THE IMPACTS OF THE NORTH CAROLINA ARBORETUM'S ECOEXPLORE PROGRAM ON CHILDREN'S CONNECTION TO NATURE

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

NCI	Nature Connection Index
ecoEXPLORE	Experiences Promoting Learning Outdoors for Research and Education
BIPOC	Black, Indigenous, People of Color
CTN	Connection to Nature

ABSTRACT

THE IMPACTS OF THE NORTH CAROLINA ARBORETUM'S ECOEXPLORE PROGRAM ON CHILDREN'S CONNECTION TO NATURE

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Outdoor experiences are a vital component in child development and wellness; however, more and more children spend less time outside. This phenomenon became even more evident during the COVID-19 pandemic, with device usage among children increasing drastically around the world. Lack of time outdoors and increased device usage may inhibit the cultivation of connection to nature (CTN) and lead to poor conservation ethics and negative environmental attitudes. However, one program, ecoEXPLORE, embraced technology as a way to foster outdoor exploration and teach children about their local environment. EcoEXPLORE, founded in 2016, is a predominantly online program that mediates outdoor experiences for North Carolina children through citizen science and online resources. In this current age, devices are not going anywhere, and this mixed-methods study on ecoEXPLORE discovered an online, science program that increased CTN among program users.

Keywords: citizen science, connection to nature, conservation, environmental education

CHAPTER ONE: INTRODUCTION

During the COVID-19 pandemic, environmental and outdoor education organizations received a devastating hit to visitor attendance (Collins et al., 2020). These organizations were no longer able to facilitate in-person outdoor programs, and by the end of 2020, an estimated 11 million children in the United States missed out on participation in outdoor education (Collins et al., 2020). In 2020, environmental education organizations lost an estimated $600 million in revenue, and countless had to terminate staff, temporarily close, or shut down permanently (Collins et al., 2020; Higgins, 2020). To continue providing science education to the public, many organizations moved online as a way to reach new audiences (Andrews, 2020; Higgins, 2020; Lygren et al., 2020). Throughout the COVID-19 pandemic, most of the population relied on technology and devices to complete work and attend online school and events (Burns, 2020; Li & Lalani, 2020). To keep up with the changing times during the pandemic, organizations like the North Carolina Arboretum and the Great Smoky Mountains Institute at Tremont engaged with the public via YouTube, Zoom, and Facebook (The University of North Carolina System, 2020; Weber, 2020).

In 2016, several years before the COVID-19 pandemic, the North Carolina Arboretum developed a predominantly online, science program called ecoEXPLORE. The word ecoEXPLORE is an acronym for "Experiences Promoting Learning Outdoors for Research and Education" (ecoEXPLORE, 2019), which is the intended goal of the program. EcoEXPLORE encourages children, five through 13 years old, to explore the outdoors, learn about native wildlife and the environment, and engage in citizen science online (The University of North Carolina System, 2020). Children spend an increasing amount of time on screens (Friel, 2020; Khaddage et al., 2011; Singaravelu, 2013; Thomas et al., 2019), and ecoEXPLORE was designed with technology at the forefront, as a way to motivate outdoor

exploration through the devices children are already familiar with using (Marchal, 2016). Users take photographic observations of any wildlife they find and upload these photos to their personal dashboard on the ecoEXPLORE website (ecoEXPLORE, 2019). If they are clear and identifiable photos, staff and volunteers send these observations to iNaturalist, an online citizen science network (iNaturalist, 2019). Each observation is submitted under a county-specific iNaturalist account, such as "avery_nc" for Avery County, allowing users to participate within the science community while retaining anonymity as a minor. Through citizen science, these observations contribute to the global iNaturalist database, which has over 90 million observations, and supply biologists with scientific data that may benefit their research in the field of wildlife and science conservation. Since ecoEXPLORE's launch in 2016, the online community has steadily grown, but activity tripled during the pandemic. As families across North Carolina used ecoEXPLORE to enhance their outdoor experiences, the need for online resources and tools in science and environmental education became apparent.

Since ecoEXPLORE is a relatively new program, no academic research exists on the program's impacts on users. Although similar to Kids in Parks, ecoEXPLORE is unique in that it focuses on science literacy and citizen science, with the end goal of improving understanding of the natural world (Blue Ridge Parkway Foundation, n.d.). More established virtual programs, like iNaturalist and eBird, are also successful in engaging participants in observation-based learning and citizen science, but most of these programs target older participants (iNaturalist, 2019; Kelling et al., 2013; Nugent, 2019; Nugent, 2018; Sullivan et al., 2009). For example, a user must be older than 13 years old to create an account on iNaturalist unless on a teacher or family group account (iNaturalist, 2019), which excludes an entire age demographic of young learners who are already making wildlife observations and engaging with the outdoors. EcoEXPLORE bridges the gap between science technology and younger audiences and provides a secure platform for users as young as five years old to

contribute to the science community (ecoEXPLORE, 2019). Since ecoEXPLORE is an incentivized program where users can earn points, prizes, and badges, users get even more enjoyment when uploading photos, submitting activity sheets, and attending online programs. The program also offers science activities and videos, most designed using Next Generation Science Standards and environmental education practices, to strengthen science literacy (Marchal, n.d.). With all of these resources and opportunities for young learners, the ecoEXPLORE program has the potential to be a nationwide online science program.

One of the goals of ecoEXPLORE is to improve a child's connection to nature (Marchal, 2016). Experiences in nature support all aspects of a child's development, and a strong connection to nature (CTN) can indicate the likelihood of an individual developing pro-environmental behaviors (Chawla, 1998; Clements, 2004; Hughes et al., 2018; Martin et al., 2020)). Over the past 30 years, there has been a growing desire to study human behavior and attitudes about the environment (Geller, 1995; Kals et al., 1999; Mayer & Frantz, 2004). In 2010, Cheng and Monroe developed the first children's connection to nature index, which consisted of 22 statements on a 5-point scale. The suggested age range was between eight to ten years old, and the index included statements like "being outdoors makes me happy" and "I like to hear different sounds in nature" (Cheng & Monroe, 2010). The findings from this research highlighted the importance of access to the outdoors in improving a child's CTN (Cheng & Monroe, 2010). Since this initial survey, multiple others now exist studying biophilia, nature connection, and pro-environmental attitudes and behaviors. Most of these scales are lengthy (over 15 statements), challenging for a young participant to understand, and inappropriate for short surveys (Richardson et al., 2019). In 2019, a condensed scale called the Nature Connection Index (NCI) was released and consisted of six statements similar to Cheng & Monroe's (2010) survey on a 7-point scale (Richardson et al., 2019). The NCI prompts included "being outdoors makes me happy," "I feel part of nature," and "I

always treat nature with respect." The NCI scale was successful when compared to other CTN tools and applicable to a wide age demographic, including children as young as seven years old (Richardson et al., 2019).

With the rise in device usage, new research in environmental psychology suggests increased screen time reduces one's CTN (Larson et al., 2019; Michaelson et al., 2020; Richardson et al., 2018). Michaelson and colleagues (2020) observed children in particular, and the findings implied an even weaker CTN among the youngest participants who spent a great deal of time on devices. However, device usage is only increasing, and an online science program that fosters outdoor experiences could serve as a useful tool in the science field. Virtual programs can increase student interest, engagement, and understanding of science (Chen et al., 2014; Doyle & Dezuanni, 2014), but what about CTN? Therefore, the purpose of this study was to explore the impacts of the ecoEXPLORE program on users' CTN. The research questions for this study were:

- Does the ecoEXPLORE program impact children's connection to nature?
- How does the program impact CTN, and in what ways?

The researcher hypothesized that the ecoEXPLORE program positively influenced connection to nature among users. The researcher employed an explanatory mixed-methods methodology to answer these questions. Quantitative data via pre/post survey responses answered the first question, while the qualitative portion via individual interviews addressed the second query. In an increasingly digital age, ecoEXPLORE may provide a way to explore and learn about the natural world through the devices children are already familiar with operating. Next, I will review the pertinent literature (Chapter Two), provide an overview of the methodology and methods (Chapter Three), and share the findings and implications in the journal article.

CHAPTER TWO: LITERATURE REVIEW

A Child's Connection with Nature

Experiences in the outdoors are a fundamental component of one's childhood, yet there is growing evidence that the younger generations spend less time outdoors than previous generations (Clements, 2004; Tremblay et al., 2015). When children are outdoors today, they are more likely to engage in structured play, such as organized sports, and spend less time in unstructured activities, like hiking, fishing, and free-play (Clements, 2004). When children have fewer experiences with nature, their physical, mental, and emotional well-being may suffer, and a disconnect with their environment can develop (Kellert, 2002; Martin et al., 2020; Torquati et al., 2010; Tremblay et al., 2015). To combat this dilemma, countless schools turn to the outdoors as a way to engage students with nature (Eick, 2012; Gostev & Weiss, 2007). By incorporating the science curriculum into outdoor experiences, educators saw improvements in science, language arts, civic engagement, and student learning attitudes (Clark & Lott, 2017; Eick, 2012; Holden, 2012). A substantial factor in science learning and literacy is the ability to create observations and connections with the natural world (Gostev & Weiss, 2007; Tolmie et al., 2016). However, observation-based ecology practices, which promote an understanding and relationship with nature, are scarce in Next Generation Science Standards (Merritt & Bowers, 2020).

Connection to nature. A lack of connection to the natural world and disregard for environmental stewardship could be detrimental to the health of the land, wildlife, and even humans as a species. Measuring connection to nature (CTN) among individuals can indicate the likelihood of them developing an environmentally-conscious mindset (Chawla, 1998; Hughes et al., 2018; Martin et al., 2020; Soga et al., 2016; Zhang et al., 2014). By fostering CTN, even by reading, watching, or talking about the outdoors, children are more prone to

exhibit pro-environmental attitudes and a desire to conserve wildlife (Chawla, 1998; Hughes et al., 2018; Martin et al., 2020; Miller, 2005; Zhang et al., 2014). In a world where students are more likely to care about exotic animals instead of ones in their own backyard, it is critical to teach children about local species in their surrounding environment (Ballouard et al., 2011; Ballouard et al., 2012; Cheng & Monroe, 2010; Lindemann-Matthies, 2005; Soga et al., 2016; Tomažič, 2008). By visiting local green spaces and developing a sense of place for one's community, an individual can improve one's CTN (Giusti et al., 2018; Ferreira, 2012; Jørgensen, 2016; Zhang, 2014). Increased CTN can improve overall health, sustainability, psychological connectedness, and pro-environmental behaviors through outdoor exposure (Cheng & Monroe, 2010; Martin et al., 2020; Mayer & Frantz, 2004; Richardson et al., 2020; Sandifer et al., 2015). Time outdoors supports the development of environmental practices and can lead to stronger conservation ethics as an adult (Evans et al., 2018; Hughes et al., 2018; Richardson et al., 2020; Rosa et al., 2018). Connection to nature can also be fostered directly through educational experiences that utilize the outdoors.

Environmental education. Environmental education is a vital tool in encouraging a love for local flora and fauna and improving CTN (Barthel et al., 2018; Cheng & Monroe, 2010; Ferreira, 2012; Giusti et al., 2018; Otto & Pensini, 2017; Whitburn et al., 2019). Environmental education is a form of experiential education used to promote and develop environmental literacy among all ages (Lygren et al., 2020; North American Association for Environmental Education, 2021). This type of education not only serves as an effective tool in teaching about the natural world but in fostering an appreciation for the outdoors, which could increase CTN (Otto & Pensini, 2017; Torquati et al., 2010). The outdoors is one of the most information-rich classrooms available for children, with a multitude of experiences available to enhance a child's observation, experimentation, and problem-solving skills through hands-on learning (Ginsburg et al., 2007; Kellert, 2002). Several studies found that

students were better able to build connection and an appreciation for nature after participating in environmental education or nature-based education programs (Barthel et al., 2018; Otto & Pensini, 2017; Whitburn et al., 2019). Another style of education that improves connection to nature is place-based education, which involves students directly with their local community (Gruenewald & Smith, 2008). Place-based education teaches students about all aspects of their environment (physical, cultural, and social) to ultimately improve relationships, sense of place, and appreciation for the community and local environment (Cruz et al., 2017; Gruenewald & Smith, 2008; Nichols et al., 2016). This commitment to one's environment not only increases an appreciation of the local culture and people, but it empowers students to be active, responsible citizens (Gruenewald & Smith, 2008; Holden, 2012; Nichols et al., 2016). Outdoor-oriented programs often utilize aspects of citizen science as a way for students to collect scientific data and learn about the natural world around them.

