Title

# Environmental Science Identity & Learning Ecosystems for City Youth: The Role of People, Places, and Activities



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# Environmental Science Identity & Learning Ecosystems for City Youth: The Role of People, Places, and Activities

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## Abstract

This dissertation introduces the concept of environmental science identity (ESI) as a way to help better understand and support learners' engagement with the complex, global problems we face today, which require solutions from multiple perspectives. Because examining a learner's identity incorporates their values, culture, history, and future, using the lens of ESI in environmental and science education enables educators to honor learners' knowledge and skills in culturally sustaining and meaningful ways. I additionally argue that we must look expansively at learning activities with a learning ecosystem framework to understand the full picture of how ESI is developed. With these two lenses, ESI and the learning ecosystems framework, I examined the relationship between youth development of ESI and their learning ecosystems, as well as how youth learning ecosystems may be resilient in the face of systemic disturbances like the COVID-19 pandemic in 2020-22. In Chapter 2 I argue that zoos and aquariums need to bring to bear the extensive theory and research on the construct of identity, particularly ESI, and consider the learning ecosystems in which they are embedded, in order to meet their missions of environmental conservation and inclusion. Chapter 3 is an empirical study of how environmental science learning ecosystems support ESI development, as well as the related but distinct construct of environmental identity, in middle and high school youth in urban settings. Through analysis of interviews, I found that large ecosystems or deep engagement in activities were more likely to support ESI and environmental identity development. I also found that key material and social resources for identity development were unequally distributed across contexts for learning. Chapter 4 is a mixed-methods investigation of the impact of the COVID-19 pandemic on environmental science learning ecosystems. Through quantitative analysis of a retrospective pre- and during-pandemic survey of the frequency of learning activities, and semi-structured interviews with selected youth, I found that youth increased their engagement in activities overall with significant increases in gardening, hiking or camping, and noticing the plants and animals around them. Despite fewer activities available overall, these youth

deepened their engagement in activities that interested them that were still available during the COVID-19-related shutdowns, illustrating the resilience of young people and ways in which the natural world provided science engagement amidst the stresses of the pandemic.

## Table of Contents

**List of Tables**

**List of Figures**

## Acknowledgements

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# Chapter 1: Introduction

## Problem Statement

The wicked environmental problems we face today call for input and ideas from diverse perspectives, but input from non-credentialed scientists is not always acknowledged by decision makers as it may not look or sound like dominant forms of scientific communication. However, we know that young people from diverse backgrounds and experiences engage with science in various ways that educators and informal science education program leaders may not recognize (Bevan, Calabrese Barton, & Garibay, 2018). This lack of recognition makes it difficult for their ideas to gain traction and for minoritized voices to be heard and elevated to the same importance as ideas communicated traditionally by decision-makers. One of the first places this lack of recognition occurs is in the science classroom. The fields of science and environmental education can address this equity issue by examining learning in ways that account for learners' lived experiences and interests, so that these diverse perspectives can be recognized. This recognition of knowledge and skills communicated in non-traditional but personally meaningful ways throughout schooling can then be utilized in solving environmental problems in communities.

Conceptualizing learning as shifts in identity is one way researchers and educators have addressed this need to reconcile traditional displays of knowledge with more culturally meaningful expressions (Lave & Wenger, 1991). Identity is about being recognized as a "certain kind of person" (Gee, 2000, p. 99). Brickhouse, Lowery and Schultz (2000) describe science identity as when "students see themselves as the kind of people who would want to understand the world scientifically and thus participate in the kinds of activities that are likely to lead to the appropriation of scientific meanings" (p. 443). As identities are constantly negotiated between people, researchers must also attend to issues of power and positionality, thus challenging traditional (and dominant) expressions of scientific knowledge when undertaking studies of science identity (Calabrese Barton & Tan, 2010; Nasir & Cooks, 2009; Tzou & Bell, 2012). Understanding of what science identity looks like and how it can be supported may allow education practitioners to build experiences that engage all learners in meaningful ways and contribute to solving environmental problems. It is with this in mind that I propose environmental science identity (ESI) to bring the frameworks of science identity to the discipline, spaces, and practices of environmental science learning, which brings science out of the lab and into outdoor spaces and fieldwork and therefore offers different affordances for science identity development particular to environmental issues and spaces (Stroupe & Carlone, 2021).

While understanding how one program, activity or place supports identity development is helpful, in reality it unfolds over time and place. Each context has different affordances shaping how identity is expressed and negotiated (Holland, Lachicotte, Skinner & Cain 1998). By looking across contexts, we can understand how young people are supported, or not, in taking on a science identity holistically, since one place or activity typically cannot provide everything a person needs to develop a strong identity (Shaby & Vedder-Weiss, 2020). To account for this, I additionally apply a learning ecosystem framework that accounts for the variety of activities and contexts learners engage in around a topic that can help explain the many ways people learn about topics and take on identities. The notion of a learning ecosystem framework is gaining traction in STEM education research (Allen & Peterman, 2019) and can yield a nuanced understanding of the affordances of each context and how they interact to support identity development (Shaby & Vedder-Weiss, 2020).

By bringing together the concepts of learning ecosystems and identity development to the context of environmental science learning, I aim to contribute to our understanding of how young people authentically learn environmental science, apply it in personally meaningful ways and have their voices heard in solving the complex, local and global environmental problems we face today.

**Learning Ecosystems Can Be Studied Like Natural Ecosystems**

In order to examine the activities and resources youth draw on to engage with environmental science issues and topics, the studies in this dissertation primarily draw from Barron's (2004) research on "learning ecologies" framework that describes the physical, digital, social, and cultural resources that an individual uses for learning. Barron (2004) describes the four contexts within a learning ecosystem as home, school, community, and distributed contexts. The National Research Council (2015) employs a similar definition for STEM learning ecosystems, describing them as "the dynamic interaction among individual learners, diverse settings where learning occurs, and the community and culture in which they are embedded" (p. 5).

The terms "learning ecosystem" and "learning ecology" have largely been used interchangeably in literature but I am choosing to use "learning ecosystem" throughout this dissertation to focus on the characteristics of a system. Hecht and Crowley (2020) similarly emphasize that this terminology allows the focus to remain on the system and its complex interactions across time and place. A learning ecosystem includes "interactions between and among elements of the learning ecosystem including but not limited to youth, educators, families, and the material elements they engage with, such as classroom spaces or nonhuman nature" (Hecht & Crowley, 2020, p. 5). Investigating relationships, interactions, and feedback cycles as education researchers the way that natural scientists examine natural ecosystems can open up additional avenues for educational research.

One example of transferring these concepts from natural science to learning ecosystems is by invoking the concepts of natural ecosystem diversity and richness (Corrigan, Buntting, Jones & Loughran, 2018; Hecht & Crowley, 2020). This allows us to move the more descriptive language of learning ecosystems into measurable indicators of health and change (Sparrow et al., 2020) as ecologists use when examining natural ecosystems. One key metric for monitoring natural ecosystems we can take advantage of is species richness which considers the balance of species in an ecosystem (Fedor & Zvaríková, 2019). In a learning ecosystems, we can similarly consider the balance of activities across contexts so that no single one dominates.

Measuring diversity and richness over time in ecology are one important way to understand the resilience of an ecosystem (Sparrow et al., 2020). Like in natural ecosystems (Walker, 2020), learning ecosystems also need to be resilient in order to withstand disturbances and keep functioning. A resilient learning ecosystem is:

> A characteristic of such a resilient system, analogous to a resilient natural ecosystem, would be a high diversity of educational providers and science education niches—a diversity of niches too great to be described by the overly simplistic dichotomy of formal and informal education providers. Finally, such a system, by virtue of its complexity and redundancy, would be able to withstand repeated perturbations, be they political or economic. (Corrigan et al., 2018, p. 14)

Importantly, this dissertation study took place during a global pandemic in 2020 that fundamentally changed how young people live and learn for over a year. Due to shelter-in-place or "safer at home" orders, students were kept out of schools, museums, and even parks and beaches to slow the spread of COVID-19 starting in March 2020. At the very least, these measures interrupted the 2019-2020 school year, but many students continued to remain home for at least part of the 2020-2021 school year. By documenting and quantifying these changes in environmental science learning for young people, we can identify gaps and assess the resilience of these learning ecosystems, much like ecologists assess the resilience of natural ecosystems after a disturbance. In understanding the resilience of learning ecosystems under the pandemic "disturbance", we can potentially apply lessons from this moment to adapt and rebuild more resilient learning ecosystems for youth that will better survive the next disturbance and reorganize into a stronger system to better serve all students.

By focusing both on the system and individual learners, researchers can look at systemic inequities and issues but also understand individual learning processes through identity development (Hecht & Crowley, 2020). The framework echoes sociocultural theories that draw attention to the dynamic processes of learning that occur across time and space in varied settings (Esmonde, 2017) and can not only help understand the different affordances of learning contexts, but also the reciprocal influences of activities that have deep content, place, and/or social connections for learners that have potential to reinforce identity work across settings (Barron, 2004). Like Ching, Santo, Hoadley and Peppler (2014)'s work on social learning ecologies, in using the learning ecosystem framework in environmental education, we can begin to understand the material resources like scientific tools, exhibits at institutions, physical resources in natural areas as well as the social resources like experts, peers, family, and instructors across an ecosystem that support students' identity development.

## Developing the Environmental Science Identity Construct

### *ESI is Founded in Frameworks of Science Identity Research*

In order to move toward equitable and inclusive experiences in science and environmental education across a learning ecosystem, we need to understand science education and learning in new ways. Research on STEM educational programming has begun to recognize that students come to engage with STEM from many different meandering "pathways" including "workforce development, civic engagement, and science literacy" and not just with the goal of becoming PhD credentialed scientists (Bevan et al., 2018, p. 7). However, Bevan et al. (2018) critique that the pathways approach continues to orient programs and research toward traditional science perspectives instead of including unique contributions (also known as an assimilationist perspective). In contrast to assimilation, research and education motivated by understanding inclusive learning environments takes difference (in values, culture, history, or future) into account and looks to understand how educators and learning environments support learners in expressing their knowledge and skills in culturally sustaining and meaningful ways. The construct of identity as a process and outcome of STEM education is commonly used in research motivated by inclusion frameworks as it looks to incorporate unique expressions of knowledge and skills and understand how those are received by those in power (Rahm, 2021).

Learning researchers use different frameworks to understand the complex processes of identity development, assertion, and recognition. Essentially, identity is about being recognized "as a certain kind of person" (Gee, 2000, p. 99). It includes how people understand themselves, relate to, and are seen by others (Urrieta, 2007). This means a two-way negotiation between a person and who they are interacting with, as they tell and show them who they are while the other interprets and opens or closes space for these assertions (Holland et al., 1998). Studying discourse (Brown, Reveles & Kelly, 2005; Gee, 2000), practices (Nasir & Cooks, 2009; Nasir & Hand, 2008), actions, resources, and positionality (Holland at al., 1998), are all approaches to understanding these negotiations and assertions of identity. While there are many approaches and frameworks to understand how identity is constructed, negotiated, and changed, sociocultural researchers see identity as an outcome of life (and learning) that is multifaceted and flexible. These theoretical perspectives have shaped the research methods I employ in this dissertation.

In this dissertation I draw on Carlone and Johnson's (2007) science identity framework that conceptualizes three aspects of science identity: competence, performance and recognition. This conceptualizes science identity as knowing the content and practices, performing science identity through discourse, tools, and practices, and recognizing oneself and being recognized as a science person. To further develop the ideas of performance in this dissertation I drew upon Nasir and Hand's (2008) concept of practice-linked identities. There are identities people "come to take on, construct, and embrace that are linked to participation in particular social and cultural practices" (p. 147) and view participation as integral to who one is. They view learning as "shifts in use of artifacts (both cultural and cognitive) for problem solving, sense making, or performance" (Nasir & Cooks, 2009, p. 44). Their research focuses on the ways learning settings make resources available for these shifts in participation and therefore learning, identity development, and engagement (Nasir & Hand, 2008). They found that access to resources (material and social) was integral to the nature of engagement in the activity and therefore development of practice-linked identities. It is this focus on access to material and social resources for ESI development across spaces in a learning ecosystem that can help uncover how differences in learning contexts can support (or hinder) identity development.

Additionally, a figured worlds framework also offers complementary ideas with a learning ecosystem framework. Holland et al. (1998) elaborate on the social and cultural nature of identity and agency while describing figured worlds, or frames of social life that are “historically contingent, socially enacted, [and] culturally constructed” (p. 7). In focusing on identity with this framing, they describe identity formation as a process of learning actions, practices, and language of a culturally constructed identity (how one should act) and then using these actions and processes to affect those around us. In using these resources, one elicits their own sense of who they are and acts in that way. A figured worlds framework also pulls together both social and material resources for identity development that can be found in a learning ecosystem. I therefore drew on this theoretical perspective to explore the leveraged resources of learning ecosystems as they have been constrained not only by the norms, rules and expectations of the setting but also by the COVID-19 pandemic.

***Identity Research in Environmental Education***

Even though science and environmental education (EE) share many goals (Wals, Brody, Dillon & Stevenson, 2014), identity research in EE is less developed than science identity. One example of identity research in environmental education is from Carlone et al. (2015). They found that tools that facilitated youths’ engagement with animals or nature, or boundary objects, time and space, social support and scientific knowledge and skills have allowed youth to move outside their comfort zones and move beyond “their perceptions of who they were (not ‘outdoors’ or ‘animal’ kinds of people)” and work toward “who they were asked to become” (Carlone et al, 2015, p. 1526). Another example is Tzou and Bell (2012) who focus on identity negotiation in and around environmental science, wherein they combine social identity concepts and EE practices in order to show how place and borders are constructed and therefore how youth are positioned and position themselves when constructing identities in EE.

While both studies take place within EE settings, they do not focus on aspects of STEM even though STEM knowledge and practice outcomes are common goals in EE experiences (Wals et al., 2014). It is this lack of research on science identity in this context that I am hoping to fill through this dissertation on environmental science identity (ESI). Like others that have introduced discipline specific identity frameworks and definitions (e.g., Buontempo, Riegle-Crumb, Patrick & Peng, 2017; Doucette, Clark & Singh., 2019; Godwin, Sonnert & Sadler, 2016) I introduce ESI to understand the specific nuances of the content area in how identity is constructed and negotiated by learners. As Stroupe and Carlone (2021) argue, field science has the potential to disrupt traditional science power hierarchies and redefine who is an expert due to the reliance on local knowledge, improvisation and problem-solving during data collection and the distribution of labor across many people, thus furthering the idea that ESI may have important distinctions from a wider science identity worthy of study.

**The Urban Context for Environmental Learning**

In order to investigate the ways that youth learning ecosystems may influence their development of environmental science identity, the ways in which they change when a "disturbance" like a global pandemic occurs, and how examining these can help address equity and justice issues in environmental and science education, this dissertation study focuses on youth in urban contexts. Urban environmental education is an emerging area of research as populations continue to concentrate in cities and away from traditional places of environmental education where there are "pristine" natural spaces (Russ & Krasny, 2017). Additionally, in most urban counties, people of color are most of the population (Pew Research Center, 2018). This provides researchers access to a large, diverse population to study that helps to understand the breadth of experiences youth have in environmental and science education. The three key features of an urban landscape: people and communities, buildings and gray infrastructure and nature (Maddox, Nagendra, Elmqvist & Russ, 2007), all offer opportunities for environmental science learning for approximately 83% of the US population (Center for Sustainable Systems, 2021). So, while urban areas are where EE is happening for most students in the US, we lack the understanding of where and how this context shapes learning and identity development.

While cities, particularly large US cities, house some of our largest EE institutions, including urban, park systems, zoos, natural history and science museums, they tend to not serve the diversity of the urban population (Dilenschneider, 2020c). While 60% of the US population identifies as White, non-Hispanic, zoos, aquariums and botanical garden audiences are 66.1% to 82.2% White, non-Hispanic (Dilenschneider, 2020c). Urban green spaces present their own challenges for engaging audiences historically underrepresented in science and the environment due to a legacy of erasure (Finney, 2014) and unequal access (Elliott, Korver-Glenn, & Bolger, 2019). Elliot et al. (2019) used Houston as a case study to show that "although Black populations had equal spatial access to nearby parks, they were legally excluded from using more than 90 percent of them" under Jim Crow laws (p. 124). They also show that as the park system expanded after Jim Crow laws were eliminated, income was a strong predictor of where new parks would be placed that minoritized communities did not have access to (Elliott et al, 2019). Similarly, Finney (2014) traced policies that actively excluded Black Americans from visiting parks. She also showed how the history of American outdoor and environment movements excluded stories of African American environmentalists and the American media doesn't publish images of Black environmentalists or African Americans enjoying the outdoors further erasing them from these spaces (Finney, 2014). It is my hope that this dissertation bringing together the frameworks of learning ecosystems and science identity in the diverse landscapes of our cities will meet the call for a nuanced understanding of the affordances of learning contexts for environmental science learning for all young people.

**Dissertation Overview**

Chapter 2 provides the theoretical rationale and characterization of environmental science identity (ESI) as a construct and argues for studying ESI in the rich contexts of zoos and aquariums. As sites of environmental learning and science, these institutions provide a unique context for understanding this new construct. Additionally, the network of the Association of Zoos and Aquariums (AZA) offers an opportunity to use shared tools and methodologies in cities across the United States in order to assure an understanding of the construct for the diversity of the United States.

In Chapter 3, I report on a qualitative study utilizing interviews of youth zoo and aquarium volunteers. I interviewed 13 youth from zoo, aquarium and natural history programs to understand the key environmental science learning activities they partake in. I also investigated the social and material resources available for identity development in these spaces. I specifically examined the relationship between the characteristics of a learning ecosystem and ESI. Additionally, I examined where the resources that support the development of these identities exist across different contexts within the ecosystem.

In Chapter 4, I report on a mixed methods study of the impacts of COVID-19 on environmental science learning ecosystems. Utilizing a modified retrospective pre-/post-survey design, I quantified how the prevalence and frequency of learning activities changed during early pandemic restrictions. Additionally, I analyzed interviews to understand how the pandemic impacted the quality of those experiences and search for why these changes occurred.

## Chapter 2: Using Environmental Science Identity to Further Zoo and Aquarium Efforts to Advance Conservation Goals with and for All

The complex, global environmental problems we face today call for solutions and participation from diverse perspectives. Zoos and aquariums play an important role in solving these problems through their conservation work, defined by the Association of Zoos and Aquariums (AZA, 2021) as "active stewardship of the natural environment, including wildlife, plants, energy and other natural resources" (p.17). Conservation features prominently in AZA zoo and aquarium mission statements (Maynard, Jacobson, Monroe & Savage, 2020) and AZA institutions contributed over 231 million dollars in 2019 to conservation (Ripple, Sandhaus, Brown & Grow, 2021). This financial contribution is a common way the AZA field reports on their contribution to conservation and therefore addressing the environmental problems of our time. As further evidence of zoo and aquariums' contribution to conservation, Maynard et al. (2020) conducted an analysis of financial and web resources of AZA organizations in North America and found that zoos and aquariums do focus on many conservation projects. While monetary and staff support for conservation projects is one direct way zoos and aquariums are meeting their conservation missions, understanding and working with their visitors is another important way to meet the conservation goals of these organizations. In fact, zoos and aquariums play a unique and important role in addressing these complex problems by not only participating in conservation directly but also by interacting with over 200 million visitors annually (AZA, 2021b).

Visitors have the potential to contribute to conservation and addressing environmental problems beyond their financial support of institutions through direct action and problem solving which zoos and aquariums can and some already do facilitate. An abundance of research in educational settings, including zoos and aquariums and other informal learning spaces, shows that participants from diverse backgrounds and experiences engage with and display knowledge of science in a variety of ways that can be different from more traditional science audiences. However, few formal or informal science education programs recognize and value expressions of knowledge and engagement outside of traditional science practices and discourse (Bevan et al., 2018). This makes it difficult for these unconventional displays of knowledge and ideas to be taken up in conversations and for historically underrepresented groups and voices to be heard by mainstream scientists and decision makers like those in conservation roles at zoos and aquariums. AZA recognizes that diversifying the workforce and visitors of its institutions is key to meeting their conservation missions, by not only authoring a Diversity, Equity, Access and Inclusion (DEAI) Position Statement in 2020, but also by adding these issues to their strategic plan and accreditation standards for institutions (AZA, n.d.a). However, alongside nearly all other informal science institutions, zoos and aquariums have more work to do to listen to and understand the new audiences they are welcoming through their doors.

To begin to address this need, the recently issued AZA Social Science Research Agenda (SSRA) points to some key questions that will help AZA reach its strategic goals around DEAI (Kubarek et al., 2020). Specifically, key research question 1 focuses inward and asks questions about institutional culture and practices that can create a welcoming and inclusive environment for a more diverse workforce, and key research question 2 asks what role institutions can play in communities striving for social and environmental justice (Kubarek, Ogden, Grow & Rutherford 2020). However, the SSRA does not include important research constructs from other educational research disciplines that are crucial for understanding how all visitors, particularly those from historically marginalized groups, engage with, learn from, and contribute to zoos and aquariums' conservation missions. In order to move toward equitable and inclusive experiences in zoos and aquariums around the science of conservation and the environment, the field needs to understand and approach science learning in new ways that brings in current research in science education. In particular, research that is motivated by understanding inclusive learning environments, and takes differences (in values, culture, history, or futures) into account, and seeks to understand how educators and learning environments may support learners in expressing their knowledge and skills in culturally sustaining and meaningful ways (Bevan et al., 2018). Specifically, the construct of *identity* and the process of *identity development* as a part of and as an outcome of STEM education is commonly used in research motivated by inclusion frameworks. Research on identity incorporates unique expressions of knowledge and skills and interrogates how those are perceived by those in power (Bevan et al., 2018). We propose that for zoos and aquariums to meet their missions for conservation and goal of engaging broader and more diverse audiences, the field must look to and apply the construct and research perspective of identity, as well as consider the broader learning context, or learning ecosystem, of which they are a part.

