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Supporting Developmentally Responsive Design in Children's Technologies

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Abstract

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Today's technologies are rapidly impacting how children learn, play, communicate, and interact with others. Popular media and common wisdom often portray children's technology use as detrimental to their growth and wellbeing. However, in recent years, a wealth of research in Child-Computer Interaction (CCI), education, and health informatics suggests that well-designed interactive application use can result in developmental and learning benefits for children. In this dissertation, I examine how to create developmentally responsive designs for children's technology, with two main investigations: (1) incorporating child development theory to distill design principles for mobile technologies that can facilitate children's interest development in a topic; and (2) bridging the CCI research and practice gap by providing designers access to an

actionable evidence-based designer's toolkit. I explore how designers can promote children's interest-driven learning—a core component of child development—through the design of mobile applications. Drawing from interest-development theory to distill the Interest-Centered Design (ICD) framework to design developmentally responsive technologies, I report on several co-design sessions with children that supported ICD strategies and the design of *NatureCollections*, a mobile app that facilitates children's interest in their natural surroundings. I also report on a series of observational and app deployment field studies during which I evaluated multiple dimensions of the *NatureCollections* app and by extension the ICD framework in supporting children's interest-driven learning and pro-environmental behavior change. Additionally, I examine families' experiences with the *NatureCollections* app and explore parent-child tech-related tensions during a transitional phase of child development. Although the *NatureCollections* app designs support the underpinning characteristics of interest development in children, encouraging children to spend more time in and learn about nature, and families valued their shared experiences around nature, families' app experiences were influenced by tweens' transitional period of parent-child relationships.

I also survey CCI research that supports the developmental needs of children, which served as the foundation for the content presented in the Interaction Design and Children (IDC) designer's toolkit. Through co-design workshops with children's technology designers to evaluate the toolkit, I discuss current practices and needs, new barriers to using CCI research, and design considerations for the toolkit. For example, designers desire the research to discuss how the design choices supported children's developmental goals and include how to generalize the actionable design strategies beyond the system presented. The contributions of this work are

threefold: (1) Theoretical– a theory-based Interest-Centered Design (ICD) framework for mobile technologies to promote children’s interest development in a topic, along with a generative theory expanding the Joint Media Engagement (JME) framework in a new context of nature-based exploration. (2) Artifact design– the NatureCollections App and the IDC Designer’s Toolkit, that facilitate new explorations, draw new insights, and imbue new possible futures. And (3) Empirical understanding– how the NatureCollections app designs, and by extension the ICD framework, support children’s interest development, family shared experiences around nature, and parent-child tech related tensions during tweens’ transitional period of development. An additional contribution is a generative empirical understanding of the child-computer interaction research-practice gap.

TABLE OF CONTENTS

Chapter 1.	Introduction	1
1.1	Thesis Statement and Research Questions	4
1.2	Contributions	7
1.3	Dissertation Overview	9
Chapter 2.	Background and Related Work.....	14
2.1	Child Development and Developmentally Responsive Designs.....	15
2.1.1	Cognitive Developmental Theory.....	16
2.1.2	Social Cognitive and Learning Theories.....	18
2.1.3	Positive Technological Development Theory.....	19
2.1.4	Developmentally Responsive Designs.....	20
2.2	Child Computer Interaction and Child Development	21
2.2.1	Child Development and Technology Use	22
2.2.2	Children’s Applications in the Marketplace	23
2.2.3	Family Joint Media Engagement	24
2.2.4	Technology-Related Tensions between Parents and Children.....	26
2.3	A Theoretical Model of Interest Development	27
2.3.1	The Connection Between Interest and Child Development.....	28
2.3.2	Children’s Connection to Nature	29
2.3.3	Designing Mobile Technologies for Nature Exploration.....	33
2.4	Child-Computer Research-Practice Gap	36
2.4.1	HCI Translational Research.....	37
2.4.2	Research-Based Design Tools	38

2.5	Summary of Related Work.....	40
Chapter 3.	Interest-Centered Design Framework.....	43
3.1	Background and Motivation.....	44
3.2	Design Framework to support interest development.....	47
3.2.1	Interest-Centered Design Principles	48
3.3	Co-Designing a Nature App with Child Designers.....	50
3.3.1	Participants and Context for Co-Design	50
3.3.2	Data Collection and Analysis.....	51
3.4	Interest-Centered Design Strategies	52
3.5	Applying the Interest-Centered Design Framework to the NatureCollections Application	56
3.6	Discussion	59
3.6.1	Summary of Contributions.....	61
Chapter 4.	Observational Studies of NatureCollections App.....	62
4.1	Exploratory In Situ Case study with Child-Parent Dyads.....	64
4.1.1	Method	64
4.1.2	Results.....	66
4.1.3	Discussion	72
4.2	Observational Study with a Comparison Group	75
4.2.1	Method.....	75
4.2.2	Results.....	80
4.2.2.1	NatureCollections App Group.....	80
4.2.3	Discussion.....	90
4.3	Summary of Contributions	94

Chapter 5.	NatureCollections App Field Deployment Study	96
5.1	NatureCollections and Children’s Time in Nature.....	98
5.1.1	The Three-Week Experimental Study Design and Method.....	98
5.1.2	Results.....	105
5.1.3	Discussion.....	112
5.2	Nature-Based Explorations for Families	115
5.2.1	Method.....	116
5.2.2	Results.....	119
5.2.3	Discussion And Design Implications.....	132
5.3	Summary of Contributions.....	138
Chapter 6.	Translating Child-Computer Interaction Research.....	139
6.1	Method and Analysis.....	140
6.1.1	Review and Coding Process.....	141
6.1.2	Author Survey.....	143
6.2	Children’s Supported Developmental Qualities And Behaviors In IDC Research.....	144
6.2.1	Social Interaction & Connectedness	144
6.2.2	Learning.....	144
6.2.3	Expression.....	146
6.2.4	Play	146
6.2.5	Personal growth	146
6.2.6	Health and well-being.....	146
6.2.7	Emerging Categories of Supported Behaviors and Developmental Qualities	147
6.3	Results	148
6.3.1	IDC Research Contributions.....	148

6.3.2	The role of the child and other stakeholders in the design process	150
6.3.3	Theories, models and framework that inform IDC research.....	152
6.3.4	Criteria that inform the design choices	154
6.3.5	How has IDC research seized on the opportunities presented in Yarosh’s paper?.....	157
6.4	Author Survey Results	159
6.4.1	Values Informing Author’s IDC Work	159
6.4.2	What Motivated IDC Researchers to Conduct Their Work.....	160
6.4.3	Intended Research Impact on the World.....	161
6.4.4	Ethical Considerations of IDC Researchers.....	161
6.5	Conclusion and Future Work	162
6.6	Summary Of Contributions	163
Chapter 7.	Interaction Design & Children Designer’s Toolkit	165
7.1	IDC Toolkit Design.....	166
7.1.1	Developing the Toolkit Content.....	168
7.1.2	Toolkit Design	170
7.2	Toolkit Evaluation Workshops.....	170
7.2.1	Participants.....	171
7.2.2	Procedure	171
7.2.3	Analysis.....	174
7.3	Results	174
7.3.1	Using Academic Research in Industry.....	174
7.3.2	Toolkit Design Feedback	180
7.4	Discussion	186
7.4.1	Toolkit Redesign.....	186

7.4.2	Implications for IDC Authors and Future Directions	189
7.5	Summary of Contributions	193
Chapter 8.	Discussion and Conclusion.....	195
8.1	Incorporating Theory into Design	196
8.1.1	Developmental Responsive Design	196
8.1.2	Challenges to Distilling Theory-Driven Design Considerations	197
8.2	Toolkit Beyond the Design Process	200
8.2.1	Toolkit for Educational Courses	200
8.2.2	Toolkit to Guide the Assessment of the Development Responsiveness of Existing Children’s Application.....	201
8.3	Contributions	202
8.4	Future Work	204
8.5	Conclusion.....	206
References.....		209
Appendix A: NatureCollection App Design Specifications		228
Appendix B: IDC Designer’s Toolkit Design		229

LIST OF FIGURES

Figure 3.1: Screens of the NatureCollections app 1: Onboarding “What are your interests?” 2: My Collections. 3: Photo Classification. 4: Challenges. 5: Challenges details and progress	57
Figure 4.1: A tactile interaction with a plant while using NatureCollections app.....	66
Figure 4.2: Primary focus of photos taken by children while using NatureCollections, coded as either other people (n = 12), selfies (n = 0), nature (n = 200), or ambiguous (n = 5).....	66
Figure 4.3: a. Student taking a close-up shot of a flower b. One student pointing a nature element to her peers c. Students walking and scanning their surroundings.....	75
Figure 4.4: The relationship between individual dimensions of situational interest, examples of specific NatureCollections app features, and themes from our data analysis.	67
Figure 5.1: Average minutes spent outside per day for NC and Photo groups during pre and post app use	106
Figure 6.1: The percentage of papers that involved studies or systems intended for children of each age (when an age range is given, each year in the range is counted).	158
Figure 7.1: IDC online designer’s toolkit.....	167
Figure 7.2: Card detail and stepped translational research guide	169
Figure 7.3: IDC Toolkit re-design (a) homepage (b) “card” overview detail (c)research request form ...	188
Figure 7.4: Example of a card detail page	192

LIST OF TABLES

Table 1-1. Research Questions	7
Table 3-1. Design principles and strategies to guide the design of mobile technologies that support interest development.....	47
Table 4-1. Demographic characteristics of participants, who shared their data (n = 49, across all classrooms).....	76
Table 4-2 App Class Assignment	77
Table 5-1. Demographic characteristics of participants	99
Table 5-2. Group start dates.....	101
Table 5-3. Demographic characteristics of families and their children.....	117
Table 6-12. Codes addressing developmental qualities IDC aspires to support in children, the percent of papers that were tagged with this code, and trends over time.....	145
Table 6-3. Codes addressing primary contributions, the percent of papers that were tagged with this code, and trends over time.....	148
Table 6-4. Codes addressing for whom IDC designs, the percent of papers that were tagged with this code, and trends over time.....	150
Table 6-5. Codes addressing theories and models, the percent of papers that were tagged with this code, and trends over time.....	153
Table 6-6. Codes addressing values in the technical design, the percent of papers that were tagged with this code, and trends over time.....	155
Table 6-7. Opportunities for IDC proposed in the IDC 2011 paper, the percent of papers that were tagged with this code, and trend over time.....	159

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DEDICATION

I dedicate this work to the memory of my mother, Khadijeh Qteishat.

CHAPTER 1. INTRODUCTION

Children are avid adopters and users of technology. Today's technologies are rapidly impacting the way children learn, play, communicate, and interact with others (Kawas, Yuan, et al. 2020; Read and Markopoulos 2013; Yarosh et al. 2011). In the popular press, technology is often portrayed as detrimental to children's growth and wellbeing (Lanette et al. 2018). However, in recent years, there has been a wealth of research evidence suggesting that interactive app use can have developmental and learning benefits for children (Griffith et al. 2020; Hirsh-Pasek et al. 2015; Papadakis, Kalogiannakis, and Zaranis 2018). Using theoretically driven design considerations to account for children's developmental needs when designing technologies for them can lead to better products and services that benefit children's mental, physical, and emotional growth, helping them realize their full potential and live creative, fulfilled, and connected lives (Bers 2012; Hirsh-Pasek et al. 2015; Papadakis and Kalogiannakis 2017; Yarosh et al. 2011). Child developmental theories provide an explanatory lens as to whether children's behaviors are related to their developmental stage, age, family relationships, or cultural and social factors (Charlesworth 2016; McDevitt 2013). Children's applications that are age-appropriate and developmentally responsive meet the following key conditions they (1) take into consideration the developmental stage of the child when formulating content and activities, (2) support children's positive developmental-related tech-mediated behaviors, (3) employ an interaction design that is appropriate to the child's cognitive and motor skills, and (4) consider the situated social contexts of the indented technology use (Bers 2012; Hirsh-Pasek et al. 2015; Papadakis and Kalogiannakis 2017).

Despite the evidence-based benefits of research apps, the most readily available children's apps in the app store do not incorporate child development, education, or literacy knowledge (Papadakis et al. 2018; Vaala, Ly, and Levine 2015). Moreover, there's a significant gap between children's touchscreen interface designs as implemented in market apps and their developmental appropriateness for the intended children's ages (Hiniker et al. 2015; Soni et al. 2019). My dissertation research explores how designers might incorporate foundational child development theories and research-evidence insights to meet children's growth and learning needs when designing children's applications.

Designers of children's technologies rarely account for children's cognitive, physical, social, and emotional needs when designing applications to support their developmental growth (Bruckman, Bandlow, and Forte 2009; Chiong and Shuler 2010; Lanna and Oró 2016; Papadakis and Kalogiannakis 2017; Papadakis et al. 2018; Vaala et al. 2015; Verenikina and Kervin 2011). The majority of the apps in the marketplace are entertainment-oriented and lack explicit consideration of how children learn (Hirsh-Pasek et al. 2015; Papadakis et al. 2018). Self-proclaimed educational app designs simply reproduce entertainment games and puzzles in a digital format focused on multimedia content with animated cartoons and music without harnessing the unique affordances of smart devices to support children's learning (Hirsh-Pasek et al. 2015). The popularity of smart devices among children is due to the technological features of these devices, such as the large screen displays with high resolution, ergonomic and lightweight design, and the short start-up time with visual content viewing (Papadakis and Kalogiannakis 2017).

