support from formal school experiences, however, Eric remembered continuing to develop his individual interest in nature. He said of this period “Everything fascinated me! Every living thing fascinated me.”

Eric spent 2 years studying biology in college but did not have the money to complete his degree. As an adult, Eric recalls spending many years working in urban community gardens, exploring and photographing plants in a large urban park, and continuing to learn about natural history through informal walks and clubs. He enthusiastically described an independent inventory of the plants and insects in a large vacant lot near his home that he is currently engaged in. The lot is a block long and half a block wide and offers Eric a chance to wed his interests in photography and nature through this photographic study. When asked why he would take up such a study, he described his interest this way:

*I'm always astounded at the beauty you find in the oddest places, and in the diversity of life in places like that, that you ordinarily would not think would have very much life. In looking at it, it looks like a waste*

*place, an abandoned plot and going in and taking time to look here and there and to look closely—there's wonderful things you can find.*

Eric attributed this long-term persistent interest in nature, particularly this kind of nearby nature, as coming from two primary early sources: his family, especially his grandmother, and his long-term experience with the natural history museum.

### 3.4.2 | The environmental educator

Ada, 33-years-old and Latinx, is the school garden coordinator for a nonprofit organization that specializes in supporting urban agriculture. Ada attributed much of her adult interest in nature to experiences with her mother and with the Girl Scouts. She experienced differing attitudes toward nature in the home—positive from her mother, negative from her father—which provided an interesting example of how positive situational interest experiences, coupled with the early development of individual interest, can buffer negative input for some. Ada's story also illustrates the importance of adult mentorship and advocacy for her developing interest in the environment. Latinos are underrepresented in the sciences, including environmental science. Ada recalls struggling with science in school and credits a high school teacher as supporting her pathway to science. She ended up receiving her Bachelors in both Biology and Fine Art and a Masters in Ecology. She selected the categories of environmental educator, community garden manager, and environmental artist to describe herself.

Ada moved several times throughout childhood because of her father's work but grew up primarily in large cities. She recalls being attracted to pockets of green and climbing trees on her block at a very young age. She frequently played out of doors, improvising games and transforming toys, such as doll figurines, into tools to dig in whatever dirt she could find.

Her parents' contrasting relationships with nature offered very different perspectives for Ada. Her mother was the daughter of an Eastern European immigrant and grew up hunting. Ada recalled ample opportunities that her mother provided for her situational interest in nature to grow. Her mother frequently took Ada to the park for walks and went fishing with Ada. In addition, her mother had studied microbiology and modeled an interest in science for Ada. Her father, who immigrated to the United States from a Latin American Caribbean island, had more negative attitudes toward outdoor recreation, which Ada attributed to a cultural "big stigma" wherein he associated getting dirty and playing outdoors with poor people. When Ada went camping for one of the first times with friends in high school, she described her father's reaction this way: "He's like, why would you want to go camping? Like we came to this country to sleep on a mattress! Why would you want to sleep on the ground?"

Ada reflected that her father's discomfort with spending time outdoors was also related to his sense of not belonging. She recalled an attempt by her mother to take the whole family hiking, which turned "disastrous," in part, because of her father's distrust and discomfort of "not seeing anybody else like us around there." The tension that Ada perceived between her parents' orientations toward nature was not absolute, however. She recalled that her father shared her interest in horseback riding, which she did throughout childhood and which served as common ground for spending time with her father outdoors. Ada perceived her mother as the stronger positive influence on her interest in nature and articulated that her father's discomfort did not outweigh this.

Ada also had a short, but memorable experience as a Girl Scout. Although she only participated in the Scouts for about a year in elementary school, she had a strong association with the scout leader and vivid recall of activities, such as building forts, making fires, and hiking with the troop. When asked about the development of her interest in nature during her middle childhood years, she said, "I can categorically tell you it was from Girl Scouts."

Ada did not recall in-school experiences that supported her interest in nature until high school. She described a transition period from situational to individual interest happening during high school with the support of a key mentor, Ms. Z., who was Ada's homeroom teacher. Ms. Z. was a Biology and Advanced Placement Environmental Science teacher and Ada heard Ms. Z. talking about the class, which excited her. Ada remembers liking science

classes beginning in elementary school, enjoying how the classes could help explain questions she had about the world around her. This interest continued into high school, where she took biology and did well. She also found that her interest in art dovetailed with interest in science, helping her to draw, for example, anatomical figures more accurately. However, Ada was not in any advanced classes and recalls being initially discouraged from taking the Advanced Placement Environmental Science class by her advisor. However, by this time she had a strong individual interest in nature and she persisted.