Science education in and around the environment needs to address equity issues, including lack of recognition, erasure of knowledge, and ignorance of contributions from those outside of STEM and even scientists historically underrepresented in STEM in order to solve the mounting environmental problems we face (Stapleton, 2015). This requires that we study learning in ways that account for learners' lived experiences and interests (Bevan et al. 2018), so that these diverse perspectives can be recognized and put to use in solving environmental problems - this is what is missing in the SSRA. One way zoos and aquariums can meet their missions and DEAI goals is by cultivating a science identity, or as we propose an environmental science identity, in key audience segments that can expand participation and engagement in problem solving needed to solve environmental crises and meet our missions (Calabrese Barton & Tan, 2010). Understanding learners' identity development is a powerful way researchers have conceptualized these diverse displays of knowledge (Bevan et al., 2018). The construct of identity focuses on how learners are taking up and applying the knowledge, skills and practices of a discipline in personally meaningful ways while attending to issues of power and positionality, challenging dominant expressions of knowledge (Calabrese Barton & Tan, 2010; Nasir & Cooks, 2009; Tzou & Bell, 2012). This task is something zoo and aquarium educators are equipped to do as they meet visitors where they are in every interaction. In science, understanding what identity looks like and how it can be supported may allow practitioners to build experiences that engage all learners in meaningful ways and contribute to solving environmental problems by specifically focusing on identity development.

In order to understand STEM learning about the environment with equity and justice in mind, we propose a new construct of study, environmental science identity (ESI), to bring the identity framework to environmental science learning that we cultivate at our institutions. While many researchers have focused on science identity (Calabrese Barton et al., 2013; Vincent-Ruz & Schunn, 2019), and fewer researchers focus on ecological identity (Clayton & Opotow, 2003; Thomashow, 1995), the notion of environmental science identity affords us the ability to take STEM knowledge and skills about the environment out of the classroom or lab and into our zoo and aquarium spaces and the field where we work that have their own complicated histories and affordances that shape identity development. Additionally, we encourage the field to understand and connect to other environmental learning activities, within what scientists call the *learning ecosystem* (Barron et al. 2004), in order to better foster ESI development as a single place can't offer everything to every person all the time. Each person needs to be supported by a rich learning ecosystem as they navigate the complex and continuous process of identity development. As researchers and educators in AZA and informal science education institutions more broadly, we propose that researchers, educators, scientists, and leaders - together need to move farther as a field in bringing clarity to the muddy construct that is identity in our unique and powerful places of learning and connection to the environment.

## Theoretical Foundations of Environmental Science Identity

### *Science Identity Research*

We begin with the notion of identity development from a sociocultural perspective within the realm of education research. Education researchers from this perspective think about identity in several ways and use different frameworks and artifacts to understand the complex processes of how an identity comes to be, is asserted, and recognized in social life. It is understood as both a product (a certain identity) and a process (identity development, identity work or negotiation) that is not static and highly dependent on context. However, at its most basic sense identity is about being recognized "as a certain kind of person" (Gee, 2000, p. 99). This identity definition includes how people understand themselves and how they relate to others (Urrieta, 2007). Recognition of an identity is a two-way negotiation between a person and who they are interacting with, as one signals and asserts who they are while the other interprets and gives space (or not) for these assertions (Holland et al., 1998). Approaches to understanding these negotiations include studying discourse (Brown et al., 2005; Gee, 2000), practices (Nasir & Cooks, 2009; Nasir & Hand, 2008), actions, resources, and positionality (Holland at al., 1998). What all these approaches have in common is the view that identity is an outcome of social life and is multifaceted and ever-changing, regardless of which artifact is used to understand how identity is constructed, negotiated, and/or changed.

Science identity research focuses on how people relate to and enact the traditional practices and norms of science, and what influences that development or recognition as a "science person" (Bevan et al., 2018). The field of science has its own discourse, practices, credentials and specialized tools and a long history of exclusion of nearly anyone who isn't a cisgender, heterosexual white male. In fact, there is a plethora of research around understanding science identity in a variety of audiences and settings (Calabrese Barton, Menezes, Mayas, Ambrogio & Ballard, 2018). One rich example of science identity research in learning settings comes from Calabrese Barton et al. (2013) where they research middle school science learning both in and out of the classroom that they describe as a "complex web of figured worlds" for students that includes small group and whole class activities, different tasks, and social activities. They focus on the authoring of identities or the actions, relationships and leveraged resources used at a given moment that are constrained by norms, rules and expectations of the spaces they operate in (Calabrese Barton et al., 2013, p. 38). It is this nuanced understanding of what is at play when we ask a visitor to "do science", by asking them to, for example, make animal observations, that is missing in our field's current understanding of environmental and conservation learning that is missing and therefore preventing us from engaging everyone and meeting our missions.

While identity research in science learning settings is well-developed, in environmental education (EE) contexts it is less so, even though the two educational traditions share many practices and goals. Additionally, both fields are attempting to address DEAI issues that can be supported by identity research. For example, Carlone et al. (2015) describe physical things, or boundary objects, that allow identity work as an 'animal' or 'outdoors' person in an environmental education context. Another example of research on identity negotiation in and around environmental science is Tzou and Bell (2012). They bring together social identity concepts and EE in understanding how place and borders are constructed and how youth are positioned and position themselves in constructing different identities in EE. While both of these studies take place within EE settings, they do not focus on aspects of STEM even though STEM knowledge and practice outcomes are common goals in EE experiences and were in these programs.

***Considering Environmental Identity***

Distinct from science identity, but important to understand in thinking about how identity influences people's relationship to nature and conservation, are the constructs of environmental or ecological identity. These refer to a person's connection to the natural environment and a belief that the environment is important to and a part of us (Clayton & Opotow, 2003; Thomashow, 1995). Environmental identity "encompasses multiple meanings as well as a recognition of the dynamic nature of identity" (p. 8) about how the environment is defined, the degree of similarity between self and parts of nature and their standing as valued components of community (Clayton & Opotow, 2003). Clayton and Opotow (2003) argue that environmental identity should be studied to understand how it motivates environmental action as other models have failed to explain it.

Environmental identity has been a productive area of research since its introduction almost two decades ago and experiences like those at zoos and aquariums can influence its development. Nature program experiences alter how participants see the world including enacting appreciative and protective interactions (Williams & Chawla, 2016). Engaging in local environmental projects starts the development of or reinforces an environmental identity as Gallay, Pykett and Flanagan (2021) found in their study of African American and Latinx students. Experiences in landscapes and places impacted by climate change foster identity development, particularly around pro-environmental action and motivation (Stapleton, 2015; Young et al., 2020). As all three of these engagement types are prevalent in the zoo and aquarium community, the potential to understand and influence identity is within our reach.

***What is Environmental Science Identity***

However, ESI is more closely related to science identity and the research tradition that focuses on securing more equitable science experiences in and about the environment by valuing the diverse ways students engage with and use environmental science knowledge and skills. In studying ESI as an outcome and process of education about the environment, we center science in ways that environmental identity does not as it focuses on the science specific ways of knowing and practices and how those are taken up and applied by learners. Within the larger field of STEM identity research, researchers have focused on identity related to specific STEM disciplines like science (e.g., Vincent-Ruz & Schunn, 2019), and math (Cribbs, Hazari, Sonnert & Sadler, 2015), and even specific scientific disciplines like physics (e.g., Doucette et al., 2019). We argue that the discipline of environmental science also requires special attention in the realm of identity research as it often requires work in the field which comes with its own history of exclusion (Finney, 2014) in addition to the traditional means of marginalization in science. Being outside of a laboratory offers unique opportunities to understand identity development as well. Stroupe and Carlone (2021) argue that field science has unique opportunities to expand the definition of an expert and roles non-scientists can take on, focuses on community work and contribution which allows for genuine contributions from non-scientists, and has built in awe, curiosity and wonder as so much of field science is searching for “natural treasures”.

It is this lack of research on identity in zoos and aquariums that we are calling the field to engage in. ESI requires special attention because it can move learning out of the classroom and into the outdoors and our institutions which creates different negotiations in authoring a science identity as seen by Carlone et al. (2015) and Tzou and Bell (2012). A focus on ESI in zoos and aquariums also expands the research into pedagogical practices of environmental education, informal science, and science communication that emphasizes different content knowledge, behaviors, and skills and creates a new set of figured worlds than existing research on science or environmental identity and the settings they have been studied. As we are proposing a new construct, qualitative and quantitative lines of inquiry will provide a full picture of its validity and utility to the field.

If having a certain identity is being recognized “as a certain kind of person” (Gee, 2000, p. 99), having ESI is being recognized as an environmental science person at a certain time in a certain place. I believe Carlone and Johnson (2007) have created a framework that best incorporates the ideas of science identity into one model that describes different dimensions of what it means to be an environmental science person. They model science identity as made of three constructs: performance, recognition, and competence (Carlone & Johnson, 2007). Performance incorporates the social performance of the scientific community - the discourse and using the specific tools of the discipline (Carlone & Johnson, 2007). Environmental science has a whole host of tools that visitors to zoos and aquariums get to see and experience. Recognition is the recognizing oneself as a scientist or science person and having others do the same (Carlone & Johnson, 2007). With interactions with over 200 million people, zoos and aquariums can go far in helping folks see themselves as scientists and recognizing the environmental scientist in everyone. Competence is about having the knowledge and understanding of the environmental science content (Carlone & Johnson, 2007). A person high in the competence dimension would know about their environment and environmental issues and would have a nuanced understanding of human-environment interactions (i.e., the socio-ecological system).

A person can have the knowledge of environmental science but not express that knowledge according to the cultural norms of the discipline by forming an argument in a different way or writing a song or making a cartoon. Without the performance dimension, others may not recognize one as a scientist, even though a person is competent and recognizes themselves that way. Someone with a strong environmental science identity would display strong content knowledge both publicly and privately and garner the recognition from the community of practice as having done so. The difficulty with this comes in pushing the field to shift definitions of its social practices to provide a more inclusive community that includes and legitimizes the contributions of everyone in the way that they "perform" them. The recognition and the negotiation of identities as described by Calabrese Barton and Tan's and Carlone's work may not align with all scientists' and science educators' ideas of participation and performance. ESI development is contingent upon the push and pull between the learner and educator in what counts as performance of science knowledge and skill as described in the performance and recognition dimensions.

**Science Identity in Informal Science Institutions**

The last decade has seen the exploration of how informal science institutions (ISIs) can support science identity development, particularly as identity has been named as one of the six strands of science learning supported by informal environments (National Research Council

(NRC), 2009). Science identity is a strong predictor of participation in informal science activities (Vincent-Ruz & Shunn, 2019) and plays a self-reinforcing role in outcomes of science center visits in adults (Shein, Falk & Li, 2019). Additionally, Dou, Hazari, Dabney, Sonnert and Sadler (2019) found that "students with greater family support are more likely to have disciplinary experiences that might help them identify with STEM" (p. 634). When looking at historically marginalized groups like women and girls, informal learning experiences allow for the exploration of activities and then through continued participation, the meaningful engagement in the practices and communities of science in more expansive ways (McCreedy & Dierking, 2013). This research points to some of the ways science identity is impacted by ISI visitation and participation, but zoos and aquariums are perceived as different from other ISIs by the public and not as particularly aligned with STEM learning in the eyes of visitors (Gupta et al., 2020) so particular research in these unique settings is needed.

When looking at educational programming at zoos and aquariums specifically, we see some insights into the strengths of this setting in supporting science identity development. For example, Archer et al. (2021) found that taking on authentic animal care tasks like cleaning and creating enrichment were instrumental in allowing nondominant youth identities to be leveraged and linked to science practices of the institution. This points to how the unique tasks of animal care present in zoos and aquariums may be key in supporting identity development while the unique environmental and conservation science activities available in zoo and aquarium programming remain understudied.

However, when looking at visitation to a zoo or aquarium, the influence on identity is less clear. DeWitt, Archer and Mau (2016) found that visiting a zoo or aquarium was negatively related to future participation in science and science identification, perhaps because of the different (more diverse) demographics of visitors to zoos and aquariums as compared to other ISIs and overall lower levels of science capital in those visitors. This different pattern of visitation between ISIs was also found in Godec, Archer and Dawson (2021) study of participation patterns of young people interested in STEM. They found partially served but generally interested young people visited animal-related settings more frequently than other ISIs, but this group was also less likely to pursue science degrees and felt the least comfortable in science classrooms. This points to a special opportunity for zoos and aquariums to support identity development in a more general interest group of young people than other ISIs where they see science as an academic pursuit. The large number and greater diversity of zoo and aquarium visitors allows for more opportunities to support science identities and engage young people who would likely not go on to be career scientists but due to their interest and supported identity can become engaged in environmental problem solving. By supporting more people in developing ESI, we will create more engagement with environmental problem solving, thus achieving our missions. However, more research on identity (science, environmental, and/or environmental science identity) development of visitors and program participants needs to take place in zoos and aquariums so we can understand the particular negotiations that take place within our institutions and programs and really take advantage of our diverse visitorship and unique opportunities for science participation.

**Considering Learning Ecosystems as Contexts for Identity Development**

Identity development is a complex and ever-evolving process that is highly context-dependent with different affordances shaping how identity is expressed and negotiated (Holland et al., 1998). In order to gain a better understanding of the process, researchers need to look across contexts to understand the affordances for identity development and how young people are encouraged or prevented from taking on an identity such as science identity as one context can't provide everything every learner needs to develop it (Shaby & Vedder-Weiss, 2020). This variety of contexts calls for a research framework that accounts for the variety of places and activities learners engage with around a topic.

An increasingly popular framework to account for the places and activities as described above is the concept of a "learning ecosystem". Used across education research and policy to help explain the many ways and places people learn topics and take on identities, it describes the physical, digital, social and cultural resources that an individual accesses across time and settings for learning (Barron, 2004). This framework has been gaining traction in STEM education research for some time as we better understand learning as a life-wide, life-deep and lifelong pursuit that needs stronger connections for young people (Allen & Peterman, 2019; Bevan, 2016). In fact, the SSRA recognizes that understanding the role of zoos and aquariums as part of various learning ecosystems (in key research question 4) is important in moving the field forward (Kubarek et al., 2020). The learning ecosystem framework can not only help understand the different affordances of learning contexts but also the reciprocal influences of activities that have deep content, place, and/or social connections for learners that have potential to reinforce identity work across settings (Barron, 2004). Like Shaby and Vedder-Weiss (2019) we call for research across young people's ecosystems in order to create a more nuanced understanding of the unique affordances of each environment (particularly zoos and aquariums here) for their science identity development and of the interaction between contexts.

Barron (2004) further describes learning ecologies as "the accessed set of contexts, compromised of configurations of activities, material resources and relationships, found in co-located physical or virtual spaces that provide opportunities for learning" with "the person as the organizing central node in the system" (p. 6). This positioning of the learner at the center also means positioning the individual in the practices, structures, and institutions contextualized by family, culture, and global contexts (Ito et al., 2013). ISIs have been paying particular attention to the access part of the STEM learning ecology as they grapple with diversifying audiences but have lacked attention to the positioning of those new visitors in the practices and structures of institutions and therefore fall short of their DEAI goals. The National Research Council (2015) has advanced the definition of STEM ecosystems to employs Barron's ideas in STEM learning as "the dynamic interaction among individual learners, diverse settings where learning occurs, and the community and culture in which they are embedded" (p. 5) which is modeled from Bronfenbrenner's (1979) ecology model. If we recall that identity is an outcome of social life and is multifaceted and ever-changing, a learning ecosystem framework naturally supports understanding the complex process across time and place as contexts present different opportunities for identity development and negotiation.

Until now education researchers and practitioners have largely used the terms "ecology" and "ecosystem" interchangeably, but like Hecht and Crowley (2019), we are choosing to use the term "ecosystem" to highlight the system and interactions and complexities of the interactions across time and place as those are key to understanding identity development and the parallels with ecosystem terminology from the natural sciences to help inform the research practices and theory. Drawing from the natural sciences, we can describe ecosystems by their size, diversity and richness (Corrigan et al., 2018; Hecht & Crowley, 2019). While used in more descriptive ways by others, we propose the following definitions and measures of learning ecosystems, pulling from natural sciences practices. Ecosystems can have different numbers of activities and thus be different sizes. A rich ecosystem considers the number and frequency of these activities, like measures of species richness (Fedor & Zvaríková, 2019). Additionally, a diverse ecosystem balances the number of activities across contexts so that no single one dominates, like measures for species diversity (Fedor & Zvaríková, 2019). A rich, diverse learning ecosystem presents a myriad of opportunities for individuals to explore and take-on a new identity like ESI and like a natural ecosystem, can better withstand disturbances that would disrupt this complex process.

Learning ecosystems have additional parallels with natural ecosystems research, such as investigating relationships and interactions, and systems and feedbacks that open up additional avenues for educational research. A learning ecosystem, like a natural ecosystem, includes a myriad of interactions which create complex interactions for identity development. Learning ecosystems include those "interactions between and among elements of the learning ecosystem including but not limited to youth, educators, families, and the material elements they engage with, such as classroom spaces or nonhuman nature" (Hecht & Crowley, 2019, p. 5). These concepts, like in natural ecosystems, can help us understand the resiliency of the systems in a community and for a learner (Hecht & Crowley, 2019).

Research on science identity provides some clues on how a resilient ecosystem can support identity development. For example, Aschbacher, Li and Roth (2010) found that students who participated in multiple science activities, received solid support across multiple communities and "were more likely to consolidate their science identities and persist in their S[T]EM aspirations, becoming High Achieving Persisters, than students with less breadth and depth of support" (p. 578). Interactions between family support and STEM disciplinary experiences have been found to help students identify with STEM (Dou et al., 2019). However, ecosystems may not have desired interactions that support identity development. Godec et al. (2021) found that the most interested group of students were most likely to engage in everyday science activities like talking about science at home but were less likely to visit ISIs than their peers and reported feeling uncomfortable in those out-of-school science settings. They attribute this difference in participation between groups to processes of "privilege, exclusion, the effects of structural inequalities and the failure of the sector to serve minoritized communities" (p. 19). This disconnect between interest and ISI visitation is just as alarming in a learning ecosystem as it would be in a natural ecosystem and is a window into how understanding the interactions of ecosystem elements help us see the full picture of identity development.

Therefore, we propose the AZA and broader ISE field need to focus on understanding both the system and individual learners, in order to look at systemic inequity and associated issues but also understand individual learning processes through identity development (Hecht & Crowley, 2019). Through understanding where people go to learn about and experience the natural world, zoos and aquariums can better support visitors in developing ESI Through cultivating and supporting this identity in visitors, zoos and aquariums can better reach their conservation missions by understanding the complex negotiations people undertake when interacting with the science of conservation and the environment. As we diversify our audiences and workforce, zoos and aquariums need to critically examine what they may be asking people to give up, with respect to their identity, when interacting with exhibit interpretation and educational programming so that we may create an inclusive environment. This means moving away from an assimilationist perspective, or risk alienating large portions of the public and missing out on their unique perspectives and roles in solving the mounting environmental crises.

**Recommendations for the Field**

Understanding environmental science identity development, and the learning ecosystems in which we are embedded, can help zoos and aquariums understand visitor learning much like how science identity research has opened clues to how all learners interact with the content and practices of science. It is this understanding of visitors' learning processes that will help zoos and aquariums achieve our missions. By leveraging the backgrounds, knowledge systems, and experiences of visitors, we bring more ideas and skill sets to the table to solve the complex environmental problems we are facing. Returning to the AZA Social Science Research Agenda which aims to help us promote social science to do just that, identity is only mentioned in looking inward at our culture and identity (key research question 1) and not where we can truly leverage this construct in understanding a person's intellectual and social-emotional development (key research question 4) (Kubarek et al., 2020). Additionally, STEM identity researchers are often motivated by and interested in addressing diversity, equity, inclusivity and justice issues in the field which links to research question 2 - understanding the role of our institutions in the context of striving for environmental and social justice.

As a field we must not forget about this construct in the next 10 years of research. Understanding how experiences at zoos and aquariums, in interaction with other experiences, support science identity, environmental science identity and environmental identity will open up insights into how we can bring everyone together to meet our missions by developing best practices for youth programming, interpretation, and community and conservation programs. The unique positioning of zoos and aquariums as places to interact with nature AND science creates a rich context for understanding how these identities develop, interact, and influence behavior change and collective action that are both mission critical.