Designers of children's technologies often rely on design principles used for adult interfaces that fail to account for the cognitive and physical abilities of children (Druin 1996; Hiniker et al. 2015; Soni et al. 2019). Despite the fact that the market is saturated with "educational" applications for children, the majority have not been validated and tested (Guernsey 2014; Papadakis and Kalogiannakis 2017; Papadakis et al. 2018; Vaala et al. 2015). Additionally, children's technology designers are seldom educated in key developmental needs or trained in child-centered methods to include children in the product design cycle (Kaur, Kalid, and Sugathan 2019). Moreover, industry designers working on children's technologies rarely use academic research findings due to barriers to accessing and implementing said academic research (Colusso et al. 2017; Geldof and Vandermeulen 2007). Academic research to design applications that are appropriate for children's developmental needs is often difficult to find, scattered across different disciplines, and offers fragmented suggestions (Buie, Hooper, and Houssian 2013; Colusso et al. 2017; Sas et al. 2014). Currently, designers do not have access to a guide to create and evaluate children's educational applications (Hirsh-Pasek et al. 2015). Though prior work has looked at ways to bridge this research-practice gap in Human-Computer Interaction (HCI) (Bansal et al. 2012; Buie et al. 2013; Colusso et al. 2017; Hörig, Marincola, and Marincola 2005; Sas et al. 2014), little work has been done to examine the needs of designers working on children's technologies.

In my dissertation, I describe how my research begins to address these gaps in knowledge and explore ways to support designers in the creation of developmentally responsive technologies for children. My dissertation work is focused on two main investigations; (1) incorporating foundational child development theory to distill design principles for mobile technologies to

facilitate children's interest development in a topic, and (2) bridging the CCI research and practice gap by providing designers access to actionable evidence-based designer's toolkit.

1.1 THESIS STATEMENT AND RESEARCH QUESTIONS

This dissertation work demonstrates the following thesis statements:

T1: Incorporating child development theories into a design framework can enhance the developmental responsiveness of the resulting designs.

T2: Providing designers access to theory-based design frameworks and actionable research-based design recommendations can promote the design of developmentally responsive technologies for children.

By investigating (1) the process of incorporating theory into applicable design recommendations to facilitate the responsiveness of design to aid in child development, and (2) the implications for research translation practices to guide CCI authors to make child-specific interaction design research, I argue we can provide accessible evidence-based children's research to support children's developmental growth and, at the same time, fit within designers' current practices and industry demands.

More specifically, this dissertation aims to answer the following research questions:

RQ 1: How can designers promote children's interest development with mobile technologies?

RQ1.1 What are the primary design considerations required to promote children's interest-driven exploration, particularly of their natural surroundings?

RQ1.2 How, and to what extent, do the interest-centered design principles and strategies embodied in the NatureCollections app trigger children's interest in nature?

RQ1.3 Does the NatureCollections app succeed at getting children to spend more time outside? And does the app impact their connectedness to nature?

RQ1.4 What are the design implications for supporting tween children's technology use through a transitional period of parent-child relationships?

RQ 2: What are the research contributions, values, and developmental needs the CCI community aims to support when advocating for developmental responsive designs for children?

RQ 3: What are industry practitioners' practices, barriers, and needs related to using academic research in their design work for children's products?

RQ 4: What are the design considerations for a designer's toolkit that can best support designers in accessing and applying child-computer interaction research to their design work?

To support **T1**, I examine research questions RQ1 and RQ2. RQ1 explores the process of drawing from child interest-development theory into a design framework for technologies. Interest is a key developmental and psychological state of engagement, experienced in the moment, and a predisposition to engage repeatedly with particular topics, events, or ideas over time (Hidi and Renninger 2006). Interest is central to learning—a core component of child development (McDevitt 2013) and plays a critical role in motivation for behavioral change (Azevedo 2013). I examine theory-based design considerations to promote children's interest-

driven exploration of their natural surroundings. Connection to nature in adulthood relies on repeated direct nature interactions and positive experiences during childhood (Louv 2008). Research questions RQ1.1–RQ1.4 evaluate the embodiments of the interest-centered design framework into the design of children’s mobile applications to encourage children to spend more time outdoors, promote their interest and learn about nature, and draw additional design recommendations for tweens’ technology use during a transitional period of parent-child relationships. To address the border applicability of T1, RQ2 examines children’s developmental qualities, the role of the child in the design process, and the theories and models that guided the design choices of children technologies in the full papers published at the Interaction Design and Children (IDC) conference.

To support **T2**, I investigate research questions RQ3–RQ4, in which I uncover additional barriers for children’s technology designers to use academic research insights. For example, designers find CCI research to miss critical details of the system design and interactions. They desired for the research papers to describe how children used the design features, discuss children’s developmental implications of the design choices, and provide generalizable design recommendations beyond the system presented. To this end, I also design and evaluate a toolkit intended to bridge the theory and practice gap in child-computer interaction by providing designers actionable research-based design recommendations to promote the design of developmentally responsive technologies for children. Table 1 shows how each study I conducted addresses my research questions.

Table 1-1. Research Questions

		Co-design Study	Observation Studies	3-Week App Deployment Study	Examining IDC published research	Co-evaluation of the Designers' Toolkit
	Interest-Centered Design Framework NatureCollections App					
T1	RQ 1: How can designers promote children's interest-development with technologies?	X	X	X		
	<i>RQ1.1:</i> What are the primary design considerations required to promote children's interest-driven exploration, particularly of their natural surroundings?	X	X			
	<i>RQ1.2:</i> How, and to what extent, do the interest-centered design principles and strategies embodied in the NatureCollections app trigger children's interest in nature?		X			
	<i>RQ1.3:</i> Does the NatureCollections app succeed at getting children to spend more time outside? And does the app impact their connectedness to nature?			X		
	<i>RQ1.4:</i> What are the design implications for supporting tween children's technology use through a transitional period of parent-child relationships?			X		
	Examining CCI published research					
	RQ 2: What are the research contributions, values, and developmental needs the CCI community aims to support when advocating for developmental responsive designs for children?				X	
	Interaction Design and Children Designer's Toolkit					
T2	RQ 3: What are industry designers' practices, barriers, and needs related to using academic research in their design work for children's products?					X
	RQ 4: What are the design considerations for a designer's toolkit that can best support designers in accessing and applying child-computer interaction research to their design work?					X

1.2 CONTRIBUTIONS

My dissertation presents three main types of contributions— theoretical, artifact, and empirical.

These specific contributions are as follows:

1. A theory-based Interest-Centered Design framework for mobile technologies to promote children's interest development in a topic.
2. Generative theory that expands the Joint Media Engagement (JME) framework in a new context of nature-based explorations.
3. A design artifact that facilitates new explorations, draws new insights, and imbues new possible futures (Wobbrock and Kientz 2016). The NatureCollections app features embody interest-centered design strategies and show how mobile technologies can facilitate children's interest development in their natural surroundings.
4. Another design artifact contribution from this work is the Interaction Design and Children Designer's Toolkit, the purpose of the designer's research-based toolkit is to enable generative design-driven activities to help us understand the needs of designers who work on children's technologies.
5. A generative, empirical understanding from several observational and field deployment studies of how the NatureCollections app features support the underpinning characteristics of interest development in children, encouraging children to spend more time and learn about nature. Additionally, families valued their shared experiences around nature, however, NatureCollections app experiences were influenced by tweens' transitional period of parent-child relationships.
6. And lastly, an empirical understanding of the current state of the child-computer interaction research-practice gap and an evaluation of the research-based designer's toolkit. Children technology designers find CCI research papers to miss critical details such as a full description of the system design and how children interacted with it. Additionally, designers

desired the research to discuss how the design choices supported children's developmental goals and include how to generalize the actionable design strategies beyond the system presented.

1.3 DISSERTATION OVERVIEW

My dissertation is presented in eight chapters.

In **Chapter 2, Theoretical Foundations & Related Work**, I discuss the theoretical underpinnings of my dissertation and summarize related literature. I review related work in child development, children's technology use, and child-computer interaction. This literature describes foundational child development theories, their role in fostering children's positive technological experiences, and their relation to developmentally responsive designs for children. Furthermore, it covers empirical investigations concerning the Joint Media Engagement (JME) framework and child technologies, along with design needs for practitioners. I describe the theoretical model of interest development in children that drives the first investigation in this dissertation (T1). I report on prior research about interactive technologies in outdoor settings and environmental psychologists' perspectives on the importance of repeated positive experiences in nature during childhood to foster a sense of connection to nature. Lastly, I discuss related work that informs the dissertation's second investigation (T2), the Child-Computer Interaction (CCI) research-practice gap, challenges of research translation, and tools used in design practices.

Chapter 3, Interest-Centered Design Framework, details the formative research to incorporate child interest development theories to distill design principles and strategies to design developmentally responsive technologies (T1). I explore how designers can promote children's

interest development in a topic through a mobile application design (*RQ1*). I derived the four key design principles of the framework from Hidi and Renninger's interest development model: (1) personal relevance, (2) focused attention, (3) social interactions, and (4) opportunities for continued engagement. I then report on several co-design sessions with children that supported the interest-centered design strategies and the NatureCollections (NC) app features (*RQ1.1*). I describe the process of designing the NC app, a mobile application that connects children with their natural surroundings and promotes their interest in nature.

Chapter 4, NatureCollections Observation Studies, presents two observational *in site* studies: (1) a case study with 18 child-parent dyads; and (2) an observational study with a comparison group at a local school with 57 sixth graders. These studies provide empirical data to evaluate T1 by examining how and to what extent the NatureCollections app design and, by extension, the interest-centered design framework promote children's interest in their natural surroundings (*RQ1.2*). Both studies showed that the NC app features succeeded in drawing children's attention to their natural surroundings and engaged in tactile interactions with natural elements, like feeling shells and sand texture and holding branches and leaves to learn about them. Children showed excitement while using the NC app and engaged in nature-themed conversations with peers and parents. These findings demonstrate that the NC app design fostered the underpinning characteristics of situational interest development and supported interest-driven learning in children—a core component of healthy child development.

Chapter 5, NatureCollections App Deployment, describes the three-week experiment deployment field study of the NatureCollections app with children and their parents. This study

focuses on whether the app succeeds at encouraging children to go outside and providing opportunities for continued engagement and connection to nature over a long period of time (*R.Q1.3*). Study results showed that the NatureCollections app significantly increased children's time outdoors compared to the Photo app. Children in both groups said they felt happy and excited about spending time in nature. Furthermore, children in the NatureCollections group reported that time spent outside with the app increased their curiosity about the types of species and plants they saw and photographed and even sought to look up information online about the plants and animals they observed. In contrast, children in the basic Photo app group did not display this level of curiosity about what they saw in nature, and the photos they took were driven largely by the aesthetic qualities of natural elements. These findings suggest that NatureCollections promotes positive development-related behaviors and supports children's interest and connectedness to nature.

Here, I consider the dynamics of parent-child interactions during NatureCollections app use—as a critical component to foster positive technological development in children, by investigating joint family NatureCollections app experiences during nature-based explorations within the broader context of parent-child tech-related tensions (*R.Q1.4*). Not only does this study contribute to design guidelines for joint family nature-based explorations, but it also points to recommendations for designers to consider in the context of parent-tween screen time tension. Findings from chapters 4 and 5 support T1 by helping to answer RQ 1.2–RQ1.4 and providing empirical evidence that incorporating child development theories into the design of children's technologies can enhance the developmental responsiveness of the designs and support children's interest-driven learning positive development-related behaviors.

Chapter 6, Translating Child Computer Interaction Research, presents a foundational study to synthesize evidence-based research and summarize actionable design recommendations for the Interaction Design and children designer's toolkit described in detail in Chapter 7, In support of T2. In this chapter, I report on the results from examining the published Interaction Design and Children (IDC) research papers' value contributions and the key developmental behaviors and qualities the research aimed to support in the past two decades. The study analysis showed that CCI researchers continue to support children's development, learning, and creative growth, and increasingly value play and children's health and wellbeing. Researchers are committed to employing and innovating methods to include children in the design process. In recent years, published research has increasingly leveraged children's development theories and models, and researchers are more likely to build systems in service of research questions rather than to capitalize on technical novelty. By extension, these findings support T1 by answering RQ2.

Chapter 7, Interaction Design & Children Designer's Toolkit, investigates designers' practices, barriers, and needs related to using academic research in their design work for children's products (RQ3). Here I describe the design, development, and evaluation of a research-based online toolkit presented in a developmentally appropriate format for children's technology (RQ4). The toolkit aims to bridge the research-practice gap in child-computer interaction and design research by providing industry designers and user experience (UX) practitioners access to evidence-based, synthesized, and actionable design recommendations. I present the design of the toolkit and the co-design workshops with children's technology

designers and UX practitioners to evaluate the toolkit. Study results reveal current practices and needs, new barriers to using CCI research, and design consideration for the toolkit.

Designers report consulting the academic research at the beginning of the product lifecycle, particularly to advocate for children's views and developmental needs in their design work. Similar to prior research, designers found many of the research terms and language used in research papers confusing, additionally, designers pointed out critical missing information such as a detailed description of the system features and design and a description of how children interacted with the designed system. Another critical barrier is often research studies are narrowly focused while designers need to be informed by a broader context of child development goals and abilities. These findings supported T2 by helping answer RQ3 and RQ4 and provided key implications for the re-design of the Interaction Design and Children designer's toolkit navigation, organization, and content that can best support industry designers' practices. Additionally, I discuss opportunities for the CCI community to better meet industry practitioners' needs, including translating research to actionable recommendations and directions for future studies.

CHAPTER 2. BACKGROUND AND RELATED WORK

This chapter introduces related research that lays the foundation for this dissertation work. As noted in the Introduction, this work is bound by the following two statements:

T1: Incorporating child development theories into a design framework can enhance the developmental responsiveness of the resulting designs.

T2: Providing designers access to theory-based design frameworks, and actionable research-based design recommendations can promote the design of developmentally responsive technologies for children.

Given these theses, I first present an overview of foundational child development theories, describing their role in fostering children's positive technological experiences and how they relate to developmentally responsive designs for children.

Second, I discuss the connection between Child-Computer Interaction (CCI) research and child development, including sections about technology use and apps for children in today's marketplace. I then describe how Family Joint Media Engagement (JME) practices can support children's developmental needs with technologies and outline parent-child tech-related tensions during transitional periods of children's development.