Citizen science. Citizen science is another approach to getting people outside and involved with their environment. Citizen science is a form of scientific research that relies on the collection of public observation, which advances scientific understanding and data collection (Bonney et al., 2009). In recent years, "community science" and "participatory science" have also described citizen science as a way to include all participants in a region. However, for this purpose, and since "community science" often refers to underserved communities impacted by environmental justice, citizen science is the applied term (Cooper et al., 2021). Like ecoEXPLORE, most citizen science programs help participants learn about the wildlife they observe and involve them directly with research by sharing their findings with scientists (Bonney et al., 2009; iNaturalist, 2019; Makuch & Aczel, 2019). Through this process, younger generations, in particular, can contribute to the science community and gain knowledge and respect for native wildlife - all while scientists gather essential data for their studies (Newman et al., 2012; Soanes et al., 2019). Even the observations of younger

children, such as those in the ecoEXPLORE program, serve as valuable information in wildlife research and citizen science (Castagneyrol, 2020; Marchal, 2016). Beyond increased science understanding, citizen science and other science programs can encourage individuals to spend more time outdoors, benefiting all aspects of their wellbeing.

The Outdoors & Community Wellness

Increasing CTN among individuals can benefit the overall health of a community. Given the rise in obesity and sedentary behavior in younger generations (Daniels & Hassink, 2015; Friel et al., 2020), there is a need to get children outside and physically active. Excessive sedentary activity and screen time may increase the risk of obesity, unhealthy diet, depression, and overall poor quality of life (Stiglic & Viner, 2019). Ginsburg et al. (2007) discovered positive correlations between unstructured outdoor activities and physical and mental health improvements. Outdoor free play not only benefitted the children in this study, but it also strengthened relationships with parents and guardians. Experiences in natural green spaces, whether a small city park or large wilderness area, have all shown equal benefits to mental health, which highlights the importance of outdoor activity for children and their families, especially in urban areas (Barnes et al., 2019; Birch et al., 2020). Natural stimuli reduce stress, improve attention, boost mood, regulate emotions, and foster compassion and wonder for the outdoors (Bratman et al., 2001; Lumber et al., 2015; Sandifer et al., 2015; Torquati et al., 2010). However, communities of marginalized and underrepresented individuals who may not have access to the outdoors are at a disadvantage to receive these health benefits.

Social justice and the outdoors. When planning the future of outdoor programs, underserved and marginalized communities should be at the forefront of decision-making to build a safe, accessible outdoors for all. Countless natural areas, outdoor centers, and nonprofit locations are simply not equitable for participants. In cities across the United States,

low-income, BIPOC youth lack access to abundant green spaces (Nesbitt et al., 2019). Some natural areas and parks also hold social barriers, including racism, harassment, lack of cultural and religious needs, and differing perceptions of safety (Public Health England, 2020; Stodolska et al., 2019). Science and environmental education can be a tool for social and racial justice in rural and urban regions. By providing students with the resources to engage in science, youth are able to recognize their influence on political, economic, and environmental justice in their community (Eppley, 2016). Outdoor programs that are accessible and do not rely on transportation or resources to access natural areas can serve youth from low-income, urban, rural, and indigenous communities (Chang et al., 2019; Rubio & Richard, 2019).

The COVID-19 pandemic only exacerbated the inequalities that exist among access to green spaces. Across the United States, physical activity among children declined because of the pandemic (Tulchin-Francis et al., 2021). The pandemic also had a negative impact on children's mental health due to the changes in school norms, cancellation of sports and group activities, and lack of insight regarding COVID-19 (Cowie & Myers, 2020). Dzhamboy et al.'s (2020) research found that frequent exposure to greenery helped combat depression and improved mental health in children during the pandemic. However, the COVID-19 pandemic restricted access to most natural areas, and children, primarily in marginalized communities who did not have a yard or garden, were unable to connect with nature at local parks (Dzhambov et al., 2020; Lufkin, 2020; Public Health England, 2020; Vaughan et al., 2013). The pandemic exposed the health inequalities among youth from low-income, marginalized communities and highlighted the need to connect these youth with the outdoors (Larson et al., 2019; Montero, 2018). Without access to outdoor experiences, individuals do not profit from the health benefits and lose interest in the natural world, decreasing their

CTN (Miller, 2017). An online program, such as ecoEXPLORE, would provide outdoor education and citizen science opportunities at the touch of one's finger, where a user can learn about nature and explore their local surroundings whenever and wherever.

Technology and the Virtual World

The large decline in time spent outdoors may be in part to the increase in technology and sedentary activities, such as watching television and using electronic devices (Aivazidis et al., 2006; Clements, 2004; Feijoo et al., 2009; Hunter, 2015; Khaddage et al., 2011; Miller 2005; Tremblay et al., 2015). In addition, increased screen time can decrease CTN among youth (Larson et al., 2019; Michaelson et al., 2020; Richardson et al., 2018). However, technology does have the potential to serve as a powerful instrument in education. Online resources and activities are helpful tools alongside in-person instruction (Hunter, 2015). With the accessibility of technology in the twenty-first century, educators can share their knowledge online via e-learning, virtual classrooms, and massive open online courses (Hunter, 2015; Roberts, 2005; Singaravelu, 2013; Tabuenca et al., 2019). Online programs can also provide an alternative form of education for those who may struggle in the traditional classroom, such as those with communication or learning difficulties (Doyle & Dezuanni, 2014). Technology in the sciences can be very appealing for many students, as there are a plethora of resources online, such as videos, maps, quizzes, and discussion boards (Doyle & Dezuanni, 2014; Maier, 2010). Though there are downfalls to virtual programs, like technical difficulties, students expressed interest in online classes since the equipment is relatively inexpensive, devices are portable, and they can occur at any time (Hunter, 2015; Khaddage et al., 2011; Roberts, 2005; Singaravelu, 2013). Because of the COVID-19 pandemic, over 1.2 billion children moved online from their classrooms, and educators taught through remote and digital platforms (Li & Lalani, 2020). Schools across the globe used

virtual learning to teach – from Zoom and Google Classroom to YouTube videos and mobile applications.

Online programs in environmental education. Over the past several years, environmental and science education programs have experimented with online learning. Whether these online programs are standalone or coexist with in-person programming, the literature suggests they can be as effective as online courses and virtual field trips (Chen et al., 2019; Tabuenca et al., 2019). Some research suggests these styles of virtual learning are even more effective than traditional environmental education at increasing attitudes about environmental issues and biodiversity awareness (Aivazidis et al., 2006). Chen and colleagues (2019) discovered virtual field trips were as successful as in-person trips at increasing science interest and self-esteem among students. Online tools may foster a more well-rounded approach to environmental and science education by being readily available, visually engaging, and serving as an online classroom where students can share ideas (Doyle & Dezuanni, 2014; Maier, 2010). Most online resources are easy to access and free of charge, making environmental awareness and education readily available (Tabuenca et al., 2019). By sharing one's thoughts and experiences of the outdoors online with peers, students better retained outdoor memories, improved CTN, and cultivated environmental opinions (Ardoin et al., 2015). Individuals can also discover web pages, videos, activities, and other people interested in similar topics to further enhance their learning (Hunter, 2015; Tabuenca et al., 2019). The ecoEXPLORE program is one of the many free programs on the Internet open to the general public, with educational content easily accessible on social media, YouTube, and the website (Tolley, 2020). With the ever-changing technology, and a societal shift to mobile devices (Feijoo et al., 2009), the younger generations can effortlessly adapt to interactive, online science-related programs.

Mobile Devices and the Outdoors

Mobile devices offer opportunities to learn anywhere, at any time, given they are accessible, portable, and user-friendly for all ages (Khaddage et al., 2011). Through mobile applications and games, one can enjoy learning about a variety of subjects and participate in particular niches (Nugent, 2019; Newman et al., 2012). Science mobile apps, like eBird and iNaturalist, allow users to be a part of the science community and contribute data directly to the source. No longer are science enthusiasts passive consumers of the content, but they get to instantly contribute to new research through their involvement (Feijoo et al, 2009; Khaddage et al., 2011; Maier, 2010). Citizen science often relies on technology since most observations are made in the moment while outdoors (Nugent, 2019). In the science community, there is a growing push for mobile applications to appeal to a wider demographic of users to further improve data collection and reach underrepresented groups (Newman et al., 2012). If these applications are gamified and fashioned to be fun and educational, they can engage the younger generations and create new opportunities for youth to be involved with science firsthand.

Gamification & exergaming. The Pokémon Go application is an example of an online program found on one's device that gets kids outside. Pokémon GO is an active video game, designed around the Pokémon franchise, that uses augmented reality (AR) to create Pokémon creatures in one's own neighborhood (Dorward et al., 2016; Gao, 2017). The game provides opportunities to explore natural areas, visiting parks and historic sites, while also encouraging social interaction with other players. Through the nature of the game, it promotes physical activity via incentivized movement, but it also has shown positive effects on improved mood and morale (Gao, 2017; Van Ameringen et al., 2017). Many users reported positive changes to their mental health and social behavior, such as spending time with others, making new friends, and boosting self-esteem and productivity (Loveday &

Burgess, 2017; Van Ameringen et al., 2017). Innovative gaming technology, such as this form of "exergaming," provides incentivized opportunities to promote physical activity among children and explore public parks, centers, and museums (Gao, 2017; Wagner-Greene et al, 2017). Without intention, Pokémon GO exposes users to basic science concepts, such as habitat preference, species abundance, biodiversity, climate, and resource scarcity (Dorward et al., 2016). If this application aimed toward conservation and documenting real wildlife, users could collect more data in a week than has been collected in 400 years (August, 2016; Dorward et al., 2016). An application like this game that encourages real species observations could be an essential tool for education and engagement (Dorward et al., 2016).

Nature-based applications. Other outdoor applications, such as mobile orienteering and geocaching games, promote outdoor activity and exploring local spaces (Fränti et al., 2017), but they are not always educational. Two applications excel as informative tools in the science community, and they are eBird and iNaturalist. Both platforms help improve conservation efforts across the globe through public observations of wildlife (Kelling et al., 2013; Nugent, 2019; Nugent, 2018; Sullivan et al., 2009). EBird applies the practices of the Next Generation Science Standards and provides users with incentives for participation, resulting in a massive data collection (Kelling et al., 2013; Nugent, 2019). This application accepts all birders, from novice to expert, and creates a community where new users can learn alongside professionals in the field (Sullivan et al., 2009). It is a remarkable tool for bird identification and conservation but is limited in functionality since it is only for bird species. INaturalist is a similar application that relies on user observations from the public (Nugent, 2018) but accepts all organisms and uses image recognition software to identify the species (iNaturalist, 2019). By uploading observations of wildlife, which are time-stamped and geotagged, users contribute to citizen science and scientific research (Nugent, 2018). One of the main goals of iNaturalist is to connect people with nature, and many users report a

strong CTN (Altrudi, 2020). However, most of these users are experienced in the outdoors and may already have these beliefs. Some researchers question iNaturalist's ability to foster true CTN since the program mainly classifies species for the user (Altrudi, 2020).

ecoEXPLORE. The ecoEXPLORE program, created with Pokémon GO and iNaturalist at its forefront, is an online program that aims to grow one's knowledge of local flora and fauna and build authentic CTN. The North Carolina Arboretum developed the ecoEXPLORE program in 2016 specifically for children (five through 13 years old) as a resource to get them outside and use technology to engage with science (ecoEXPLORE, 2019; Marchal, 2016). Users upload wildlife observations to the mobile-friendly ecoEXPLORE website and earn points for their findings. Users can earn up to five points per observation and points depend on various factors, such as a correct identification or taking a photo at a partner organization (ecoEXPLORE, 2019). Users can exchange these points for science-related prizes and work toward badges by completing activity sheets and attending virtual or in-person programs related to the badge (ecoEXPLORE, 2019). The program encourages place-based education by motivating kids to explore their local surroundings while learning about native species and building a connection with nature. Most of the educational activities meet state standards and increase science literacy among users (Marchal, 2016). During the COVID-19 pandemic, activity on ecoEXPLORE increased by 350% and met the needs of countless families wanting to get their kids outside (The University of North Carolina System, 2020). Since ecoEXPLORE's establishment, no research existed on the program and whether it was successful at achieving its mission and goals. Given ecoEXPLORE is a new science program predominantly online, a study exploring its impacts on users was long overdue. Therefore, the purpose of this study was to examine the impacts of the ecoEXPLORE program on children's CTN.