In the meantime, we can begin to apply what we've learned from other contexts to support science identity development now. All professionals interacting with visitors should attend to power dynamics and work to flatten the (perceived or real) hierarchies present in interactions (Fraser, Morrissey, Flinner & Dirk 2020). When possible, allow visitors and program participants to undertake authentic science and animal care tasks in supportive environments (Archer et al., 2021) and highlight the multiple identities and perspectives of people in current conservation and animal care projects as representation can help people see themselves in those roles and begin to help negotiate the many identities people hold and are developing into a possible future self. Field science has the unique opportunity to expand the definition of expertise as it requires problem solving and improvisation, which can reduce power hierarchies and allow participants to expand their identity into science (Stroupe & Carlone, 2021). Creating environments of mutual care and respect, collaboration and distributed expertise can help people take risks and "try-on" new identities in safe spaces (Archer et al., 2021; Riedinger, 2012). Stroupe and Carlone (2021) also found that field science is a community effort that upended participant narratives about science learning. These practices are already within reach of our zoo and aquarium professionals and with attention way help all visitors develop identities to meet our missions with us.

Many zoos and aquariums are already building a rich learning ecosystem through partnerships with other places of learning and environmental care and research in their communities. School partnerships like Fresno Zoo's partnership with Golden Academy allow students to have the zoo as their classroom which supports ESI development by building authentic science experiences across contexts that build on and honor students' knowledge. New York City's Urban Advantage program builds upon school partnerships with multiple ISIs across the city supporting middle school teachers and students in doing authentic science tasks in formal and informal contexts through in-school activities, field trips, and family visits to these rich sites of learning (Urban Advantage, 2021). Zoos and aquariums can support families in bridging home and our experiences through signage and live interpretation that builds from common experiences in home environments with questions and prompts that encourage conversations and sense-making together and practice at home.

# Chapter 3: Environmental and Science Identities and Learning Ecosystems: How Experiences Across Contexts Support Youth Identity Development

## Introduction

Youth engage in a variety of science and environmental activities throughout their lives, but how do these experiences work together to support youth in developing an identity related to the environment and/or science? In order to understand learning about the environment in this way, I propose a new construct of study, environmental science identity (ESI), to bring the science identity framework to environmental science learning (Lindell, Ballard, Khalil, Kubarek & Watanabe, in review). While much research has focused on science identity (Calabrese Barton et al., 2013; Vincent-Ruz & Schunn, 2019), and some, but fewer, researchers focus on environmental identity (Clayton & Opotow, 2003; Thomashow, 1995), the notion of ESI affords us the ability to take STEM knowledge and skills out of the classroom or lab and into outdoor spaces that have their own complicated histories and affordances that shape identity development (Finney, 2014). In order to gain a better understanding of the process of ESI development, researchers need to look across contexts to understand the affordances for identity development and how young people are encouraged or prevented from taking on an identity such as science identity, as one context cannot provide everything every learner needs to develop it (Shaby & Vedder-Weiss, 2020). Thinking about learning contexts and all their components as "learning ecosystems" is a useful framework across education research and policy to help explain the many ways and places people learn topics and take on identities and has been gaining traction in STEM education research for some time (Allen & Peterman, 2019). With these concepts in mind, I sought out to investigate the relationship between middle and high school youths' learning ecosystems and their environmental and science identities.

### *Learning Ecosystems*

This study's ecosystem framework primarily draws from Barron's (2004) research on "learning ecologies", a framework that describes the resources that an individual uses across time and settings for learning. Barron (2004) further describes learning ecologies as "the accessed set of contexts, comprised of configurations of activities, material resources and relationships, found in co-located physical or virtual spaces that provide opportunities for learning" with "the person as the organizing central node in the system" (p. 6). Middle and high school youth have the agency to seek out experiences that are of interest to them and align with their current and/or desired identities. Barron (2004) describes the four contexts within a learning ecosystem: home, school, community and distributed contexts. This framework is an extension of Bronfenbrenner's (1979) ecological perspective of human development that continues to be used and refined by psychology and educational researchers.

I am utilizing "learning ecosystem" instead of "learning ecology" to bring out the focus on the system and its interactions (Hecht & Crowley, 2019). Additionally, this language highlights the parallels to natural ecosystems that are characterized by their size, diversity and richness in order to understand their health and resiliency, which are also important in the learning context (Corrigan et al., 2018; Hecht & Crowley, 2019). While we lack the research to quantify diversity and richness like our colleagues in the natural sciences, we can begin to apply these same characteristics relative to one another to understand them. For example, one youth may do many activities (large) and access resources across all four contexts (diverse) while another may do fewer (small) across the four contexts (diverse). If youth are only accessing one or two contexts, their learning ecosystem is less diverse than those previously described.

**Contexts of Learning Ecosystems.** Each context within a learning ecosystem provides youth with different learning opportunities as well as different affordances for identity development. The different configurations of people, materials, and norms create different negotiations of power and therefore identity as young people navigate the world. These experiences are shaped by youth and the youth are shaped by the experiences in the negotiations of who the youth are and want to be as afforded, or not, by the materials and people of the activity and context. It is because of these differences that a single context, place, or activity cannot provide all the affordances and opportunities youth need to develop their identities and they must develop a full ecosystem of activities and places to access all the resources they want and need. In the following paragraphs I will provide a brief overview of what places and activities may be part of the contexts of an environmental science learning ecosystem.

***Home.*** Activities and resources in the context of home are generally discussed as "everyday science learning" or "family science learning" (National Research Council, 2009). Most of these activities and conversations do not have the explicit goal of teaching science or about the environment, but these topics come up as part of everyday life and routines (NRC, 2009). A young person's question of why something is the way it is presents an opportunity to teach and learn science and scientific reasoning (NRC, 2009). Everyday life experiences are full of opportunities to explore science concepts and/or skills but those opportunities are not always taken up due to a variety of factors including family knowledge, comfort, interests, or priorities (Sha, Shunn, Bathgate & Ben-Eliyahu, 2016). Family routines that result in learning about their local environment can be as simple as regularly hiking, birding, or gardening where families grow to understand the local ecosystem components, changing seasons and even climate patterns. In a study of STEM identity in undergraduates, habits of talking with friends and family about science throughout everyday life experiences across childhood were a predictor of STEM identity in college (Dou et al., 2019). Family conversations are where youth share what they're learning in other contexts and start to apply them to their daily routines and where youth have some control over sustainability practices like recycling, or reducing plastic, energy and water consumption (Collins, 2015).

***School.*** The school science context is well documented and is where most young people experience direct instruction and learning, primarily through science texts and talk, about the environment in science coursework (NRC, 2014). The Next Generation Science Standards (NGSS) include disciplinary core ideas on many environmental science topics including climate change (earth science), interdependent relationships and the cycle of matter and energy in ecosystems (life science) for middle and high school students (NGSS Lead States, 2013). In high school, students begin to choose coursework that aligns with college and career goals, and opt in to specialized coursework like Advanced Placement (AP) biology, chemistry, or environmental science. Even though the science classroom is a common experience, it can still feel foreign and difficult for students due to the specific jargon and discourse of science (Aikenhead, 1996). Researchers apply the construct of science identity to understand the negotiations learners undertake to express their developing knowledge and skills (and therefore identity) and how those with power respond to these oftentimes non-traditional expressions of knowledge (Bevan et al., 2018).

***Community.*** The community context includes activities traditionally labeled as "informal science learning". While we often recognize designed settings like museums, nature centers, zoos and aquariums (NRC, 2009), important in environmental science learning, particularly in the urban context, are parks and other designed green spaces. Unlike the school context in the learning ecosystem, these activities and settings are mostly freely navigated by learners according to their wants, needs, and interests (NRC, 2009). Youth also opt in to community-based programming to pursue interests outside of the school day and as they grow older again pick experiences that align to future college and career plans. However, these settings and activities are not evenly distributed across a city or metro area nor are they evenly accessible and welcoming for all audiences (Bevan et al., 2018; Elliott et al., 2019; Finney, 2014).

***Distributed***. The distributed context for environmental science learning includes nature documentaries and television shows, books and magazines, and the many digital resources accessible to youth. Unsurprisingly, several studies have found positive correlations between television viewers and science interest (NRC, 2009). The internet has transformed the distributed context as it not only allows for consumption of related information through search and newsfeed algorithms but also allows youth interactive content in ways traditional media could not (NRC, 2009), but isn't as well studied as traditional media sources. A single search on YouTube can lead to hours of videos on environmental science content and Google Earth's Voyager program brings virtually every ecosystem in the world onto a computer for exploration. The distributed context continues to change dramatically in content and usage as demonstrated by the recent pandemic. During the COVID-19 pandemic, internet usage increased dramatically in adolescents (Nagata et al., 2022) and we are just beginning to understand what this means for youth.

**Urban Learning Contexts.** A learning ecosystem is learner specific, with them as the organizing node of the system. This means that it is only made up of the physical and material aspects they have access to which means where they live and how they navigate that space matters. Notably, this study focuses on environmental science learning in urban and suburban contexts. Urban environmental education is an emerging area of research as populations continue to concentrate in cities and away from traditional "pristine" places of nature and environmental education that are outside of cities (Russ & Krasny, 2017). Additionally, community resources like museums, botanical gardens, and zoos that bring the natural world to people in designed spaces, are concentrated in cities and large metro areas. Many cities also include large park systems where urban youth can still be immersed in nature, like the Cleveland Metroparks and the New York City park system. However, urban green spaces present their own challenges for engaging audiences historically underrepresented in science and the environment due to a legacy of erasure from outdoor media and the environmental movement (Finney, 2014) and unequal access, explicitly through Jim Crow laws, and implicitly through unequal development and socioenvironmental succession (Elliott et al., 2019).

***Previous Research on STEM Learning Ecosystems***

Current research on STEM learning ecosystems has continued to expand from Barron's (2004) study on computing experiences and technological fluency in high school students. By focusing on a particular skill, Barron was able to ask about specific contexts and activities for learning technological fluency and gain an overview of learning ecologies in a quantitative way and show that youth with more experience utilized more resources. Ching et al. (2014) used a learning ecosystem framework to study social learning ecologies of youth in the "Hive NYC Learning Network, as sustained engagement in digital media and technology-related activities often requires access to resources" (p. 2). They sought to understand the dynamic nature of the students' ecosystems and set out to characterize the redundancy of support and diversity of sources which echo the sentiments of Hecht and Crowley's (2019) concept of resiliency. They found that if support becomes inaccessible, youth can lose motivation to continue their learning, but that a strong affiliation with an organization can reduce this impact because it builds redundancies in the social learning ecosystem of youth (Ching et al., 2014). Falk et al. (2016) bounded their study of a STEM ecosystem in a completely different way in their study of STEM interest pathways. They selected a specific community, therefore bounding it geographically, and used the school curriculum and community resources to frame questions about learning ecosystems, going beyond the "T" in STEM like the previously mentioned studies. This geographic bounding also helped the researchers find systemic gaps in the learning ecosystem and design "interventions" early in their project to build new community partnerships that bring key community resources to students.

***Environmental Science Identity and Environmental Identity***

I developed the concept of an environmental science identity (ESI) out of the research around science identity conceptualized through sociocultural theories (Lindell et al., in review). In this tradition, identities are conceptualized as flexible and context dependent as they are "situated in historically contingent, socially enacted, culturally constructed 'worlds'" (Holland et al., 1998, p. 7). Research on science identity focuses on how people enact the practices and norms of science and how people come to recognize themselves or be recognized as a "science person" (Bevan et al., 2018). A youth's identity is developed through interactions with people as the youth shows and tells them who they are and the other interprets those activities and responds by opening or closing spaces for those assertions to take place as bids for recognition are accepted or denied (Holland et al., 1998).

One popular way this has been conceptualized is through the framework developed by Carlone and Johnson (2007) which can be applied to the discipline-specific identity definitions like ESI. Carlone and Johnson (2007) include three domains: performance, recognition and competence. Competence focuses on the knowledge and skills of the domain and being confident in those (Carlone & Johnson, 2007). Performance incorporates the social performance of the scientific community - the discourse and specific tools of the discipline (Carlone & Johnson, 2007). The discourse of science not only includes the jargon but the structure of argument (claim, evidence, and reasoning format), mirroring the ideas of discursive identity conceptualized by Brown et al. (1998). It also includes ways of sharing information written, spoken, and graphically in the norms of the discipline. Recognition is recognizing oneself as a scientist or science person and having others do the same (Carlone & Johnson, 2007). While Carlone and Johnson (2007), included both self and outside recognition in their framework, they focused more on recognition by others when understanding science experiences of women of color as their analysis illuminated how recognition helped make sense of the distinctive experiences for women on different science trajectories. Recognition also helped understand the interactions and intersections of their personal identities with a science identity. Others utilizing the Carlone and Johnson framework have added focus on self-recognition aspects like Dou et al. (2019) and Patrick, Borrego, and Prybutok (2018). I have included both in the framework for ESI as both aspects are important in understanding identity development.

Some researchers have conceptualized discipline specific identities like a physics identity (Doucette et al., 2019) in order to better understand the experiences of different learners within the nuances of the discipline. ESI grows out of these definitions and frameworks of science identity. Like Carlone and Johnson (2007) I define ESI through a cluster of characteristics. Someone with a strong ESI, has knowledge and skills in the discipline that they can apply in personally meaningful ways. They feel part of a community of environmental science people or envision a future in the field. By focusing on the specific practices and contexts of environmental science that include field science and lab science contexts, we can continue to understand the ways youth engage in these contexts and with the knowledge and unique skills of the disciplines of environmental sciences (Lindell et al., in review). Taking students out of the lab and classroom and into the field for learning and engagement creates different negotiations in authoring a science identity as seen by Carlone et al. (2015). Carlone et al. (2015) show how an outdoor herpetology program pushed youth outside their comfort zones but could be brought back into engagement with tools and practices that enabled their boundary work in this new place for learning. A focus on ESI expands the learning settings from classrooms and labs to the outdoors and the pedagogical practices of environmental education, that emphasizes different content knowledge, behaviors, and skills and may intersect with different figured worlds than other science content areas. Additionally, field science presents different science practices and power negotiations not present in other scientific disciplines that may disrupt historical power negotiations due to the improvised and constantly changing conditions (Stroupe & Carlone, 2021).

In the field of environmental education, several researchers have theorized around an environmental identity (EID), which I see as overlapping but distinct from ESI. EID is a specific identity that has been used in environmental education contexts for almost two decades (Clayton & Opotow, 2003; Williams & Chawla, 2016; Young, Carsten Carter & Pettit, 2020) that also recognizes that identity is context dependent. However, Clayton and Opotow (2003) critique other identity theories that ignore the non-human relationships with nature and the larger non-human context of identity development (Clayton & Opotow, 2003). EID focuses on how people relate to and orient themselves in the natural world (Clayton & Opotow, 2003). Clayton's (2003) framework for EID includes "the salience of the identity, the identification of oneself as a group member, agreement with an ideology associated with the group, and the positive emotions associated with the collective" (p.52). This framework echoes ideas of recognition (salience and identification as a group member) in science identity frameworks but adds emotion and ideology as part of the framework, making it unique from the identities explored in science and other STEM fields

Students enter learning contexts and green spaces with particular interests, knowledge, identities and ideologies that shape how they interact with these spaces and what aspects of their identities are most salient. While ESI is more closely related to science identity, there are common behaviors that are exhibited by people with each of these identities, like spending time in nature, but one key difference is the thought process that is happening during those experiences in nature. Someone with a strong ESI may be thinking about why a certain plant looks the way it does or how an unexpected animal came to be there, while someone with a strong EID may be reflecting on how insignificant they feel among the redwoods or how their behaviors impact the river they are walking alongside. As people can hold multiple identities at once, it is possible that someone can claim both of these identities, but one may be more salient than the other in different contexts.

**Identity Development Through Practices and Artifacts.** Identity is not only shaped through interactions with others (social resources) but also with key practices and artifacts that signal to youth (and others) that they are a certain kind of person. Nasir and Cooks (2009) suggest that "shifts in use of artifacts (both cultural and cognitive) for problem solving, sense making, or performance" ( p. 44) are key parts of developing a certain identity. They found that access to material and social resources in particular contexts was important in engaging in activities that support youth identity development. In the context of field science and ESI material objects for identity development have already been shown to be important. Carlone et al. (2015) found that access to important field work equipment like waders, headlamps, and aquaria were important for young people who were at the edges of their comfort zone to engage with the activities and nature and at times increasing their participation in the practices of science. Tools and clothing are also strong signals to others of an identity, like with the red aprons youth docents wear that signal to the visiting public and peers that these youth know science (Adams & Gupta, 2013).

**Identity Development Across Time and Place.** Every context has different resources and negotiations for identity expression and development (Holland et al., 1998), highlighting the utility of the learning ecosystem framework for understanding identity development. The development and transfer of key practices of an identity is one way this key research has been conceptualized. Azevedo (2011) has conceptualized and traced “lines of practice” to understand long-term engagement in interest-driven pursuits and can also help explain identity engagement. Interest and identity are tightly related, and many researchers include interest in their study of identity (Buontempo et al., 2017; Godwin, Potvin, Hazari & Lock 2013; Vincent-Ruz & Shunn, 2018). Azevedo’s (2011) lines of practice are “a specific subset of a person’s preferences (in and beyond the hobby practice) attuned to a subset of conditions of practice in his or her life” (Azevedo, 2013, p. 488). Social and physical materials are essential in supporting lines of practice and different communities create different conditions for pursuit of these lines of practice, highlighting the need for research that goes beyond a single program or place and focuses on personal learning practices, like social lines of practice, as well as traditional practices of the discipline, like observational lines of practice in Azevedo’s (2013) study. This focus on materials supporting interest development in different settings aligns with a learning ecosystem framework that also acknowledges the different materials in different contexts.

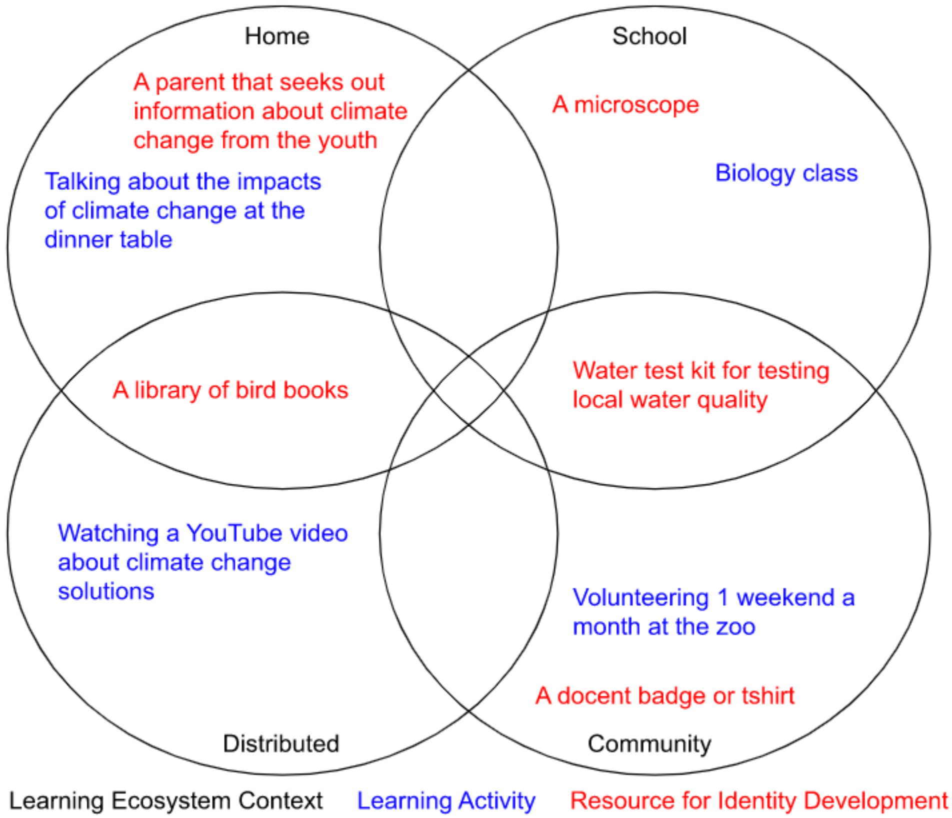
When looking across contexts of a learning ecosystem, we can see that they influence self-recognition of a science identity. Dou et al. (2019) "found that talking with friends or family about science [home context], as well as reading or watching fiction and nonfiction science media [distributed context], had significant positive influences on students' STEM identity" (p. 632). Additionally, Vincent-Ruz and Shunn (2019) recently found that science identity was a strong predictor of informal science participation (community, home and distributed contexts) and weaker predictor of formal experiences (school context) which may be related to issues of access to opportunities. Ching et al. (2014) traced social learning ecosystems over time for youth in their digital media and technology-related activities to understand how individuals across contexts (family, peers, teachers, and informal instructors) supported youth in their pursuits and projects and found that redundant social resources helped sustain youth motivation. Crowley and colleagues at the Activation Lab (http://activationlab.org) have used an ecological view of interest and identity development through both qualitative and quantitative means across many age groups as an additional model for a mixed-methods approach to understanding the relationships between these frameworks and have several validated measures available on the website (Activation Lab, 2019). Taken together, these studies show emerging work in understanding how learning experiences across contexts support identity development and warrant further study with a framework designed to conceptualize these varied experiences, such as a learning ecosystem.