*Well, what happened was I was discouraged from taking the class because I was not in any advanced classes...but I like science...and if I fail, then I fail. But at least I get to learn something...And I remember talking to Ms. Z about it because she was very excited. She was like "Oh yeah, yeah, take the class! This is when we're gonna have it next semester" and then I remember my advisor saying that. I was like, well I'm gonna take it anyway because I was just a stubborn kid...But Mrs. Z wrote me a note and said Ada can be in this class, and I did not get good grades in it but I learned—I still learned how to make quadrant studies, I still learned how to identify plants, I still learned what acid mine drainage is, and that, I think, alone sparked the interest...I changed what I thought I was going to do...I thought I was going to be just like a teacher. I honestly did not even choose a college until my last semester of my last year of high school. I had no clue. But with that, I started thinking about science. I started thinking about the outdoors and that at least I really like it out here. It's interesting to me, instead of school being just like "oh I have to do this."*

Ada went on to study both Biology and Art as an undergraduate, taking 6 years to complete her degree. Ada's identified her interest in nature making the final transition to individual interest when she spent several months doing an ecological footprint study off-the-grid in a New England state. During the program, she found peer mentors, particularly another young woman in the program, who supported her learning process. She describes this period as when she was able to overcome her fears of being out in nature—at night, with creatures—and described how she emerged with feelings of respect instead. She described her realization this way, "there was more of a respect for it [nature]. So, like I can't see everything but that's okay. I'm not supposed to know everything. I'm part of this. I'm not higher than this or bigger than this."

Ada reflected that her interest in nature translated into a series of environmental education jobs as an adult, including her current job that focuses on urban gardening with youth. She described how food and nature have been connected throughout her life and linked her current work as farmer educator and beekeeper both to memories of visits to her father's country of origin in which she recalled seeing people climb trees to pick fresh fruit and also to her role as the manager of food and waste during her experience in New England.

### 3.4.3 | The ecologist

David, 41-years-old and White, is the conservation planning manager for a large, statewide, environmental nonprofit. David described a childhood rich with experiences across the learning ecology that supported his developing interest in nature. David's story also includes examples of varied interests and how he brought these disparate interests together. He recalled family activities and positive in-school and out-of-school experiences that together provided a strong foundation for his professional work with nature. His robust set of opportunities and interest development led David to receive a Bachelor of Science in Ecology and Evolution and a Masters in Conservation Biology. He selected the categories of both research and applied scientist to describe himself.

David moved to a rural area at the age of 4 and recalled being given a lot of freedom by his parents to be outside in an unstructured and unsupervised way, either alone or with friends. These earliest experiences are an example of the situational interest that David perceived his parents supporting through their encouragement of his interaction with nature. Although their careers were not connected to the environment or nature—his mother was a banker and his father was an electrician—they both showed an avocational interest in nature. His mother took the

family hiking occasionally and the family went to state parks and nature centers several times a year, often for educational events, such as a raptor demonstration. David recalled fishing regularly with his father. They would also spend time exploring a lake that was nearby to their house looking for beaver lodges. His father, who had some general interest in birds, would bring binoculars.

*...one time we went back there and...through the woods at the end of the wetland and there was a gigantic, white bird. You know...in the wetland and just like—we were both kind of blown away by it and we're like trying to figure out what it was and like we watched it for a while. I remember going back home and I guess we had that Reader's Digest North American Wildlife ... I remember going home and looking through that and finding out like "oh it was a great egret"...*

In this example, David's exposure to nature moves from situational interest, where his father provides the dominant environmental support, to individual interest, where his curiosity propels him to seek out information on his own.

David remarked that there was a strong science program in his school district. In upper elementary school, he was encouraged to do a leaf-collection, a classic naturalist activity, which he described as "really exciting." In middle school, teachers used the school campus to have students collect data, such as water quality samples. David also recalled being engaged in some structured out-of-school experiences, including a brief experience with scouting in elementary school and robust participation in afterschool science clubs and competitions in high school.

David also described the impact of media on his interest development. There was one particularly potent experience, which involved watching a video on the Galapagos Islands in a middle school class that David recalls as a very inspirational moment. This provides an example of a transition of his interest in nature from situational to individual interest.

*We watched a documentary about the Galapagos and it just like blew my mind. It felt like it was something new that was just discovered even though, you know...Galapagos has been known about for a long time before that, but you know...just the way they presented it was like there's something out there to be discovered...they talked about a number of species and they talked about Darwin's finches and other bird species and the adaptations and you know, kind of how they had never—the documentary probably played up all these species that have never encountered people before, so they had no fear. It was just like super, super inspiring.*

David's interest in nature was not exclusive. From an early age, he describes building and engineering as interests. He recalls working alongside his father, who was an electrical contractor, as being essential to his sense of self as a child, saying that "I had this big interest in engineering and more technical things." As a teenager, he built bat boxes, which connected his twin interests in building and nature. He also described a very robust individual interest in film-making throughout high school, during which time he created a film company with friends and made some documentary films about teen issues.