CHAPTER THREE: METHODS

Methodology

This study used an explanatory mixed-methods design to collect both qualitative and quantitative research. The researcher employed a mixed-methods approach to gather close-ended quantitative data via pre/post surveys and open-ended qualitative data via 1-on-1 interviews (Creswell & Creswell, 2018). The survey responses generated descriptive data regarding the population of ecoEXPLORE users as a demographic and measured the impacts of ecoEXPLORE on users' connection to nature (CTN) (using the Nature Connection Index (NCI)), and the individual interviews expanded on these quantitative responses. Combining two methods provided the researcher with a well-rounded viewpoint on the phenomenon, in this case, how ecoEXPLORE impacted CTN in children. This methodology combines several methods to provide informative, comprehensive, and beneficial data for ecoEXPLORE (Johnson et al., 2007; Levitt et al., 2018).

The specific mixed-methods approach for this study was an explanatory sequential design (Creswell & Creswell, 2018; Levitt et al., 2018), whereby the researcher gathered a large data set from quantitative research and built upon these findings through a qualitative portion (Creswell & Creswell, 2018; Levitt et al., 2018). The qualitative results were analyzed second and offered further depth into participant responses and their viewpoints on nature and ecoEXPLORE (Ivankova et al., 2006). A sequential mixed-methods approach has been used in the field of ecopsychology to gather new insight beyond questionnaire and survey responses (Larson et al., 2009; Michaelson et al., 2020; Mustapa et al., 2020). Putting numerical values on feelings, perceptions, and experiences about the outdoors can be complex, but providing the opportunity for participants to explain their responses can create richer data. For example, Mustapa and colleagues (2020) were able to pull from a large

sample size using questionnaires to gather a smaller set of individuals for focus groups and art drawings to measure and assess children's CTN. Michaelson et al. (2020) noted in their research on CTN that the mixed-methods methodology strengthened their study and the quantitative data supported their qualitative findings. Another study by Larson and colleagues (2009) interviewed children after completing the Children's Environmental Perceptions scale and found similar themes around external factors not included in the survey. Most CTN research relies on surveys or questionnaires, but qualitative perspectives reveal what these nature connections look and feel like to a child (Chawla, 2020). There are known limitations to the explanatory design since finding the time and resources to collect and analyze data can be a challenge (Ivankova et al., 2006); however, the ecoEXPLORE program already had pre/post surveys established within the website. Given these previous implementations in place and a supportive ecoEXPLORE staff, the researcher offset the time and resources often hindering this mixed-methods design.

Quantitative Method. The quantitative method in this study was pre/post surveys. As part of administrative assessment, the ecoEXPLORE program already had a pre-existing pre/post survey system implemented on the website that all users were required to complete. Users submit a new user survey when they join (pre-survey) and fill out a post-survey each time they earn a badge – a requirement to receive the physical badge in the mail. The North Carolina Arboretum implemented Richardson et al.'s (2019) NCI index into this survey during the summer of 2021 (see Appendix B for the complete user survey). CTN is a growing interest in outdoor education and ecopsychology, and the development of questionnaires has skyrocketed since the 1990s (Geller, 1995; Kals et al., 1999; Mayer & Frantz, 2004). Cheng and Monroe (2010) produced the first child-specific index in 2010, and there are now multiple scales exploring biophilia, environmental perceptions, and nature connection among younger demographics (Barthel et al., 2018; Giusti et al., 2018; Otto & Pensini, 2017). Still,

most of these scales are lengthy (over 15 statements), challenging for a young participant to comprehend and complete, and not suitable for a short survey format (Richardson et al., 2019). Several shorter CTN scales exist like the NR-6 (a condensed Nature Relatedness Scale) index, but these statements ("my connection to nature and the environment is a part of my spirituality" and "my ideal vacation spot would be a remote, wilderness area") are too complex for the ecoEXPLORE demographic and may limit what a child defines as nature (Nisbet & Zelenski, 2013). The North Carolina Arboretum chose Richardson et al.'s (2019) Nature Connection Index (NCI) for the ecoEXPLORE program because these statements most aligned with the program mission and were age-appropriate for users.

The NCI scale consists of six statements on a 7-point Likert scale and measures the five main nature connection pathways: emotion, compassion, beauty, meaning, and contact (Lumber et al., 2017; Richardson et al., 2019). These pathways originate from the biophilia hypothesis (Kellert & Wilson, 1993) and further psychometric studies to determine the top five CTN indicators (Lumber et al., 2017). Each pathway indicates one's affinity in this area for nature – emotion implies a participant's emotional attachment to nature, beauty indicates how aesthetically pleasing a participant finds nature, meaning infers how impactful nature is on an individual, contact comes from how much time one spends outside, and compassion refers to one's respect for their environment. A sixth pathway arose within the NCI scale and this was sense of belonging, which encompasses several of the pathways and describes one's interconnectedness, or relationship, with nature. The NCI scale is an effective CTN tool, validated by the Nature Relatedness Scale, the Nature in Self Scale, and the Monitor of Engagement with the Natural Environment Survey (Richardson et al., 2019). The six statements are:

1. I always find beauty in nature
2. I always treat nature with respect

3. Being in nature makes me very happy
4. Spending time in nature is very important to me
5. I find being in nature really amazing
6. I feel part of nature (Appendix A)

Each statement correlates with at least one of the five pathways, and a high score implies a strong CTN (Richardson et al., 2019). The first item measures beauty, the second denotes compassion, the third and fifth statements quantify emotion, the fourth statement gauges meaning and contact, and the last item, "I feel part of nature," describes sense of belonging (Richardson et al., 2019). The NCI items were the only portion of the users' pre/post surveys analyzed in this study, and though completion of these surveys was a requirement for all users, children could opt-out of contributing their NCI responses. The researcher collected these responses over four months and analyzed them using SPSS Statistics software through paired and independent t-tests, linear regression models, and an ANOVA test (Creswell & Creswell, 2018; Field, 2013)

Qualitative Method. The qualitative method used in this study was individual interviews. These were one-on-one interviews with an ecoEXPLORE user and the researcher. Parents or guardians could be present during these conversations, but the researcher encouraged them to refrain from sharing their responses and respect those shared by their children. Individual interviews provided insight into specific survey responses and were the preferred method over focus groups to prevent bias or groupthink (Marshall & Rossman, 2016; Moore et al., 2008). Interviews are also useful for those working with a younger audience and wanting a deeper understanding of a program or specific topic. In this case, interviews used alongside the Nature Connection Index (NCI) added complexity and a personal story to the quantitative responses of those interviewed (Giusti, 2019). There are many benefits to interviews with children, such as listening to personal stories, providing an

open-ended conversation, participating in one-on-one experiences, and involving this age demographic directly with the research that impacts them (Moore et al., 2008). A researcher can better serve a specific age group by understanding how a program impacts or benefits them, and these interviews uncovered how and in what ways ecoEXPLORE impacted CTN by expanding on the NCI surveys (Barthel et al., 2018; Giusti, 2019).

The researcher used the survey information to send recruitment emails to parents of ecoEXPLORE users who earned at least one ecoEXPLORE badge during the four-month quantitative period. The number of individuals depended entirely on those who volunteered, and in the end, the researcher selected eight ecoEXPLORE users. Since ecoEXPLORE is a statewide program, the interviews took place over Zoom and lasted 20 to 30 minutes. The researcher recorded these Zoom sessions to gather audio and visual footage and immediately deleted the files after transcription. The interview questions were scripted and opened with general ones about the child ("what is your favorite animal"), transitioning into questions about ecoEXPLORE and CTN (see Appendix C for all interview questions). If a child was in the younger age range of participants (five through seven years old), the researcher altered the questions slightly to make them more age-appropriate. Interviews lasted between 20 to 30 minutes, and participants could withhold replies or withdraw at any point from the research. Given most of the questions addressed the six NCI items, the researcher coded the interviews using the six nature connection pathways. Through *a priori* coding, the researcher used the six nature connection pathways as the main themes, and an additional one arose, which was environmental awareness (Marshall & Rossman, 2016). As part of a mixed-methods study, these conversations were essential for the researcher to develop a deeper understanding of ecoEXPLORE's impact on CTN, specifically looking at what components of the ecoEXPLORE program influenced CTN among users (Creswell & Creswell, 2018; Marshall & Rossman, 2016).

Participant Selection

For this study, the participants of both the quantitative and qualitative components were active users in the ecoEXPLORE program - this means they were involved with the program during the research time frame (September 2021 through January 2022) and earned at least one badge. Participants were also between the age range required for ecoEXPLORE (five through 13 years old), and almost all users were North Carolina residents, though not a requirement. Users earn a badge by submitting at least six observations of different species related to a specific badge, for example, plant photos for the "Botany Badge" or bird photos for the "Ornithology Badge." In addition, a user must submit three challenge activities, which are rooted in environmental education curricula. The four months of quantitative data collection covered various science-related badges, including ichthyology, water, mammalogy, and rodents. During this time frame, ecoEXPLORE users could have also attended virtual or in-person ecoEXPLORE programs associated with these badges. The successful completion of a badge usually takes one to two months. After completing a badge, the website notified users to fill out a post-survey and denote any changes since joining ecoEXPLORE and earning a badge. This study only analyzed the NCI responses among the pre/post surveys since the NCI is a valid scale. Almost half of the users surveyed submitted more than one post-survey since they earned several badges over the time frame, and the research team only used their first post-survey for data analysis. This study only included data from those who signed consent for the quantitative and qualitative portions. In all, the research team collected 60 individual responses from the surveys. This number depended on how active users were during the four-month time frame and whether they gave consent.

The research team invited all ecoEXPLORE users who earned one badge during the quantitative portion (September through December) to participate in the qualitative interview via email. Those interested in an interview reached out voluntarily, and the researcher

selected eight individuals – four boys and four girls. The average age of ecoEXPLORE users, as indicated by the quantitative data, was 8.9 years old, and the average age of interviewees was eight years old. Interview participants ranged from six to ten years old, covering an age range of five years. It was important to maintain intentional communication throughout the interviews to create a trusting environment where participants felt comfortable sharing their thoughts and ideas (Marshall & Rossman, 2016). The compensation for interviewees was 20 bonus points, applied to their ecoEXPLORE account within a few days of their interview. The sample size of eight individuals was kept relatively small given the time restraints of the master's program and the feasibility of transcribing, coding, and analyzing the interview data.

Role as a Researcher

The researcher, Meghan McDevitt, is an employee of the North Carolina Arboretum and works with the ecoEXPLORE program. Though the researcher had access to the user information provided in the surveys, the statewide coordinator of ecoEXPLORE worked with the research team to provide the necessary data on an encrypted thumb drive. The statewide coordinator removed identifiable data, such as name and address, and only kept email addresses to recruit interviewees for the qualitative portion. Indirect identifiers, including age, gender, and ethnicity, remained in the dataset to investigate demographics, and the data lived in an encrypted spreadsheet on a password-protected computer. The researcher could not influence the survey responses but may have unknowingly interacted with a potential participant through the website, programming, or social media.

Since this study involved minors, and required approval from the institutional review board, consent was a key element throughout the research (Creswell & Creswell, 2018). This study required signed informed consent by both the parent and child for the pre- and post-surveys. The interview portion gathered additional informed consent from both the parent/guardian and the child, and the researcher also obtained child assent before beginning

each interview. This study may have unknowingly involved vulnerable populations, such as those with varying neurological or physical (dis)abilities; however, the Western Carolina University's IRB Board assessed this study as minimal risk to participants given the subject matter. As an ecoEXPLORE staff member in an administrative role, Meghan was reflexive and communicated research requirements with participants throughout the study, reminding participants that there were no consequences to responses and users could opt-out at any time. The findings could impact the ecoEXPLORE program and the researcher as an employee of the North Carolina Arboretum; yet, no prior research existed on ecoEXPLORE that could sway the outcome of this study.