***Research Questions***

It is with these frameworks in mind that I am investigating the relationship between middle and high school youths' learning ecosystems and their environmental and environmental science identities. Specifically, by interviewing middle and high school youth engaged in environmental and science learning activities that fit within the contexts as described by Barron (2004), I examined the relationship between characteristics of a learning ecosystem, the specific contexts within an ecosystem, and the aspects of ESI and/or EID youth described. Additionally, I examined where the resources that support the development of these identities exist across different contexts within the ecosystem. Figure 3.1 shows the relationship between resources, activities and contexts in this study. Youth engaged in these activities likely exhibit characteristics and self-recognition of both ESI and EDI, but one or the other may be more prominent or supported in different contexts; so in my analysis I attempted to explore the relative salience of the identities the youth express in the contexts discussed, in order to understand the resources that may support one identity over the other or other factors that support youth in their development of either identity.

Figure 3.1

*The Relationship Between Learning Ecosystem Contexts, Activities and Resources*




Three specific questions are addressed:

1. Do the youth describe having an ESI and/or EID?
2. How do the characteristics of a learning ecosystem relate to EID and ESI development for middle and high school youth?
3. How are resources for EID and ESI development distributed across learning contexts?

**Methods**

***Participants***

Participants were recruited as part of a mixed-methods study on science identity and learning ecosystems from zoo, aquarium and museum youth programs. Due to the nature of targeted recruitment, these youth are highly interested in topics related to the environment. Many of these programs are volunteer docent programs and (when not operating under a pandemic) provide youth with instruction on environmental science and conservation topics as well as skill-building in science communication and public speaking as their main duty is to serve as a docent. Some of these programs also include animal care tasks, like cleaning enclosures and/or assisting keepers in other tasks like feeding and observing animals. The 13 participants span ages 13 to 18 with an average age of 16.2. 23% of the participants identify as male; 69% female with one participant declining to state their gender identity. 69% of participants identify as White, 15% multiracial, one (7.7%) Asian, and one participant declined to state their race. Participants lived in multiple metropolitan areas across the US. Most pseudonyms were chosen by the participants and represent their gender identity but not necessarily their racial or ethnic identities.

***Interview Protocol***

Interviews focused on understanding influential aspects of participants' learning ecosystems and what, if any, aspects of those places influenced their knowledge, practices, competency, and recognition of environmental and environmental science identity. Similar to Ching et al. (2014), I used a semi-structured "funnel protocol" to ask how youth pursue learning related to the environment across settings in a learning ecosystem (Seidman, 2013). The "funnel" refers to the narrowing of questions based on youth responses. For example, participants were asked, " In the past few years, where have you learned about the environment and what do you do there?" to start and then using what settings or activities students first mentioned, I asked how those activities and/or places were structured in order to explore the affordances of places and activities through talking about the social and material aspects but also to explore in more depth what helps youth identify with environmental science (Ching et al., 2014; Perin, Connor & Oxtoby, 2020). For example, "What did [someone they mentioned] and you talk about or do together?" If needed, I asked them to tell me about a specific time that was meaningful in hopes of eliciting specific material or social resources. The interview protocol wasn't meant to create an exhaustive list of learning activities, but those that likely influenced their learning and identity development most. Additional identity questions focused on the performance and recognition subdomains of identity. For example, "When you think about any of the things you've talked about so far today where you learn about the environment, do you feel like you're doing science in those places?" (For the specific protocol, see Appendix A). Due to the geographic spread and the ongoing coronavirus pandemic, interviews took place over Zoom and ranged from 30 minutes to an hour. They were recorded with Zoom and transcribed utilizing Rev transcription services for analysis.

***Data Analysis***

I conducted analysis in multiple stages that I will describe in the following paragraphs. I started with many deductive codes at the outset of analysis but also inductively developed codes as analysis progressed which I will describe further below in each stage of coding. To start, I developed deductive coding of learning ecosystem elements (Barron 2004), resources for identity development (e.g., Nasir & Cooks, 2009; Perin et al., 2020) and ESI (Carlone & Johnson, 2007) based on previous research across these constructs I described above. Additionally, I developed inductive codes from themes in the interview protocol including specific learning activities (e.g., birding) and resources (e.g., observation protocols) youth described. At the outset of the research, I did not plan to investigate EID in detail in addition to ESI but throughout the interview process it became apparent that many youth were describing and signaling to me aspects of EID that governed their learning activities. Therefore, I applied Clayton and Opotow's (2003) description of EID, as well as emergent themes of environmentally responsible behaviors (recycling, using reusable bags) to develop additional codes to capture EID which will be described further below.

Using Dedoose for qualitative coding, I first identified the broad learning contexts and activities in those contexts with a focus on the elements of the learning ecosystem that students identified according to the framework developed by Barron (2004), with additional inductive codes based on activities youth commonly discussed in interviews, like watching YouTube videos and birding. This decision to start with learning activities and contexts was made out of concern for the importance of context given the fundamental role it plays in learning and identity (Holland et al., 1998). Additionally, by starting with learning contexts and activities, I was able to maintain larger excerpts of interviews, preserving student narratives and voice. An example of the learning ecosystem coding scheme can be found in Table 3.1.

Table 3.1

*Learning Ecosystem Codebook Example*

| Code | Definition | Examples or Child codes |
|---|---|---|
| Parent Code - Learning Ecosystem Contexts (adapted from Barron, 2004) | | |
| Home | Resources or activities done at home or with members of immediate family members at multiple locations that are not community specific | Gardening, hiking/walking, birding |
| School | Activities and resources that take place at school or with school-based groups/peers | Courses, after-school clubs, |
| Community | Activities and resources at community-based organizations/locations | Zoo or aquarium visit/program, 4-H, Parks, Camps |

| | | |
|---|---|---|
| Distributed | Activities that can be accessed across a wide variety of contexts and/or move across contexts, including but not limited to media, particularly internet-based activities | Shows, books, magazines, social media, YouTube |

In the second coding pass, I coded for the resources for identity development; those material and social resources available in these contexts as well as the people they discussed in these contexts. This coding pass also included deductive of affordances in the different learning contexts from material (specimen, instrument, artifact, etc.) and social interactions like brokering, knowledge building, and emotional support (Ching et al., 2014; Nasir & Cooks, 2009; Perin et al., 2020). I developed additional codes inductively to account for material resources specific to the contexts of ESI and EID being discussed. For example, the instrument code was modified to include animal observation protocols as that came up several times in interviews and serves a similar role as a scientific instrument as described by Perin et al. (2020). The physical setting was identified as an important theme during this coding pass as many youth described specific aspects and feelings associated with places where they were learning about the environment. Additionally, the "green thing" code was developed after recognizing the importance (and common) of items like reusable bags, water bottles, and utensils were to youth in signaling who they were and applying the knowledge they hold about environmental problems. Table 3.2 provides example codes adapted from the previous studies cited.

Table 3.2

*Resources for Identity Development Codebook Example*

| Code | Definition | Examples |
|---|---|---|
| **Parent Code - Material Resources** (Perin et al., 2020); (Nasir & Cooks, 2009) - these are the objects/materials that support science identity development as they are part of the practices and performance of doing science | | |
| Instrument/ observation protocol | A specialized object for scientific observation or research | Water test kit, iNaturalist for ID, animal behavior data sheet (ethogram) |
| Specimen | An object understudy/observation | birds, plants, exhibit animals |
| Physical Setting | Aspects of the place at large that are instrumental to their interactions with it. Places where the activity is dependent on the setting | River, lake, field, forest, exhibit |
| Green Thing (Lutzenhiser, 2002) | An object that signals environmentally friendly practices/an environmentalist | Reusable bag, metal straw |
| **Parent Code - Social Roles/Resources** (Ching et al., 2014; Nasir & Cooks, 2009) - these are *things that people do* at, to, or for the kids being interviewed - social ecosystems for youth | | |
| Brokering | Shares information about additional programs, helps students access additional resources, provides academic or career related advice | Counselor talking about undergrad majors<br>Parent making sure students have after school activities to choose from |
| Knowledge Building | Gives direct instruction on interest-related pursuits or feedback on something youth created, facilitates learning experiences, conversations that build knowledge | Conversation about birds while cleaning the exhibit.<br>Giving a presentation on threats to tigers |
| Emotional Support | Encourages youth in their pursuits; checks in | "How are you" "How's volunteering going" |

Finally, in a third pass, I coded for identity related expressions. I developed deductive codes for ESI from the Carlone and Johnson (2007) science identity framework that brought the constructs of science performance, competence and recognition into the specific discipline of environmental science. I also deductively included an interest code and future environmental science plans (i.e. college majors and careers) as these are commonly used markers of identity (Hazari, Sonnert, Sadler & Shanahan, 2010). During the interviews some participants also expressed an environmental or environmentalist identity as described by their connected relationship to nature and motivations to care for it as described by Clayton and Opotow (2003). As this was not part of the original plan, I then developed codes for EID. I explore this theme through additional codes for interest, recognition and performance mirroring the Carlone & Johnson (2007) framework for science identity. For example, when youth described being connected to nature that is recognizing their EID or when youth describe environmentally responsible behaviors like recycling and not using plastic bags or straws, I coded EID performance as those are practices of someone with a strong EID.

Table 3.3

*ESI and EID Codebook Examples*

| Code | Definition | Examples |
|---|---|---|
| **Parent Code - Environmental Science Identity** | | |
| Env. Sci. Competence (Carlone & Johnson, 2007) | Feeling like they have the knowledge and understanding of the environmental science content and skills of environmental science | I know more than my peers about that.<br>That was really easy for me. |
| | Some expressed negative competence or hedged their statements of competence | I don't know everything but I'm learning a lot.<br>I don't know everything, but I know more than my friends. |
| Env. Sci. Performance (Carlone & Johnson, 2007) | the social performance of the environmental scientific community - the discourse and specific tools of the discipline, sharing the knowledge they have of the discipline | "I definitely talk to them about climate change and climate change trends. I'll see something, like plastic on the ground or smokestacks blowing off smoke, and I'll kind of just go off on a tangent…" |
| Env. Sci. Recognition (Carlone & Johnson, 2007) | recognizing oneself as a scientist or science person in the context of the environment and having others do the same | "They can see me, I think, trying to think about things with that more of a scientific eye. I think they definitely see me as someone who understands science." |
| **Parent Code - Environmental Identity** | | |
| Env. Performance (Carlone & Johnson, 2007; Clayton & Opotow, 2003) | the social performance of environmentalism/environmentally friendly things. EID is typically associated with a greater commitment to conservation and pro-environmental behaviors.<br>Telling others about connecting to nature, doing environmentally friendly things | When I'm at the stingray pool, I really try to make guests feel comfortable and safe touching them.<br><br>Recycling, refusing plastic |
| Env. Recognition<br><br>(Clayton & Opotow, 2003) | Participants expression of a sense of connection to some part of the nonhuman natural environment, based on history, emotional attachment, and/or similarity, that affects the way in which we perceive and act toward the world<br>Others describe them in this way as well. | Hiking feels like an escape.<br>I have a passion for nature<br>I connect to nature<br>I love hanging out in the woods |

Once all coding was completed, I crafted participant profiles that described their overall learning ecosystem and identity (Seidman, 2013). Participant profiles helped identify trends or themes in identity development and learning ecosystem characteristics and identify cases for cross-comparisons to search for ways learning ecosystems may support identity development (RQs 1 and 2). Therefore, I characterized their identity as stronger ESI or EID from an overall impression of the interview, the number of times the interviewee discussed the particular themes of identity, as well as any specific statements related to who they are and/or want to be. I coded these statements in interviews as recognition of ESI or EID and weighted them more strongly when constructing profiles of the youth and characterizing their identity. Using code counts of identity themes assumes that the participants all talk about things at the same rate, which they don't, and so using this kind of approach to make inferences has some flaws, which may skew analysis which is why the differences between participants isn't weighted heavily but it was useful at looking comparing within a youth's interview to understand how they relate to environmental science (ESI) and nature (EID) and characterizing their own identity. However, some youth had nearly the same number of ESI and EID codes, without a strong statement toward either identity and are characterized as equal in the table. Only one youth (Maria) had very few codes for either identity in her interview and was characterized as none. I included the major learning activities they discussed with key quotations about their experiences there. This allowed me to characterize the depth of the engagement across the ecosystem (amount of time, commitment to activities) as well as the size (impression of the number of activities involved in the conversation). I also outlined the major learning activities the participant discussed in the interview. The profile included the post-interview memo that summarized the content of the interview and overall impressions and themes coming up throughout the interview process and specific key quotes. This allowed cross-comparisons of youth with similar identities to find commonalities and differences in their learning ecosystems.

Additionally, I developed profiles for each learning context (Seidman, 2013) in order to understand where common social and material resources for identity development were located (RQ 3). I used Dedoose to locate where resource and context codes co-occur to identify common resources in a learning context but also the unique resources there as well. I also paid specific attention to see which contexts had more codes for ESI and EID in order to understand if there were particular resources or activities there that may be supporting identity development. From student and learning ecosystem profiles, I iteratively distilled themes of identity development for these youth in relation to the contexts and resources in which their identities took shape. I also actively sought out counterexamples during theme analysis (Seidman, 2013).

## Results

Overall, I found that the youth in urban and suburban environments in this study described using a variety of contexts and activities to learn about the environment. Twelve youth identified learning activities in all four contexts while one participant did not discuss any activities in the context of distributed resources (media/the internet). Many youth described experiences with nature as being important and at times formative for them. In the urban setting, park systems like the Cleveland Metroparks and the zoo or aquarium provided these experiences of interacting with nature. Many youth also had the privilege of visiting many national parks both near and far. In the following section, I will describe how these identities were developing in the youth participants, then I will explain findings regarding how ecosystem characteristics related to these identities. Lasly, I will report on how the resources for identity development were distributed across these contexts within learning ecosystems.

### *RQ1: Do the youth describe having an ESI and/or EID?*

In regards to identity overall, through my analysis as described above, I found that youth identify with the environment two different ways: 1) a deep connection to the environment and commitment to protecting it, which I define as environmental identity (EID) and/or 2) an identity associated with a scientific understanding of nature and the environment, continuing to explore the environment and environmental problems in that way and applying that knowledge and practices in personally meaningful ways (ESI). For example, Amy expressed her EID when she said,

> "[my experience] makes me more connected to nature, because of all my experiences I've had, I have more, I've been there, I've seen what it can do, and I've seen how beautiful this world can be, we can't worsen it. So I think it's given me, being all these places, seeing all the nature, all the animals, and how it can affect the animals, I think it's really given me a unique perspective about how we can't ruin it."

This stands in contrast to Samantha's ESI statement of others' recognition of her as an environmental science person that uses science knowledge and practices to understand the environment.

> "My friends in school and outside of school and also my family, they think that I have a really good understanding of the environment. They can see my passion for wanting to know about biology and marine biology. They can see me, I think, trying to think about things with that more of a scientific eye. I think they definitely see me as someone who understands science."

Four youth had a stronger EID and seven more strongly expressed ESI (Table 3.4). This assessment was made through a combination of statements made by them and the number of codes for each identity in their interviews. For example, Gabby wants to be a nurse in the future (neither EID or ESI in her statement about future plans) but then described how she wants

> "to be involved with the environment, so I've been kind of thinking, into the future, what if I had the opportunity to help with medical equipment? It would be, 'So, let's figure out a way to make this equipment that's been wrapped in plastic, come up with something new'".

She had nine instances of EID codes and five of ESI, making her EID more salient than an ESI but also separated out the science part of her identities in alignment with the health field and not environmental science. In contrast, Debbie is an example of a youth that expressed both identities, she described herself as a "science nerd" (so not quite identifying with the specific discipline of environmental science) and had almost equal instances of EID (five) and ESI (six). Only Maria couldn't be characterized with either identity being particularly strong, because she made no strong statements for either identity and had few codes for each as well (three for EID and four for ESI).

***Characteristics of the Learning Ecosystems***

The majority (eight) of youth interviewed had large ecosystems where they described at least five core activities and other peripheral activities during their interview (Table 3.4). Those with small ecosystems described four or fewer core activities with little to no other activities mentioned. Nine youth described what I characterized as deep learning ecosystems where youth described engagement in activities frequently, in depth and/or over years (Table 3.4). Shallow learning ecosystems are characterized by light or infrequent engagement over time

Table 3.4:

*Participant Information*

| Pseudonym | Age | Location | Stronger Identity | Ecosystem |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Amy* | 16 | OH | EID | Large & Shallow |
| Debbie | 14 | TX | equal | Large & Shallow |
| Emily* | 16 | OH | ESI | Small & Deep |
| Gabby | 17 | MO | EID | Large & Deep |
| Hank* | 18 | MO | ESI | Large & Deep |
| Helen* | 17 | OH | ESI | Large & Deep |
| Ingrid* | 13 | OH | ESI | Large & Deep |
| J* | 17 | OH | ESI | Large & Deep |
| Maria | 17 | CA | none | Large & Shallow |
| Ronald | 17 | NY | EID | Small & Shallow |
| Samantha | 17 | MD | ESI | Small & Deep |
| Sheldon* | 17 | OH | EID | Small & Deep |
| Violet* | 15 | TX | ESI | Small & Deep |

*has relevant family background of activities

Five youth described large and deep environmental science learning ecosystems in their interviews. Helen is one of those five youth - she described several activities in depth including volunteering at the zoo and local parks, hiking, in-depth research with the internet and books, and school coursework and also mentioned five other activities in passing like going to botanical gardens, museums and watching nature documentaries. She has been volunteering at the zoo and parks for several years and hiking with her family for most of her life. Amy was one of three youth that have large and shallow ecosystems. She talked about as many activities as Helen but didn’t talk in depth about any of them. Even though she’d been volunteering at the zoo for a few years, she didn't describe any details about what she did there, despite many probing questions. Utilizing code counts like this has its limitations as it assumes participants are equally talkative and therefore has its limitations, therefore I used other information from their interviews like length of time they’d engaged in activities and how they connected activities together as part of this assessment. Four youth had small but deep learning ecosystems. While they only described a few core activities, they engaged in these activities frequently and over several years and talked in detail about the activities they did there to learn about the environment and/or environmental science. Samantha is one such youth; she discussed her environmental science class and volunteering at the aquarium. She's been volunteering at the aquarium over several years and has engaged in several activities there that she's connected to other learning activities. For example, she's engaged in several lectures on their dolphin program and done additional research on dolphin rescue and rehabilitation above her required duties of interacting with guests at exhibits. She contrasted this deeper engagement and learning with school environmental science when she said, "at the aquarium, it's really about getting an understanding, not only that you can kind of share to guests, but also so that you can use what you've learned in your own life to protect the environment." Only one participant had a small and shallow learning ecosystem. Ronald's learning ecosystem is discussed in the next section.

***RQ2: How do the characteristics of a learning ecosystem relate to EID and ESI development for middle and high school youth?***

**Ecosystem Size May Increase Identity Salience.** Youth with small ecosystems (five) were more likely to have few expressions of identity expressed through the constructs coded for and be characterized as having a weaker salience of ESI or EID. Three of these five youth had fewer than 10 statements related to the constructs of identity, despite how long we talked or how talkative they were overall. For example, Sheldon only described two core activities (both in the community context) but has been doing them both for several years and often throughout his high school career; he showed and expressed both identities but with caveats. For example, when asked about his understanding of science about the environment, he responded "I would say if I was to see something at the zoo, I'd be able to properly understand and explain it. I just don't think I would get, um, excited about it." Here we see him expressing competency but missing the affective response of peers he recognizes as having ESI. He also expressed reservations around self-recognition of ESI as he's surrounded by more "science-y" people than him. His small ecosystem may be due to the COVID-19 pandemic and impending high school graduation but also may signal these identities becoming less salient for him as he looks to college and starting studies in business or law.

Ronald had a similarly small learning ecosystem with a new but salient EID and a developing ESI. His interest in the environment was sparked by the youth climate strike in 2019. When COVID-19 canceled his summer 2020 program at an art museum, he pivoted to explore his newfound interest in the environment and joined an aquarium volunteer program (it was still a digital program at the time) where he is developing an understanding of the environmental science knowledge and skills. COVID-19 continued to hinder that development when his school canceled the AP environmental science course the following year due to budget cuts. Ronald's small ecosystem may be due to a combination of factors including his newer interest in these topics and COVID-19 restrictions restricting his ability to find activities that let him explore his developing identity.

Many more youth described larger ecosystems with several core activities as described previously and they were more likely to express stronger or more frequent markers of ESI or EID. For example, Gabby expressed a more salient EID during her interview and described activities across all contexts. Her interest in the environment started with teen camp at the zoo which grew into volunteering at the zoo. She also described hiking and her AP environmental science course as important learning activities. However, her most influential moment was an event for youth at the zoo where an activist/influencer running across the country to raise awareness about plastic pollution gave a presentation. This person and issue resonated with her and continues to influence her actions two years later, which reinforces her developing EID. On the other hand, Hank expressed a stronger ESI, and also described activities across all the contexts. Hank described even more activities than Gabby but also expressed a deep understanding of what species of plants and animals live in his region and how they interact with each other when talking about the activities he is involved in. Finally we have J, who expressed both identities strongly and equally. She described as many activities in her interview as Hank and connects to nature through hiking and cycling (EID) but also is deeply involved in coursework in order to become a wildlife biologist or ecologist in the future (ESI).