David began college as a film major intending to make nature videos, another example of his efforts to connect two primary individual interests. However, in his third year of college he transferred his major to Ecology and Evolution after experiencing a science class that he perceived as changing his perspective of what science could be.

*...after I got on to the core classes, I kind of had the idea I should really go and take an ecology class and Plant Ecology was offered...like the first week of class, I was like just completely hooked on it and everything...Just part of a relation to science is an active thing...I had a feeling that, you know, we had everything figured out...but I didn't really fully comprehend that there's active research going on...that there's still stuff to figure out...I guess I had thought we had figured out biology and stuff like that...the*

*frontiers that everyone was talking about of discovery were space, were physics or stuff like that...but once I kind of realized that like there's a lot we don't understand about really simple stuff, you know, that kind of made it even more exciting.*

David's individual interest solidified as he moved into adulthood, which was apparent by his self-initiation of nature-based inquiry activities and persistence with those activities. For example, after hearing about an opportunity to work at an ecological field station, David recounted that he sought out the professor who managed this program and ended up working with him for 2 years in college. He continued his studies of ecology, postcollege, through an internship with an environmental government agency and then went on to receive a master's degree in Conservation Biology. His deep and persistent interest in nature is evident today in his professional work as an ecologist and conservation planner.

## 4 | DISCUSSION

Analysis of these life history interviews reveals that for these 18 adult naturalists, elements across the learning ecology worked in concert to support interest development. Our use of participant recounted life histories may include some bias due to inevitable inconsistencies in individual memory and perspectives. However, the life histories also offer a unique window into how an adult who has made a lifelong commitment to the study and engagement of nature perceives the elements along their pathway that supported their interest.

For these 18 participants, persistent exposure to nature, across the learning ecology and throughout their childhoods, was critical for their long-term commitment to engagement with nature. Independent outdoor time was ubiquitous among these 18 participants across age, gender, race, type of childhood community, and naturalist identity. Early childhood exploratory play (Ainley & Ainley, 2015; Bulunuz & Jarret, 2015) and conversation (Ainley & Ainley, 2015) are key components of interest development, especially for developing science interest. There are numerous examples of successful scientists and Nobel Laureates including the entomologist and naturalist E. O. Wilson and the physicist Richard Feynman, citing early childhood play as key for their interest development (Bulunuz & Jarret, 2015). Direct experiences with nature through childhood play has been shown to be a common and important feature of early childhood experiences for adults who remain engaged with nature (Charles, 2009; Chawla, 2007; James et al., 2010; Prévot, Clayton, & Mathevet, 2016).

We found that frequent exposure to nature was typically coupled with strong structural support from mentors, such as family members and other significant adults. Adult recognition of emerging youth interest (Heddy & Sinatra, 2017) and the active brokering of additional learning activities are key components for youth interest development (Bell, Bricker, Reeve, Zimmerman, & Tzou, 2013). Family members modeling interest and providing encouragement have been shown to be factors for early science interest development (Dabney, Chakraverty, & Tai, 2013). For some of these 18 participants, adult support came in school, as with Ada's high school teacher advocating for her to take Advanced Placement Environmental Science; for others, the support came from out-of-school settings, as with Eric's family encouraging him to explore nature independently and participate in programs at the local museum of natural history. Ada and Eric's recollections are emblematic of instances recounted throughout the 18 interviews, which highlighted how consistent family support and/or ephemeral support from perceptive nonfamilial adults played critical roles for interest development.

The 18 participants recollected situational and individual interest episodes throughout childhood and described these episodes as occurring in a nonlinear, layered sequence. The Hidi and Renninger (2006) four-phase model of interest development's use of finer grain categories within situational (triggered and maintained) and individual (emerging and well-developed) interest were not useful in this analysis of interest development over the longer timescale used in life history interviews. The model's frame as a linear, sequential building of interest also was not reflected in these life history data. Although situational interest was more prevalent between the ages of 6 and 12,

there were numerous examples within participant recollections where we saw a nonlinear path from situational interest to individual interest to situational interest again. David's experiences in upper elementary and middle school, for example, show several of these concurrences, which suggests a fluidity between situational and individual interest over the course of a lifetime that is not currently accounted for in the model. Articulating the potential for overlapping situational and individual interest would be a useful addition to the model when it is being applied to interest development at a long timescale, such as a life history.