As part of the EOE thesis handbook, I have chosen the manuscript thesis format option. This option requires chapters 1-2-3 plus a full-length manuscript aimed at a specific journal and formatted as such. In this option, the following chapter will be my complete manuscript, which will include chapters 4 and 5 of this paper. I have chosen to submit to the Environment & Behavior Journal, which requires authors to submit a manuscript of 25 pages (not including references and tables or figures), written in APA format, with a 150-word abstract.

JOURNAL ARTICLE

The Impacts of an Online, Citizen Science Program on Children's Connection to Nature

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The Impacts of an Online, Citizen Science Program on Children's Connection to Nature

Outdoor experiences are a vital component in child development and wellness; however, more and more children spend less time outside. This phenomenon became even more pronounced during the COVID-19 pandemic, with device usage among children increasing drastically around the world. Lack of time outdoors and increased device usage may inhibit the cultivation of connection to nature (CTN), which may lead to poor conservation ethics and negative environmental attitudes. However, one program, ecoEXPLORE, embraced technology as a tool to explore the outdoors and learn about one's local environment, thus increasing their time outdoors. EcoEXPLORE, founded in 2016, is a predominantly virtual program that mediates outdoor experiences for North Carolina children through citizen science and online resources. In this current age, devices are simply not going anywhere, and this mixed-methods study on ecoEXPLORE found that a predominantly online, science program increased CTN among program users.

Keywords: citizen science, connection to nature, conservation, environmental education, ecoEXPLORE

The Impacts of an Online, Citizen Science Program on Children's Connection to Nature

Outdoor experiences benefit emotional, mental, and physical well-being, and they are especially formative in the development of young children (Barnes et al., 2019; Bratman et al., 2012; Kellert, 2002; Tremblay et al., 2015). Spending time outdoors helps children regulate their emotions, improve attention and cognitive reasoning, reduce stress, and increase physical activity (Clements, 2004; Larson et al., 2019; Montero, 2018). When children are unable to experience nature or access green spaces throughout their childhood, they cannot reap these associated health benefits and often become detached from the natural world, resulting in a low connection to nature (CTN) (Martin et al., 2020; Miller, 2005; Torquati et al., 2010; Tremblay et al., 2015). Measuring CTN is a way to evaluate one's relationship with nature and may predict the likelihood of developing pro-environmental attitudes and engaging in conservation actions (Chawla, 1998; Hughes et al., 2018; Martin et al., 2020; Soga et al., 2016; Zhang et al., 2014). A lack of CTN among younger generations may be detrimental to the health of humans, wildlife, and the entire planet (Cheng & Monroe, 2010; Hughes et al., 2019; Kellert, 2002).

Studying CTN is a growing area of interest in the science field as a way to better understand human behavior and perceptions of nature (Kals et al., 1999; Mayer & Frantz, 2004). In 2010, Cheng & Monroe developed the first children's connection to nature index, which consisted of 22 statements, such as "being outdoors makes me happy" and "I like to hear different sounds in nature" (Cheng & Monroe, 2010). The findings from this research highlighted the importance of outdoor experiences in increasing a child's CTN (Cheng & Monroe, 2010). By increasing CTN, children can improve their overall health, sense of place, connectedness, and environmental mindset (Cheng & Monroe, 2010; Martin et al., 2020; Mayer & Frantz, 2004; Richardson et al., 2020). A high CTN supports the development of

strong conservation ethics, and these environmental practices are likely to carry into adulthood (Evans et al., 2018; Hughes et al., 2018; Richardson et al., 2020; Rosa et al., 2018).

With younger children spending more time on devices than ever before, it is vital to provide opportunities for them to get outside. Too much sedentary activity can lead to an increased risk for obesity, poor diet, depression, anxiety, and a low CTN (Larson et al., 2019; Martin et al., 2020; Michaelson et al., 2020; Richardson et al., 2018; Stiglic & Viner, 2019). Michaelson and colleagues (2020) observed children in particular and their device usage, and the findings implied the youngest participants who spent a lot of time on screens had the weakest CTN. The COVID-19 pandemic only exacerbated the importance of outdoor spaces and recreation for young people, as children moved to virtual learning and physical activity and mental health plummeted among children (Cowie & Myers, 2020; Tulchin-Francis et al., 2021). Organizations that once offered in-person outdoor education programs were required to temporarily close or permanently shut down (Collins et al., 2020). By the end of 2020, over 11 million children in the United States could not participate in environmental education because of the pandemic, resulting in an estimated 600 million dollar loss in revenue (Collins et al., 2020; Higgins, 2020). As with most schools, outdoor environmental education organizations resorted to online programming as a way to reach new audiences; yet, one organization was already doing this (Andrews, 2020; Higgins, 2020; Lygren et al., 2020).

In 2016, the North Carolina Arboretum created a predominantly online, citizen science program called ecoEXPLORE that encourages children to take their devices outside. This name is an abbreviation of "Experiences Promoting Learning Outdoors for Research and Education" (ecoEXPLORE, 2019), which is the intention behind the ecoEXPLORE program. EcoEXPLORE encourages children, five through 13 years old, to get outdoors, learn about native wildlife, and engage in citizen science online (The University of North Carolina System, 2020). Children spend an increasing amount of time inside and on screens (Friel,

2020; Singaravelu, 2013; Thomas et al., 2019), but ecoEXPLORE motivates outdoor experiences by providing ways for children to use their devices outside (Marchal, 2016). Users take photographic observations of anything they find in nature and upload these photos to their personal dashboard on the ecoEXPLORE website (ecoEXPLORE, 2019). If they are clear photos, volunteers send these observations anonymously to iNaturalist, an international and online citizen science network (iNaturalist, 2019). Since its launch, the ecoEXPLORE community has steadily grown; however, participation tripled during the pandemic, averaging 600 active users annually.

EcoEXPLORE is a relatively new program, and thus, there is no academic research studying its impact on users. Similar programs exist, such as the Kids in the Park program, but ecoEXPLORE focuses more on science literacy and citizen science (Blue Ridge Parkway Foundation, n.d.). More established online citizen science programs, like iNaturalist and eBird, successfully engage participants in observation-based learning, but most of these applications target older participants (iNaturalist, 2019; Kelling et al., 2013; Sullivan et al., 2009). EcoEXPLORE bridges the gap between technology and the younger audience to provide a secure platform for users as young as five years old to be a part of the science community (ecoEXPLORE, 2019). The program incentivizes users to continue with ecoEXPLORE since they can earn points, prizes, and badges by attending online programs and submitting photos and challenge activities. The program offers ample resources, meeting state standards and environmental education needs to strengthen science literacy (Marchal, n.d.; Tolley, 2020). Given the program design, ecoEXPLORE serves as a tool to enhance outdoor experiences, improve science literacy, and foster CTN across ecoEXPLORE users.

In an increasingly digital age, a study is long overdue examining the influence of an online, science program on CTN. The purpose of this research was to discover whether ecoEXPLORE, a program that promotes interactions with nearby nature, influenced CTN.

Virtual programs can increase student understanding, interest, and engagement in science (Chen et al., 2014; Doyle & Dezuanni, 2014), but what about CTN? The research questions for this study were:

- Does the ecoEXPLORE program impact children's connection to nature?
- How does the program impact CTN and in what ways?

We hypothesized that a) ecoEXPLORE would improve CTN among users and b) it would do so through facilitating time outdoors and increasing knowledge about the natural world. Through a mixed-methods study, we answered both of these research questions. We addressed the first question through Richardson et al.'s (2019) Nature Connection Index (NCI), administered via pre/post-surveys over four months, and gained insight into ecoEXPLORE users' CTN. Then we conducted interviews to address the second question and further understand the mechanisms of ecoEXPLORE that strengthened CTN.

Literature Review

A Child's Connection with Nature

Experiences in the outdoors are a fundamental piece of one's childhood and development, benefitting emotional, mental, and physical wellness (Barnes et al., 2019; Bratman et al., 2012; Tremblay et al., 2015). However, more and more children are spending less time outdoors, and there is a growing rise in obesity and sedentary behavior among younger generations (Daniels & Hassink, 2015; Friel et al., 2020). Excessive sedentary activity and screen time may lead to an increased risk in obesity, poor diet, depression, anxiety, and a negative connection to nature (CTN) (Bratman et al., 2012; Martin et al., 2020; Michaelson et al., 2020; Richardson et al., 2018; Stiglic & Viner, 2019). When children are outside, they partake in more structured play, such as organized sports, and spend less time hiking, fishing, and exploring their natural surroundings (Clements, 2004; Ginsburg et al., 2007). Unstructured activities and experiences in green spaces, whether a small park or large

wilderness area, are all linked to improved physical and mental health, not only for the child but for the family members engaged as well (Barnes et al., 2019; Ginsburg et al., 2007).

Outdoor Access is Social Justice. Outdoor experiences are particularly important for those who are underrepresented and lack access to green spaces (Nesbitt et al., 2019). Though outdoor organizations and parks provide vital learning opportunities, which can empower urban and rural communities most impacted by environmental issues, many are simply inaccessible, possessing physical, cultural, and social barriers like racism and harassment (Eppley, 2016; Nesbitt et al., 2019; Stodolska et al., 2019; Vaughan et al., 2013). The COVID-19 pandemic only exacerbated the importance of outdoor spaces and recreation for youth. Over the pandemic, physical activity and mental health drastically declined among children across the globe (Cowie & Myers, 2020; Tulchin-Francis et al., 2021). Nature exposure is valuable for everyone – it reduces stress, fosters CTN, and improves overall wellbeing (Larson et al., 2019; Montero, 2018). Without proper access to the outdoors, individuals cannot experience these health benefits and often grow up to become disinterested in the natural world (Martin et al., 2020; Miller, 2017; Tremblay et al., 2015).

Connection to Nature and its Importance. A lack of connection to the natural world and disregard for environmental stewardship is detrimental to the health of the land, wildlife, and even humans (Cheng & Monroe, 2010; Hughes et al., 2019; Kellert, 2002; Zhang et al., 2014). Assessing connection to nature (CTN) among young individuals can predict the likelihood of them developing pro-environmental attitudes and a desire to conserve and protect biodiversity (Chawla, 1998; Hughes et al., 2018; Martin et al., 2020; Zhang et al., 2014). A high CTN benefits overall health and sense of place and leads to strong conservation ethics, which can carry into adulthood as lifelong passions (Cheng & Monroe, 2010; Evans et al., 2018; Hughes et al., 2018; Mayer & Frantz, 2004; Richardson et al., 2020; Rosa et al., 2018). One can develop a strong CTN by regularly visiting green spaces and

spending time outdoors, but it can also be improved through reading, watching, and talking about the natural world (Giusti et al., 2018; Ferreira, 2012; Miller, 2005; Soga et al., 2016). In a world where children are more likely to care about exotic animals instead of ones in their own backyard, it is critical to effectively teach children about native species and their local environment through outdoor exploration (Ballouard et al., 2011; Lindemann-Matthies, 2005; Schuttler et al., 2019; Tomažič, 2008).

Outdoor Resources & Education Opportunities

Various education strategies incorporate the outdoors into practice, which helps reduce sedentary activity and increases CTN among children. Schools that encourage nature play and outdoor classrooms notice improved skills and attitudes about learning, knowledge retention, and civic engagement (Clark & Lott, 2017; Eick, 2012; Gostev & Weiss, 2007). Students can better create observations of the natural world, which is a substantial factor in science learning often overlooked by standards (Gostev & Weiss, 2007; Merritt & Bowers, 2020; Tolmie et al., 2016). Beyond the traditional classroom, environmental education is a form of experiential education that increases environmental literacy and stewardship through hands-on learning outdoors (Ferreira, 2012; Lygren et al., 2020; Otto & Pensini, 2017; Whitburn et al., 2019). This type of education not only serves as an effective tool in teaching about the natural world but in fostering an appreciation for the outdoors, which increases CTN (Otto & Pensini, 2017; Torquati et al., 2010). By participating in environmental education and nature-based programming, students can build a richer connection to nature and appreciation of the world (Barthel et al., 2018; Otto & Pensini, 2017; Whitburn et al., 2019). A final style of education that improves CTN is place-based education, which involves students directly with their local community (Gruenewald & Smith, 2008). Place-based education teaches students about all aspects of their environment (physical, cultural, and

social) to ultimately improve relationships, sense of place, and gratitude for the community and local environment (Cruz et al., 2017; Nichols et al., 2016).