**Importance of Richness or Depth of Experiences for Identity Development.** In order to explore learning ecosystem characteristics in a different way, I looked to the depth or richness of experiences youth described. Especially when looking at Violet, who runs counter to the size trends above. She only discussed a few learning activities like Sheldon and Ronald but unlike them expressed a strong identity (ESI in her case). However, she described very deep engagement with these few activities, unlike the two boys. Unlike Ronald who's plans have been disrupted by COVID-19, when Violet's engagement with the zoo was paused due to the pandemic, she pivoted to distributed resources like websites, podcasts, and YouTube channels to continue to learn about the environment and other STEM topics. She also described many conversation topics with family and friends that were sparked by learning about an environmental problem online and then using them as sounding boards to discuss potential solutions, both personally and at a systemic level. The four youth (Violet, Helen, Samantha, and Ingrid) with the strongest environmental science identities (over 10 expressions of identity related constructs) all have deep ecosystems.

Ecosystem richness or depth of experiences may support identity development because it allows youth to respond to challenges or disruptions like those presented by COVID-19. J joined

Violet in turning to distributed resources when her usual activities were canceled. Ingrid took advantage of pedagogical shifts at school to pursue her interests in environmental science. Her teacher shifted to explicitly link content to the real world contexts and encouraged students to bring back additional research they did with their free time. This created a feedback loop that strengthened her identity and deepened her engagement in learning activities. Additionally, several youth described how the depth of their engagement and/or they increased the frequency of hiking, camping, and or just hanging out in nature during the pandemic.

In summary, I found that for most youth, larger, deeper ecosystems seem to support both ESI and EID, and limited ecosystems are less likely to support youth in developing strong identities (Table 3.4). Youth with larger ecosystems and deeper engagement expressed multiple aspects of ESI or EID and the smaller and simpler ecosystems youth had fewer aspects of ESI or EID.

***RQ 3: How Are Resources for Environmental and Environmental Science Identity Development Distributed Across Learning Contexts?***

I found that ESI was expressed and supported in community and home contexts most often (Table 3.5), perhaps pointing to the importance of these contexts in developing identity. In the community context, EID and ESI performance codes co-occurred often with zoo and aquarium settings and activities (8 & 20 times respectively). Seven of the eight youth expressed positive environmental science competence due to their zoo and aquarium experiences in the community context. Recognition of an EID was more common than ESI in the community context (eight and two youth discussed, respectively) as parks and zoos are where urban youth are experiencing and connecting to the non-human world (self-recognition of EID). The home context seems to be where identity related performances happen but also EID performances of sustainability practices happen. Home is also where these identities are being recognized by people important to youth.

Table 3.5

*Number of Youth Expressing Identity Constructs in Contexts*

| Context | EID | | | | ESI | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Interest | Perf. | Recog. | Plans | Interest | Comp. | Perf. | Recog. | Plans |
| Community | 4 | 5 | 8 | 4 | 0 | 8 | 10 | 2 | 1 |
| Distributed | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 0 |
| Home | 1 | 6 | 6 | 1 | 0 | 2 | 8 | 4 | 0 |
| School | 1 | 3 | 4 | 2 | 3 | 4 | 4 | 2 | 0 |

When looking closely at statements about performing these identities, I noticed that at times youth met resistance. While largely supported, two youth were met with annoyance when talking about their environmental knowledge, like Violet whose brothers would rather she stop talking at the dinner table. They both laughed off these moments as minor family dynamics and didn't seem to take them to heart. Introducing sustainability practices at home was also met with resistance at times for Violet as well as Gabby. Gabby used humor again to deflect from this resistance, making fun of him saying, "He is like the old people that are like, 'I don't want to change. Nothing is ever going to change. Everything is the same.'" Both girls were encouraged to act by their values by their families but as Violet said, "they're like, that's great, you do you, but we're not gonna stop. Like, they're still trying to- not to use it, you know? But they're maybe not as diligent as I am." Again, both girls didn't take these things to heart and it didn't seem to impact their identity development as they both expressed how their families supported their personal choices overall.

**Examining Resources for Identity Development Across Learning Ecosystem Contexts.** In the previous analysis, home and community contexts seem important places where identity development occurred with more than half of youth performing and/or being recognized for EDI or ESI in these places or during activities that take place there. In the next phase of analysis, I looked at the co-occurrence of material resources for identity development across learning ecosystem contexts in order to examine what, if anything, was enabling those performances or recognition of identities in those places (Table 3.6). In the following sections I will explore the most common co-occurrences.

Table 3.6

*Code Co-Occurrence of Contexts and Material Resources for Identity Development*

| | Community | Distributed | Home | School |
|---|---|---|---|---|
| Artifact Produced During Activity | 8 | 2 | 3 | 5 |
| Green Thing | 0 | 0 | 3 | 0 |
| Instrument/Obs Protocol | 7 | 1 | 2 | 3 |
| Physical Setting | 12 | 1 | 7 | 5 |
| Specialized Clothing | 2 | 0 | 0 | 0 |
| Specimen | 20 | 3 | 13 | 5 |

**The Physical Setting is Important for Both EID and ESI.** Notably, both home (seven co-occurrences) and community (twelve co-occurrences) contexts provided a physical setting that allowed youth to experience a connection to nature (EID) and/or understand environmental science and problems (Table 3.6). Seven youth described key aspects of the physical setting in the community context when talking about learning activities during their interviews. As Sheldon described being on a beach really helped cement concepts and problems he'd been learning and discussing at the zoo:

> "it really opens your eyes I think to the different problems, the different problems that are affecting it. Because you see a lot of stuff on the beaches. Cause not only do you see the wildlife in the different areas, but you also get to see like, you know, a lot of trash along the routes, you know, you'll see tires all along the beaches. And so it's just kinda really opens your eyes to different problems that affect nature in itself."

When learning about and connecting to nature and environmental problems, being in it was discussed by most of the youth.

Virtually all youth with a strong EID or ESI had a history of nature experiences with their families (home context), from a habit of hiking to summer vacations in the natural parks, these youth expressed aspects of physical settings that support their interest and identities. Maria ran counter to this pattern; it was on annual trips to state and national parks with her classmates that Maria experienced the same connection to the natural world. Many youth described how they continue to appreciate and seek out these settings as part of their environmental learning which supports both EID and ESI.

Related to this is where youth can undertake the study of a specific specimen and learn about and study its behavior and natural history. Specimens were discussed 20 times within community contexts (Table 3.6). At the zoo and aquarium, eight youth discussed how they see (and talk about) the same animals sometimes over the course of several years while some programs also give youth the opportunity to work with the keepers that take care of these animals. These experiences allow for deep engagement related to personal interests that can be flexible and shift as spontaneous things occur. Violet described one memorable occurrence when she was helping a keeper take weights of birds in the aviary.

> "They're like, normal birds you see in America, and so it- we were just talking about like, how even here they have this problem with like, they're losing habitat or people are just, you know, going for them… which brought up the whole, um, like when you're using toxic chemicals to like, kill weeds in your garden. And so we kind of went on this very huge, long tangent while we were- about this- all this ... Like, it started very simple and then it got into like, we were talking about chemicals and like, that- that kind of like- the ramifications of using toxic chemicals. Like, it gets the job done but at the same time, you know, you're killing x, y, and z. And so that was probably one that I just had that was, you know, stuck with me. I did a lot of research after that one."

When working with keepers, youth not only get to learn more about the animals at the zoo by talking to an expert but they also talk about larger topics that spurn new ideas and interests. Youth also discussed specimens in the home context 13 times where activities like birding and gardening allow youth to understand local species in new ways (Table 3.6).

**Artifacts of Participation.** Artifacts produced from participation in activities, like PowerPoint presentations and projects were created most often in community (8 instances) and school (5 instances) contexts (Table 3.6). Some youth had the opportunity to create presentations for their peers as part of community-based programming, like Hank who has given several presentations to other youth volunteers at the zoo on various animal species he's especially interested in. When interactions with guests were limited due to the pandemic, Ronald and his peers created digital interactives for families to use while the aquarium was closed and Amy and her peers created a board game for later use with families. All of these projects provided youth with opportunities to learn with their peers and share their knowledge with others, both important acts for learning and identity development. Schoolwork allowed for similar presentations and projects to be created but the audience was limited to their classmates and teacher in most cases.

**Science Instruments and Protocols.** Six youth were able to do systematic observations of animal behavior and/or visits to the zoo veterinary hospital as part of that programming. Helen described observation protocols for observing people and animals in her volunteer program.

> "Sometimes we'd go somewhere else, take data on something specifically like the rainforest and the orangutans or something. And then other times we would take data on people, where people were walking in and out, what way they were talking about. And then another time we basically were allowed to split up around the zoo and sketch how we would personally improve and exhibit."

This activity brought together many scientific and engineering practices, an important performance of ESI, and allowed Helen to apply her cumulative knowledge to the activity which builds competency in the subject area as well. An additional three youth described instruments and protocols used in school, mostly on field trips and related to water quality measurements. Six of these nine youth expressed a strong ESI which could point to the importance of these types of experiences in developing ESI.

**People Provide Recognition and Social Resources for Identity Development.** When coding for who youth discussed when talking about learning experiences, parents, peers, and zoo and aquarium guests were the most prominent people. Seven youth discussed how their parents recognized their EID and/or ESI and an additional two described encouragement from parents in their pursuits. Five youth discussed identity recognition from peers. Six youth expressed that the zoo or aquarium volunteer program was where they found people "like them" for the first time and made deep friendships. As J expressed,

> “I met some really great people who are also passionate about the environment and that was really neat because I hadn't really found that anywhere else. And so it was just like an opening to, yeah, there's a whole community of people out there who are passionate about the environment and conserving it as well.”

J first started out by recognizing her own passion about the environment (EID self-recognition) and that same passion in others. She continued to describe joining a community of peers that can become a positive feedback loop in pursuing her interests and developing a stronger identity through additional practices (performances) of that community.

In these zoo volunteer programs, the ability to interact with guests allowed youth to “perform” their developing identities and receive recognition of their developing expertise and identities. For example, Samantha expressed that

> “It was really cool getting to see people of all ages and learn about these animals and me being able to tell them about it, like for horseshoe crabs, how their blood can be used for vaccines and just research. That's really cool, getting to actually open people's eyes up to that and hearing them being surprised and learning about out it and finding it interesting.”

Ingrid also described that it was “a really good feeling” seeing people learn from her. Some youth, including Ingrid, facilitated animal interactions with zoo and aquarium guests where they helped connect guests to the animals and in a different way, sometimes more in line with an EID. As Ingrid described,

> “It's really interesting when the little kids, they really just want to show you, they can do it and they are so proud. And then seeing the parents be proud of their kid because you helped them accomplish something that might be scary to them, I think that really is my

mission at the end of the day. It's my personal goal is to make people feel more comfortable around animals and not only see the dangerous side…"

Unlike peers and parents, zoo guests do not know youth and identity recognition from them meant something different for some youth. While youth may feel that parents are obligated to listen to and encourage them, these strangers sought them out as a knowledgeable person, increasing their feelings of competency and chances to perform their identities.

***A Note About School Experiences***

In the previous section materials for identity development were prominently discussed within home and community contexts but all youth did talk about the school context, if only in passing. Many of the youth interviewed have access to environmental science courses in high school (including but not limited to AP), but some youth expressed dissatisfaction with this experience because it was either too easy because of their other experiences and/or because of COVID-19 impacting the school environment in various ways (limited interaction, digital experiences, no field trips). These COVID-19 related sentiments are echoed in Duckworth et al. (2021) which found that students in remote learning suffered socially, emotionally and academically. Samantha however expressed strong connection between her AP coursework and experiences at the aquarium and home where she applies things she learned in AP biology and environmental science at the aquarium in order to conserve the environment. Teachers and counselors at school are also instrumental in recognizing developing identities of youth. For example, Ingrid was encouraged to take an accelerated science class which boosted her competence in the domain of science in general and has carried over to other contexts as she is now a self-proclaimed "science person." Ronald was encouraged by counselors to write about his newfound EID when applying to colleges undeclared and Sheldon to think about environmental law or sustainability practices for business to tie his EID and future plans together.

### *A Note About Distributed Resources*

While it may seem that distributed resources do not play a role in identity development because so few of the material resources for identity development are there (Table 3.6) and few identity related themes were discussed when youth talked about the distributed context (Table 3.5), 12 of the 13 youth discussed accessing distributed resources. Often youth would follow-up on conversations or current events with internet research like Helen who said,

> "I would go on a hike, I'd take a picture, I'd be curious about what was in the picture, and I'd Google research or I would ask my dad, who has been hiking a lot. I actually recently got a couple of books."

As these interviews took place during the COVID-19 pandemic, several youth discussed the early videos of empty city streets, clear air, and animals returning to the urban environment. They not only seek out media related to the environment but also use various resources to follow-up on interesting topics to further their knowledge base and engage in environmental problem solving.

## Discussion

### *ESI and EID Are Both Supported by Various Learning Activities*

Youth expressed aspects of both an environmental identity (EID) and environmental science identity (ESI) with most youth expressing a more salient identity during the interview as expressed through direct statements and/or additional aspects of identity like performance and interest. Youth may seek out opportunities related to their identity which is supported in these environments as they take up what is most relevant to them. That is, a youth may enter a zoo volunteer program because they are drawn to animals (EID) and express a stronger connection to nature through repeated engagement in the program while a youth you sought out the same program because they want to be a marine biologist really resonated with the discussions and activities about climate change causes and solutions, they were able to engage in with peers and visitors. While Vincent-Ruz and Shunn (2019) found science identity to be a strong predictor of informal science participation, we have yet to explore how specific disciplines or content interests are explored across time and place like Azevedo's (2013) lines of practice. Further research is needed to explore these two identities as both have a role to play in supporting young people in their learning and development and understanding how we can support them in environmental action (Ballard, Dixon, & Harris, 2017; Clayton & Opotow, 2003).

***Larger and/or Deeper Learning Ecosystems Support ESI and EID Development***

Regarding the first line of inquiry, youth that described more activities (a bigger ecosystem) expressed stronger identities. However, level of engagement in those activities may also matter, as exhibited by Violet, who only described a few activities but frequently and deeply engaged in her volunteer program at the zoo. Perhaps it is a combination of number and frequency of activities that supports sustained engagement in activities that support identity development across time and place or youth with more salient identities make sure to keep engaged over time and sometimes that means engaging in different activities, across many contexts, or at other times they are able to find an activity that they can do often enough. This echoes findings by Vincent-Ruz and Shunn (2019) who found that science identity was a predictor of informal science participation.

***Home and Community Contexts Seem to Have Important Resources for Identity Development***

ESI was expressed and supported in community-based and home contexts most often and virtually all youth with a strong EID or ESI had a history of nature experiences with their families. Youth discussed parents and peers as important thought partners as well as important reinforcement and recognition of developing identities. Recognition by others has been found to be important by Carlone and Johnson (2007) who explained the important role of receiving recognition from those important to the women of color in their study and Roberts and Hughes (2022) who describe how informal science programs improved perceived recognition by others. For many of these youth, getting recognition from strangers (zoo and aquarium guests) was particularly rewarding and salient parts of their volunteer experience at that place.

Additionally, experiencing and connecting to the non-human world happens with these people and in community-based places like the zoo, aquarium and park systems both near and far. Connectedness to nature is correlated with EID (Mayer & Frantz, 2004) and place-based experiences are fundamental to environmental education (Kudryavtsev , Stedman & Krasny, 2012). It seems that these physical places are also important to EID and ESI development and in line with these ideas.

Scientific instruments or protocols were prominent at the zoo or aquarium (and sometimes school) where youth were able to use them in activities or undertake systematic observation protocols of animals. These are important resources for identity development as described by Perin et al. (2020) where instruments were associated with girls "feeling like a scientist" and supporting their learning.

***Limitations***

The youth interviewed in this study, all come from zoo and aquarium youth volunteer programs. These programs are large time commitments that only deeply interested youth participate in. Not only are these youth highly interested in the environment as evidenced across their interviews, but this study has also shown that this setting provides many material and social resources for identity development. Both may limit the generalizability of these findings. However, other contexts are rich in like-minded peers and activities (with materials) that support identity development like museums, laboratory (or field science) mentorships and internships, as well as home. Gardening and bird watching were part of several youths' learning activities that helped support environmental (science) identities.

**Conclusion**

In conclusion, this study points to a relationship between learning ecosystems and both ESI and EID development in youth. This could be due to a relationship like science identity and informal science participation (Vincent-Ruz & Shunn, 2019) where identity predicted participation. However, Roberts and Hughes (2022) recently found that informal science education programs increase science identity recognition in girls and Cohen, Hazari, Mahadeo, Sonnert and Sadler (2021) found that early STEM experiences likely contributed to STEM identity capital which can be formative for STEM identity development later in life. Further research is needed to understand what the causal relationships (if any) between ESI and EID and learning ecosystems are.

Environmental science youth programs can work to understand the other learning activities youth currently participate in and what else is available to them so that youth can create learning ecosystems that provide numerous resources for identity development. Undertaking an exercise like Ching et al.'s (2014) social learning ecosystem mapping could help organizations in geographic proximity to one another identify where youth are getting what support they need and meaningfully fill gaps to create ecosystems that are resilient to disruptions (Hecht & Crowley, 2019). A lens at both the system and individual level can work in concert to understand the system and interactions that work for all learners.

# Chapter 4: Measuring the Impact of COVID-19 on Youth Environmental Science Learning: How Learning Ecosystems Changed in Urban Contexts

## Introduction

We are just beginning to understand the full impact of COVID-19 pandemic, and the safety measures put in place in response to our education landscape and student learning as we pass the two-year mark of the pandemic. Thus far, much of the conversation has focused on the extent of students' learning loss due to pandemic disruptions in schooling (Donnelly & Patrinos, 2021). When looking particularly at science learning, a recent survey of science educators found that in the first impacted school year of the COVID-19 pandemic (2019-2020), teachers and students were spending less time on science in distance learning than prior to the pandemic (WestEd, 2020) and in the 2020-2021 school year included more asynchronous science instruction (Gao, DiRanna, & Fay, 2022). With approximately 18.5% of time spent in school in K-12, we also need to consider how other sources of learning have been impacted (National Research Council, 2009). In a survey of museum staff during the pandemic, after frontline staff, museum education departments experienced the most layoffs and furloughs in 2020 (Krantz & Downey, 2021).

Taken together, this suggests there was a substantial decrease in available science learning activities for youth, aligning with the learning loss conversation, but what was their actual experience? In this chapter, I will describe the impact of COVID-19 on youth environmental science learning activities based on survey and interview data gathered as part of a larger study in 2020 through 2022 in order to better understand how resilient learning ecosystems are so I can better prepare for the next disturbance. While environmental science learning is a distinct subset of science learning, it warrants particular attention as it exists in the intersection between science education and environmental education. Both educational traditions include a plethora of pedagogical techniques, places for learning, and traditional (e.g., science knowledge and skills) and non-traditional (e.g. socioemotional skills) outcomes (Wals et al., 2014). This unique positioning may give us a vivid picture of youths' experiences during the COVID-19 pandemic across multiple contexts and settings.

***What is a learning ecosystem?***

The learning ecosystems framework provides one powerful way to understand the suite of learning activities that young people engage in. This more holistic look at activities allows us to better understand how and where learning occurs that can help us explore the full experience of youth during the pandemic. Barron (2004) describes learning ecologies as the places, resources and relationships youth access across several contexts, with youth as the central organizing node of the system. She further groups these activities and resources into home, school, community and distributed contexts that share goals and practices, mediational tools for learning, and other sociocultural factors for learning (Barron, 2004). Barron originally advanced the framework to understand technological fluency development and self-initiated learning (Barron, 2004; Barron 2006), and others have extended this work to understand STEM learning pathways in particular communities (Falk et al., 2016) and larger systemic issues of "sustainable, just, and equitable educational improvements" (Hecht & Crowley, 2020).

I am focusing on this systems level to this study and therefore are adopting the language of a "learning ecosystem" instead of utilizing the term learning ecologies in order to draw on the parallels to natural ecosystems (Hecht & Crowley, 2020). While Barron (2004) placed youth at the central organizing node, in natural ecosystems there is no organizing node and I instead look to the overall structure of the environmental science learning ecosystem (Hecht & Crowley, 2020). Ecosystem scientists and many natural resource managers manage ecosystems to make sure processes and resources are conserved or maintained; similarly, I aim to highlight the same role in learning ecosystems, maintaining their services and resources for all learners (Brussard, Reed & Tracy, 1998). Ecosystem scientists use consistent monitoring of natural ecosystems using indicators to understand how change is impacting the resources and processes of the system and create policies and management plans to maintain or improve the ecosystem (Sparrow et al., 2020). In a learning ecosystem, youths' experiences can be indicators of overall system health and change (Hecht & Crowley, 2020). Just as "a resilient [natural] system responds to a disturbance by changing the relative amounts of its different parts and how they interact, thereby changing the way it functions" (Walker, p.11, 2020), I suggest that youth's ecosystem shifts are indicators of learning ecosystem health as I continue to monitor the ramifications of the COVID-19 disturbance in order to understand the resilience of the ecosystem.

Barron's (2004) learning ecosystem framework segments resources and activities into contexts for learning into four key contexts: school, home, and community contexts, and includes distributed resources (media and digital resources) that youth access across time and place. In the case of the COVID-19 pandemic, each of these contexts were affected differently by early restrictions to limit the spread of the virus. I suggest that utilizing this learning ecosystem framework, which considers all these resources and ways of learning beyond schools, can help us shift away from the deficit-focused "learning loss" discussion that only looks at the school context and traditional measures of learning. This will enable us to better document the actual learning experiences of students in the pandemic. In the following paragraphs, I'll first discuss the typical practices and affordances of the four contexts before describing how these changed during the pandemic.