However, the application of the model using the grain size of situational and individual interest was useful in understanding the broader type of interest being experienced across the life history. Experiences that are indicative of situational versus individual interest include different amounts of external, environmental supports, internal drive, and curiosity to persist with engagement. As described by Hidi and Renninger (2006), the situational interest that typically relies on external supports is sparked by something in the environment and is more fleeting, and may or may not persist over time. In contrast, individual interest is typically self-generated, wherein the individual begins to generate curiosity questions and show resourcefulness in efforts to gain additional knowledge, including persistence in the face of challenges. For these 18 participants, encouragement and external support was still of value during phases of individual interest development.

Our analysis of these 18 life histories suggests that while situational and individual interest episodes occur throughout the learning ecology, they do not occur at the same volume in different settings. For example, situational interest was more likely to be seen in out-of-school experiences, as in Eric's mushroom walks with his grandmother. From these cases, it appears that the strength of these out-of-school experiences may be in supporting situational interest. For these 18 participants, out-of-school programmatic experiences did not appear to provide them as many opportunities to develop an individual interest as other aspects of the learning ecology. Instead, we heard participants more often recollect individual interest episodes as occurring during school and independent outdoor time.

Reflecting Azevedo's (2011) notion of interest as lines of practice, the life histories also reveal how the intersection of different interests supports the development of deep individual interest and a naturalist identity. In Azevedo's account, the object of interest should not be thought of as a particular content area, such as nature, but instead as a set of interrelated activities. In all three of our cases, as well as other participant recollections, we saw examples of how participants wove together interests, such as photography, art, and building into their interest in nature. These intersections helped support increased knowledge of and value for nature in the participants' experience. They used these interests to improve observation of natural phenomena, such as the drawing that Ada did of anatomy, as well as to support their interest in stewardship of the natural world, such as with David's construction of backyard bat boxes. Interests develop best when those activities overlap in ways that allow people to be successful and to connect and express other skills, knowledge, and identities that are important to them. We saw many examples of this convergence in our data.

The overlapping and interweaving of both lines of practice and episodes of situational and individual interest can be considered together as a reflection of the deeply layered ways that people develop the kind of lifelong interest in nature that these 18 participants express. Taken together, these layered patterns of lines of practice and situational and individual interest development are important for out-of-school educators to consider. Specifically, we identify two important questions for science educators, especially those in informal settings, such as our partner museum that is working to support the development of 21st century naturalists: How can programs provide an opportunity for children to experience some semblance of independent outdoor time if they are not afforded this by their families? And, how can informal programs provide structural support and mentorship to youth participants in ways that both trigger situational interest, but also extend to supporting individual interest development? These questions are less salient where there are other opportunities in the learning ecology to grow individual interest. But for those youth that may not have as many opportunities or strong structural supports to engage with nature, informal education programs have an important role to play in providing more than just exposure. They might consider the ways in which they can design their programs to go beyond merely sparking interest and toward

supporting the development of lifelong interest in science and nature by providing strong adult mentors and experiences that foster individual interest development.

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## APPENDIX: INTERVIEW PROTOCOL

1. Could you talk to me a little about your interest in nature? When did it emerge?
2. Can you describe a little about where you grew up? What kind of neighborhood was it? What kind of community? [country, city, anything unique about that time period]
3. How did nature experiences figure in your experience of those places?
4. How did your family support your interest in nature? Are there specific memories that you have with family members that helped shape your attitude towards nature? [probe re: family structure]
5. [What kind of relationship do your parents have with nature? Are they naturalists? What were their jobs?] [Is nature a unique interest in your family? Intrinsic and personal vs. familial and contextual?].
6. Did your family do any activities with you that involved nature?
7. What about activities that happened outside of school. Did anything like museum visits, scouting, camping, field trips, extracurricular activities help support your interest in nature? [Any of those particularly memorable? Pls. explain. As a young child? Older child? Adult. Include all.]
8. Did you do any certificate or workshop type programs as a child that helped advance your interest in nature? (these could include museum-based camps or certificate programs as an adult, etc.)
9. I'm also interested in the impact of the school on your relationship with nature. Can you describe some memorable experiences with nature that you had through school? [glean some info on elem, middle school, high school]
10. [If not raised yet] What about in college and beyond?
11. Was there someone in your life who was a mentor for you around nature? Tell me about that.
12. I'm curious about how indirect exposure to nature themes might have impacted you. Are there some examples of nature-themed books or TV that stuck with you?
13. Now that you've been thinking through some of these early experiences, can you take a moment to reflect and then describe for me a moment or moments that you'd identify as pivotal—things that either put you on the path towards nature or helped you stay on that path?
14. Is there anything you want to share about your early experiences with nature that we haven't covered?