Citizen Science. Citizen science is another approach to getting children involved with the natural world. Citizen science is a type of scientific research that relies on the contributions of public observations to large data collections, advancing scientific knowledge (Bonney et al., 2009). In recent years, "community science" and "participatory science" have also described citizen science as a way to include all participants in a region. However, for this purpose, and since "community science" often refers to underserved communities impacted by environmental justice, citizen science is the applied term (Cooper et al., 2021). Citizen science encourages individuals to document the species they find while outside, and these observations get shared with scientists across the globe (Newman et al., 2012; Soanes et al., 2019). Citizen science programs, like ecoEXPLORE, help children learn about the wildlife they observe while playing an active role in the science community (Bonney et al., 2009; iNaturalist, 2019; Makuch & Aczel, 2019; Newman et al., 2012; Soanes et al., 2019). Through interactions and engagement with citizen science, participants build an affinity for conservation, stewardship, and environmental justice (Castagneyrol, 2020; Makuch & Aczel, 2019; Soanes et al., 2019). Since citizen science is typically collected online, younger generations already have an advantage given their familiarity with devices.

Technology in the Outdoors

The large decline in time spent outdoors may be due to increased technology use and sedentary activities (Clements, 2004; Khaddage et al., 2011; Miller, 2005; Tremblay et al., 2015). Increased screen time also correlates with decreased CTN among youth (Larson et al., 2019; Michaelson et al., 2020; Richardson et al., 2018). However, because of technology, people have more opportunities than ever to pursue interests and learn new hobbies online through web pages, videos, and online forums that are free and available on the internet

(Hunter, 2015; Tabuenca et al., 2019). Technology also serves as a powerful tool in education by making online resources and programming, like Zoom and Google Classroom, even possible (Hunter, 2015; Roberts, 2005; Singaravelu, 2013; Tabuenca et al., 2019). Virtual classes, like in-person programs, come with their challenges; yet, students gravitate toward online classes since they can be done anywhere at any time on devices students already own and may be more accessible for those who struggle in a traditional classroom (Doyle & Dezuanni, 2014; Hunter, 2015; Khaddage et al., 2011; Roberts, 2005; Singaravelu, 2013). Literature suggests that virtual programs and field trips can be just as effective as in-person environmental education at increasing science interest, retention, and confidence (Aivazidis et al., 2006; Chen et al., 2019; Soga et al., 2016; Tabuenca et al., 2019). With the move online during the pandemic, it became apparent there was a need for more engaging online programs in the outdoor field.

Mobile Applications and Science. Mobile devices offer even more opportunities to explore one's interests since they are accessible, portable, and user-friendly (Khaddage et al., 2011). Through science-oriented mobile applications, individuals can enjoy learning about the natural world while contributing data directly to scientific research through citizen science (Khaddage et al., 2011; Newman et al., 2012). Ebird and iNaturalist are two well-known citizen science applications that help improve conservation efforts across the globe and rely on species observations from the public (Kelling et al., 2013; Nugent, 2018; Sullivan et al., 2009). While iNaturalist is a noteworthy tool to learn about native species, it targets an older audience, and users must be older than 13 years old to create an account. One of the goals of iNaturalist is to connect people with nature, and though many users report a strong CTN, some researchers question its ability to grow authentic CTN since the program solely classifies species (Altrudi, 2020). Most science programs also forego the gamification aspect, which can stimulate self-directed learning and appeal to a broader demographic (Newman et

al., 2012; Palaniappan & Noor, 2022). A prime example of gamification is the Pokémon Go application, which uses augmented reality (AR) to generate Pokémon creatures near one's location (Dorward et al., 2016; Gao, 2017). This style of active gaming motivates users to explore their surroundings to find Pokémon, and it consequently increases social interactions, physical activity, and mental health among users (Gao, 2017; Van Ameringen et al., 2017; Wagner-Greene et al., 2017). The game also teaches basic science concepts, such as habitat preference and resource scarcity (Dorward et al., 2016). One research study suggested that if the public put the same amount of energy into documenting real species, users could collect more data in a week than in the past 400 years (August, 2016; Dorward et al., 2016).

EcoEXPLORE – An Online, Science Program

In 2016, the North Carolina Arboretum developed the ecoEXPLORE program specifically for children (five through 13 years old) as a way to experience nature through technology and citizen science (ecoEXPLORE, 2019; Marchal, 2016). Inspired by environmental education practices, iNaturalist, and Pokémon Go, ecoEXPLORE is a predominantly online program that provides resources to get kids outside. Users take photos of species they see while outdoors and upload them to the mobile-friendly website. Observations are worth various points, and users can exchange these points for science-related prizes. Users can also earn themed badges, like the Botany Badge, by submitting badge-related activity sheets and photos and attending virtual or in-person programs (ecoEXPLORE, 2019). Through these opportunities, users explore their local surroundings, learn about native species, and build CTN. The goals of the ecoEXPLORE program are to increase science literacy, environmental awareness, and CTN, but academic research on the program's efficacy did not exist until this study. Therefore, the purpose of this study was to examine the impacts of the ecoEXPLORE program on children's CTN. If children spend less time outdoors and more time on devices, resulting in low CTN, a virtual platform that brings

these two aspects together is a crucial resource. The COVID-19 pandemic highlighted the need for a program, such as ecoEXPLORE, in the outdoor field when in-person programming is not feasible. The ecoEXPLORE program is a successful tool that uses the technology children regularly use to expand their knowledge of the natural world and improve CTN.

Materials & Methods

We chose an explanatory, sequential mixed-methods design, in which we collected quantitative survey data first, followed by interviews with a smaller subset of participants from these responses (Creswell & Creswell, 2018; Levitt et al., 2018). This approach allowed us to use closed-ended, quantitative questions via surveys to generate descriptive statistics for the population of ecoEXPLORE users as well as gauge the mechanisms for the impacts of ecoEXPLORE on users' CTN via open-ended, qualitative interviews (Creswell & Creswell, 2018; Johnson et al., 2007; Levitt et al., 2018).

Quantitative Method

The quantitative method for this study was a pre/post-survey. As part of general assessment for ecoEXPLORE, the program had pre/post evaluation surveys already embedded into the website, which users were required to complete. During the summer of 2021, the North Carolina Arboretum added Richardson et al.'s (2019) NCI index into their surveys to assess CTN. After a review of other CTN scales, including ones designed for children (e.g., Connection to Nature Index: Cheng & Monroe, 2010), the ecoEXPLORE program chose the NCI scale because the statements most aligned with the goals of the program and were age-appropriate. The NCI scale consists of six statements on a 7-point Likert scale and measures the five main nature connection pathways: emotion, compassion, beauty, meaning, and contact (Lumber et al., 2017; Richardson et al., 2019). These pathways originate from the biophilia hypothesis (Kellert & Wilson, 1993) and further psychometric studies to determine the top five CTN indicators (Lumber et al., 2017). The NCI scale is an

effective CTN tool, validated by the Nature Relatedness Scale, the Nature in Self Scale, and the Monitor of Engagement with the Natural Environment Survey (Richardson et al., 2019). The six statements are:

1. I always find beauty in nature
2. I always treat nature with respect
3. Being in nature makes me very happy
4. Spending time in nature is very important to me
5. I find being in nature really amazing
6. I feel part of nature

Each statement correlates with at least one of the five pathways, and a high score implies a strong CTN (Richardson et al., 2019). The first item measures beauty, the second denotes compassion, the third and fifth statements quantify emotion, the fourth statement gauges meaning and contact, and the last item, "I feel part of nature," describes sense of belonging (Richardson et al., 2019). The NCI items were the only portion of the users' pre/post surveys analyzed in this study, and though completion of these surveys was a requirement for all users, children could opt-out of contributing their NCI responses. Children submitted pre-surveys when they joined ecoEXPLORE and post-surveys every time they earned a badge. The researcher collected these responses over four months and analyzed them using SPSS Statistics software through paired and independent t-tests, linear regression models, and an ANOVA test (Creswell & Creswell, 2018; Field, 2013).

In all, we collected 60 NCI responses from the ecoEXPLORE program. Though the study received 113 pre/post surveys, we excluded over half because of age restrictions, lack of consent, duplicate submissions, or other complications. Participants scored their NCI responses on a 7-point Likert scale; however, since the NCI is a weighted index and each item has its own unique values for the Likert scale numbers, the researcher reassigned

participant responses with these weighted values. The weighted scale ensured that the data represented all six items of this index accordingly, and with the scale being out of 100 points, we could see any score discrepancies more clearly (Richardson et al., 2019) (See Table 1).

Qualitative Method

The qualitative method for this study involved individual interviews with ecoEXPLORE users. We used individual interviews rather than focus groups to prevent bias related to groupthink and gain insight into user-specific survey responses (Marshall & Rossman, 2016; Moore et al., 2008). This approach is helpful when working with a younger audience (Giusti, 2019). We invited ecoEXPLORE users who completed the pre/post-surveys to participate in follow-up Zoom interviews. Of the 60 survey respondents, 15 individuals volunteered for interviews, and the researcher selected eight participants. Scripted questions guided the interviews (see Appendix C), and we allowed follow-up questions to arise naturally out of conversation (Creswell & Creswell, 2018). Parents or guardians could be present during these conversations, but the researcher encouraged them to refrain from sharing comments and excluded their responses from the analysis. We collected both audio and visual recordings for transcription and immediately deleted the files after. The research team used *priori* codes drawing from the six NCI pathways (Lumber et al., 2017; Marshall & Rossman, 2016) to transcribe and theme the interviews. THE NCI pathways encompassed six themes, and a seventh theme arose, which was environmental awareness.

Participant Selection

For this study, the participants for both the quantitative and qualitative portions were active users in the ecoEXPLORE program - this meant they were involved with the program during the research time frame (September 2021 through January 2022), earned at least one badge, filled out the pre/post surveys, and met the age requirements (five through thirteen years old). Users earned a badge by submitting at least six observations of species related to a

specific badge and completing the associated activity sheets. Several badges were available during the four months of data collection, covering topics like ichthyology and mammalogy, and because of this ability to earn multiple badges, over half of the participants submitted more than one post-survey. For those who submitted several forms, we only used the initial post-survey, and in the end, we gathered 60 individual responses for the study. For the qualitative portion, we invited these 60 users to participate in voluntary interviews and selected eight individuals – four boys and four girls. The average age of ecoEXPLORE users in the quantitative data was 8.9 years old, and the average age of interviewees was eight years old, ranging in age from six to ten. For participating, the researcher awarded 20 bonus points to users and added them to their ecoEXPLORE account after the interview.

Role as a Researcher

I, Meghan McDevitt, was an employee of the North Carolina Arboretum and worked for the ecoEXPLORE program during this study. To stay reflexive and keep communication clear, I reiterated the research requirements throughout the study and reminded interview participants that there would be no consequences for their responses. The State-wide Coordinator of ecoEXPLORE also helped remove identifiable information, such as full names and addresses, and gave the research team the de-identified data on an encrypted thumb drive. We gained IRB approval and requested informed consent from the guardian and child for both the pre- and post-surveys and interviews. The informed consent for interviews obtained audio and visual recordings for transcription, and we gathered child assent from each participant before their interview. If either party did not provide consent or wished to withdraw from the study at any point, we excluded their responses.

Results

Quantitative Data

Through IM SPSS Statistics software, we analyze the 60 pre- and post-survey responses. We tested the Nature Connection Index (NCI) items for reliability, and the overall scale had a Cronbach alpha value of .90, which is an "excellent" value for internal consistency of items (George & Mallery, 2013). The following tests ran through SPSS analyzed composite NCI mean scores and demographic information. These additional tests allowed the research team to look at external factors that may have influenced NCI scores.

Mean Differences. The research team first conducted a paired sample t-test to compare the pre- and post-survey composite mean difference, which measured the change in mean score between the two surveys, whether positive or negative. This paired sample t-test examined the pre-survey (M=59.97, SD=21.36) and post-survey (M=78.45, SD=24.72) and found the composite mean difference statistically significant (M=18.48, SD=22.39, 95%CI [12.70, 24.27]) at the .05 level of significance ($t(59)=6.40$, $p<.001$) (See Table 2). The skewness was .53, indicating a fairly symmetrical dataset, and the kurtosis value was -.55, which means the data had a marginally flatter bell curve (Figure 1). Overall, 70% of users increased their score, 12% had a negative change, and 18% were neutral. We then ran individual paired sample t-tests for the six NCI survey items and found all of the mean score differences were statistically significant ($p<.001$), correcting the alpha for repeated testing using the Bonferroni method (See Table 3).