In the school context, environmental science learning activities are included primarily in coursework related to science as the Next Generation Science Standards (NGSS) includes environmental science knowledge and skills standards throughout the grades, mainly in the life and earth science standards (NGSS Lead States, 2013). Horizon's (2018) survey of schools and science teachers found that almost all high schools (97%) offer biology/life science courses over half (66%) also offer environmental science courses as well and almost half of high school students (48%) have access to AP Environmental Science. Content delivery in the science classroom setting is dominated by science talk and text (NRC, 2014). When asked specifically about NGSS practices, about half of middle and high school students engage students in these practices regularly (Horizon, 2018).

Science and environmental learning in informal contexts, particularly those community-based resources like museums, nature centers, and community-based organizations, are more interest driven as youth and families engage with them at their leisure and by choice (NRC, 2009). While museums, gardens, nature centers and zoos may have goals for visitors, individual learners and groups determine their own learning as they come in with their own motivations and interact with what elements they want (NRC, 2009). Learners can engage with exhibits, demonstrations or shows, and short-and long-term programs (NRC, 2009). Without teachers like the school context, these spaces rely on labels, objects, recorded messages and videos, guides and the occasional interpreter for delivering content and communicating scientific ideas (NRC, 2009). While Barron (2004) described bridging that youth did across contexts, schools and institutions bridge these contexts through field trips and other collaborations that offer students learning opportunities that can take advantage of affordances both contexts offer (Bevan et al, 2010; Falk et al., 2016).

The home context differs from these school or community contexts in yet another way as many conversations and activities about the environment or science at home do not have the explicit goal of teaching (NRC, 2009). For example, the family garden does not explicitly teach youth about the important ecological concept of plant and animal interactions, but through engagement and conversation, families learn about beneficial and harmful insects to their flowers and vegetables. Some people do deliberately pursue science learning in this context through a variety of means. For example, a teenager may see a video about plastic pollution in the ocean and then embark on research using a variety of distributed resources (a fourth context from Barron (2004)) to learn about how to reduce their plastic usage and find suitable alternatives for them and their families. It is this variety of interactions and affordances that work together across time and place to build knowledge and skills for youth.

Our study focuses on environmental science learning in urban settings because they have a concentration of community resources that comes with a concentration of people and capital resources. While many people typically see the urban setting as devoid of nature, urban park systems like Cleveland's Metroparks, provide important pockets of green space for contact with nature and environmental learning opportunities (Russ & Krasny, 2017). These urban contexts have shifted environmental education into new places that warrant specific attention in research (Russ & Krasny, 2017). However, these community resources are unevenly distributed, and green spaces have been a weapon of redlining and segregation for decades, impacting access and therefore learning ecosystems for youth (Elliott et al, 2019). This makes studying learning ecosystems from the perspective of the learner important as it describes what the learner has access to and not simply what learning activities and resources are present in a community.

***What we already know about COVID-19 impacts on educational settings***

The school context has been studied throughout the pandemic. Haderlein et al. (2021) collected survey data over the first year of the pandemic (April 2020 to March 2021) in order to show how formal education shifted from the immediate response in the early stages to what the 2020-2021 school year looked like across the United States. They found that almost half of students in fall of 2021 were attending school remotely (49%) with an additional 20% in a hybrid model concluding that “many students did not have access to in-person learning throughout most or all of the 2020–2021 school year” (Haderlein et al., 2021, p.16). When looking specifically at school science education during the pandemic, Gao et al. (2022) surveyed California districts on NGSS implementation, teachers on instructional shifts, and interviewed county science leads in order to understand shifts in science instruction and NGSS implementation. They found that science became a lower priority for most districts, particularly urban districts (Gao et al, 2022). In Gao et al.'s (2022) survey of mostly middle and high school science teachers (90% taught at that level), 78% of teachers reported doing more asynchronous instruction and 45% reported doing more teacher or peer led demonstrations than before COVID-19 disruptions in the 2020-2021 school year. This shift changes the nature of classroom instruction significantly as it could reduce the science talk and teachers reported less hands-on manipulation of materials for most students (Gao et al., 2022). While the research outlined above speaks to the trends at large, we know that the impacts of the COVID-19 pandemic across a variety of measures have fallen disproportionately on those that have intersecting marginalized identities (Tai et al., 2021).

Research in the informal education sector during the pandemic is also beginning to paint a picture of the toll on youth educational opportunities. During the beginning of the COVID-19 pandemic in 2020, many of these institutions closed their doors as ordered by public health officials as they were deemed non-essential. Some institutions were able to redistribute staff and financial resources to create learning opportunities and virtual visits during this time (Bradshaw et al., 2021). Visitors also redistributed where they would most likely visit as we learned more about the virus, with public parks (including botanical gardens), zoos and aquariums topping the list (Dilenschneider, 2020b). These places are all important places for environmental science learning in urban contexts. Collins et al. (2020) surveyed outdoor and environmental science education programs in April 2020 and found that over 12,000 staff were already either furloughed or let go early in the pandemic. Two-thirds of museums cut back on programming, education and other public service aspects in 2020, with 35% of museum educators experiencing some change in their employment status (Krantz & Downey, 2021). The largest changes in museum education were in K-12 school programs, family and youth programs (Krantz & Downey, 2021). However, many of these institutions used remaining resources to pivot to digital engagement with free and fee-based education programs showcasing the exhibits, trails, and people who create and care for them (Bradshaw et al., 2021; Janz, 2021). This digital engagement is remaining high even as most places have returned to normal or close to normal operations (Dilenschneider, 2021).

### *Research Question*

Based on early research and reporting, youth opportunities for science and environmental education were negatively impacted during the height of the COVID-19 pandemic, with less science instruction in K-8 (WestEd, 2020) and few resources available for informal learning as well. However, these studies surveyed teachers, instructors, and administrators, not the learners directly. In order to address this gap, I undertook this analysis of environmental science learning experiences of middle and high school youth during the COVID-19 pandemic to examine the impact of all the documented reductions in in-person EE programming and shifts to virtual offerings had on youth experiences. Specifically, I ask: “What environmental science learning activities and contexts were most affected by the COVID-19 pandemic?” I can then use this to better understand the resilience of the environmental science learning ecosystems of youth.

## Methods

### *Recruitment*

Participants were recruited through advertisements to mailing lists of youth coordinators at 11 informal environmental and science learning institutions between November 2020 through the end of 2021. I used a convenience sample of institutions where I still had contacts working with or at least in contact with youth participants through email or other electronic means. These institutions were in urban centers in New York, California, Ohio, Missouri, Illinois, Texas, and Maryland, which are among the most populous cities and metro areas in the United States and include several distinct US regions with varying responses to the pandemic. Recruitment started with targeted institutions in large urban centers within the Association of Zoo and Aquarium (AZA) network and expanded to similar institutions based on recommendations and introductions from these professionals. The mailing lists typically included current and past participants in youth volunteer and/or educational programming like summer camp, internships and advisory groups and varied in size from less than 50 to several thousands of youth. Interested youth completed a contact form to enter the consent and research enrollment process.

### *Sample*

Twenty-nine youth aged 13-18 completed the survey with an average age of 16. 62% of survey participants were female, 24% male, 7% nonbinary with an additional 7% declining to respond. 55% of participants were White, 24% Asian, 14% Multiracial (3% declined response). This sample when compared to the US general population is over representative of female participants and it also overrepresented Asian and multiracial individuals. However, when compared to the visitor demographics of the Association of Zoo and Aquariums (AZA) institutions, it mirrors the percentage of female visitors while underrepresenting male visitors (55% and 46% respectively) (AZA, n.d.b).

### *Survey Construction and Data Collection*

The learning ecosystem survey asked about the frequency of experiences and activities across contexts where learning occurs including home, school, community and distributed sources. It was constructed based on related items for other subject matter learning ecologies (Barron, 2014). Activities such as classes, clubs, hobbies and visitation to museums and parks are just some of the questions on the survey (full item stems used in the survey can be found in Table 4.1).

Table 4.1

*Survey Items*

| Item stems | Context |
|---|---|
| I read books or magazines about nature or the environment. | Distributed |
| I visit websites or online forums about nature or the environment. | Distributed |
| I explore the environment around my home | Home |
| I take required classes (science, English, social studies, etc.) that teach about the environment. | School |
| I discuss nature or the environment with teachers or other students. | School |
| I visit a natural history museum, zoo, or aquarium in person or online. | Community |
| I garden or grow plants at home. | Home |
| I visit parks, community gardens, and/or nature centers. | Community |
| I have support on homework about the environment from others. | Distributed |
| I follow people and/or comment on social media posts/channels about nature or the environment. | Distributed |
| I attend (in-person or online) community events or clubs about nature or the environment. | Community |
| I attend after-school programs with my classmates about nature or the environment. | School |
| I camp, hike, or participate in other hobbies with my family where we explore and learn about nature or the environment. | Home |
| I notice the plants and animals around me when I'm out in my community. | Community |
| I volunteer (in-person or online) with institutions or organizations in my community that help the environment or nature. | Community |
| I post and/or share pictures or videos about nature and the environment on social media. | Distributed |
| I talk about the environment and/or environmental problems with my family. | Home |
| I hang out in nature. | Home |
| I attend camps (in-person or online) about nature or the environment. | Community |

| | |
|---|---|
| I take classes (in-person or online) in school specifically about the environment, plants, and/or animals. | School |
| I take classes (in-person or online) outside of school about nature or the environment. | School |

This survey is an adapted retrospective pre-/post-survey design to capture data for two time points in a single survey. This means that for each item stem, participants responded twice, once for each time period, before the COVID-19 pandemic (approximately six months to one year before March 2020) and the first six months to one year during the COVID-19 pandemic (data collection took place from November 2020 through December 2021). Participants were asked to indicate the frequency of each activity on a scale that ranged from never to every day that was converted to a 0-7 scale for analysis (Table 4.2). The retrospective pre-/post-test format is a common method in educational settings to measure gains in program outcomes. This format has been shown to be no more susceptible to social desirability bias or implicit task demands than other surveys in professional development settings across a variety of fields (Klatt & Taylor-Powell, 2005). While the population is different, this concern is justified in this survey design for this age group. Studies on the retrospective pre-/post-survey design in school age children focus on the accuracy of self-reported knowledge and skills gains versus traditional pre- and post-survey design studies. The concern of accuracy of self-assessment is less applicable in this case but does show that the format has a history of use with this age group. As surveys were not sent before the COVID-19 pandemic, a retrospective framing is required to capture participants' experiences prior to COVID-19.

Table 4.2

*Response Scale*

| Label | Scale score |
|---|---|
| Never | 0 |
| Once | 1 |
| Every couple of months | 2 |
| Once a month | 3 |
| A few times a month | 4 |
| Once a week | 5 |
| A few times a week | 6 |
| Every day | 7 |

In January 2020, I completed a content alignment study with eight formal and informal science and environmental educators to improve face and content validity. Following revisions, I performed four cognitive interviews with youth in the target age range via Zoom (Fowler, 2009). Participants read each question aloud and were asked to think aloud as they decided on their answer for each time period. Additional prompts, if needed, were to describe what specific things they were thinking of and defining words they used. Participants were encouraged to ask questions about things they weren't sure about when responding to the survey as well. These interviews informed further editing of question wording and confirmed scale interpretation by participants. The survey reliability was calculated using the psych package in r (Revelle, 2022). The psych package utilizes pairwise correlations with the available quantitative data to calculate Cronbach's alpha. For this survey, Cronbach's alpha is 0.95.

Enrolled participants completed the survey through Qualtrics as part of a larger study on learning ecosystems and identity development in youth. Youth received two reminders, each a week apart to complete the survey and were entered to win one of four $50 Amazon gift cards upon completion of the survey.

### *Interview Protocol and Data Collection*

Thirteen research participants were interviewed following their survey participation (Table 4.3). These focal youth interviews were conducted on Zoom and lasted approximately 40 minutes but up to one hour. Open-ended questions about their learning ecosystem focused on where and how they learn about the science of the environment over the past couple of years in order to understand the most salient activities youth do to learn about and explore the environment. Similarly, to Ching et al. (2014), I used a "funnel protocol" to ask how youth pursue interests related to the environment across settings in a learning ecosystem. The "funnel" refers to the narrowing of questions based on student responses. Using what settings or activities students first mentioned, I then asked how those activities and/or places were helpful in that pursuit. If needed, I asked them about a specific time that was meaningful in hopes of eliciting specific activities in those places and people. Youth usually described if these activities were impacted by COVID-19, or how the places and activities were prior to COVID-19 to contrast what they look like at the time of their interview, if there was time youth were asked explicitly about how COVID-19 impacted that activity if it wasn't already discussed.

Table 4.3:

*Focal Youth Information*

| Pseudonym | Age | Location |
|---|---|---|
| Amy | 16 | OH |
| Debbie | 14 | TX |
| Emily | 16 | OH |
| Gabby | 17 | MO |
| Hank | 18 | MO |
| Helen | 17 | OH |
| Ingrid | 13 | OH |
| J | 17 | OH |
| Maria | 17 | CA |
| Ronald | 17 | NY |
| Samantha | 17 | MD |
| Sheldon | 17 | OH |
| Violet | 15 | TX |

### *Data Analysis*

**Statistical Analysis of Survey Responses.** In order to understand changes in the frequency (rating scale responses) and prevalence of learning activities during the pandemic, I compared the retrospective pre- responses to the during-pandemic responses. The prevalence of an activity was also calculated by converting the rating scale responses to 1/0 scoring, with 1 being any non-zero response and never remaining 0. It is reported as the percentage of students reporting that activity. Due to the limited number of responses that prevented statistical validity assessments, I not only compared the scale score of the survey (the sum of their responses) but also examined the individual items and activities that fall within the same context together. I bring these together to begin to understand how different contexts have been affected by the ongoing COVID-19 pandemic and the early pandemic response.

In order to compare changes in frequency of activities I compared the means of the pre-pandemic responses to during pandemic responses utilizing a paired t-test. However, responses on most items showed a non-normal distribution and the sample size is limited. This distribution violates a key assumption of a paired t-test so I also performed a Wilcoxon signed-rank test. The Wilcoxon signed-rank test is generally recommended over the t-test when there is a small sample size and non-normally distributed data (Meek, Ozgur & Dunning 2007). Unlike paired t-tests, the Wilcoxon signed-rank test uses the ranks of absolute values of the difference scores and not the true difference (Welkowitz at al., 2012). An analysis performed by Meek et al. (2007) shows that when the null hypothesis is false, the t-test performed as well as or better than the Wilcoxon signed-rank and they recommend that a t-test be performed unless an exact calculation of the probability of a Type I error is needed. Since I don't want to overstate the impacts of the COVID-19 pandemic and report the mistaken rejection of a null hypothesis, I performed both procedures. The two tests (paired t-test and Wilcoxon signed-rank test) returned the same p value for three of the 21 questions with the Wilcoxon test returning a higher p-value for 13 questions. Even though our sample violated the assumptions of the t-test, the t-test performed as well as or better than the Wilcoxon signed-rank when the null hypothesis is false.

**Qualitative Analysis of Interview Data.** While I used survey data to examine what (if any) changes occurred to learning ecosystems, interviews with young people allowed us to explore how changes have transpired and some of the effects of those changes (Merriam & Tisdell, 2016). This explanatory sequential design can also provide some triangulation of the survey results (Merriam & Tisdell, 2016).

Interviews were transcribed using a commercial transcription service, verified and corrected by the interviewer, and uploaded into Dedoose for qualitative coding. Interviews were first coded for ecosystem activities and places via deductive codes similar to the activities from the survey according to the framework developed by Barron (2004). Additionally, I developed inductive codes from topics in the interview protocol including specific learning activities (e.g. birding) youth referred to. By starting with learning contexts and activities, I was able to maintain larger excerpts of interviews, preserving student narratives and voice (Deterding & Waters, 2018). An example of the learning ecosystem coding scheme can be found in Table 4.4.

Table 4. 4

*Learning Ecosystem Codes*

| Parent Code | Child Code Examples |
|---|---|
| Home | Gardening, Hike/Walk, Birding |
| School | Class, Club |
| Community | Zoo Volunteering, Museum Visit, Naturalist Talk |
| Distributed | TV show, documentary |

Following this pass of coding, passages related to COVID-19 were identified for further analysis and description of impacts. These impacts were inductively coded for themes and included codes for change in frequency of an activity, change in nature of activity, or changes in opportunities available when youth described canceled activities. Changes in nature of activity included shifts in methods of delivery, responsibilities, interactions, and many other impacts that will be described in the following section.

## Results

### *Learning Ecosystem Trends*

**Before the pandemic.** In order to understand the impacts of the pandemic, I first looked at learning ecosystems before the disturbance. Prior to the pandemic, the most prevalently reported learning activities on the survey were exploring the environment around their home and visiting a natural history museum, zoo, or aquarium (97% of respondents reported doing each of these activities at least once in the past year) (Table 4.5). The learning activities youth reported with the highest average frequency were taking required classes where the environment was discussed (5.7 mean or between once a week and a few times a week), noticing plants and animals around them (4.8 or a few times a month to once a week), and hanging out in nature (3.9 or almost a few times a month) (Table 4.5). The least prevalent activities prior to the pandemic were school-based after-school activities (38%) and taking classes outside of school (45%) (Table 4.4). When responding about activities prior to the pandemic, the least frequently reported were attending camps (1.3 mean), school-based after school activities (1.4) and taking outside classes (1.6), with all of these being done between once a year to every couple of months (Table 4.5). When looking at the scale score, the average prior to the pandemic was 61.2 out of 147 (Table 4.5).

Table 4.5

*Descriptive Statistics*

| | before n | during n | before mean (sd) | during mean (sd) | before prevalence | during prevalence |
|---|---|---|---|---|---|---|
| Books/ Mags | 29 | 28 | 2.9 (1.75) | 3.1 (1.82) | 90% | 89% |
| Websites/Forums | 29 | 27 | 2.9 (1.92) | 3.3 (1.94) | 83% | 85% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Explore | 29 | 28 | 3.8 (1.69) | 4.3 (1.90) | 97% | 96% |
| Required Classes | 29 | 28 | 5.7 (2.29) | 6.1 (1.56) | 90% | 96% |
| School Talk | 29 | 27 | 3.7 (2.21) | 4.1 (2.02) | 90% | 96% |
| Museum, Z and A | 29 | 28 | 3.6 (1.61) | 3.6 (1.73) | 97% | 96% |
| Garden | 28 | 27 | 3.1 (2.37) | 3.7 (2.60) | 86% | 81% |
| Parks and Nature Centers | 29 | 28 | 3.4 (1.80) | 4.0 (1.86) | 93% | 96% |
| Homework Support | 28 | 26 | 3.0 (2.62) | 3.5 (1.86) | 68% | 73% |
| Social Media Follow | 28 | 28 | 2.4 (2.64) | 3.1 (2.74) | 57% | 71% |
| Community Events | 29 | 28 | 2.1 (2.05) | 2.6 (2.18) | 72% | 71% |
| After-school | 29 | 27 | 1.4 (2.26) | 1.6 (2.02) | 38% | 48% |
| Hike and Camp | 29 | 28 | 2.6 (1.62) | 3.2 (1.96) | 83% | 82% |
| Notice | 29 | 28 | 4.8 (2.26) | 5.6 (1.50) | 93% | 100% |
| Volunteer | 29 | 28 | 3.0 (2.22) | 3.8 (1.71) | 72% | 89% |
| Social Media Create | 29 | 28 | 1.6 (1.99) | 1.9 (2.32) | 62% | 54% |
| Family Talk | 28 | 27 | 3.8 (2.08) | 4.2 (1.94) | 93% | 93% |
| Hang Out | 29 | 28 | 3.9 (2.01) | 4.5 (1.84) | 90% | 96% |
| Camps | 29 | 28 | 1.3 (1.47) | 1.3 (1.86) | 69% | 46% |
| Elective Classes | 29 | 28 | 2.9 (2.58) | 3.6 (2.71) | 76% | 75% |
| Community Classes | 29 | 28 | 1.6 (2.31) | 2.0 (2.39) | 45% | 50% |
| Scale Score | 26 | 24 | 60.2 (26.13) | 72.3 (25.85) | | |

These results about learning activities prior to the pandemic are largely expected as the research participants were recruited from museums, zoos and aquarium mailing lists making them likely visitors from the year prior. These youth are also likely very interested in the environment so the high prevalence of exploring the environment and hanging out in nature are expected leisure time activities that align with their interests prior to the COVID-19 pandemic. Attending camps approximately once a year is expected as they are primarily a summer offering from community-based institutions. Attending after-school clubs and activities infrequently may be due to a lack of offerings or competing activities in that time frame. For example, in Gabby's interview echoed several participants when she said,

> "... we have an Environmental Club at school. Unfortunately, just because of my schedule and my workload, I'm too busy to attend, which is unfortunate. I'm taking two APs and two weighted classes right now. So, I spend a lot of time trying to get my homework done for that, so and get it going and getting help. So, we do have Environmental Club, and they do a lot of stuff trying to help make our school more environmentally friendly."

Gabby is just one of many interview participants that were aware of different opportunities for environmental science learning but were limited in what they had time to participate in. Many of the high school juniors and seniors were overloaded with homework from Advanced Placement (AP) courses as well as many extracurricular activities (including volunteer responsibilities at the zoo or aquarium) to fill out a college application based on their goals.