Third, I describe the theoretical background that drives this dissertation's first investigation (T1 above). Here, my focus is on incorporating interest development theory into a design framework for children's mobile technologies to promote their interest in their natural surroundings (see Chapter 3) as individual interest plays a central role in children's learning— a core component of optimal child development, (Azevedo 2013; Hidi and Renninger 2006; Ito et al. 2013) and motivation for pro-environmental behavior change (Broom 2017; Louv 2008;

Wells and Lekies 2006). I discuss the environmental psychologists' perspectives of child-nature connection and the importance of repeated direct nature positive experiences during childhood. I report on prior research about interactive technologies in outdoor explorations that have primarily focused on supporting children's learners' motivation in science inquiry and increasing their physical activities.

Fourth, I describe related work illustrating the Child-Computer Interaction (CCI) research-practice gap and the translation challenges. I also summarize existing Human-computer Interaction (HCI) design tools that translate theory and research-based evidence into resources for design practitioners. This section is particularly relevant to this dissertation's second investigation (T2 above).

Finally, I conclude this chapter with a brief summary of key concepts and how they shaped my two investigations.

2.1 CHILD DEVELOPMENT AND DEVELOPMENTALLY RESPONSIVE DESIGNS

Throughout this dissertation, I advocate for theory-driven and evidence-based designs for children's technologies. Foundational theories of child development provide a framework for thinking of various aspects of children's developmental needs, including physical, social, emotional, and cognitive growth. First, incorporating child development theories in designing technical systems for children can effectively support children's growth and learning needs (Antle 2013; Read and Markopoulos 2013; Yarosh et al. 2011). Second, development theories provide researchers with guidance on evaluating the designs of those technical interventions for children (Antle 2013). In what follows, I summarize two foundational theories of child

development and a more recent theory of positive technological development¹. Grounding in these theoretical perspectives, I describe the core components of developmentally responsive designs that promote children's growth and meet their development needs.

2.1.1 *Cognitive Developmental Theory*

Jean Piaget, a clinical psychologist, formed the influential theory of cognitive development in children. Piaget theorized that children do not just acquire knowledge, but rather they construct meaning and understanding through the interactions and experiences of the world around them — a concept known as constructivism (Piaget 1952). Piaget argued that children are innately curious and explorative, and they organize what they learn from their environment to form a mental representation of the world—known as *cognitive schemas*. Piaget (1952, p. 7) defined a schema as "a cohesive, repeatable action sequence possessing component actions that are tightly interconnected and governed by a core meaning."

Another major idea in Piaget's theory is the concept of assimilation and accommodation (Piaget 1952). Piaget viewed children's intellectual growth as a process of adjustment and adaptation to the world. In the process of taking in new information that fits with preexisting beliefs, children assimilate this knowledge into existing cognitive schemas, perceptions, and understanding. Piaget argued that children revisit existing cognitive schemas and perceptions to accommodate for new information that doesn't fit into their schemas by altering their beliefs.

¹ There is no single child development theory that accounts for all aspects of children learning and growth. Each theory has a different perspective on how to support child development and many complement and build on each other.

Instead of viewing children as miniature adults, Piaget noted that intelligence changes as children grow and described four distinct cognitive stages. The sequence of the stages is culturally universal, however, the rate of when children pass through those stages is determined by biological maturation and interaction with their environments. Piaget's Stages of Cognitive Development include:

- *Sensorimotor* (birth to around age 2): Infants learn through their senses (e.g., hearing, touching, or seeing) by exploring the environment around them. During this stage infants do not yet have a stored mental picture of the world and acquire a range of cognitive abilities including object permanence, self-recognition, deferred imitation, and representational play.
- *Preoperational* (around ages 2 to 7): Children can mentally represent the world through language and mental imagery. During this stage children can think of objects symbolically, such that they can pretend that an object is something different than what it really is. Children are not yet capable of logical reasoning, and their thinking is dominated by how the world looks.
- *Concrete operational* (around ages 7 to 11): Children can perform inductive reasoning around concrete events — that is, they can logically generalize from a specific experience. During this stage children begin to understand objects may have different properties and can mentally reverse those states. Children also become less egocentric and begin how others might think and feel.
- *Formal operational* (around ages 12 to adulthood): Tweens and teens are able to reason logically about abstract ideas; that is, they no longer need to think of representational examples to understand concepts. During this stage, adolescents begin to think more

critically about moral or ethical issues. Adolescents can also deal with hypothetical problems and are able to devise their own solutions and answers

This foundational theory provides a lens on the developmental cognitive stages of children's lifespan from infancy to adulthood. It describes the importance of supporting children's interactions and explorations of their world to acquire new skills and discover knowledge. This theory provides guidance and practical considerations to account for children's abilities when designing children technologies and their digital experiences.

2.1.2 *Social Cognitive and Learning Theories*

Lev Vygotsky's sociocultural learning theory emphasized the role of social interaction with parents, teachers, and peers on children's cognitive development. Like Piaget, he believed that children learn through active experiences in their environment. Vygotsky argued that children's social interactions with others plays a central role in the process of "making meaning." Vygotsky believed that cognitive tools passed through social and cultural contexts, such as language and writing, helped learners make sense of the world around them and form meaning (L.S. Vygotsky 1978).

Cognitive development in Vygotsky's theory stems from social interactions that guide learning within the Zone of Proximal Development (ZPD) as children and their peers co-construct knowledge. The ZPD exists in between the range of what children can achieve on their own, and those they can only achieve with the guidance and encouragement from a skilled knowledgeable other. Vygotsky advocated for cooperative learning and viewed children's interaction with more

knowledgeable peers as an effective way of developing skills and strategies. Others can facilitate children's learning through social scaffolding—that is providing just in time support using a variety of cognitive tools to assist learners move towards new concepts, skills, and understandings.

Child computer interaction community can leverage Vygotsky's sociocultural learning theory by supporting children's meaningful social interactions with their parents and peers. Additionally, the theory provides strategies for designers to scaffold children's learning, these include (1) showing or demonstrating a skill or activity and not just describing them (2) connecting learning to prior knowledge and shared experiences (3) encouraging cooperative learning where children learn from each other and (4) providing opportunity for peer feedback.

2.1.3 *Positive Technological Development Theory*

Most recently, Bers' theory of positive technological development (PTD) provides a model to design digital experiences that promote children's developmental needs (Bers 2012). PTD framework advocates for technical-based systems to foster developmental qualities that can lead children to positive and fulfilling life outcomes. The PTD theoretical framework consists of three main components: (1) developmental assets, (2) technology-mediated behaviors, and (3) situated practice in various contexts.

The PTD framework extends the developmental assets model from Positive Youth Development termed the Six Cs to the domain of digital technologies (Lerner et al. 2005; Umaschi Bers 2006). Bers argues that these Six Cs individual assets —competence, confidence, character, caring,

connection, and contribution—when incorporated in the context of technological interventions, can lead to positive developmental trajectories. The second component of the PTD framework guides the types of digital activities, experiences, and programs that promote positive technological development by linking the six Cs to specific technology-mediated behaviors. These behaviors include technology-mediated communication, collaboration, creativity, content creation, community building, and conduct choices. Bers argues that the extent to which technology can support these behaviors depends largely on technical affordances of designs, interactions, and the context of the technology use. The third component of the PTD framework emphasizes the social context of technology use in enriching children’s technological development. While the PTD framework considers the design features of technology for promoting growth, it advocates accounting for the dynamics of parent-child interaction or shared play experiences among children peers.

2.1.4 *Developmentally Responsive Designs*

Although each of these theories take a distinct approach to support child development and learning, they share common underpinning conditions to foster optimal developmental needs in children and guide the developmentally responsive mobile applications. These four conditions: (1) take into consideration the developmental stage of the child when formulating content and activities, (2) support children’s positive developmental-related tech-mediated behaviors, (3) employ an interaction design that is appropriate to the child’s cognitive and motor skills, and (4) consider the situated social contexts of the indented technology.

Despite the abundant research on child development and educational theories, the link between such theoretical work and CCI designs is insubstantial (Antle 2013; Giannakos et al. 2020; Read and Markopoulos 2013; Yarosh et al. 2011). Researchers in child and educational psychology have long studied how children grow, learn, and change. As noted above, foundational theories of child development describe essential knowledge of the cognitive, physical, emotional, social, and educational growth that children go through from birth and into early adulthood. Consequently, the CCI research community must incorporate child development theories to design better children's technologies with a deeper understanding of why and how children behave. Additionally, developmental theories provide an explanatory lens as to whether children's behaviors are related to their developmental stage, age, family relationships, or cultural and social factors.

2.2 CHILD COMPUTER INTERACTION AND CHILD DEVELOPMENT

As a field, CCI has been significantly influenced by Seymour Papert, who investigated how children could use and benefit from computing to support their development and learning. Papert invented the Logo programming language for children to think about their own thinking and learning (Papert 1980), and later designed the Lego Mindstorms—a construction toy kit that allowed children to build and program their own robots. Papert worked closely with Piaget and extended his constructivist learning theory to develop a highly influential learning theory called constructionism (Forman and Pufall 1988). Where Piaget's theories explained how knowledge is constructed, Papert's constructionism proposes "that children can learn to use computers in masterful ways and that learning to use computers can change the way they learn everything else" (Papert 1980, p.8), bringing revolutionary concepts and ideas to the forefront of science education. New technological designs embody constructionism, allowing children to explore

their personal interests and providing opportunities to design and create projects that can facilitate learning. Although CCI researchers have focused on designing interactive technologies that address children's needs and interests and that help them learn, play, and develop, they seem to have drifted away from their roots, no longer grounding their work in theoretical frameworks (Giannakos et al. 2020; Yarosh et al. 2011).

Additionally, Papert's views on supporting children to become co-creators, rather than passive recipients, have been widely endorsed by the CCI community (Papert 1993). A significant part of CCI research has focused on child-centered methodologies that bring children into the design process and advocated for co-design and evaluate technologies with and for children (Druin 2002).

2.2.1 *Child Development and Technology Use*

Prior research has demonstrated that technology and media can positively and negatively influence children's development. Many studies from previous decades documented the adverse effects on children's behaviors, primarily focused on the content children were exposed to and the media they consumed. These studies noted increased children's aggression due to viewing violent content (Nikkelen et al. 2014), children's increased inattentive and hyperactive behaviors with lower executive functions due to viewing television in infancy (van Egmond-Fröhlich, Weghuber, and de Zwaan 2012), increased children's risk of obesity, and other adverse health conditions due to inadequate physical activities linked to screen time (Danner 2008). However, a recent systematic review of the literature studying the association between media viewing and children's development found that the relationship is more complex and nuanced, and that the likely effects of children's media consumption depends on variety of factors such as children's

individual characteristics, their families, and social contexts (Kostyrka-Allchorne, Cooper, and Simpson 2017).

Despite the research establishing the associations between viewing specific media content and risks to children's health and development, interaction technologies are increasingly used to design solutions to support children's growth, learning, behavior, and relationships. For example, using educational applications on tablets or viewing educational programs enhance young children's language acquisition and literacy skills (Mares and Pan 2013; Neumann 2018). Emerging technologies, such as wearables, motion sensing devices (e.g., Kinect and Wii consoles) and augmented reality sports games encourage physical activities for children and adolescents (Graham and Hipp 2014:2014). Networked technologies and video games promote collaboration, creativity and community-building among youth (Ito et al. 2019), and information-seeking behaviors in online spaces predicts academic success and healthy development in adolescents (K. Chua and Mazmanian 2021; Romer, Bagdasarov, and More 2013).

2.2.2

Children's Applications in the Marketplace

The increasing popularity of smart mobile devices and the fast-growing application marketplace offers remarkable opportunities for access to educational content and support for creative use and developmental skills, particularly for children. The intuitiveness of touch-screen interfaces, the ease of installing applications, the portability, and the relatively low cost of many of these devices contribute to their growing popularity for children and educational purposes. Additionally, an increasing body of research has revealed that well-designed mobile applications positively improve children's learning and developmental skills (Griffith et al. 2020). However,

despite the evidence-based research about these apps, the vast majority of self-proclaimed educational apps do not meet the developmental needs of children (Papadakis et al. 2018; Vaala et al. 2015). The majority of app designs do not incorporate child development, education, or literacy knowledge (Vaala et al. 2015). Additionally, many of the children's touchscreen interface designs implemented in popular apps are not developmentally appropriate for the intended children's ages (Hiniker et al. 2015; Soni et al. 2019).

A recent analysis on children's apps by the Cooney Center (Vaala et al. 2015) found that most apps do not support the intended educational quality, child development goals in the app's underlying curricula, or provide any kind of research testing for learning efficacy of these apps with children. They also found that an underwhelmingly small percentage of apps mention consulting educational or child development experts during app design. Furthermore, children's UX designers and practitioners are rarely educated in children's developmental needs or trained in child-centered methods to include children in the product design cycle (Kaur et al. 2019).

2.2.3

Family Joint Media Engagement

In addition to studying the potential of technology to support children's development, a growing body of research has explored how technologies and digital media use can bring family members together and documented the benefits of families' co-engagement to support children's learning and growth. These practices are commonly known as Joint Media Engagement (JME) (Takeuchi and Stevens 2011). When parents and children engage in conversations and meaning-making together, children understand media content better and how it fits their family values. Prior work examined JME in different contexts such as co-viewing (e.g., watching TV shows or movies)

(Takeuchi and Stevens 2011), play (e.g., video games) (Stevens, Satwicz, and McCarthy 2008), learning (e.g., eBook readings) and augmented reality games (e.g., Pokemon Go) (Sobel et al. 2017).