User Demographic. We conducted a linear regression model to compare users' age and composite mean differences. The mean age of ecoEXPLORE users was 8.9 years old; however, the test showed no correlation between age and NCI score. As one can see in Figure 3, this scatterplot demonstrates the lack of correlation with heteroscedasticity. When the researcher looked at the composite mean difference at each end of the age spectrum, the six

five-year-olds improved their mean NCI score by 25.83, and the four 13-year-olds improved their mean NCI score by 34.67, suggesting age, whether young or old, was not linked to a higher CTN among ecoEXPLORE users. The next test was an independent samples t-test to examine user gender and composite mean difference. This group of participants did not include any non-binary or nondisclosed genders in the data set. The composite mean difference for the males (N=35) (M=18.26, SD=21.8) was no different from the females (N=25) (M=18.8, SD=23.62), and the p-value was not statistically significant (t(58)=-.09, p=.93). Levene's test for equality of variances indicated equal variability across the two genders, F(2, 58)=.15, p=.70, implying that gender did not have a significant impact on an ecoEXPLORE user's NCI score. We conducted an independent t-test for ethnicity, and, given only eight participants identified as BIPOC individuals, the research team divided ethnicity into two categories (White/Caucasian=0, BIPOC=1). The BIPOC users represented in this study identified as Latinx, African American, South Asian, or Native American. The test found that White/Caucasian participants (N=52) (M=18.52, SD=23.15) and BIPOC participants (N=8) (M=18.25, SD=17.81) had a very similar composite mean difference with no statistical significance (t(58)=.03, p=.98). Additionally, Levene's test revealed that the population variances were equal, F(2,58)=1.69, p=.20), and one can conclude that ethnicity did not influence CTN among these ecoEXPLORE users.

***User Location*.** The final test conducted was an ANOVA test to look at residential locations of ecoEXPLORE users. Most participants in this study lived in Suburban neighborhoods (N=26), then rural areas (N=24), and lastly urban locations (N=10). Rural ecoEXPLORE users saw the greatest overall improvement in their NCI score (M=26.00), then urban participants (M=15.30), and suburban children increased the least (M=12.77) (Table 5). Figure 4 shows a visual distribution of the composite means for both the pre- and post-surveys and user location. Rural ecoEXPLORE users had the highest NCI score initially

(*M*=64.25), followed by suburban users (*M*=59.88), and lastly urban users (*M*=49.90). In the post-survey data, rural users maintained the highest score (*M*=90.25) out of 100 points, then suburban participants (*M*=72.65), and lastly urban children (*M*=65.20). We used the Tukey HSD test to compare mean scores across location categories and found rural versus suburban responses had the lowest p-value (*p*=.09) (Table 6). Though not statistically significant, it is worth noting since the 24 rural users had the greatest improvement in mean score, while the 26 suburban users had the weakest improvement. The results of the ANOVA test suggested NCI scores improved among ecoEXPLORE users despite location; however, participants did start with varying pre-test scores, with urban users joining ecoEXPLORE with the lowest NCI scale and rural users joining with the highest. Through these tests, we observed improvements to NCI scores across users and confirmed the first hypothesis that ecoEXPLORE positively influenced children's CTN.

Qualitative Data

The research team conducted qualitative interviews to explore the possible impacts of the ecoEXPLORE program on users' connection to nature (CTN), addressing the research question: "how does the program impact CTN and in what ways?" Interviews were coded and themed by the six nature connection pathways (emotion, beauty, contact, meaning, compassion, and sense of belonging) in the Nature Connection Index (NCI) (Richardson et al., 2019). A seventh theme arose and was environmental awareness. The qualitative data is presented below through these seven themes and representative quotes.

Emotion. The emotion pathway discovers an individual's emotional attachment to nature, which can improve CTN and overall wellbeing (Lumber et al., 2017; Richardson et al., 2019). The interview questions that addressed this pathway explored positive feelings that arose when outdoors, like wonder, happiness, and appreciation. Such questions included "how does being outside make you feel?" and "what do you enjoy most about nature or

spending time outside?" All participants voiced positive feelings, with seven out of the eight using the word "happy." The researcher asked one specific participant confused by this question how they would feel if they were unable to go outside, and the child looked visibly upset, stating "well, if that means we couldn't play any football, I'd be pretty mad sad." In this instance, child 6, who was one of the youngest participants, had a difficult time naming emotions, but was able to connect outdoor activities with joy. Children expressed happiness outdoors when they got to spend time with family or friends ("because I get to play with my mom outside"), explore or play games ("I enjoy nature because nature is so fun to play in") and observe wildlife ("I enjoy being in nature… seeing all the plants and trees and birds"). One child also shared the feeling of peace when outdoors, reflecting "what I enjoy most is the sun on my face and the wind going through my hair, and I think it feels really nice," hinting toward a deep, personal connection with nature. In contrast, a few children voiced other feelings besides positive ones, such as discomfort and fear. Child 5 said they felt happy when outside "unless it's really, really hot" and child 7 thought the outdoors was not fun "when it's like freezing cold outside." These replies indicated that ecoEXPLORE users enjoyed being in nature as long as their needs are met.

Beauty. The beauty pathway gauges whether an individual finds the natural world aesthetically pleasing (Lumber et al., 2017; Richardson et al., 2019). Interview questions regarding this pathway included "do you think nature is beautiful?" and "are all things in nature beautiful?" All eight interview participants agreed that nature was beautiful, with one individual using the word "nice" to describe it. Children named animals, flowers, plants, and "pretty stuff" as beautiful parts of nature. One user even mentioned "the sky at like the sunset." For those who answered with animals, I asked whether they thought snakes, spiders, and other frequently "scary" animals could be beautiful. Two of these participants expressed appreciation but not beauty for these animals ("I actually love spiders, I know it's just crazy

to some people, but I love spiders" and "I like spiders because they catch flies and I don't like flies. But yeah the only creature of nature I don't like is snakes"). A second question, which asked whether everything in nature was beautiful, was posed to the participants, and about a quarter of the users disagreed. For example, some individuals thought certain parts of nature could be scary or "ugly," like the animals listed above. I asked the same child who used the word "nice" this follow-up question, and he said, "I'm not really sure, I never really think about nature as beautiful, I just think about it as what it is…" These question responses suggested that most of the ecoEXPLORE users could identify parts of nature as beautiful, especially those stereotypically associated with beauty in American culture, but may not have the words to describe the complexities of nature that are not traditionally beautiful.

Contact. The contact pathway assesses one's experience with nature and the frequency of interactions, which can strengthen CTN (Lumber et al., 2017; Richardson et al., 2019). The correlated interview questions were "do you spend more time outdoors now that you've joined ecoEXPLORE?" and "do you think you are seeing more 'nature' or less through ecoEXPLORE?" All participants shared that they spent a large amount of time outside, some stating every day, before joining the ecoEXPLORE program. Despite this, all participants voiced an increase in time outdoors and what species they saw because of the program. When asked whether ecoEXPLORE helped them get outside more, participants said they went on more walks ("Well most times we play outside. But mommy takes me on walks and to the lake to take pictures") and visited more natural areas ("while we're at the park, we look for stuff to take pictures of"). Participants also voiced a need to spend time outside so they could find specific species for their ecoEXPLORE badges ("probably more, because some days, it's just like okay… let's go out and look for the stuff for observations so we can get our badge. And we probably wouldn't do that if we weren't"). The Ichthyology badge, which focused on fish species, was a recent badge that required children to find or catch fish

in nearby bodies of water for observations, and though it was challenging, three participants claimed it as their favorite badge ("I liked how we had to go fishing and I've only caught a minnow when I went fishing with my grandpa, but um I actually did caught a fish"). This increased time in nature and exposure to one's environment also helped users see and learn more about native flora and fauna. Child 7 shared ecoEXPLORE helped when outside because "then I can actually understand what I am looking at. I mean I can understand like that's a bird, this is grass, but there's more to it than 'this is this'." Through ecoEXPLORE, these participants increased their interactions with nature, developed a richer understanding of the natural world, and observed more of the biodiversity around them.

Meaning. The meaning pathway explores nature as a concept (Lumber et al., 2017; Richardson et al., 2019). To understand the importance of nature to the participants, we first had to learn what the word "nature" meant to them. The interview questions related to this pathway were, "what do you think the word nature means to you?" and "do you think nature is important and why?" All eight of the participants described nature with words like "wildlife," "plants," and "outside." Some of these responses were "plants and animals and birds," "everything around us wherever we go," and "animals and the pretty stuff that God made." I then asked participants whether nature could be inside, and only a few children agreed ("Uh yes, because you can have pets" and "I guess our food, our food could be nature"). Most users believed that nature had to be outside and did not include their physical house or manmade products. Child 7 said nature was "the space around us and pretty much outdoors… where we are not in bricks," and child 6 stated a similar belief that nature was "not a house and not a patio… just basically our backyard." These thoughts indicate a possible disconnect between participants and where most of their household items originated from, i.e., nature. When I asked ecoEXPLORE users whether nature was important, all participants agreed and primarily expressed its importance to living creatures ("food for

animals," "bees help pollinate plants," and "it helps you breathe"). Two children added that it was "important to me that we keep it safe" and "important as part of the world. We should be protecting it," suggesting a greater awareness of environmental impact. When I asked the participants why it was important to them on an individual level, most listed its benefit to human needs ("you can build houses out of wood," "so we can go outside to our backyard and play," and "nature gives us shelter, because our walls… are made out of wood"). This question also stumped three of the participants ("it's important, um, I don't really know"). The replies to this question, especially from the younger children, implied a more anthropocentric understanding of nature, weighing the practical uses as more important than other benefits, such as the aesthetics or symbolism of nature (Kellert, 1993).

Compassion. The compassion pathway is rooted in a moralistic desire to care for and respect nature (Lumber et al., 2017; Richardson et al., 2019). A strong score in compassion indicates one's ethical desire to advocate and protect the natural world. The main question that assessed this pathway was, "do you respect or care for nature?" The whole group believed they respected nature and did this by taking care of the natural world ("we can respect nature by not tearing it. If we see nature we don't even like, we should leave it how it is"), being a good steward of the environment ("I guess we don't litter, and we try not to use too much electricity" and "we pick up trash we see in nature"), and showing kindness to wildlife ("I respect nature by looking at the beautiful plants and animals. And saying hi to all the butterflies"). Three participants shared personal stories or observations of deforestation and pollution near their homes. A few users shared that ecoEXPLORE helped them care more about their environment ("I think it helps me have a better relationship with nature" and "it helps me understand what I'm looking at, so like if we've been doing something we don't know we're doing wrong, we can stop it"). We can deduct from these comments that

ecoEXPLORE users cared for their environment and were able to name various positive ways to respect nature.

Sense of Belonging. The sense of belonging pathway assesses how an individual sees themselves in nature - whether a part or separate. This pathway encompasses several of the NCI pathways (i.e., compassion and meaning) and other psychological perspectives to understand one's interconnectedness with nature (Richardson et al., 2019). The questions included in the interview specifically for this pathway were "do you feel a part of or separate from nature?" and "do you feel connected to nature?" The concept of feeling a part of nature was challenging for over half of the participants, specifically the younger users. Those who felt a part of nature had a wide range of reactions, some feeling connected in a primal, scientific manner ("we are definitely a part of nature, because… we are mammals"), while others only felt a part of nature when recreating ("if I'm outside playing… I guess like I'm a part of nature. If I'm just sitting in my house, I guess, I'm just not really sure"). Four users struggled with a definite response to this question – feeling a part of nature but not having the words to describe why. Child 5 even mentioned, "if I was part of nature, they might think of me as like a hermit or something," implying judgment or a negative association with someone who spends too much time outside. Later on, I asked whether participants felt connected to nature, and they could verbalize much more concrete replies. Children felt connected to nature when they recreated outdoors ("when we're like playing football in our backyard, or like in nature"), appreciated nature's beauty ("nature is pretty… so nature feels connected to me"), and learned or reflected on the species around them (everything needs everything else. Like the birds need the trees for their nests, and the trees need the ground"). Participants recalled times when they felt connected to nature, and in a sense, a part of nature, through the activities they enjoyed outdoors. These thoughts encapsulated the complexity and interconnectedness of this unique pathway.