**During early pandemic restrictions.** Next I looked at the responses in the pandemic timeframe to see if any large shifts in frequency or activity prevalence were occurring. Surprisingly, the scale score increased to 72.0 during the pandemic restrictions (Table 4.5). The most prevalent activity that youth reported engaging in via the survey during the early pandemic restrictions was noticing the plants and animals around them (100% reported doing this at least once) (Table 4.5). Youth described different reasons for this, but the most prevalent reason was about the increase in screen time and restrictions on where they could go. As Helen described in her interview, the increased amount of time behind a computer for school and homework made her realize how much being out in nature was part of who she was.

> "So I feel like it's [COVID] increased my respect for it [the environment] because it [COVID] made me realize how much it was a part of me, because I've always been, at least around the Metroparks, like the Emerald Necklace (Park system)...

> My dad would take me out hiking since I was a kid, really little. And so, I'd say that I've... It's a very normal part of my life, to just go out and hike. And the fact that I wasn't able to was revelatory and made me realize I need outside time. I'm not going to be able to just sit indoors all day with a window. I would need to actively take my toes and walk outside."

Several other youth contrasted the amount of time behind a computer for school with the need to go outside in their interviews.

Virtually all youth (96%) reported doing several activities at least once during the pandemic restrictions: exploring the environment around their home, visiting parks, museums, zoos or aquariums, hanging out in nature and taking required classes where the environment is discussed (Table 4.4). Given that almost all of these activities can be done outside (exploring nature, visiting parks) or exclusively online (courses), these activities were aligned with public health guidelines.

The activity with the highest reported frequency during the pandemic restrictions was taking required classes where the environment was discussed (6.1 or just over a few times a week) (Table 4.5). The next most frequent activity was noticing the plants and animals around them was reported at 4.6 (between a few times a month and once a week). In interviews, many youth described their own awareness of their increased time spent in nature and/or noticing the plants and animals around them during the pandemic restrictions. For example, Amy described this as "taking in nature" on walks with her friends during the pandemic, and as Ingrid described "[being] able to see really what's around us" with more frequent walks and hikes outside with her family.

The least reported activity during early COVID-19 pandemic restrictions by youth respondents was attending camps (46%) and the least frequent activity during the pandemic was attending camps (1.3 mean) (Table 4.5). Youth also report that after-school activities and posting related topics on social media both remained infrequent during pandemic restrictions (1.6 and 1.6 means respectively) (Table 4.5).

### *Learning Activity Changes*

I first looked at the scale score on the survey for each time frame to capture the overall trend in learning ecosystems changes. It increased from 60.2 before the pandemic to 72.3 during restrictions. This is a statistically significant ($t(33) = 2.10$, $p = 0.31$ $t(22) = -3.0085$, $p = 0.006$; $V = 36.5$, $p < 0.01$) increase in the overall frequency of environmental science learning activities during pandemic disruptions. Surprisingly, youth reported increases in the frequencies of almost every activity during early pandemic restrictions. Visits to natural history museums, zoos and aquariums, and attending camps were the only activities that remained unchanged during pandemic restrictions. The largest changes in frequency were reported for noticing the plants and animals in their community and volunteering with institutions or organizations (0.8 increase during the pandemic for both). I now expand on how each of the key contexts of young people's learning ecosystems change during the COVID-19 restrictions: school, distributed resources, home and family, and community.

**School-based Activities.** When looking at school-based activities, youth reported an increase in the frequency of coursework related to environmental science and nature in both required courses and elective courses (0.5 and 0.6 increase respectively). In required classes like biology and chemistry, this represents a change from once a week to a few times a week while elective coursework was less frequent (up to once a month). After-school activities remained infrequent both before and during the COVID-19 restrictions (about once a year). While the frequency of the four school-based activities increased during pandemic restrictions, none of these changes were significant under either test (Table 4.6).

Table 4.6

*School-based Activities*

| | Required Classes | | Elective Classes | | School Talk | | After-school | |
|---|---|---|---|---|---|---|---|---|
| | Before | During | Before | During | Before | During | Before | During |
| mean | 5.7 | 6.1 | 2.9 | 3.6 | 3.7 | 4.1 | 1.4 | 1.6 |
| t-test p-value | | 0.21 | | 0.15 | | 0.59 | | 0.93 |
| Wilcox p value | | 0.43 | | 0.11 | | 0.46 | | 1.00 |

While the frequency of these activities didn't significantly change, the quality of these experiences may have suffered. During interviews, youth discussed several impacts that COVID had on their school-based learning experiences; youth lost field trip opportunities (3 participants) and interactions with students and teachers (2 participants), with both of these presenting barriers to learning. Ingrid in particular was frustrated with online learning, explaining,

> "...But I really do enjoy in-person learning as well because you get to interact with people without having to raise your hand or remember to be on mute. So I think that it was just

> something that you were going to live with, but not something that I would want to do again."

And even when students returned to classrooms, there were still barriers to interactions as pandemic precautions still prevented normal interaction. Amy described it as

> "[T[here was nobody next to me, we were really far distanced, and nobody could hear each other because again, there's these big plastic boards in between us. So even if I wanted to talk to somebody, it was really difficult."

An additional change in the quality or nature of the school context was about time. Three students said in interviews that school took less time overall, either because zoom sessions were shorter than in-person class periods or that there were less (or no) extra-curricular activities. For example, Maria said her zoom sessions were 45 minutes shorter than in-person classes were scheduled (from 2 hours down to 75 minutes). While Gabby described how she choose to skip classes "... when they said, 'Grades don't matter,' I was like, 'Well, I'll go to class,' and there'll be days where I'll just be like, 'I'm going to go on this hike.'" This particular student showed agency in choosing which activities she'd rather do during the disruptions presented by the pandemic.

I found that shifts at school weren't experienced as negative for all youth, however; some youth experienced more freedom from their teachers to explore and present topics that were of interest to them and were given more flexibility with project-based learning which also allowed students to focus on their interest. Project-based learning and assessment allows for this flexibility in student action while still being evaluated according to the standards without the need for standardized tests. For example, Ingrid is one student who took advantage of the changes in school to learn more,

> "I had a lot more time, I could always research a topic and our teacher always told us, 'Yeah, you're free to, if you want to tell us some more stuff about what you learn.' And what was really nice is that from the activities that we did, it always came with a back of, 'Here's how we relate it to the world, not just in a classroom.' So that really helped us see the bigger picture."

It is this sort of interest-driven work that may have driven some of the increased frequency in activities reported in the surveys.

**Distributed Resources for Learning.** When looking at learning activities and resources that youth access across contexts, I saw a similar result to the school-based activities, with modest increases reported by youth during the early pandemic restrictions across all activities in the survey. The activity with the largest increase in frequency was in following people and/or commenting on social media posts related to science and the environment during the pandemic (Table 4.7).

Table 4.7

*Distributed Resources and Activities*

| | Books/Mags | | Websites/ Forums | | Homework Support | | Social Media Follow | | Social Media Create | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Before | During | Before | During | Before | During | Before | During | Before | During |
| mean | 2.9 | 3.1 | 2.9 | 3.3 | 3.0 | 3.5 | 2.4 | 3.1 | 1.6 | 1.9 |
| t-test p-value | | 0.63 | | 0.12 | | 0.47 | | 0.11 | | 0.19 |
| Wilcox p value | | 0.65 | | 0.15 | | 0.51 | | 0.13 | | 0.17 |

In contrast to the prevalence in surveys, in interviews, only one participant described how they turned to the internet and books for research when they couldn't do other activities during COVID related shutdowns. As J described,

> "...[B]efore COVID, I went to presentations, and I went on some naturalist hikes, but mostly since then, it's just been off of the internet and doing reading books, doing my own research files on social media sites."

Two other youth described how videos they saw online early in the pandemic shutdowns, of animals in urban areas, and the lack of smog, really sparked their interest. They were shocked by how quickly things changed due to the pandemic restrictions with respect to impacts on nature and described having new realizations about the environment.

**Home and Family Activities.** Activities centering in the home context and/or with family also saw increased frequency during the pandemic restrictions. Notably, youth reported significant increases for three of the four activities (Table 4.8). Gardening and hiking or camping saw a statistically significant increase (0.6 for both) with both tests. Talking about the environment and/or environmental problems with family approached significance ($p < .10$) as well.

Table 4.8

*Home Context Activities*

| | Explore | | Garden | | Hike and Camp | | Family Talk | |
|---|---|---|---|---|---|---|---|---|
| | Before | During | Before | During | Before | During | Before | During |
| mean | 3.8 | 4.3 | 3.1 | 3.7 | 2.6 | 3.2 | 3.8 | 4.2 |
| t-test p-value | | 0.26 | | 0.05* | | 0.03* | | 0.09** |
| Wilcox p value | | 0.27 | | 0.05* | | 0.04* | | 0.10** |

*p < .05. **p < .10.

These findings were corroborated in interviews with five participants discussing increased regularity of going hiking or for walks with family and friends. As one participant described,

> "So, my parents, they just really enjoy walking and hiking. That's a thing that we've always done, whether it was through mountains or flatlands, because Ohio's pretty flat, but we just started doing it a lot more during COVID or when we really just had the time."

Three other participants also described how they had more time and/or flexibility in their schedules early in the pandemic that allowed them to increase the frequency of the activity with their family or friends. Many continued to describe how these activities were safe ways to spend time together with friends and leave home with their family.

This increased time and frequency in nature lead to different realizations for some participants. As Ingrid described,

> "...getting out into nature and seeing how things were at some point in time and how they've changed really tells you how much humans have really hurt the earth in a way and how it would take so much time to restore what has happened, but small steps can make up for some of that."

This sentiment echoes the increase in noticing plants and animals around them reported in the surveys described below (Table 4.9).

**Activities in the Community Context.** Finally, as previously mentioned, two of the eight activities within the community context saw no change during the early pandemic restrictions - visits to museums and similar institutions and attending camps (Table 4.9). Attending camps was the least frequently reported activity in both time periods, consistent with the fact that most camps are only offered in the summer. Youth reported performing the other activities in this context with increased frequency during the early COVID-19 restrictions; noticing the plants and animals around them and hanging out in nature were statistically significant increases.

Table 4.9

*Community Context Activities*

| | Museums, Zoo and Aquariums | | Parks and Nature Centers | | Community Events | | Notice | | Volunteer | | Hang Out | | Camps | | Community Classes | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before | During | Before | During | Before | During | Before | During | Before | During | Before | During | Before | During | Before | During |
| mean | 3.6 | 3.6 | 3.4 | 4.0 | 2.1 | 2.6 | 4.8 | 5.6 | 3.0 | 3.8 | 3.9 | 4.5 | 1.3 | 1.3 | 1.6 | 2.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| t-test p-value | 0.91 | 0.15 | 0.29 | 0.05* | 0.18 | 0.07** | 0.49 | 0.34 |
| Wilcox p-value | 0.90 | 0.25 | 0.29 | 0.05* | 0.29 | 0.08** | 0.21 | 0.40 |

*p < .05. **p < .10.

However, when community-based activities were discussed in interviews, young people discussed canceled talks or events were most frequently discussed (three participants) which runs counter to the reported increase in frequency from the survey data (from 2.1 to 2.6 during the pandemic); however, but perhaps an overall increase in offerings available counteracted this.

Like the school context, the frequency of activities may not have changed significantly, but the nature and quality of the experience changed with some community-based activities. Almost every interviewee talked about their volunteer experience at length and raised the impacts of the pandemic, not surprising given the youth were recruited through their volunteer programs at large science education institutions. Participants described how volunteer programs shifted substantially during the pandemic, with almost all of them stopping for some period of time either because the facility was closed or under limited operations or due to cuts in funding and staffing. Many programs returned online for substantial periods of time with youth attending lectures, online animal encounters, or even vet procedures so they could stay connected to the facility and each other. For example, Gabby explained the breadth of activities available for her while the program was online with,

> “I definitely teach a lot during COVID. We got to do a lot more citizen science projects, so Frog Watch, iNaturalist, stuff like that, and that honestly was super easy for me, or I mean, even just going and sitting in at different seminars. So, I got to go to a seminar about veterinary, and they did a vet procedure on Zoom, which was really neat, and that's

> kind of the stuff that it definitely has changed, a lot more stuff online, but it's offered a bigger perspective into the world."

Similarly, Ronald described how his entire youth program experience was online during the COVID-19 restrictions, where he worked with other youth from across New York City to build online interactives for families to "visit" the zoo or aquarium while the facilities were closed.

When youth were allowed to come back to the zoo or aquarium, they were often allowed back with less frequency and with modified responsibilities. Sheldon described a large decrease in frequency of volunteering,

> "I would say though, decrease the time you're allowed to volunteer there. So we went from, you know, being able to study, uh, um, um, being able to volunteer there, like every other day to now where I'm only really able to volunteer there like once or twice a week. Um, so it's a lot harder, I would say, getting hours and just being able to be around the zoo."

Amy described how they "weren't allowed to talk to people" and worked together behind the scenes to re-imagine activities they do with guests for launch in the summer. Even when they were able to do docent duties, it was still difficult as Violet and Sheldon described how spacing and mask wearing made it difficult to have conversations about the zoo. However, Some youth enjoyed the new and different activities in their programs and were given flexibility by their supervisors to pursue their particular interests during this time like re-designing activities and doing presentations for each other.

***Vignettes in Learning Ecosystem Shifts***

Until now, I've looked collectively at the trends in learning ecosystem changes during the pandemic and used focal youth interviews to explore some mechanisms of those changes as well as impacts. An additional analysis that can shed light on why changes in learning activities may have occurred is through the lens of individual learners. What follows are two brief vignettes of unique cases to explore other pandemic stories.

**A smaller ecosystem during early pandemic restrictions.** In contrast to the overall trend, four of the interviewed case study youth reported decreases in learning activities overall during the pandemic restrictions. Two of these decreased by 1 point or less than 1% while the other two reported larger changes of 16 and 11. Sheldon reported this largest decrease representing a contraction of 10.8% in his scale score. We spoke during spring of his senior year where he was preparing for the transition from high school to college under a year of COVID related disruptions. Sheldon wanted to keep pursuing his environmental science related activities until he left for college, but the added hurdles of pandemic related disruptions seemed to expedite his transition out of high school programming. Sheldon may show us how this transition to college may be a common disruption to learning ecosystems for youth that do not want to pursue science or environmental careers but still have an interest in the environment.

**An expanded pandemic ecosystem.** Ronald reported the largest growth during the early pandemic restrictions in his learning ecosystem. His scale score increased 62 points, a change almost four times larger than Sheldon's. His interest in the environment was sparked during the Fall of 2019 during the student climate strike. When his original spring break programming at an art museum was canceled early in the pandemic, he found the exclusively on-line youth programming at the aquarium to take its place. As he explained,

> "[I]t was like, because during quarantine that's when I really kind of had a little bit more time to research about opportunities in New York City, um, environmentally, that's how I came across [the program]. So, um, if COVID didn't exist, it would kind of just like maybe like would have changed everything. You know what I mean? 'Cause that's how I originally found [the program] was through quarantine and having like a little bit more time in quarantine. And so I searched up, you know, environmental opportunities in NYC

and I found [the program] and I read about them and I saw that they were remote and I, and I, you know, I applied and stuff, so yeah. So yeah, so it was kind of like due, due to COVID that I kind of was in this situation'

What started as luck in finding a new opportunity in the early stages of the pandemic, grew into a larger environmental science learning ecosystem as early pandemic restrictions shifted priorities and the availability of activities.  This program allowed his interest and learning to grow as he was surrounded by peers that shared this interest for the first time.

## Discussion

### *Changes in learning ecosystems before and during the COVID-19 restrictions*

I found a statistically significant increase in overall environmental science learning activities reported by youth respondents during the early pandemic restrictions and statistically significant increases in some specific activities. The increase in environmental science learning ecosystems during the pandemic in this small study appears to counter the results of Gao et al. (2022), Krantz and Downey (2021), and Collins et al. (2020), who all point to decreased environmental science learning opportunities in school and community contexts. However, the fact that science teaching in school decreased may well be WHY youth turned to other environmental science learning activities during the early pandemic restrictions. Even as delivery formats shifted to virtual in the formal and informal learning spaces, the frequency of most activities was relatively unchanged, and may have even increased slightly, making opportunities for learning broadly available throughout the pandemic. As several of the focal youth described, when one activity decreased, they often replaced it by increasing the frequency of activities they already enjoyed, like hiking. If we are concerned with the resilience of youths' learning ecosystems during the pandemic, our findings seem to suggest that youth were doing more with less, increasing the frequency of some activities even if fewer activities were available overall.

### *School Context*

When looking particularly at the school context, as found by Gao et al.'s (2022) survey of school districts, access to high-quality science pedagogical practices and materials has been limited for youth in distance and hybrid learning environments and youth spoke to the difficulty of interacting with peers and teachers during school over the course of the pandemic which echoes these claims. As we all have experienced, masks and other barriers to limit the spread of virus particles have made social interactions more difficult. In a learning environment, this particular barrier is troubling as not only are teachers providing information verbally often, but the social aspects of learning from each other are hindered.

Field trips are a particularly impactful environmental education pedagogical practice that youth no longer had access to during the early pandemic restrictions, but I do not know if that was because of school and district policy or because of budget cuts at the places youth would be going (Collins et al., 2020; Krantz & Downey, 2021). The loss of field trips presents other barriers to learning as this is where school-based topics connect to the community and real-world applications of science (Behrendt & Franklin, 2014). Participants described how they didn't get to go to the water treatment facility to learn about wastewater in their community, or to the zoo or aquarium to connect to their environmental science course. Field trips also can present the opportunity to use scientific tools and investigate real-world problems like water quality in their community which are particularly impactful for developing science-related identities (Perin et al., 2020).

However, some focal youth experienced positive changes in science pedagogical practices that allowed the more environmental science learning activities. Their teachers encouraged them to pursue their interests in the project-based learning their teachers shifted to during the early pandemic restrictions. They encouraged students to bring back related information to share with the class and explore their backyards and neighborhoods. It is this type of interest-driven pursuits that may explain the increases I saw in our survey results.

Focal youth mentioned after-school activities and clubs being canceled during the pandemic, but these were largely not environmental science learning activities as evidenced by lack of change in their surveys. The high school-aged focal youth described being heavily involved in AP coursework and other activities in order to have desirable college applications and balancing their interests and those needs which could explain the seemingly disparate results in afterschool activities.

***Home and Community Contexts Are Resilient***

While it may seem counterintuitive that youth reported no change in their visits to science institutions during the pandemic when so many of these institutions closed their doors for at least a short period of time, many zoos were able to stay open with modified practices during COVID-19 restrictions as many are largely outdoors, the majority of AZA institutions (60%) were reopened in some capacity by mid-June 2020 (Vernon, 2020). Many institutions also pivoted to online events when the public could not visit, still teaching about the animals and the people who care for them every day (Bradshaw et al., 2021). Youth acknowledged pauses in their programs and went on to describe modified program operations online or in-person. Early in the pandemic, people planned on returning to usual visitation patterns after three to six months (Dilenschneider, 2020a), and in late 2020 with the news of vaccines, this metric increased to higher than pre-pandemic levels (Dilenschneider, 2020d), which all falls within the timeframe of the year-long reflection of the survey. After the summer of 2020, many camps returned to at least modified operations during the following spring and summer, which would account for their unchanged frequency.

Not surprisingly, youth reported significant increases in activities within the home, but perhaps more surprisingly, also significant increases in activities in community contexts. Particularly, I also found that families and friends already comfortable with hiking and camping or just hanging out in nature increased this practice as a way to spend time together and away from screens. Additionally, the frequency of gardening increased in the pandemic. As access to the outdoors at home and in communities was largely unaffected by early pandemic restrictions and time outdoors even encouraged by public health officials due to its mental health benefits (Slater, Christiana & Gustat, 2020), it is unsurprising that these learning activities increased. Perhaps it is this commitment to activities before the pandemic that allowed them to continue these and other activities amidst the pandemic disruptions to our lives.

Whereas we might have expected young people to sit at home with devices and screens, it is heartening that I saw an increase in activities in community contexts. Since families were staying closer to home, youth were noticing changes in their local environment like never before. Talking with family and friends about the environment and environmental problems may follow from the increases in the previously mentioned activities as science talk at home is largely spontaneous and reactive to the context and current events (NRC, 2009). With families spending more time at home during various waves of the pandemic (Our World In Data, 2022), participants described how they repeatedly visited the same green spaces; I suggest this might allow them to notice changes between visits and become familiar with its inhabitants. Those observations and the stark pictures of empty streets and clear air sparked many conversations about environmental problems early in the pandemic for focal youth. These conversations about current events would continue, allowing for spontaneous environmental science learning and perhaps environmental problem solving around the proverbial (or literal) dinner table (NRC, 2009).

Like Barron (2006) described youth in this study used a variety of activities to pursue their interest and further their knowledge, despite the hurdles early COVID-19 restrictions presented. The flexibility of home and community contexts in particular allowed youth to respond to the disruptions of the COVID-19 pandemic by changing the frequency of activities that they could do when others beyond their direct control were restricted. Luckily access to contexts that provided activities and resources to pursue their environmental science interests and build knowledge and skills in that area (Barron, 2004) were less hindered by restrictions as environmental science learning can easily happen outside. Youth also described increased discretionary time that they used to pursue activities to learn and spend time outside, like those in Barron's 2006 study as well.