JME research on parents' and children's shared game experiences found that virtual and in-person collaboration promoted social interactions during and around video gameplay (Stevens et al. 2008). These interactions allowed parents and their children to transfer and share knowledge around common interests (Stevens et al. 2008; Takeuchi and Stevens 2011). Prior work also found that access to devices created shared family moments during family time, encouraged family meaningful conversations around shared interests, and supported family collaboration and creativity (Yu et al. 2017; Yuill, Rogers, and Rick 2013). Yu et al. described how families used their mobile devices to look up information to help family decision-making during vacations and achieve consensus among members. Vacation photos the family took on their devices also helped form positive experiences around shared memories and brought family members together (Yu et al. 2017). Sobel et al. noted that families who played Pokémon Go, a location-based mobile game, appreciated that the gameplay increased shared family time outdoors (Sobel et al. 2017). Parents also felt that playing the game with their children facilitated spontaneous conversations leading to family bonding experiences.

Recently, HCI researchers have been interested in innovating technologies to bring family members together, from supporting family collaboration and creativity to exploring new forms of interactive communication (Ferdous et al. 2016; Wallbaum et al. 2018; Yarosh et al. 2013; Yuill et al. 2013). For example, Yarosh et al. designed ShareTable, a system that allows separated

parents and children to interact remotely and play together (Yarosh et al. 2013). Other work investigated tangible storytelling systems to support communication between grandparents and their grandchildren (Wallbaum et al. 2018), and Ferdous et al. designed a system, TableTalk, that transforms personal phones into a shared display to enrich family mealtime interactions and experiences (Ferdous et al. 2016). Across all these studies, researchers discovered that the design of digital experiences plays a meaningful role in fostering joint family engagement, nurturing family connections, and sharing positive experiences with technology.

2.2.4

Technology-Related Tensions between Parents and Children

Though research documents the benefits of technology for children's growth, many parents are worried about their children's screen time and concerned with the amount of time their children spend on their mobile devices, playing video games, watching YouTube, and talking to their friends over social media platforms (Common Sense Media 2016). These concerns are amplified by society and media messaging that stresses the risks of children's screen time (e.g., Twenge 2017). Consequently, parents are faced with pressures to mediate their children's technology use and enforce screen time limits. Research has found that children's views about their family's technology rules are somewhat conflicted. Children wanted their parents to guide their technology use and teach them how to be responsible with their devices, but, at the same time, they wanted their parents to stop controlling their technology use and let them do what they wanted with their devices (Hiniker, Schoenebeck, and Kientz 2016). Prior research on family mediation strategies found that screen time rules focused on when, where, and how much teen children can use their devices—parents control which games, apps, and social sites their children can access. Parental mediation theory describes three parental technology mediation roles:

parents as *co-users* of media with their tween children; parents as *monitors*, actively monitoring their tween children's technology activities; and *restrictive* parents who restrict their children's online access and interactions (Clark 2011; Livingstone et al. 2017). Researchers have found that parental mediation of children's screen time is more nuanced in practice and is influenced by parent-child relationship dynamics and parents' confidence in their technical knowledge to understand and manage their tween's technology use.

2.3 A THEORETICAL MODEL OF INTEREST DEVELOPMENT

Interest development plays a critical role in children's learning and motivation to engage in any domain, especially science, technology, engineering, and mathematics (STEM) topics (Azevedo 2013; Hidi and Renninger 2006; Ito et al. 2013). Hidi and Renninger define *personal interest* as a psychological state characterized by focused attention and positive feelings toward a certain content, as well as a predisposition to re-engage with the content repeatedly (Hidi and Renninger 2006). Interest differs from related constructs such as motivation, in that engagement is accompanied by a positive emotion (affective component) and perceptual and representational activities associated with attention (cognitive component). Hidi and Renninger's four-phase model of interest development describes how an internally driven personal interest emerges from an initial external stimulus. Although the model was developed with academic interest in mind, prior work has used it to study interest development in informal settings (Ko and Davis 2017).

Each of the four phases in the model is distinct and sequential in its order of development and progress. In the first stage, a triggered situational interest results from the introduction of an environmental stimulus that is personally relevant, intense, or otherwise unexpected. This

external stimulus sparks positive feelings and focused attention, which form the basis of a maintained situational interest when they are sustained over an extended period through meaningful interactions. Both a triggered and a maintained situational interest are externally supported by other people and/or structured tasks. Without such external support, an interest may become dormant or disappear altogether. During repeated engagement with a particular content, an emerging individual interest develops as an individual starts to value the content based on prior experiences engaging with it. An emerging individual interest requires some external support in the form of encouragement from others and an environment that provides opportunities for re-engagement. Lastly, a well-developed individual interest results when an individual has formed an enduring predisposition towards a topic that is marked by deep positive feelings and accumulated knowledge. Although each phase of Hidi and Reninger's model is distinct, they share common characteristics that contribute to and support interest development. These characteristics include focused attention on personally relevant content, supportive social interactions, and opportunities for continued engagement.

2.3.1

The Connection Between Interest and Child Development

One of the key components of child development is learning or acquiring knowledge, skills and changes in behavior from stimuli in the environment. As described in the previous section, interest is central to learning in any domain, including science (Azevedo 2013; Hidi and Renninger 2006; Ito et al. 2013; K. Ann Renninger et al. 04). Learners are more likely to focus on, commit to, and persist in a learning activity when they care about and find enjoyment in it—in other words, when they are interested in the activity. Interest-driven learning is characterized by self-motivated engagement in a topic over the short- or long-term (Azevedo 2013; K. Ann

Renninger et al. 04). A learner who engages in interest-driven learning feels personally connected to the topic and can make connections to prior knowledge and experience (Hidi and Renninger 2006; Ito et al. 2013). Much of the research on interest-driven learning centers on informal learning contexts, such as after-school programs (Ahn et al. 2016; Davis and Fullerton 2016; Pepler 2013; Pinkard et al. 2017), museums (Cahill et al. 2011), and science centers (Zimmerman, Reeve, and Bell 2010). Compared to formal classroom settings, which often follow a predetermined structured curriculum, informal learning contexts afford greater freedom for learners to pursue their interests in a self-directed manner (Azevedo 2013). Self-directed, interest-driven learning is also highly social (Azevedo 2013; Ito et al. 2013).

In this dissertation work, I focus on interest development in nature-based informal settings as central to supporting interest-driven learning about nature. The unstructured quality of natural environments lends itself to engaging child learners in self-directed activities guided by their curiosities and inclinations. However, survey data suggests that a lack of interest is critical when considering children's diminishing time in nature (The Nature Conservancy 2011). Therefore, there is a need for interventions that promote children's interest development in nature to support nature-based science learning and encourage children to become responsible stewards of the environment (Broom 2017; Louv 2008; Wells and Lekies 2006).

2.3.2

Children's Connection to Nature

In the last few decades, environmental psychologists and scientists have become increasingly interested in understanding how people form and experience a connection to nature, what is often referred to as a *human-nature connection* (HNC). HNC broadly refers to a sense of interconnectedness between oneself and nature. Some researchers have offered an evolutionary

explanation (i.e., humans have an innate tendency to seek connections with nature) (Anon 1995). Other researchers have focused on psychological dimensions of HNC, including constructs such as inclusion with nature (Schultz 2002), environmental identity (Clayton 2003), and nature relatedness (Nisbet, Zelenski, and Murphy 2008). Research using a variety of HNC measures consistently finds that the amount and frequency of time spent in nature plays a critical role in fostering a sense of connection between humans and nature, (e.g.; (Kals, Schumacher, and Montada 1999; Nisbet et al. 2008; Tam 2013).

Across the diverse approaches to understanding HNC in environmental and conservation psychology, all approaches agree on (1) the importance of repeated direct nature interactions and experiences during childhood, and (2) the essential role that HNC plays in establishing pro-environmental choices and behaviors in adulthood (Giusti et al. 2018; Ives et al. 2017; Tam 2013). Direct experiences with nature during childhood represent fundamental moments for creating a long-term connection with nature, and, ultimately, becoming committed stewards of the environment.

Although childhood is recognized as a critical period for developing a connection to nature, most existing work exploring HNC does not focus specifically on children (Giusti et al. 2018; Ives et al. 2017). One exception is Giusti et al.'s framework (Giusti et al. 2018), assessing where and how children connect to nature. In addition to its focus on children, this framework distinguishes itself from other work by characterizing the specific kind of experiences that people tend to connect to while in nature, as well as a recognition of the connection between children's mind, body, and nature experiences (Giusti et al. 2018).

Giusti's framework depicts HNC as an *ability* and identifies a group of specific abilities displayed by children who are connected to nature. Examples include "being curious about nature" and "knowing about nature." In Giusti et al.'s terms, one would say that a child connected to nature is capable of being curious about nature (first ability) and capable of knowing about nature (second ability). Closely related to HNC abilities are specific *qualities* of nature-based activities that have a high potential to connect children to nature. They include nature-based experiences that are child-driven (i.e., chosen by the child), engage children's senses (e.g., touch, hearing), and are fun, joyful, or amusing. If children's nature-based experiences exhibit these qualities, they are more likely to demonstrate HNC-related abilities. In other words, abilities reside in children, whereas qualities are aspects of the nature-based experience.

A key principle to Giusti's framework is that children's HNC abilities progress over time and as they engage with nature. The framework divides this progression into three consecutive phases: (1) *being IN nature*, (2) *being WITH nature*, and (3) *being FOR nature*. Each phase is marked by a distinct set of HNC abilities. For instance, during the first phase—being IN nature—children demonstrate a curiosity to explore their natural surroundings. Each of the three phases in the framework is sequential in its order of development and progress. For children to feel motivated to act FOR nature (the third phase), they must first develop the abilities to (1) feel comfortable being in the natural elements of the outdoors, i.e., being IN nature during the first phase, and (2) feeling concern for the environment, i.e., being WITH nature during the second phase. Therefore, children's ability to be curious about nature is key to developing a profound human-

nature connection (Giusti et al. 2018). Below, I identify the child-related abilities associated with each phase of Giusti et al.'s HNC framework, as well as the qualities of nature-based activities that support these abilities.

Being IN Nature

Child-related abilities: Children's HNC-related abilities include feeling comfortable in natural spaces (e.g. with dirt, mud or bugs) and being curious about nature.

Qualities of nature-based experiences: Significant nature-based activities in this phase of the framework are characterized by being child-driven, enjoyable, engaging children's senses (e.g. touch, hearing), involvement of animals, and drawing children's attention. These experiences are often accompanied by a sense of awe or "wow effect."

Being WITH Nature

Child-related abilities: Children's HNC-related abilities include acting in natural spaces (e.g. nature play), feeling attached to natural spaces, reading natural spaces, knowing about nature (like animals or plants), and recalling memories with nature.

Qualities of nature-based experiences: Significant nature-based activities in this phase are characterized by being child-driven, engaging children's senses, as well as involving creative expression and physical activity.

Being FOR Nature

Child-related abilities: Children's HNC-related abilities include caring about nature, taking care of nature, and being one with nature.

Qualities of nature-based activities: Significant nature-based activities in the third phase of the framework are characterized by thought-provocation, structure/instruction, and social/ cultural endorsement.

2.3.3

Designing Mobile Technologies for Nature Exploration

My work on designing a children application for nature exploration joins a growing body of prior research in Child-Computer Interaction exploring the potential for mobile interactive technologies to engage children in outdoor experiences. Prior research recognizes that, although technologies are often seen as the culprit, keeping children indoors and sedentary in front of a screen, they can also be used to encourage active experiences outside (Back et al. 2016; Sobel et al. 2017; Wood et al. 2019). Researchers have explored ways to design interactive experiences that mirror traditional game-play patterns, encourage children’s social interactions, and increase their physical activity (Avontuur et al. 2014; Cumbo et al. 2014; Hitron et al. 2018; Lagerström et al. 2014; Soute 2007; Soute, Lagerström, and Markopoulos 2013; Verhaegh et al. 2006; Wood et al. 2019). Another body of work has explored ways to leverage mobile technologies and augmented reality in an effort to support children’s engagement in outdoor science inquiry (Fails et al. 2014; Kamarainen et al. 2013; Land et al. 2015; Rogers et al. 2004; Zimmerman, Land, Mohney, et al. 2015; Zimmerman et al. 2016). Beyond this focus on embodied physical play and learning outcomes, designing technologies that promote children’s interactions with and connectedness to nature remains a new and underexplored area of child-computer interaction research. Harnessing the capabilities of mobile technologies, NatureCollections contributes new insights into designing interactive technologies that support children’s nature interactions and explorations.

This dissertation work on deriving interest-centered design strategies is informed by prior research that leverages mobile technologies to engage children in nature-based learning experiences. This work aims to support learners in informal settings by using location awareness capabilities, social features, built-in data collection functions, and just-in-time prompts.

2.3.3.1 Place-Based and Context-Aware Technologies

Projects that support nature explorations, such as EcoMOBILE (Kamarainen et al. 2013), iBeacons (Zimmerman et al. 2016), GeoTagger (Fails et al. 2014), and Tree Investigators (Zimmerman, Land, McClain, et al. 2015), harness the location awareness capabilities of mobile and augmented reality (AR) devices to deliver content tailored to a particular place in order to engage learners within their physical settings (Fails et al. 2014; Kamarainen et al. 2013; Zimmerman, Land, McClain, et al. 2015; Zimmerman et al. 2016). In several of these projects, mobile devices augment real-world locations with an overlay of virtual information and narratives to support scientific observations (Kamarainen et al. 2013; Zimmerman, Land, McClain, et al. 2015; Zimmerman et al. 2016). Researchers on the EcoMOBILE project reported that AR design elements enhanced learners' engagement in their scientific inquiry about a pond ecosystem by providing detailed views such as closeups of microscopic organisms that would not be possible otherwise (Kamarainen et al. 2013). Similarly, iBeacons pushed content and learning activities based on the proximate location of the arboretum visitor to the relevant nature element or place (Zimmerman et al. 2016). Tree Investigators, comparably, supported learning about tree species diversity by using an overlay of images and text to amplify learners' observations (Zimmerman, Land, McClain, et al. 2015). Researchers reported that AR enhanced

learners' observations and increased their interactions with peers during a field trip (Kamarainen et al. 2013; Land and Zimmerman 2015; Zimmerman, Land, McClain, et al. 2015). Projects such as these build off earlier efforts to leverage mobile technologies to support outdoor exploration, e.g., (Chipman et al. 2006).