Environmental Awareness. An overarching theme throughout the interviews, and thus a seventh theme, was environmental awareness. One of the goals of ecoEXPLORE is to increase science literacy, and even though interviewees came in with different backgrounds and experiences with the program, all of the participants claimed an increase in environmental awareness and knowledge since joining ecoEXPLORE. Every participant stated that ecoEXPLORE helped them see more biodiversity and learn about the species around them ("I think it helps you see… all the different kinds of things that are out in nature," "It helps me learn about nature more because it makes me be able to see stuff that we would never see before," and "I like ecoEXPLORE because I get to learn more about nature... with ecoEXPLORE, I can really go out and then I can really understand what I am looking at"). An interesting observation made by the researcher was that 75% of those interviewed recalled the scientific name of at least one species, like Green Sunfish, Pine Warbler, and Bombardier Beetle, in conversation.

ecoEXPLORE. The final interview question asked was, "why do you like ecoEXPLORE?" Over half of the participants voiced spending time outdoors to make observations as their favorite part. ("I like the observations most and seeing what you all think of the photos that I've done," "I like going out into the woods to find cool stuff to take photos of," and "I like to take pictures of the different kinds of animals"). Another main reason for enjoying ecoEXPLORE was the opportunity to earn badges ("I like the challenges and badges") and prizes ("They're all my favorite, but probably my first favorite is the prizes"). Child 5 said they like ecoEXPLORE "because it's fun. And if you get prizes it's easier to get observations, then you get more points, and get more prizes and more observations. And then it just keeps going." This final quote summarized all of the favorite parts of ecoEXPLORE and why the program appealed to these young individuals. Through these eight interviews, the researcher documented the impacts of the ecoEXPLORE program

on users and their perceptions of the natural world, confirming the program as a valuable tool in improving connection to nature among children.

Discussion

The purpose of this study was to gain a better understanding of the ecoEXPLORE program and its impacts on connection to nature. The quantitative and qualitative findings supported both hypotheses, and the ecoEXPLORE program increased connection to nature (CTN) among users. CTN improved across all demographics, regardless of gender, age, or ethnicity, among surveys, and the interview participants, who were of various ages and backgrounds, reconfirmed this. It was apparent that user age did not impact CTN among ecoEXPLORE users, with 13-year-olds improving just as much as younger ones. However, in CTN research, these high scores are not often seen among preteens, and studies suggest scores usually decline once children reach ten years old (Hughes et al., 2019). If youth are prone to low CTN once they hit adolescence, the ecoEXPLORE program may provide a resource to maintain relatively high CTN among these preteen and early teen years (Hughes et al., 2019). Another finding that contradicts previous studies in North Carolina was that participants in rural locations scored the highest on the Nature Connection Index (NCI), indicating ecoEXPLORE is a positive resource for children in more remote areas (Eppley, 2016; Schuttler et al., 2019). When looking at the composite mean for the pre-survey (M=59.97), one can see that the average user already has an established level of CTN. Although there are users who initially scored lower than 50 points, this high baseline among ecoEXPLORE users implies that children who join the program may already have a greater CTN and may even pursue the program because of this. This idea was further confirmed in the interviews when children mentioned spending a large amount of time outside before joining the program. Nevertheless, ecoEXPLORE improved CTN, even for users with a

strong CTN, and the resources and opportunities provided through the program may lead to even stronger conservation ethics and environmental activism (Hughes et al., 2019).

Incorporating the Qualitative with the Quantitative Data

When we analyzed the mean scores of the NCI items individually (Figure 2), users scored the lowest in the "I feel part of nature" item. This item correlates with the sense of belonging pathway and is a multifaceted concept describing one's interconnectedness with nature (Richardson et al., 2019). The interviews confirmed the complexity of this pathway when four out of the eight users struggled to answer questions about sense of belonging. In particular, younger users could not find the words to describe why they felt a part of nature, which may explain why the overall score is lower and more varied. Though "I feel a part of nature" was the lowest item scored, it saw the second-largest improvement among users suggesting ecoEXPLORE helped them better understand this concept and feel more connected to the natural world. The statement "spending time in nature is very important to me" is one other item worth noting, and it represented both contact and meaning. The researcher noticeably observed an increase in contact and time in nature among interview participants, but the meaning pathway challenged most users. To address this pathway, I asked participants to explain what nature meant to them and why it was important. Although users shared replies, most of the responses implied an anthropocentric understanding of nature and its practical uses. Only one or two children shared other attitudes about nature, such as aesthetics or spiritual symbolism, for why it was important to them (Kellert, 1993).

Though ecoEXPLORE is a predominantly online program, with videos, activities, and virtual programs available, interview participants shared that going outside to observe native species was their favorite part. However, these participants gained the skills, knowledge, and confidence to explore outdoors because of the resources provided through the program. By completing the activity sheets required to earn a badge, ecoEXPLORE users learned about

the natural world. Through the citizen science aspect, users observed more native species, which can increase CTN, and became aware and appreciative of the biodiversity around them (Lindemann-Matthies, 2005; Ballouard et al., 2012; Tomažič, 2008). Though virtual programs can boost student understanding and engagement, ecoEXPLORE goes one step further by still providing hands-on exploration through the design of the program (Altrudi, 2020; Chen et al., 2014). In an increasingly technological world, ecoEXPLORE provides an online program where device usage does not decrease connection to nature in children (Larson et al., 2019; Michaelson et al., 2020; Richardson et al., 2018).

Limitations & Recommendations

Several limitations arose with this study. The first constraint was the relatively small participant population (*N*=60) for the quantitative data; however, this number depended entirely on user activity during the four months of data collection. The two main badges available during this time frame were also new to the ecoEXPLORE program and may have led to fewer survey responses. Nevertheless, given the restraints of a master's program, we had limited time available and could only research over a four-month time frame. Another limitation was our interview recruitment strategy since it was entirely voluntary. Though the researcher tried to recreate the quantitative demographics on a smaller scale, matching age, ethnicity, and gender breakdown, no “urban” children volunteered, missing out on potentially useful insight. Therefore, these eight interviewees provided insight into only a fraction of the ecoEXPLORE community.

Future recommendations include a longitudinal study of the ecoEXPLORE program and CTN. A longer time frame would allow for a more substantial collection of data and the chance to see whether CTN drops off at any point. With a larger population, the research could also assess specific demographics, like BIPOC or urban children, and whether ecoEXPLORE provides an inclusive and accessible resource to reach underserved individuals

in the outdoor field. Another area of interest could be comparing CTN across other online, or possibly in-person, citizen science programs. Finally, the success of a child's experience with ecoEXPLORE relies heavily on family support. To make the ecoEXPLORE experience enjoyable, parents and guardians help transport their children to outdoor spaces, print out activity sheets, upload photos to the website, take them to programs, and much more. Since ecoEXPLORE depends on these adult figures, it may be worth measuring their CTN, interest in the outdoors and ecoEXPLORE, and family dynamics in future research.

Conclusion

This research is a first step toward understanding the impacts of an online science program, i.e., ecoEXPLORE, on participants. Though previous research suggests increased technology use resulted in low connection to nature, ecoEXPLORE increased CTN while still utilizing devices. EcoEXPLORE provided a way for all children, no matter their background, to explore the outdoors, learn about local flora and fauna, and improve their relationship with nature. This study highlights a new, innovative way of engaging children with the natural world through technology. The present research contributes to a growing body of research in environmental psychology, investigating what can influence a child's connection to nature. We hope this study will stimulate further investigation into online platforms as a means of improving connection to nature and enhancing conservation ethics among younger generations.

Tables & Figures

Table 1

The NCI items and their weighted points scale

	Response Scale Rating						
Statement	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. I always find beauty in nature	0	1	2	3	5	9	15
2. I always treat nature with respect	0	0	1	2	4	6	10
3. Being in nature makes me very happy	0	1	2	3	6	10	16
4. Spending time in nature is very important to me	0	1	2	3	6	11	19
5. I find being in nature really amazing	0	1	2	3	6	10	17
6. I feel part of nature	0	1	2	4	7	13	23

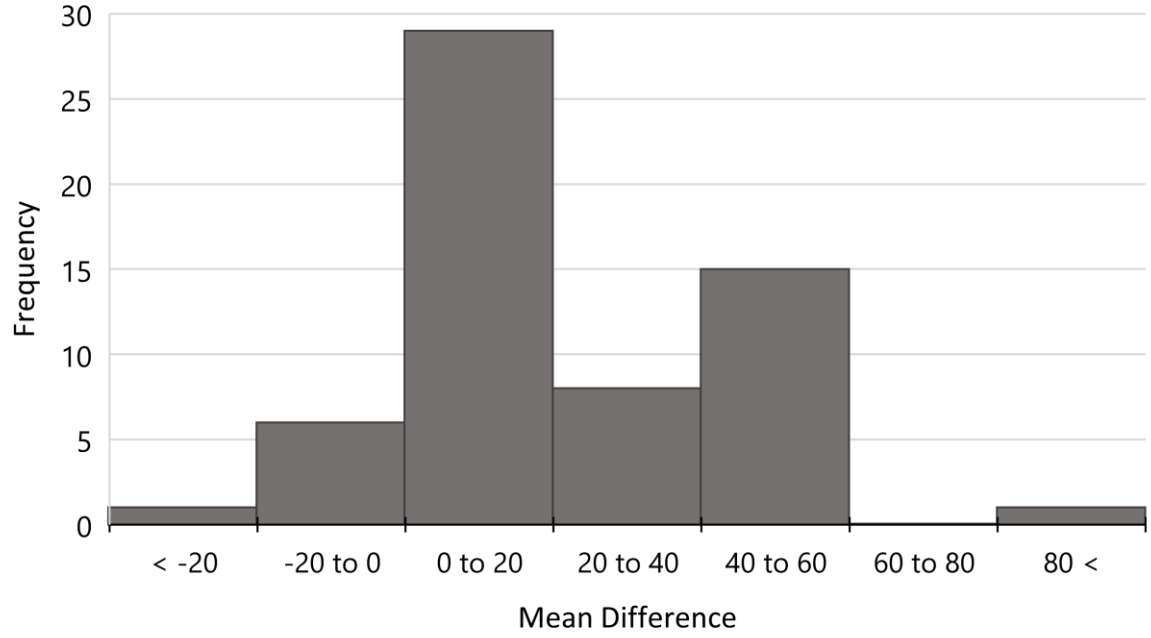
Table 2

Paired Sample T-Test for Composite Mean Score

Composite Score	Paired Differences					t	df	Significance
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				Two- Sided p-value
				Lower	Upper			
Post - Pre Survey	18.48	22.39	2.89	12.70	24.27	6.40	59	<.001

Figure 1

Frequency of Users Given Their Composite Mean Score Difference



Note. One can see in this histogram a distribution bell curve highest at the mean 18.48.