In fact, place-based, outdoor and nature experiences (at home or community parks or gardens) are among the richest learning environments in this subject area (Clark, Heimlich, Ardoin & Braus, 2020; Smith, 2012). It is this finding that problematizes the discussion of learning loss during the COVID-19 pandemic when it comes to environmental science learning. While youth may have lost access to high-quality learning experiences in school, they increased their activities in other contexts which are richer and may provide not only stronger learning outcomes traditionally measured when considering learning loss but also improves local ecological knowledge, problem-solving skills, environmental attitudes, and behaviors (Clark et al., 2020).

### *Implications*

This study creates a complex picture of rich learning ecosystems despite difficult conditions. It also illustrates how difficult it can be to evaluate the impacts of a single program as youth undertake a variety of activities related to their interests. Educators and evaluators, when interpreting results from program evaluations, should consider the other activities that youth in their programs might engage in as I found that youth engage in multiple activities around their interests where they also learn knowledge and skills.

Exploring the rich learning contexts outside of school also continues to problematize the idea of learning loss during the pandemic. This study also adds to the body of literature about how much learning happens outside of school (National Research Council, 2009), so even though students' school experiences were greatly impacted by the pandemic and test scores suffered (Donnelly & Patrinos, 2021), the ongoing discussion of learning loss discounts the important learning that happens elsewhere and may not be assessed on these standardized tests. I challenge educators and policy makers to expand their conversation about learning during the pandemic to highlight the rich learning environments in other contexts and explore how they did (or did not) fill in gaps for students when school buildings were closed.

I know that this particular group of youth are all interested in the environment and for at least some time, committed to volunteering at their local zoo, aquarium or museum which required a decent commitment of their time. It may be that this commitment and/or interest in the environment helped them find the activities that allowed them to continue their environmental science learning. Further research is needed, however, to delve more deeply in the nature and nuances of youth environmental science learning ecosystems. Specifically, more insights could be gained by following the lead of our colleagues that study natural ecosystems and develop measures to quantify the abundance and diversity of learning ecosystems so that they can be systematically monitored as well. For example, data on the experiences of different demographic groups in a geographic area can illuminate access and inclusion problems that need to be addressed through various means. Longitudinal monitoring of ecosystems can illuminate changes in ecosystem functioning before systems collapse and no longer serve learners.

### *Limitations*

I acknowledge there are several limitations to the conclusions we can draw from this study. Regarding the survey construction, the survey was constructed with the input of subject matter educators and administrators but lacked the input of youth which may have missed some activities that youth undertake to learn about environmental science that are less visible to educators that work with this age group. While I used cognitive interviews to help revise items and confirm that they were being interpreted as intended, I realize that allowing respondents to add to the list of activities would have reduced this limitation and included more youth voice in the survey portion of the study.

The generalizability of these findings to other racial or ethnic groups and socioeconomic levels is limited as participants are mostly white (59%) and all from middle and upper-class communities. The realities of data collection in the pandemic and the typical audience of long-term youth programming made it difficult to get a sample more representative of urban youth. The far-ranging impacts of the COVID-19 pandemic have been unequally distributed and have fallen disproportionately on minoritized and/or low-income communities (Tai, Shah, Doubeni, Sia & Weiland, 2021) making them less likely to respond to this survey. This also likely means that youths' ability to respond to disruptions in learning activities during the pandemic was not as extensive as the youth in this study. Additionally, the socio-economic status of these individuals likely gave them access to more economic and social resources to respond to pandemic disruptions. Additionally, those resources also create more stability during the wider social and economic disruptions. Further research with a larger, more representative sample size is needed to unpack the educational learning experiences for all youth during the pandemic and understand the effect on their learning ecosystems.

The limited sample size of this study warrants cautious interpretation and generalization not only due to the above concerns about representativeness but also because larger samples reduce sampling errors (Fowler, 2009). The clustered nature of sampling in this survey further raises that concern. However, this small study was information rich as focal youth explained the shifts they made as they navigated pandemic-related disruptions. These surprising findings warrant further investigation with a larger sample size to see if the trend holds once sampling error is reduced.

**Conclusion**

I saw youth expand their environmental science activities and pursue their particular interests that grew their learning ecosystem during early pandemic restrictions. I also saw youth make active choices to pursue their particular interests when given the opportunity in school and community-based programs. This research suggests a resilience in learning ecosystems for these youth, but the causes are unknown.

The resilience in learning ecosystems is based on quantity but does not speak to the quality of learning experiences. Focal youth described many barriers to their learning at school, either online or in-person due to the pandemic. Other programs also shifted activities for youth as well that may have impacted the learning experience. Materials for learning and identity development are dispersed throughout a learning ecosystem and there may be key activities for learning (quality) that experienced more disruption than others that inhibit not only identity development but more traditional measures of learning as well.

Additionally, these youth all live in urban and suburban settings and are from middle and upper-class communities; is it this access to resources that allowed them to keep pursuing their interests during pandemic related disruptions? More research is needed to untangle the factors that helped these youth continue to pursue their learning during the pandemic so that we can create rich, resilient ecosystems for all youth that can withstand disruptions at the personal and global scale.

# Chapter 5: Conclusions

In this dissertation study, I have developed and defined the construct of environmental science identity (ESI) based on other science identity theory and research motivated by equity and inclusion in the sciences. As others have argued, disciplinary specific identities within science warrant their own lines of study due to the particular practices, histories and cultures of scientific disciplines (e.g. Hazari et al., 2010; Prybutok et al., 2016). Environmental science, and environmental education, often moves learning and research out of the laboratory and into the outdoors that comes with its own unique negotiations of power and positionality, both supportive and not, for participants. For example, Finney (2014) has described the history of erasure and then exclusion of Black Americans in the outdoors that creates unique power negotiations and barriers to participation for that community. However, Carlone and Stroupe's (2021) argument that field science helps disrupt historical narratives of how science works also helps establish the need for ESI. They argue that the ways in which field science is bound to the natural world requires the use of local knowledge and people and the improvisation of techniques and equipment that reduces or can eliminate the power imbalances of science and who counts as an expert. These are just two examples of how and why ESI should be studied across all the contexts where environmental science learning and practice happens.

In this study, I suggest that ESI is unique from science identity and environmental identity (EID) and that middle and high school youth develop ESI through activities across a variety of contexts. I define ESI using the science identity framework developed by Carlone and Johnson (2007) that includes 3 key factors: competence, performance and recognition. Competence focuses on not only having the knowledge and skills of environmental science but feeling confident in that, similar to self-efficacy. A person high in the competence dimension of

ESI would know about the environment and environmental issues while having a nuanced understanding of the socio-ecological system. Performance incorporates the social performance of the scientific community including using the jargon, talk and physical and mental tools of science. Finally, recognition was defined as seeing oneself as a scientist or science person and receiving that from others (Carlone & Johnson, 2007). As Carlone and Johnson (2007) found, being recognized as a scientist by groups important to a person could be key in minoritized communities continuing to a successful science career. Taken together, a person with a strong ESI not only does environmental science but is recognized by others as doing so and is able to perform the skills and apply the knowledge of environmental science. I have focused on the development of ESI in middle and high school youth because middle school is an important time for studying identity as this is when participation, interest, and identity with science shifts for girls and other non-dominant youth and needs to be scaffold and supported for continued development (Calabrese Barton et al., 2013). While in high school, students begin to select their field of study in order to select courses and extracurricular activities that align for college major requirements (Kim, Sinatra & Seyranian, 2018).

I have argued that the best way to understand ESI is through a learning ecosystems framework. Learning ecologies was first developed by Barron (2004) to describe the resources and activities youth undertake to build technological fluency, she established contexts for activities where youth not only spend time but also with unique resources and opportunities for learning: home, school, community, and distributed resources where youth can engage with people and resources to develop their knowledge and skills. Barron (2006) argues that "a learning ecology is best conceptualized as a dynamic entity that can be characterized by the diversity and depth of learning resources and activities" (p. 217). While Barron's use of “diversity” is not quite the same as colleagues in the natural sciences, I and others (Hecht & Crowley, 2020) argue that understanding the framework as a learning ecosystem, can strengthen the framework and help us understand the resilience of ecosystems and undertake ecosystem monitoring like natural scientists.

The COVID-19 pandemic provided a unique opportunity to investigate what learning activities and resources were available for youth during the profound disturbance. Due to shelter-in-place or “safer at home” orders, students were kept out of the many places of environmental and science learning to slow the spread of COVID-19. In understanding the resilience of learning ecosystems under this disturbance, we can apply lessons from this moment to adapt and rebuild more resilient learning ecosystems for youth.

In chapter 2, I argued that understanding and engaging with the construct of ESI can help zoos and aquariums (and all EE providers) understand how all visitors and program participants are interacting with the content and practices of conservation science on display. Through studying the learning ecosystem of environmental science as a whole and individual learners’ particular activities and resources, we can both address systemic inequity in environmental science and how individuals craft their own learning ecosystems that support identity development (Hecht & Crowley, 2019). Cultivating and supporting identity development in visitors can help zoos and aquariums reach their conservation goals by understanding the negotiations people undertake when they interact with the science of conservation and the environment at our institutions (Calabrese Barton & Tan, 2010). As a member of the zoo and aquarium field, I argue that in order to diversify our audiences (AZA, 2020), we need to critically examine what we may be asking people to do when they visit our institutions and engage with the science that is the foundation of our work. This will create inclusive spaces to bring together more people with new ideas and skills sets to help address the conservation challenges and complex environmental problems we face (Bevan et al, 2018).

In Chapter 3 I empirically explored the relationship between learning ecosystems and ESI development in young people through interviews with middle and high school students. Through qualitative analysis of 13 interviews with young people that explored what learning activities youth undertook across and what resources for identity development were present across their learning ecosystems, I found that large and/or deep learning ecosystems supported ESI and environmental identity (EID) development in youth. EID is a particular type of identity that focuses on our relationship and orientation to the natural world (Clayton & Opotow, 2003). People with an EID feel a sense of connection to nature and are more likely to act in an environmentally responsible way (Olivos & Aragonés, 2011) that is distinct from but likely related to ESI. Additionally, I found that home and community contexts have important material and social resources to support identity development. These places in particular have emotional support and recognition of developing identities, animals and plants for youth to study scientifically, and access to the scientific instruments and/or protocols of the discipline. Supporting youth in finding and continuing engagement in a variety of activities across contexts may be important in cultivating these identities that can support youth in meaning-making and utilizing the knowledge and practices of environmental science in personally meaningful ways. Without crafting large and deep learning ecosystems that provide activities across contexts, with resources throughout, these learning ecosystems may be sensitive to disturbance and less resilient, like natural ecosystems (Hecht & Crowley, 2020).

In Chapter 4 I analyzed quantitative and qualitative data from youth to understand the impact of the COVID-19 pandemic on urban environmental science learning activities. Youth reported the frequency of environmental science learning activities prior to and during the early COVID-19 pandemic and I conducted focal youth interviews that explored other changes in learning activities during the pandemic restrictions. Youth reported a statistically significant increase in environmental science learning activities during the pandemic, pointing to a resilience in the ecosystems created by these youth. While the frequency of most activities was relatively unchanged or increased a slight but insignificant amount during the pandemic, the collective impact of these shifts was an increase in learning activities. Youth reported significant increases in activities within the home and community contexts. I found that families and friend groups already comfortable with hiking and camping or spending time in nature increased this practice during the pandemic, aligned with the public health messaging around safe activities (Slater et al., 2020). While the frequency of environmental science learning activities in the school context remained unchanged during the pandemic, some youth spoke of a decrease in quality of those experiences as they shifted to virtual learning. These findings suggest a resilience in environmental science learning ecosystems as youth were able to respond to disruptions presented by the pandemic that could help us understand how to systematically create learning ecosystems that are resilient and support all youth.

### Zoos and Aquariums as a Place to Design for ESI Development and Further Study

Zoos and aquariums are uniquely positioned as places for people to interact with nature and science, creating an important opportunity for designing programs to support ESI development, as well as a ripe context for understanding how ESI is developed and influences action on behalf of the environment. As the largest EE providers in the world (AZA, 2021b), many zoos and aquariums also have cohesive practices and messaging that can create ideal research conditions at a large scale, and this can impact program design to address equity and inclusion issues through offering best practices in educational programming, interpretation, community engagement and conservation.

During interviews, youth discussed many learning activities that allowed them to practice and assert their developing ESI through identity-related performances where they could share their knowledge and enact the practices and use the tools of environmental science. Over half of the youth interviewed in Chapters 3 and 4 expressed competence in the science of the environment as a result of their zoo and aquarium experiences. The sustained nature of much youth programming allows participants to watch (and talk about) the same animals over time, allowing for the study of specific specimens that support identity development in science (Perin et al., 2020). Some of these programs also allow youth unstructured time with zoo and aquarium staff that allow for deep conversations with subject matter experts. These conversations are related to personal interests and flexible to shift to spontaneous things in the environment, current events or their lives. Youth in these studies also had access to observation protocols and other scientific tools that allow youth to practice the skills of science and continue to build competency in the domain while at times contributing to scientific research and connecting to the larger mission of the zoo or aquarium.

The construct of identity is not just about feeling like a certain kind of person, but also being recognized as such; therefore, interactions and identity negotiations with key people are important in developing one's identity (Carlone & Johnson, 2007; Holland et al., 1998). Many interviewed youth discussed how the volunteer programs at zoos and aquariums were where they met people "like them" for the first time, or the only place where there are people like them where they can "geek out" on their interests and participate in an expert community (Ito et al., 2009). Because many of the youth in this study were docents at zoos and aquariums, I found that guest interactions they had as docents gave youth ample opportunities to gain competence in their knowledge and demonstrate their domain specific knowledge and skills (and therefore identity) for others. Unlike their peers and parents who also provide recognition as an environmental science person, zoo and aquarium guests were strangers. For some youth, it was particularly striking that a stranger would seek them out for answers or to reassure their child as they interacted with an animal.

According to the survey results, the frequency of visits to these places (virtual or in-person) did not change during the COVID-19 pandemic, even though most zoos or aquariums were closed at least for a short period of time and/or faced staff layoffs. I found that youth (and program staff that remained) found a way to stay engaged even during the uncertain times. In the interviews with these youth, they described continued online engagement in activities like lectures, animal encounters and even vet procedures while they were not able to physically be at a zoo or aquarium. Many zoos were able to reopen earlier under modified operations once public health officials established that outdoor environments significantly reduced the spread of COVID-19, which also may have contributed to the lack of change in visit frequency. While these institutions managed to withstand a pandemic and still provide opportunities for youth, they may be a particularly resilient place of environmental science learning for all people.

### Importance of a Learning Ecosystem Lens for Understanding Identity

I argue that ESI is just one of many identities a person holds that is developed and enacted in social contexts as a person chooses through words and actions (Holland et al., 1998). In Chapter 3, I found that key material and social resources for ESI development are spread across a young person's learning ecosystem. So, while recognition from parents and performance of ESI happens at home, I found that there are key tools of science that youth had access to in community and school activities that are additional and complementary. While practicing key skills of ESI happens in school or at the zoo, youth also need supportive environments and activities in multiple places that are sustained across time in order to develop an ESI that youth can enact across situations. This unequal distribution of the resources for identity development across contexts of a learning ecosystem may be the key in understanding how youth develop an ESI that influences decisions that reduce their environmental impact and also collective action on behalf of the environment.

In fact, these interest-driven learning ecosystems (Barron, 2006) may be quite resilient as I saw increases in frequency of some learning activities in response to pandemic related events. This may be unique to environmental science learning ecosystems due to the restorative effects of being in nature (Hartig, Mang & Evans, 1991) or even because outdoor spaces and activities were encouraged to slow the spread of COVID-19 (Slater et al., 2020). Like many adults, youth also turned to hobbies like hiking and camping during the pandemic which also supported their mental health (Ferguson et al., 2019). Without utilizing a learning ecosystem framework to understand ESI development, I would have not been able to see that the collective impact of small shifts in the frequency of activities led to an increase in environmental science learning opportunities in the pandemic that maintained access to key resources to support identity development in youth.

### Recommendations and Implications for Research and Evaluation

This dissertation study points to important implications for research and evaluation, particularly when it comes to understanding ESI as an outcome of programming. It is important to carefully interpret how much one program or place influences identity development of participants in order to not overstate the impacts of a single program. As I showed in Chapter 3, youth with more salient identities were more likely to have large, deep learning ecosystems, which points to a cumulative effect of experiences that supports the development of ESI for youth. Additional research could uncover what types of activities may influence ESI development; for example, a large-scale quantitative study would allow for structural equation modeling of the relationships between activities and contexts and ESI salience.

### Implications for Environmental and Science Education Practitioners

Environmental and science educators should listen to youth in their programs to understand what other ways youth learn about the environment and science so that they can help youth connect the knowledge and practices across contexts. This bridging of activities could support their ESI development as they utilize the same knowledge and practices in different contexts and negotiate their identity with different people across their lives. Especially early on in identity development, educators can create safe spaces for youth to try-on new identities and roles without judgment or fear of failure by learning together and distributing expertise (Riedinger, 2012). This flattening of power structures is inherent in outdoor and environmental field work (Stroupe & Carlone, 2021) which environmental and often science educators regularly engage youth participants in. Additionally, educators should provide ample resources for identity development including traditional tools and practices of science but also recognize novel displays of knowledge and practices that youth may engage in.

### Final Thoughts

While a small-scale study, this dissertation study has begun to establish Environmental Science Identity (ESI) as a construct distinct but overlapping with environmental identity and science identity. Further research is needed to continue to understand what supports youth in developing this identity but also how developing that identity impacts youth in their everyday lives and future college and career plans as others have done with environmental and science identity. This study also highlights the importance of understanding learning outcomes in the context of the many activities youth do across time and place as it is this collection of experience that shapes their learning, identities, and actions. By recognizing the unique assemblages of knowledge, skills, and behaviors (i.e., identity) that people bring to the table when they engage with environmental problem solving, we can make the proverbial "table" more inclusive and bring more and new voices to address the local and global environmental challenges we face today.

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**Appendix A**
**Interview Protocol**

1. ...But first I want to make sure we're talking about the same thing, when I say "the environment" what comes to mind?
    a. How do you define that?
    b. Is it different from "nature"?
2. How would you describe your relationship with the environment/nature where you live?
    a. Did COVID change that relationship? Why or why not? How?
3. In the past few years, where have you learned about the environment and what do you do there?
    a. If they don't elaborate (Optional probe): Tell me about a time when you really enjoyed learning about the environment or science about the environment.
        i. Questions to get details as needed:
            1. Where were you?
            2. Who were you with?
            3. What were you doing?
            4. Were there any helpful tools, instruments, or clothing?
    b. Alternative prompt if nothing comes to mind/they say I don't know: Where do you typically spend a lot of time outside and what do you do there?
    c. Alternative prompt if nothing comes to mind/they say I don't know: What about inside? What videos, shows, podcasts, books do you read about the environment?
4. What did [someone they mentioned] and you talk about or do together? OR How was [someone they mentioned_______] helpful/work together?
5. What about [a tool/activity/material mentioned] - Why was that memorable? OR How was it helpful?
6. Have you been able to do these same activities/Were you able to do this during COVID-19 restrictions?
    a. If yes, what was the same/different about the experience?
    b. If no, did you do something new in place of this?
7. (Go back to top with) ...is there another place or time that is really memorable from the last few years?

**General Learning Ecosystem Questions**

1. Are there other places where you live where you can do things like what you've described?
2. If they haven't mentioned school, how do classes or clubs at school fit into these activities?
3. If they've only talked about school, what about outside of school, what do you do/watch/read to learn about the environment?
4. In general, is there more you want to do to learn about the environment?
    a. If yes, do you have a plan to do that? What prevents you from doing that?
    b. If no, Why? If things were to change, would that change your mind?
5. Are there other <u>places or things you do</u> to learn about the environment that we haven't talked about today that you want to tell me about?

6. Are there <u>people</u> important to you that you learn with/talk to about nature and the environment that we didn't get to talk about today?
    a. Who are they & How do they help?

**Questions about Youth Environmental Science Identity**

1. What is "doing science" to you?
2. When you spend time outside, do you think you're doing science?
3. When you think about any of the things you've talked about so far today where you learn about the environment, do you feel like you're **doing science** in those places?
    a. If so, Which ones and why? OR If not, why not?
    b. Do you think other people like your family and friends see that as doing science also, or not? Why do you think that?
    c. Was it easier or harder to do those things under COVID-19 restrictions?
        i. Did that change how you see yourself interacting with science/the environment?
4. Do you see yourself as someone who **understands science** <u>about</u> the environment?
    a. If so, can you give me an example of when you see yourself this way? OR If not, can you tell me why not?
    a. Do you think other people like your family and friends see you this way also, or not? Why do you think that?
    b. Do you still talk to or see those people under COVID-19 restrictions? How has that affected you?
5. Do you see yourself as someone who **uses environmental science to understand problems** in your community or in the world and **think about or contribute to solutions?**
    a. If so, can you give me an example of this? OR If not, can you tell me about why not?
    b. Has that changed at all since the COVID-19 restrictions? Please tell me more about that.
        i. Did this change how or what you advocate for? Or what problems you see in the first place?
        ii. Do you see any links between [this] and [the places and the resources they talked about in Section 1]?
    c. Do you think other people see you as someone who understands environmental problems and solutions, or not? Why do you think that?

**Wrap-up**

1. Is there anything you want to go back and talk about more?
2. Is there anything else you'd like to talk about that we haven't yet?