2.3.3.2 Social Media Tools for Science Inquiry

Researchers have also used social media tools and features, such as ScienceKit and Science Everywhere, to support scientific inquiry in informal community-based learning settings (Yip et al. 2014; Zimmerman and Land 2014). Researchers noted that appropriating social media facilitated social scaffolding and personal expression and supported children's learning about science in their everyday lives (Yip et al. 2014; Zimmerman and Land 2014).

2.3.3.3 Balancing Supports and Learner Autonomy

With many projects related to mobile learning technologies, researchers seek to strike a balance between encouraging children's free choice exploration—a key component of interest-driven engagement (Azevedo 2013)—and providing external support (Cahill et al. 2011; Kuhn et al. 2011; Zimmerman, Land, McClain, et al. 2015; Zimmerman, Land, Mohney, et al. 2015; Zimmerman et al. 2010). To create engaging learning experiences and guided exploration, researchers have used the built-in data collection capabilities of mobile devices to enable learners to capture, annotate, and reflect on the data they collect (Cahill et al. 2010; Kuhn et al. 2011; Quintana et al. 2004; Rogers et al. 2005). For instance, Zydeco encouraged learners to take photographs, produce audio recordings, and annotate data collection in museums to bring back to their classroom.

External support can be in the form of just-in-time information and prompts to support and direct learners' scientific inquiry. For instance, the Ambient Wood project pushes content such as pre-recorded sounds of insects scuttling into the devices, enabling the students to discover elements in their surroundings that otherwise might go unnoticed (Rogers et al. 2005). Likewise, iBeacons detect proximate devices to push relevant information and activities (Zimmerman et al. 2016).

The balance between external support and free-choice exploration can be challenging to achieve. Researchers on the Zydeco project found that introducing too much structure limited learner autonomy (Cahill et al. 2010), negatively affecting self-motivated, interest-driven learning (Azevedo 2013). Externally imposed content may also cause distractions for learners. Across some of the projects discussed, educators reported a recurrent concern that learners were looking at screens and interacting with their mobile devices instead of focusing on their surroundings (Hsi 2003; Kamarainen et al. 2013; Lyons 2009; McClain and Zimmerman 2016; Zimmerman, Land, McClain, et al. 2015). Excessive interactions with the device screens represent a challenge to promoting focused attention at their natural surroundings.

2.4 CHILD-COMPUTER RESEARCH-PRACTICE GAP

The following section describes the related work that informs the dissertation's second investigation that translates evidence-based research for an online children's technology designer's toolkit (T2). The HCI Translational Research illustrates the research-practice gap and research translation challenges in CCI. I also summarize existing Human-computer Interaction (HCI) research-based tools that share resources with designers and fit everyday design practices.

2.4.1

HCI Translational Research

Child-Computer Interaction (CCI) and HCI researchers generally aim to support industry practitioners: many focus their discussions on design implications intended to translate findings to design practice. However, prior research demonstrates the difficulty practitioners have understanding and applying these research findings due to various barrier (Buie et al. 2013; Colusso et al. 2017; Geldof and Vandermeulen 2007; Norman 2010; Sas et al. 2014). The most common barriers stem from the content of publications, including an academic writing style that seems abstract, complex, and not presented in a format that fits the design process used in industry (Buie et al. 2013; Colusso et al. 2017; Geldof and Vandermeulen 2007). Additionally, practitioners struggle to search and find relevant research for their products and face access limitations to published papers behind paywalls (Buie et al. 2013; Colusso et al. 2017). Another key barrier is that the design implications shared in the research papers might not address details considered important to designers, which may be secondary to academic research (Colusso et al. 2017; Sas et al. 2014). Consequently, the lack of these design details hinders the translations of the findings into actionable design guidelines (Colusso et al. 2017, 2019; Sas et al. 2014).

Current design implications in academic papers are often not enough to drive the appropriation of these academic results into industry practice (Colusso et al. 2017; Sas et al. 2014). Several HCI researchers have investigated ways to write design implications better; for example, Carroll et al. (1992) created an action-based guide to connect user-scenarios to concrete design implications (Carroll and Rosson 1992). Additionally, Sas et al. (2014) aimed to understand the critical challenges in translating empirical findings into actionable recommendations to inform the design. They investigated the types of design implications, how they are generated, and the

main characteristics of evaluating the applicability of these design implications (Sas et al. 2014). Colusso et al. (2017) proposed a new set of guidelines for creating translational resources, including illustrating findings and theory through examples and data excerpts, rephrasing ‘implications for design’, and integrating HCI knowledge into existing practitioner resources and practices (Colusso et al. 2017).

2.4.2 *Research-Based Design Tools*

Academics have long worked to communicate their research in venues other than academic journals and proceedings, publishing popular press books, writing blog posts, and sharing their findings with local news outlets. A common approach in the design field is to share both evidence-based research and design frameworks and methods with practitioners using physical cards. The card form factor is usable, easily accessible in practice, and concise in the presentation of information. Card toolkits are intended to be used during the early stages of design, or at the end for evaluation. A number of card-based tools exist, such as IDEO’s Method Cards (IDEO 2003), Artefact’s Tarot Cards of Tech (Artefact 2017), Envisioning Cards (Friedman and Hendry 2012), and Developmentally Situated Design (DSD) Cards (Bekker and Antle 2011). We reviewed the existing cards-based design toolkits used in practice or in research, and summarize here the purpose, audience, use, and content.

Cards-based design tools fall within the following categories:

- (1) *Methods cards* (e.g., IDEO Methods Cards (IDEO 2003) and Inclusive: a Methodology Design Toolkit (Microsoft 2018)): cards describe a collection of a diverse set of research methods to help designers tackle a design problem or choose a suitable method for their user group and appropriate evaluation methods.

- (2) *Inspiration cards* to initiate the ideation processes (e.g., The Envisioning Cards (Friedman and Hendry 2012), Tarot Cards of Tech (Artefact 2017), and Inspiration card workshops (Halskov and Dalsgard 2006)): cards facilitate a shared context and playful collaborative exploration of design ideas among different team members. These cards may include inspirational images, design situations, and questions to support designers' reflective conversations.
- (3) *Informational cards* (e.g., Developmentally Situated Design Cards (Bekker and Antle 2011), Tango Cards (Deng, Antle, and Neustaedter 2014)): cards provide brief information from research-based studies and pose a questions that encourage users to take into consideration context, user abilities, or circumstances. These cards also help create a common vocabulary for communication for specific research contexts (e.g., persuasive design).
- (4) *Activity cards* (e.g., PLEX Cards (Lucero and Arrasvuori 2010), Metaphor Cards (Logler, Yoo, and Friedman 2018), and Economy Design (Fedosov et al. 2019)): cards are used to facilitate design workshops with stakeholders.

Cards are useful in enabling diverse uses and support a flexible, hands-on approach to bringing conceptual information into design in a succinct and easy to consume format. However, physical cards can be costly to maintain and challenging to keep current as research evolves. They can also be easily misplaced, lost, or damaged and do not work as well in remote coworking teams or projects. Despite the utilization of these card-based tools in design practices, these research-based tools are not focused on sharing children's research to support different stages of children's technology design or presenting the developmental needs and abilities of a wide range of children's ages. One exception is the Developmentally Situated Design (DSD) physical cards.

The DSD cards present summarized information of specific developmental skills of children ages 5-12 due to limited space on the physical card. Though designers found the DSD cards helpful, particularly in creating a shared common language with their team, designers found the simplification of the theoretical and academic knowledge presented on the cards hard to apply without sharing real-life examples for skills and ability levels of children (Bekker and Antle 2011).

2.5 SUMMARY OF RELATED WORK

In summary:

- Developmental theories provide an explanatory lens as to whether children's behaviors are related to their developmental stage, age, family relationships, or cultural and social factors.
- Incorporating child development theories in designing technical systems for children can effectively support children's growth and learning needs.
- Development theories provide researchers with guidance on evaluating the designs of those technical interventions for children.
- Interest development plays a critical role in children's learning, motivation to engage in any educational domain, and pro-environmental behavior change.
- Technologies can positively and negatively impact children's development. However, children's technology designs that were driven by evidence-based development research improved children's growth, learning, behaviors, and social relationships.
- According to an analysis of children's market apps, the vast majority of self-proclaimed educational apps do not meet the developmental needs of children.

- Additionally, child development does not happen in a vacuum; social contexts and relationships with parents and peers impact children's growth and development. Even positive children's technology use was experienced through parent-child relationship tensions, particularly during tween and teens years, a transitional period from childhood to adulthood.
- Designers and practitioners are rarely educated in children's developmental needs or trained in child-centered methods to include children in the product design cycle. Additionally, they face barriers to accessing and understanding academic research.

In addition to these summarizing points, I want to emphasize the importance of exploring ways to reduce the CCI research-practice gap and to better understand the process of translating child-development theory into applicable design practice. In this dissertation work, I propose research-based design frameworks and tools to support developmentally responsive designs for children's technologies. Prior translational research in HCI suggests the following (Colusso et al. 2019):

- (1) Identifying relevant theories, disciplines, and steps to harvest the insights of academic scholarship for design practice.

In the first part of this dissertation, I bring to light the nuanced process of deriving theoretically driven design implications for children technologies that promote interest development. This part of the work contributes a richer understanding of steps, gaps, and interoperation of theoretical contributions for design practice.

- (2) It is instrumental to adopt a participatory design approach to connect evidence-based research to practice where designers' needs are considered.

In the second part of this dissertation, I present the analysis of a toolkit design that guides Child-Computer Interaction authors to make child-specific interaction design research accessible to practitioners, supports practitioners' current practices, and fits within industry demands.

CHAPTER 3. INTEREST-CENTERED DESIGN FRAMEWORK²

As part of investigating T1, I examine the process of drawing design principles from child interest-development theory to guide the design of developmentally responsive children’s technologies. This chapter presents the Interest-Centered Design (ICD) framework for tech-mediated applications to promote children’s interest in a topic. I describe the process of connecting design considerations for children’s mobile technologies with theoretically driven insights from child interest development theory. As described in Chapter 2, interest is a key developmental and psychological state of engagement, experienced in the moment, and a predisposition to engage repeatedly with particular topics, events, or ideas over time (Hidi and Renninger 2006). Interest is central to learning, a core component of child development (McDevitt 2013), and plays a critical role in motivation for behavioral change (Azevedo 2013). I chose to focus on children’s interest-development in their natural surroundings due to the pivotal role of time spent in nature supporting children’s learning, attention, physical health, and mental and emotional wellbeing—critical dimensions of optimal child growth. Furthermore, children’s connection to nature is essential in establishing pro-environmental behaviors in adulthood (Broom 2017; Louv 2008).

In pursuing this investigation, I asked the following research question: What are the considerations to develop children’s interest in a topic when designing interactive technologies,

² Kawas, Saba, Sarah K. Chase, Jason Yip, Joshua J. Lawler, and Katie Davis. 2019. “Sparkling Interest: A Design Framework for Mobile Technologies to Promote Children’s Interest in Nature.” *International Journal of Child-Computer Interaction*.

particularly those that promote children’s interest in their natural surroundings? The study results allowed me to answer RQ1 (how designers can support children’s interest development) and RQ1.1 (the design considerations for interest development). The contribution of this work is foremost a theory-based ICD design framework to support children’s technology designers to encourage children’s interest development through technology-mediated experiences.

In what follows, I detail the study motivation and the process of drawing on theory related to children’s interest development to derive the ICD design principles. I then report on the co-design sessions with children designers to distill a set of design strategies to implement each of the following ICD principles: (1) personal relevance, (2) focused attention, (3) social interactions, and (4) opportunities for continued engagement. This, in turn, guided the design of a mobile application, *NatureCollections*, to promote children’s interest in nature. I detail the method of distilling the design principles and strategies, report on the co-design sessions with children, and discuss the implementation of the theoretical framework in designing interest-centered mobile technologies. This work³ was peer-reviewed and published in the *International Journal of Child Computer Interaction* (Kawas et al. 2019).

3.1 BACKGROUND AND MOTIVATION

Hidi and Renninger’s interest development model, presented in Chapter 2, highlights the importance of promoting children’s focused attention and positive affect toward a particular content or activity in supporting interest-driven learning and behavior change. The model

³ I led this project from the mobile app design, implementation, and evaluative research studies and had wonderful collaborators from the Information School and the School of Environmental and Forest Sciences. Katie advised me on our paper and helped guide the design framework’s theoretical grounding in child development

describes how an externally triggered situational interest can develop into a sustained personal interest through repeated engagement in personally relevant and socially supported experiences. Hidi and Renninger's model provided: (1) guidance for how to design technologies to support interest development, and (2) focus on how to observe children's development of interest-driven participation as described in the following chapter. Specifically, I was interested in examining if a mobile technology can engage children and their parents in positive developmental behaviors during their explorations of the natural world and promote their interest in nature.

Globally, children are spending less time outdoors than the generations before them (Clements 2004; Hofferth and Sandberg 2001). In 2016, U.S. children spent 50% less time than their parents playing in nature (Association 2016; Hofferth and Sandberg 2001; Juster, Ono, and Stafford 2003). At the same time, a 2015 U.S. survey showed that children ages 7–13 spent approximately six hours per day using screen media entertainment, which excludes screen time spent for homework and while at school (Common Sense Media 2016). Spending less time in nature has negative implications for children's developing attitudes towards and interest in nature (Cheng and Monroe 2012; Soga and Gaston 2016). Indeed, a 2011 poll from The Nature Conservancy found that 49% of U.S. children reported a lack of interest in spending time in nature (The Nature Conservancy 2011).