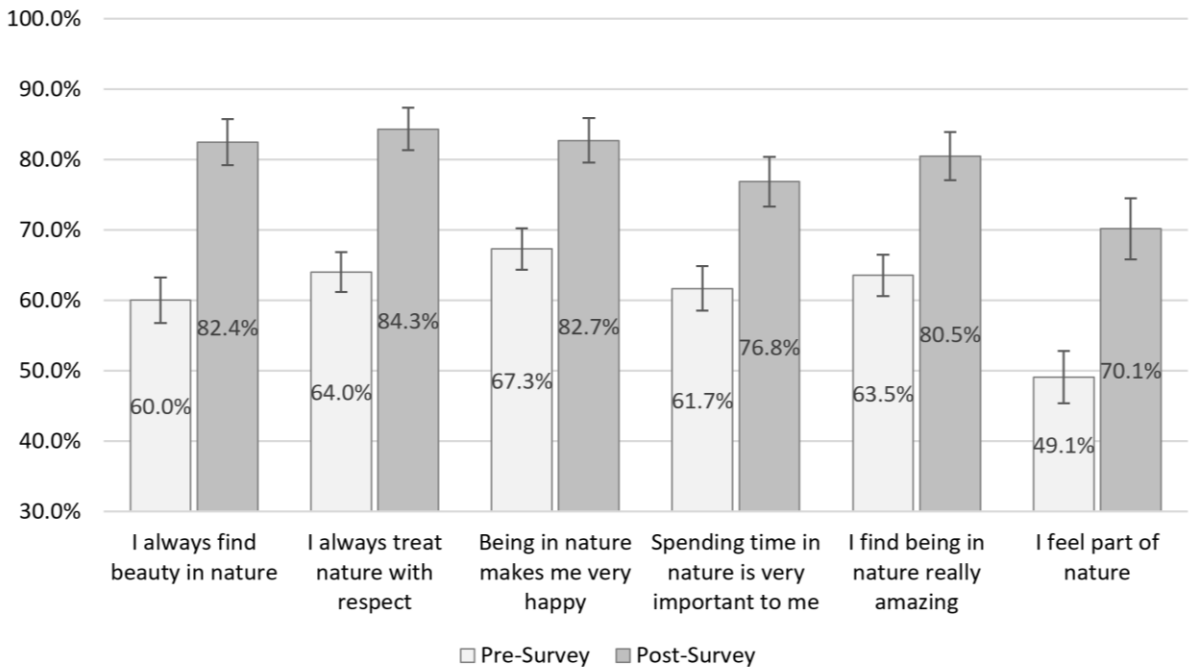
Table 3

Paired Sample T-Tests for Difference in Item Mean Score

CNI Survey Items Mean Score Difference	Paired Differences					t	df	Significance Two-Sided p-value
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
I always find beauty in nature	3.37	4.01	0.52	2.33	4.40	6.51	59	<.001
I always treat nature with respect	2.03	2.54	0.33	1.38	2.69	6.21	59	<.001
Being in nature makes me very happy	2.47	4.20	0.54	1.38	3.55	4.54	59	<.001
Spending time in nature is very important to me	2.88	5.38	0.70	1.49	4.27	4.15	59	<.001
I find being in nature really amazing	2.88	4.78	0.62	1.65	4.12	4.67	59	<.001
I feel part of nature	4.85	6.10	0.79	3.27	6.43	6.16	59	<.001

Figure 2

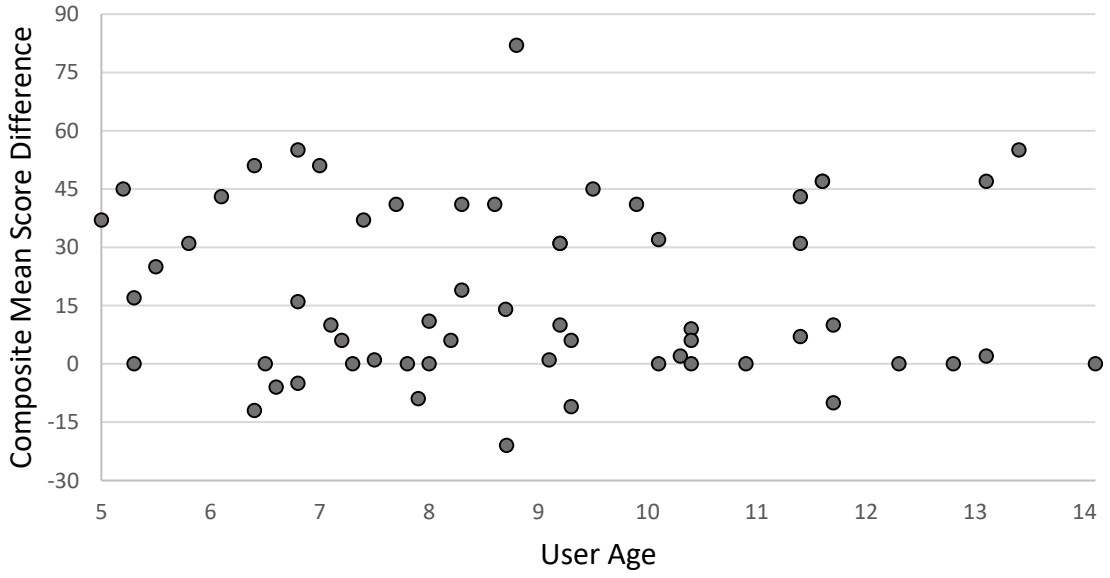
Mean Score Percentages for the Individual NCI Items



Notes. Item percentages were scored out of their maximum weighted value.

Figure 3

Scatter plot of ecoEXPLORE User Age and Composite Mean Difference



Notes. Age had no influence on increasing CTN as is seen in this heteroscedasticity.

Table 4

Independent t-Test for Ethnicity and Composite Mean Difference

t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		One-Sided p	Two-Sided p			Lower	Upper
0.03	58	0.49	0.98	0.27	8.57	-16.89	17.43

Table 5

Descriptive Statistics for Composite Mean Difference and User Locations

User Location	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Suburban	26	12.77	24.28	4.76	2.96	22.57	-21	82
Rural	24	26.00	21.51	4.39	16.92	35.08	-11	55
Urban	10	15.30	14.45	4.57	4.96	25.64	-5	37
Total	60	18.48	22.38	2.89	12.70	24.27	-21	82

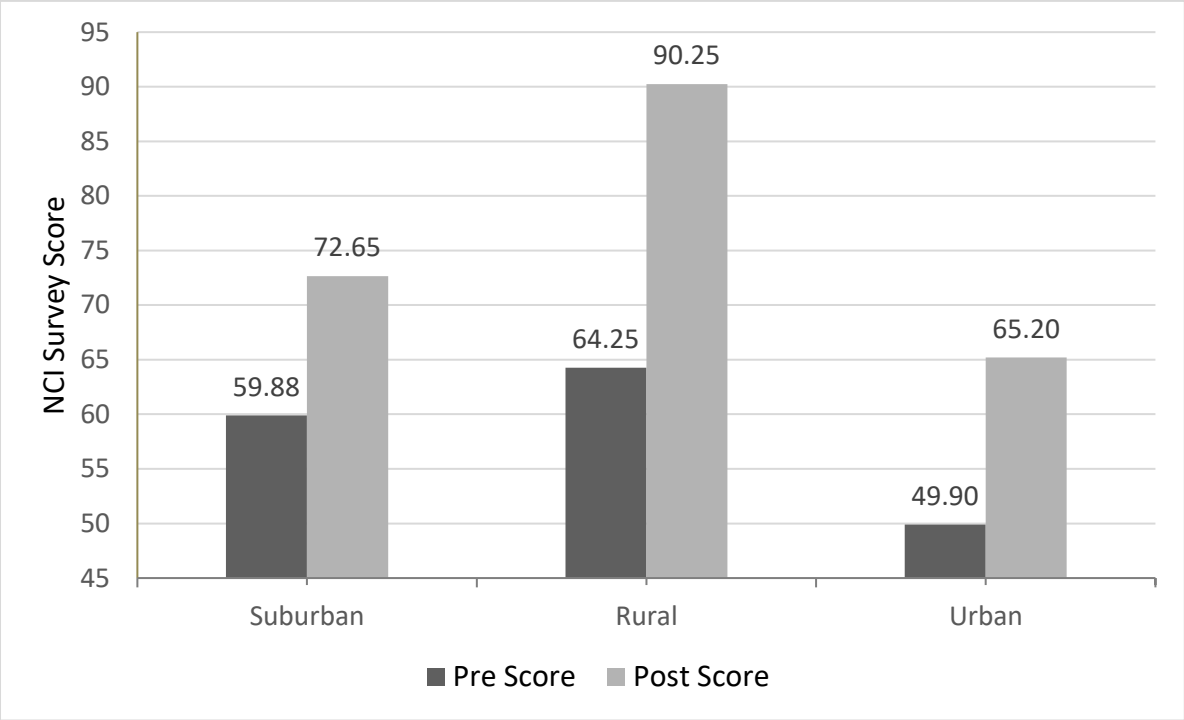
Table 6

Comparison of Composite Mean Differences among User Locations

Location (I)	Location (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Suburban	Rural	-13.23	6.19	0.09	-28.13	1.67
	Urban	-2.53	8.14	0.95	-22.11	17.05
Rural	Suburban	13.23	6.19	0.09	-1.67	28.13
	Urban	10.70	8.23	0.40	-9.11	30.51
Urban	Suburban	2.53	8.14	0.95	-17.05	22.11
	Rural	-10.70	8.23	0.40	-30.51	9.11

Figure 4

A Comparison of Pre/Post Test Scores and User Location



Note. Rural users increased the most in their NCI score and have the largest value.

End of Journal Article – the condensed reference list was omitted from this paper

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Appendix A

ecoEXPLORE User Pre/Post Survey

1. How did you hear about ecoEXPLORE: (open-ended response)

For questions 2-7, we want to know what you think. Have your parents help you if you don't know what we are asking but try to tell us what YOU think. There are no right or wrong answers. Rank: **Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), Strongly Agree (5)**

2. Tell us what you think. There are no right or wrong answers.
    a. I like science
    b. I think I am good at science
    c. I know a lot about science
    d. I learn new science topics easily
    e. I am good at using tools in science like thermometers, scales, etc.
3. Tell us what you think. There are no right or wrong answers.
    a. I know I can do well in science
    b. My friends think I am good in science
    c. My teacher sees me as someone who likes science
    d. My parents see me as someone who likes science
    e. An adult has encouraged me to study science
4. **Tell us what you think. There are no right or wrong answers.**
    a. **I always find beauty in nature**
    b. **I always treat nature with respect**
    c. **Being in nature makes me very happy**

d. Spending time in nature is very important to me

e. I find being in nature really amazing

f. I feel part of nature

5. Tell us what you think. There are no right or wrong answers.
    a. When I am older, I will need science for my job
    b. I would like to have a job that uses science
    c. After I finish high school, I will use science often
6. Think about the last week. How much time did you spend outside on a typical weekday or weekend day? Rank from 0 hours to 5+ hours.
    a. On a weekday (Monday – Friday)
        i. 0 hours, < 1 hour, 1 – 2 hours, 3 -4 hours, 5 hours or more
    b. On a weekend day (Saturday or Sunday)
        i. 0 hours, < 1 hour, 1 – 2 hours, 3 -4 hours, 5 hours or more
7. How often do you do the following activities in a year?

    Rank: Once a week, Once a Month, A Few Times a Year, Once a Year, or Never
    a. Go camping
    b. Go fishing
    c. Go hunting
    d. Go on a picnic
    e. Go to the park
    f. Look for plants and animals outside
    g. Play outside (sports)
    h. Play outside (not sports)

For questions, 8-12 you may want to work together with your parent or guardians. There are no right or wrong answers. We are interested in your ideas. (open-ended response)

8. What language do you speak?
9. Birthdate?
10. How would you describe yourself?
    a. Boy, girl, prefer not to say, self-describe
11. How would you describe yourself?
    a. American Indian, African America, Caucasian, Latinx, etc.
12. What is your zip code?
13. Which best describes the area where you live?
    a. Urban, rural, suburban

Appendix B

Nature Connection Index (6 item scale) (Richardson et al., 2019)

Please score your responses on a 7-point scale, from 1 being "completely disagree," 4 being "neutral," and 7 being "completely agree." (on the survey, these are seven separate boxes that a user would check off for each question)

1. I always find beauty in nature.
2. I always treat nature with respect.
3. Being in nature makes me very happy.
4. Spending time in nature is very important to me.
5. I find being in nature amazing.
6. I feel part of nature.

Appendix C

Interview Questions

Introduction:

- What is your name? And how old are you?
- What is your favorite animal?

ecoEXPLORE Questions:

- When did you join ecoEXPLORE?
- Do you have a favorite observation or badge you've earned?
- What is your favorite thing about ecoEXPLORE?

NCI Questions:

- In your own words, what does nature mean to you?
- "How do you spend your time outside? What do you like to do?"
- Do you feel a part or separate from nature? How?
- How does spending time outside impact you? Does it make you feel happy, sad, mad?
- Do you think nature is something that is beautiful?
- Is nature important? Why is it important to you?
- Do you think you respect or care for nature? How?
- What does connection to nature mean to you? Do you feel connected to nature?

ecoEXPLORE & CTN:

- Does ecoEXPLORE help you connect with nature? What parts of ecoEXPLORE
- Do you spend more time outside now compared to before you joined ecoEXPLORE?
- Does ecoEXPLORE helps you care or learn more about nature more? How?
- Why do you still do ecoEXPLORE? What motivates you?