This state of affairs is problematic on both an individual and a societal level. On an individual level, a failure to develop an interest in nature may negatively affect children's nature-related science learning. Personal interest—characterized by concentrated attention, positive feelings, and a likelihood to re-engage with the same topic (Hidi and Renninger 2006)—is an important

dimension of learning, including science learning (Hidi and Renninger 2006; Pinkard et al. 2017). On a societal level, prior research has found a connection between individuals' positive perceptions of childhood experiences in nature and their positive attitudes and actions towards the environment as adults (Broom 2017; Wells and Lekies 2006). Reducing habitat loss, a major driver of biodiversity loss, depends on these positive attitudes and actions (Collado et al. 2015; Louv 2008).

Whether fairly or not, networked technologies are often seen as the source of our current problems (Turkle 2011; Twenge 2017). At the same time, these technologies are increasingly used to design solutions to problems such as sleep deprivation (Choe et al. 2011), empathy decline (Konrath 2017), and decreased attention (Jones 2017). With respect to interest development, prior work has demonstrated that technological infrastructures can support interest-driven engagement and learning by allowing students to tailor activities to their personal interests and extend activities in unanticipated ways (Azevedo 2013).

Prior work conducted in the field of mobile learning technologies leveraged the affordances of mobile and networked technologies to engage children in outdoor settings. Although this work has yielded promising results with respect to promoting children's exploration of, and learning about, nature (Kamarainen et al. 2013; Land et al. 2015; Zimmerman, Land, McClain, et al. 2015), it has not placed interest development at the center of design-based investigations. In fact, a persistent challenge surfaced by this work relates to children's tendencies to engage with their handheld devices rather than with their surroundings when they are in an outdoor setting or in front of a museum exhibit (Hsi 2003; Lyons 2009). This is a particular problem for interest

development, which requires focused attention to trigger and sustain it (Hidi and Renninger 2006). In the current work, I explore ways to support the design of developmentally responsive children’s technologies, with a theory-driven design framework. I focus on children’s interest development in nature-based informal settings as a central piece in guiding children’s personal curiosities and self-directed activities—critical dimensions in meeting children’s developmental needs.

Table 3-1. Design principles and strategies to guide the design of mobile technologies that support interest development

Mobile Design Principles	Design Strategies to Support Personal Interest Development	NatureCollections Feature Examples
1. Engage Children in Personally Relevant Activities	1.1 Support children’s pre-existing personal interests through customizable activities	Onboarding Screens, My Collections
	1.2 Provide opportunities to extend activities by unlocking new content	Onboarding Screens, My Collections
	1.3 Create a personalized user interface	Onboarding Screens
2. Support Children’s Focused Attention on Their Surroundings	2.1 Draw attention to specific elements in the child’s physical surroundings	“Add Details,” Photo Classification
	2.2 Encourage self-directed sensory interactions with natural elements	“Add Details,” Photo Classification
3. Encourage Children to Engage in Social Interactions	3.1 Connect users with each other and provide conversational prompts around topics of interest	My Friends, “Add Details,” Challenges
	3.2 Create activities that involve two or more users to complete	Challenges, My Friends
4. Provide Opportunities for Continued Engagement	4.1 Display children’s accumulated progress over time	Tracking Progress, Challenges, Collections
	4.2 Promote app engagement across settings	Tracking Progress

3.2 DESIGN FRAMEWORK TO SUPPORT INTEREST DEVELOPMENT

I collaborated with researchers from the Information School and the School of Environmental and Forest Sciences to conduct this study. We explored the potential for a mobile application to spark children’s interest in nature. Drawing on Hidi and Renninger’s model we derived the key four design principles of interest development. We then identified specific design strategies to implement each of the theoretically derived design principles, through a series of sessions with

UW KidsTeam, an intergenerational co-design team of children (ages 7–12) and adults (Table 3.1). These strategies are intended to guide the design of mobile technologies that promote children’s interest-driven exploration. Below, I describe the four design principles, followed by the process of using co-design with children to identify design strategies to implement each principle.

3.2.1 *Interest-Centered Design Principles*

We derived the following four design principles by extracting core dimensions of interest development that appear in all four phases of Hidi and Renninger’s model (Hidi and Renninger 2006). This work is motivated by prior research showing that the development of a sustained personal interest in a topic begins with an externally triggered situational interest (Hidi and Renninger 2006), described in Chapter 2. Whereas a personal interest is an enduring predisposition to re-engage in a particular content, a situational interest arises in the moment and may be relatively fleeting if not supported beyond that moment (Hidi and Renninger 2006; K. Ann Renninger et al. 04). Although each phase of Hidi and Reninger’s model is distinct, they share common characteristics that contribute to and support interest development. These characteristics include *focused attention on personally relevant content*, *supportive social interactions*, and *opportunities for continued engagement*. We drew on these crosscutting characteristics to derive the four design principles that form the foundation of our interest-centered design framework. Because the characteristics appear in each phase of Hidi and Reninger’s model, our interest-centered design framework—and, by extension, the NatureCollections app that we designed using the framework—addresses all four phases of the interest development model. For instance, Hidi and Renninger’s model emphasizes social support in all four phases of interest development, from a triggered situation interest to a well-

developed individual interest. Prior research has also found social support to be an important factor in designing learning technologies [e.g.; (Ahn et al. 2016; Chipman et al. 2006; Yip et al. 2014)]. I took a similar approach for each major dimension of interest development, considering it in light of specific successes and challenges identified in prior research.

Design Principle 1: Engage children in personally relevant activities. Personally relevant activities draw on children's existing interests to foster positive feelings and engagement with new topics. A situational interest is triggered by external stimuli, which introduce personally relevant or surprising information (Hidi and Renninger 2006). Continuing to support meaningful personal experiences maintains interest over time, helping to turn a triggered situational interest into a more sustained individual interest (Hidi and Renninger 2006; Krapp 2002).

Design Principle 2: Support children's focused attention on their surroundings. This principle emphasizes the importance of providing opportunities for prolonged, focused engagement with a topic. Typically supported by external stimuli, prolonged engagement helps to maintain an otherwise fleeting triggered interest over time (Hidi and Renninger 2006).

Design Principle 3: Encourage children to engage in social interactions. Social interactions and relatedness represent a key mechanism for sparking and sustaining interest in a particular topic, helping to transform it from a situational to an individual interest (Hidi and Renninger 2006; Krapp 2003). Participatory social interactions, especially with peers, can be highly engaging, and can lead children to deepen their interest (Hidi and Renninger 2006; Krapp 2003) and to learn more about a topic (Ito et al. 2013).

Design Principle 4: Provide opportunities for continued engagement. This principle helps transform a triggered situational interest into an emerging individual interest. Emerging individual interests require some external support for opportunities to re-engage with a topic (Hidi and Renninger 2006).

3.3 CO-DESIGNING A NATURE APP WITH CHILD DESIGNERS

We employed the Cooperative Inquiry method (Druin 1999) to distill a set of design strategies to implement our theoretically derived design principles and to gather design ideas for the features of the NatureCollections app. Cooperative Inquiry is a method of participatory design in which children and adults equally and equitably partner together to ideate, design, test, and evaluate new child-focused technologies (Druin 1999; Yip et al. 2017). We conducted three 90-minute co-design sessions with KidsTeam over 3 months. Each design session consisted of activities selected to best explore and derive design strategies for the theory based design principles. In each session, we focused on one of the following three design principles: (1) *Personal Relevance* (2) *Focused Attention*, and (3) *Social Interactions*. In all three design sessions, we explored ways to support Design Principle 4: *Opportunities for Continued Engagement*.

3.3.1 *Participants and Context for Co-Design*

KidsTeam consists of both children participants and adult researchers cooperating around design activities. KidsTeam includes seven children ages 7–12 years [$M = 9.3$, $SD = 1.6$] (three girls and four boys). We recruited children that were ethnically and socioeconomically diverse in an urban area (two Asian/White, one Asian/Black, one Native/Asian, one Hispanic, one Asian, and one White). The adults were a mix of professors and graduate and undergraduate researchers. Each KidsTeam session follows the same format. *Snack time (~15 minutes)* allows children and adults

to socialize and play together. In *circle time* (~15 minutes), we present a question of the day to prime children and adults for the instructions and focus of the session. During *design time* (~45 minutes), children and adults divide into smaller groups and co-design artifacts together to create new designs and ideas or engage in design related activities. Finally, *discussion time* (~15-20 minutes), gives children and adults a chance to reflect and present to the full group and to synthesize the common design themes.

3.3.2 *Data Collection and Analysis*

We video-recorded and photographed each design session. We used a single video camera that recorded group dynamics during co-design activities and researcher-facilitated design discussions, rotating it periodically to sample as much of the small group activity as possible. All researchers took field notes and produced analytic memos immediately following each session. We began our analysis by examining the initial design themes generated during discussion time at the end of each session. The children in each design group shared their ideas and design artifacts, and a researcher distilled and documented cross-cutting themes on a whiteboard. Displaying the themes served as a validity check, as children and researchers could react to and build on the themes. Based on this initial analysis, we re-examined researchers' memos and collaboratively reviewed the artifacts produced by the children to revise and refine the dominant themes in light of our four design principles. This allowed us to identify design strategies that could be used to implement each design principle. To validate these design strategies, the first author reviewed the video data and field notes from each session to identify "critical events" representing each theme (Jordan and Henderson 1995). The research team reviewed these events alongside our analytic memos, discussing their relationship to each design strategy. The

following sections discuss each co-design session and the design strategies that emerged from them. We use pseudonyms to protect children's privacy.

3.4 INTEREST-CENTERED DESIGN STRATEGIES

1. Design Strategies for Principle 1: Personal Relevance

In the first co-design session (August 2016), we explored ways to incorporate personalization around interest-driven explorations. First, KidsTeam children participated in a 15-minute outdoor activity, where they were given a smartphone with a camera to use while exploring an outdoor garden. Second, based on our observations of the outdoor activity, we asked small group teams to reflect and brainstorm ideas for mobile app features that support nature exploration. Each design group used Bag of Stuff (Druin 1999) (large bags filled with craft materials) to create low-fidelity prototypes. The design groups then used the Big Paper (Guha et al. 2004) (large Easel sized paper for collaborative sketching) to draw design ideas.

(1.1) Support children's pre-existing personal interests through customizable activities

We observed that KidsTeam children were drawn to curating and customizing photo collections of nature that aligned with topics they found personally compelling. For example, during the co-design session, several children proposed that the app elicit what they like and provide prompts to point to those interests, as Adam [boy, age 8, Hispanic] articulated as “*Take a photo of something you like.*” We recommend that designs support children's pre-existing personal interests through a variety of customizable activities. Designs should also be flexible enough to adapt to new emerging topics of interest.

(1.2) Provide opportunities to extend activities by unlocking new content

During the co-design session, children were inspired to explore new topics and nature experiences by collecting new photos taken from different locations, as Pamela [girl, age 9,

Asian/White] shared: *“The more photos you take the more your dragon (the guiding character) grows ... and when you take rare photos then you unlock a new location to explore.”* We recommend that designs reward children’s engagement with a topic by unlocking new activities or by highlighting similar activities.

(1.3) Create a personalized user interface

We observed all children in the co-design session propose a character that shared their nature journey and provided contextual prompts to help build their nature photo collections. India [girl, age 8, Asian/Black] explained: *“Flowly, a golden flower with a smile, will guide through taking photos...If I take a photo, Flowly will grow...When you take more photos and draw nature elements you earn rewards...”* We recommend user interfaces attempt to guide the child’s app and activity experiences. Designing personalized prompts and/or compelling characters may enhance children’s feelings of personal connection to the content presented.

2. Design Strategies for Principle 2: Focused Attention

In the second co-design session (October 2016), we considered ways to direct children’s attention to their natural surroundings. We asked the KidsTeam groups to brainstorm and design ideas to support interacting directly with their natural surroundings. Each group used both Bag of Stuff and Big Paper to design their ideas.

(2.1) Draw attention to specific elements in the child’s physical surroundings

During the co-design session, children proposed challenges (e.g., scavenger hunts) that suggest a list of items to photograph, directing users’ attention to specific elements in their surroundings. Matt [boy, age 12, Asian] shared the idea of an audio feed that points to natural surroundings nearby: *“This is an audio feature that tells you about things you are looking at.”* Similarly,

several children proposed using location, time of day, and season as additional dimensions for challenges to increase engagement with a topic and to draw attention to a certain natural phenomenon, such as phenological cycles (e.g., colored leaves or flowers). Adam wanted the app to “*send challenges to take photos of different colored leaves in the fall, or collect photos of flowers in the spring.*” India proposed having “*maps [in new locations] that unlock when you collect items*” based on your surroundings. Designs can provide prompts to engage children in observational activities within a physical space.

(2.2) Encourage self-directed, sensory interactions with natural elements

We observed that children who interacted with nature elements wanted the app to support their curiosity and challenge them to identify the nature elements in their photos. Mia [girl, 10, Asian/White] suggested categorization choices to help identify nature elements. She also wanted to use smells to identify the different plants: “*[The] dichotomous key has a button to identify smell...you open it to a plant or flower and it will tell you what it is.*” Adam thought the app should support sound: “*This button is to collect sounds of birds.*” Designs can sustain interest in nature by: (1) supporting free-choice explorations, and (2) encouraging physical interactions, such as promoting sensory inspection (e.g. touch, sound, smell) of elements in one’s surroundings.

3. Design Strategies for Principle 3: Social Interactions

During the third co-design session with children (November, 2016), we explored ideas for social interactions, both in-person and virtually. The focus of this session was to generate ideas for the app to support sharing experiences and playing with others. We asked KidsTeam to prototype

ideas for social features for a mobile app. Each group used Big Paper and had mobile screen template printouts to use for prototyping features.

(3.1) Connect users with each other and provide conversational prompts around topics of interest

We initially assumed children would be most interested in designing social features like chatting and commenting on friends' photos. However, children were more interested in designing features allowing them to friend and play with their peers. Both Adam and Will [boy, age 9, White] wanted the app to help their team as a group *"to go on nature adventures"* and *"collect photos together."* They proposed having the app display their photos and track their rewards so all team members could view them. Another idea they had was for the app to support their nature explorations through prompts, as Will explains *"the app asks you why is this photo unique...to earn badges."* Prior work has shown that *conversational* prompts can support learning about nature (Crowley and Jacobs 2002). Designing to support meaningful peer and adult interactions around a shared interest (Ito et al. 2013) can contribute to recurrent engagements and positive feelings around a topic.

(3.2) Create activities that involve two or more users

All children expressed a desire to challenge their peers to match one of their photos. As Matt explained, *"You take a picture of a tree, for example, and you can crop it if you want, then send it to a group of friends and they have to guess what type of tree it is."* Adding to Matt's idea, other children suggested the app provide reply options for the shared photo. Pamela noted, *"You take photos of nature elements and you send it to your friends and they have to take a picture of the same nature element."* Design can support cooperative social activities to engage children with their peers in learning about nature together.

4. Design Strategies for Principle 4: Opportunities for Continued Engagement

In all three co-design sessions, we explored opportunities for children’s recurring engagement with nature.

(4.1) Display children’s accumulated progress over time

Children suggested ideas to track their progress, such as progress bars displaying completed challenges, a profile displaying earned badges and challenges they have yet to pursue. Design can display the child’s extended engagement with a particular topic with a reward of highlighting completed challenges and providing positive reinforcement.

(4.2) Promote app engagement across settings

Across the different co-design sessions, KidsTeam children India and Pamela proposed having challenges to collect items from different locations over multiple days. Design can engage children with activities that span multiple days, seasons, and locations to support continued engagement in the topic of interest.

3.5 APPLYING THE INTEREST-CENTERED DESIGN FRAMEWORK TO THE NATURECOLLECTIONS APPLICATION

I employed the design strategies that emerged from the co-design sessions with KidsTeam to guide the design of a mobile app, NatureCollections, to foster children’s interest in nature. The app encourages children to collect nature photos, add descriptive information to photos, and store them in collections. For each principle, we describe select app features and related strategies in braces {} (see Table 3.1 for a summary of principles, strategies, and app features).

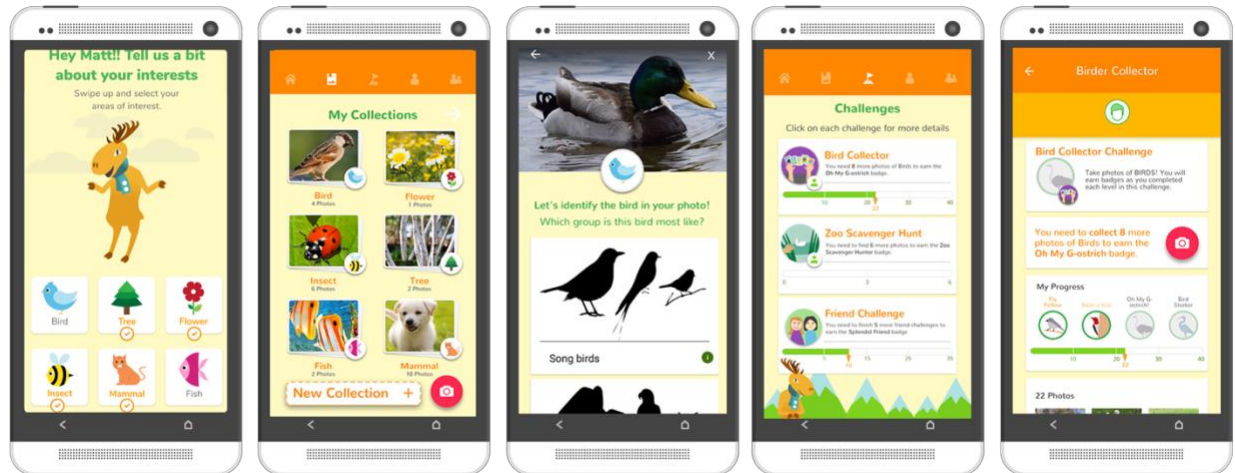


Figure 3.1: Screens of the NatureCollections app 1: Onboarding “What are your interests?” 2: My Collections. 3: Photo Classification. 4: Challenges. 5: Challenges details and progress

1. Design Principle 1: Personal Relevance

Onboarding Screens: During the onboarding process, a guide character refers to children by their name {1.3} and prompts them to enter their nature interests {1.2} (Figure 3.1, Screen 1). These interests are used to tailor which challenges they are presented during later use {1.1}. The character also provides an overview of available activities, badges, and social play {1.3}.

My Collections: Children are then prompted to add their photo to at least one “collection” (i.e., album). The app includes a set of standard collections for elements that will likely be present in their physical surroundings (e.g., birds, trees, flowers) {2.1, 4.2}. They are also able to create custom collections {1.1, 2.2}. After saving the photo, children are directed to the “My Collections” screen (Figure 3.1, Screen 2), where they can view all photos and associated descriptive text in each collection {4.1}.

2. Design Principle 2: Focused Attention

“Add Details” screen: To focus children’s attention on specific nature elements, the “Add Details” screen encourages children to reflect on and articulate observations of their photo {2.1,

2.2}. Children enter descriptive information using conversational prompts, such as a photo title (“What do you want to call this photo?”), caption (“How would you describe this photo?”), and location (“Where did you find this?”) {2.2, 3.1, 4.1}.

Photo Classification: To support focused attention and sensory engagement with an element of nature, the app provides a simple classification scheme for children to add additional information to their photo {2.1 2.2}. The classification scheme shown is determined by the preset collection associated with a photo (e.g., bird collection) {4.1}. Children are shown a series of stepped prompts to facilitate classification (Figure 3.1, Screen 3). The selected classification choices will show as tags, representing the child’s accumulated knowledge.

3. Design Principle 3: Social Interactions

My Friends: To encourage social involvement, the app allows children to add friends through unique usernames, and to view friends’ photos and badges on a “My Friends” screen {3.1}. Friends can be part of a team to complete challenges {3.2}. Friends can also challenge one another to match a photo they’ve taken to earn badges {3.1, 3.2}.

4. Design Principle 4: Opportunities for Continued Engagement

Challenges: The “My Challenges” screen presents a set of activities prompting children either to collect photos for a specific collection, classify the nature elements in photos, complete scavenger hunts, or challenge friends (Figure 3.1, Screen 4){2.1, 2.2, 3.1}. Challenges appear based on the child’s initial interest entered on the onboarding screen {1.1, 2.2}. Each collect or classify challenge has a series of four levels, requiring an increasing photo count to complete each level {1.2, 4.1}. These challenges can be setup for a team of children {3.2}.

Tracking Progress: A progress bar allows children to track their progress as they complete activities spanning days and settings (Figure 3.1, Screen 4, 5){4.1, 4.2}.

3.6 DISCUSSION

In this chapter, I have presented an Interest-Centered Design framework to guide the design of mobile technologies to reinforce children’s interest development. I have shown how the framework guided the design of NatureCollections, a developmentally responsive children’s application. Through a series of co-design sessions with children, we derived a set of empirical design strategies to implement the four theoretically derived design principles. These four design principles underpin the common characteristics that contribute to and encourage children’s interest development and include *focused attention on personally relevant content*, *supportive social interactions*, and *opportunities for continued engagement*. Because the characteristics appear in each phase of Hidi and Reninger’s model, our interest-centered design framework—and, by extension, the NatureCollections app that we designed using the framework—addresses all four phases of the interest development model. Our interest-centered design framework addresses the persistent problem of excessive interactions with mobile screens in nature (Hsi 2003; Lyons 2009), a major obstacle to supporting the kind of focused attention that is required for interest development and interest-driven learning (Hidi and Renninger 2006). Our framework leverages other aspects critical to sparking and sustaining interest development, such as personal relevance, social interaction, and opportunities for continued engagement (Hidi and Renninger 2006). Although prior work in designing children’s technologies for nature exploration primarily focused on supporting structured science inquiry in informal settings, I believe that future work on mobile learning technologies can leverage our design framework to design for interest-driven learning. Failure to take interest development into account may thwart efforts to provide rich learning experiences with mobile learning technologies.

Furthermore, the interest-centered design principles and strategies adhere to the conditions of developmentally responsive design (see Chapter 2). In addition to grounding the design framework in child development theory, a core principle of the ICD framework emphasizes social interactions—a core factor in supporting children learning experiences. Moreover, the framework’s strategies and the app features were co-designed with children, taking into consideration their developmental stage, and cognitive and motor abilities. For instance, the framework strategies encourage personalized user interfaces to account for children’s abilities and pre-existing interests and employ activities that extend their current knowledge to new content.

The interest-centered design framework can be used in the development of future mobile technologies that support children’s interest-driven participation in informal learning settings, such as in nature. Children’s technology designers can leverage the detailed design strategies along with the examples of the technical design features in designing developmentally responsive, interest-centered and learning-focused children’s applications. Additionally, the framework can provide guidance on evaluating existing interest-focused children’s mobile applications.

In the following two chapters, I evaluate multiple dimensions of the NatureCollections app design and by extension the interest-centered design framework. I present several observational and field deployment studies to examine how the NatureCollections app features (1) foster the underpinning characteristics of interest development in children (*RQ1.2*), (2) encourage children

to learn about and spend more time in nature (*RQ1.3*), and (3) impact their connectedness to nature (*RQ 1.3*). I also investigate the joint media family engagement (JME) framework in nature-based explorations and the broader context of parent-child tech-related tensions in the adoption of an app like NatureCollections by children and their families (*RQ1.4*). Findings from chapters 4 and 5 support T1 by helping to answer RQ 1.2–RQ1.4, and provide empirical evidence that incorporating child development theories into the design of children’s technologies can enhance the developmental responsiveness of the designs and support children’s interest-driven learning.

3.7 SUMMARY OF CONTRIBUTIONS

This work supports T1 by examining how designers can support children’s interest development (RQ1) and deriving theory-based design considerations to develop children’s interest in a topic when designing interactive technologies (RQ1.1). Interest-driven explorations play a critical role in supporting self-directed, personalized, and highly social learning experiences—core dimensions of child development. Specifically, I demonstrated the process of deriving Interest-Centered Design (ICD) principles from theory related to child interest development. Through a series of co-design sessions with children designers, we distilled strategies that guided the design of NatureCollections, a mobile application that engages children with nature-based exploration.

The work contributes (1) a theoretically derived Interest-Centered Design framework to guide the design of developmentally responsive children technologies that promotes interest development in a topic. (2) An artifact (*NatureCollections* App design) with a key purpose to compel new insights in child technology use in nature-based explorations.

CHAPTER 4. OBSERVATIONAL STUDIES OF NATURECOLLECTIONS APP

A growing body of research show that children’s direct nature interactions and positive experiences represent fundamental moments for creating a long-term connection with nature, and, ultimately, becoming committed stewards of the environment. Promoting children’s interest development hinges on experiences that support focused attention accompanied by positive feelings toward a certain content, as well as a predisposition to re-engage with the content repeatedly. In the previous chapter, I presented the interest-centered design framework to promote children’s interest in nature and enhance the developmental responsiveness of technology design. Drawing on Hidi and Reninger’s model of interest development, we derived a set of four design principles: (1) personal relevance, (2) focused attention, (3) social interactions, and (4) opportunities for continued engagement. Through co-design sessions with children, we developed design strategies to enact each of these principles (See Table 3-1). Using this framework, I co-designed *NatureCollection*, a mobile application that encourages children to go outside and take and curate photo collections of nature.

In this chapter, I examine how, and to what extent, the interest-centered design (ICD) principles and strategies embodied in the NatureCollections app trigger children’s interest in nature (RQ1.2). I collaborated with a team of researchers to conduct two observational field studies. The first evaluation study was an exploratory case study with 18 child-parent dyads, to investigate how, if at all, the features of the NatureCollections app trigger children’s situational interest in nature. This work was part of the same published paper documenting the work

described in Chapter 3 (Kawas et al. 2019). Prior research in the field of learning sciences emphasizes the role of parents in supporting their children's observations in outdoor settings (Eberbach and Crowley 2017; McClain 2018). To rule out parents' impact on how the NatureCollections app promoted children's interest in their surroundings, we conducted a second observational study with a comparison group at a local school with 57 sixth graders. This evaluation study assessed whether the NatureCollections app features supported the emergent behaviour of triggered situational interest in nature, in contrast to a group that used a basic photo app. We included the comparison group to ensure that any effects that we observed were not due simply to using a smartphone to take pictures of nature (Jake-Schoffman et al. 2017; Nayebi, Desharnais, and Abran 2012). This work was peer-reviewed and published in the International Conference on Computer Supported Education (CSEDU 2020)⁴.

In both of the observational studies, we decided to focus on the first crucial phase of the interest development model, because (1) a triggered situational interest is a precursor to all other phases of interest development (Hidi and Renninger 2006), and (2) the relatively short timescale for triggering a situational interest was appropriate for observational field evaluations of the app (Hidi and Renninger 2006; Krapp 2002, 2003; Pinkard et al. 2017). Additionally, both Rogers et al. and Klasnja et al. have argued that *in situ* field studies not only capture the context of use when evaluating a new mobile technology, but often uncover a range of design and usability problems that lab-based evaluations are unlikely to surface (Klasnja, Consolvo, and Pratt 2011; Rogers et al. 2007). The study's findings allowed me to evaluate T1 by determining whether

⁴ Kawas, Saba, Jordan Sherry-Wagner, Nicole Kuhn, Sarah Chase, Brittany Bentley, Joshua Lawler, and Katie Davis. 2020. "NatureCollections: Can a Mobile Application Trigger Children's Interest in Nature?" Pp. 579–92 in.

incorporating child development theory into the ICD design framework, and by extension the NatureCollections features, contributes to the app's developmental responsive designs in triggering children's interest.

4.1 EXPLORATORY IN SITU CASE STUDY WITH CHILD-PARENT DYADS

We recruited 18 children ages 7-11 ($M= 8.7$, $SD = 1.88$, 11 females and 7 males) and their parents through university email listservs and social media announcements shared on nature interest groups and neighborhood parent-social groups. Children were predominantly white (83.0%) and lived in households with a high annual income (47% had an annual household income above \$150,000), which is reflective of the relatively affluent part of Seattle, Washington, in which this study took place.

4.1.1 *Method*

We conducted three sessions with children using the NatureCollections app. Each session comprised five to seven children accompanied by their parents, held at a local park. In each session, we explained the study to both parents and children, answered questions, and obtained written consent and child assent from participants. We provided a brief introduction to the activity (i.e., verbal prompts to collect photos), before providing each child with a device and allowing them to explore the natural setting for 25-30 minutes. Researchers observed, took field notes, and asked children about their photo choices. There were three to five researchers per session. After the nature photo activity, researchers facilitated a closing group discussion, asking children to reflect on the activity and their app use experiences. We video recorded all sessions and retained children's photos.

4.1.1.2 Analysis

In our analysis of the video recordings and photos, we specifically focused on two key behavioral elements of a triggered situational interest: (1) focused attention and (2) social interaction (Hidi and Renninger 2006). Within the context of each behavioral element, we noted observational indicators to infer the affective states of participants, such as expressed cheerfulness, playfulness, enthusiasm, and excitement, as well as positive verbal statements. Because of the brief nature of the study and our focus on triggered situational interest, we did not focus our data collection explicitly on Design Principle 4: Opportunities for Continued Engagement.

To analyze the recorded sessions, we drew on video analysis strategies commonly used in the learning sciences, such as interaction analysis (Derry et al. 2010; Jordan and Henderson 1995). Two researchers watched the video recordings, coding for instances of focused attention (attention on nature, device, or people), as observed from behavioral indicators such as focused gaze on an item, the direction of the child's gaze, and verbal communication. We also coded for instances of social interaction mediated by app use or around nature elements. Through discussion, we identified salient segments for more in-depth analyses. Within these broad, etically defined (deductive) themes, researchers then open coded, allowing for the emergence of emic (inductive) sub-themes (Geertz 2008). Researchers matched their codes and descriptive observations, resolved any differences, and consolidated sub-themes to reduce overlap and redundancy. Finally, researchers repeatedly viewed the identified video segments to examine triggered situational interest moments, documenting them in detail and noting positive affect indicators.

To complement this analysis, two researchers also analyzed photos taken by children for further evidence of focused attention on nature elements. Researchers collaboratively developed a coding scheme (Smagorinsky 2008), and collaboratively coded each photo as belonging to one of three mutually exclusive categories based on the primary focus of the photo: (1) Selfies; (2) Other people; (3) Nature. Photos that were blurry or that researchers could not agree on were coded as a fourth category: Ambiguous.



Figure 4.1: A tactile interaction with a plant while using NatureCollections app.

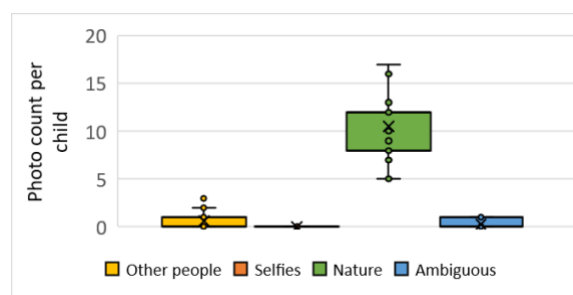


Figure 4.2: Primary focus of photos taken by children while using NatureCollections, coded as either other people ($n = 12$), selfies ($n = 0$), nature ($n = 200$), or ambiguous ($n = 5$).

4.1.2 Results

For each overarching, etically identified theme, we present salient emic sub-themes that emerged from our analysis. We include vignettes from transcribed video segments to illustrate how elements of a triggered situational interest may be supported by the NatureCollections app, and note indicators of positive affect observed in these moments. We also report photo content analysis results as an additional indicator of direction of attention.

4.1.2.1 Focused Attention – Direction of Attention

Participants using the NatureCollections app appeared to have their attention directed outwards, towards their physical surroundings, throughout the sessions. A key behavioral indicator of direction of attention was the direction of the children's gaze. We observed many instances of children shifting their gaze between the screen and their surroundings, as well as scanning their surroundings for elements of interest, suggesting that their attention was not solely on the device. Shifting of gaze to the device often occurred as children added descriptive information about their photo. Children often shifted their gaze to look at the actual object of interest, not the photo, when making qualitative observations to enter captions for the photo. Observing Emily illustrates this point:

Emily scans her surroundings for elements to photograph. She notices a cluster of spiked seedpods in the tree above her head, and takes a photo of them. When prompted to enter descriptive captions, she looks to her mother for guidance. Her mother, glancing at the app, asks: "What do you want to say about this?" Emily looks up at the seedpods above her head. "Ummm, spiky balls," she replies, and then giggles. "How do you spell spiky?" While Emily enters the caption with the assistance of her mother, several children nearby discuss the crow perched in the branches on the other side of the tree. Emily looks up, away from the screen, then finishes entering the caption. Then, looking up to the far side of the tree, she says, "Oh, if the crow was still there, I could take a picture of it and put it in the bird collection."

Children's gestures towards and discussion of elements in the environment, as well as exploring their surroundings in search of new objects to photograph, were considered behavioral indicators of directed attention. Indicators of positive affect associated with directed attention were

observed as children explored their surroundings. Children suggested playful captions (e.g., Emily’s “spiky balls”), laughed at photos they or others had taken, or expressed excitement at discovering natural elements.

An interesting element of the data was the occurrence of tactile interactions. While not observed in all children, in several instances, children photographed a nature element that they had physically interacted with in some manner. Several children picked up leaves or touched branches to examine or photograph them, or while using the classification scheme (see Figure 4.1), as this vignette shows:

Lily and Wade find several rocks and shells on the beach. They place each one in the sand, specifically positioning it for a photograph to highlight texture or lighting, like the iridescent interior side of a shell. Wade comments aloud that he appreciated how crisp and clear a shell appears in his photo, while touching the surface of the shell.

Lower device literacy and spelling skills presented barriers to some children’s directed attention outwards. This was most evident among the younger children, particularly at the “Add Details” screen. Although the app leveraged built-in speech-to-text, the majority of the children opted to enter captions using the keyboard with assistance from their parents.

Our review of the children’s photos complemented these findings. The majority (92.2%) of all photos taken were clearly of natural elements, whereas only a very small number were of peers and parents (5.2%). An even smaller proportion of photos were coded as ambiguous (2.2%), and no photos were coded as selfies (0%) (see Figure 4.2).

4.1.2.2 Focused Attention – Personal Relevance

Even while their attention was directed outward towards their physical surroundings, children employed their own individual criteria to choose which objects to focus on and photograph. Children explored their surroundings in search of objects that were interesting or unique, to be worthy of photographing, as this vignette illustrates:

David works towards the “Tree Collector” challenge, noting to his mother, “I need one more photo of a tree [to earn a badge]. I took a photo of that one, that one, that one...” as he pointed to specific trees around him. His mother points out several trees he had not indicated. David rejects her suggestions, one after another, articulating specific criteria. In one instance, he couldn’t see the base of the tree; in another, he was unable to see the leaves well enough to complete the classification scheme. He leaves the area to search for a different tree to photograph.

In several instances, children verbally expressed a disinterest in photographing the same object multiple times and sought diversity in photo subjects. In particular, children mentioned the desire to collect photos with a range of different tree shapes, in addition to different individual trees. This suggests the potential for the app to support children’s observation of their physical surroundings, as they seek to build diverse photograph collections.

When asked about his experience using NatureCollections, David compared his experience using the app to prior positive experiences using another app: *“It’s kinda like PokémonGo except without Pokémon. And in real life. So you collect trees, but as photos... so technically, in a way, it’s like PokémonGo, and the Pokémon are the [nature] photos... so it’s... NATUREGO!”*

Jessica described her experience with challenges: *“It gives me ideas on what kind of things to take pictures of... so I would look at the badges and take pictures based on how many pictures I needed to get that badge.”* When asked to reflect generally on their children’s experience of the app, several parents observed that their children appeared to have greater positive affect when using NatureCollections compared to previous experiences in the same location. As Jessica’s mother noted: *“She usually gets bored after 10 minutes of being at the park and wants to go home, but with this app she seemed to be engaged and running around looking for things to take photos of.”*

Although challenges prompted children to notice categories of elements, the children themselves chose the categories on which to focus. When asked, children explained their behavior in terms of positive affect, some expressing enjoyment in earning badges, and others expressing pleasure and interest in finding nature elements (e.g. flowers). Some seemed uninterested in the challenges or badges in general. Instead of adding their photos to pre-set collections, they created personally meaningful, custom collections (e.g., beach, feathers), searching for things that were unique or interesting to them.

4.1.2.3 Social Interactions – Peer Engagement

Although most of the children did not know each other before the session, they began interacting with the peers they met, looking for elements to take photos of together and sharing their screens with each other to show their photos and badges. Discussions between children included what they had photographed or would photograph next, and in which collection they would save the photo. Cooperative interactions also occurred, in which children collaborated to use the classification scheme to identify the elements in the photo they had taken.

Indicators of positive affect were most often observed in association with these social behaviors. Peer interactions tended to be playful, and instances of energetic interactions were most often observed among younger children in pair and group interactions. However, some children preferred to interact with their parent only. Most of the children who discovered the “Add Friends” feature quickly asked peers for their username and added them to their app. Children were generally less interested in taking pictures of people (see Figure 4.1), but a couple of children took photos of their parents and peers, adding them to their ‘Mammal’ collection or creating a custom collection for people, and often entering playful captions (e.g., “North Face Mom” and “Penguin Emojis”).

4.1.2.4 Social Interactions – Parent-Child Engagement

Parent-child interactions observed in the NatureCollections sessions varied across dyads. Some children appeared more dependent on their parents; this was most apparent in requests for direction and suggestions for photo subject, appropriate collections for photos, and descriptive text in the “Add Details” screen. Beyond directional suggestions, some parents supported close observations of specific elements in nature, as this vignette shows:

Yuri photographs a feather she found and works with her father to add details to the photo. After entering a title, her father says, “And then if you want to say something about it, that’s what ‘caption’ means. Do you want to say something about it?” Yuri hesitates. He continues, “Like... we didn’t put anything in here to tell us how big it is, right?” Yuri turns from the device and looks at the feather. “Small...” Her father replies, “Yeah, you could say small, or two inches, or something. That’s a good idea.”

Interestingly, parents also facilitated broader conversations around nature, such as which objects should be considered “nature” (e.g., Does a rock count as nature? Should the child take a photo of garbage and place it in a custom “litter” collection?). These conversations ranged from instructional to collaborative.

4.1.3 *Discussion*

Guided by the interest-centered design framework, I designed the NatureCollections app with the goal to encourage children to explore the natural world by creating, curating, and sharing nature photo collections, presented in the prior chapter. Through the exploratory *in situ* case study, I assessed whether NatureCollections may contribute to triggering children’s situational interest in nature. The study results show that NatureCollections succeeded in drawing children’s attention to and close observation of their natural surroundings. Specifically, I found evidence of children’s visual scanning of the environment, as well as tactile interactions with nature elements, such as feeling shells and sand texture, and holding branches and leaves in the process of making classification decisions. Children also engaged in nature-themed social interactions with their peers and parents as they used the app, showing how focused attention can go hand in hand with social engagement. Children demonstrated enjoyment while using the NatureCollections activities, including playful social interactions around nature with parents and peers. Consequently, these observed tech-mediated children’s behaviors facilitated positive child development. The developmental responsive design of the NatureCollections app fosters children’s curiosity, interest-driven learning, and cogitative growth. Moreover, the app encourages children’s social interactions with their parents and peers.

Several features of the app contributed to these results. First, children's experiences with the app were highly personalized (e.g., Onboarding screens, My Collections), a key factor in both interest development and interest-driven learning—core components of child development (Azevedo 2013; Hidi and Renninger 2006). They could choose what to photograph, which collections to build, and which challenges to pursue. Tracking accomplishments and earning badges contributed further to the personalized experience, particularly for older children. In prior work, children's experiences were not so highly personalized (Cahill et al. 2011; Kamarainen et al. 2013; Kuhn et al. 2011; Rogers et al. 2005; Zimmerman, Land, McClain, et al. 2015). We also identified supporting self-directed exploration and choices as being key to fostering situational interest. We acknowledge that one reason for this difference between NatureCollections and prior related work is the absence of a structured curriculum associated with NatureCollections. In our study, we did not dictate what children should photograph in part because we had no set learning objectives. Whereas prior work in mobile learning technologies has emphasized designing for scientific inquiry (Ahn et al. 2016; Cahill et al. 2011; Davis and Fullerton 2016; Kamarainen et al. 2013; Rogers et al. 2005; Yip et al. 2014; Zimmerman et al. 2010), our primary objective in the design of NatureCollections was to emphasize interest development, a critical component of interest-driven learning (Hidi and Renninger 2006). Nevertheless, we believe educators could use NatureCollections successfully in the context of a curriculum and associated learning goals without diminishing the personalized experience we observed in our study. The setting must be chosen carefully to align with the curriculum, and children be given autonomy within that setting to create, collect, and classify photographs that are most appealing to them. Follow up lessons could leverage children's photographs for further learning opportunities.

NatureCollections designs encouraged children to attend closely to their surroundings and engage in nature-based social activities. For instance, the “Add Details” feature of the app allowed children to describe their photographed nature element in their own terms and reflect on what they had photographed. When engaging with this feature, children prolonged their gaze and inspection of the nature element. They also engaged in conversations with peers and parents about the object of inspection. This feature contrasts to features used in prior work, such as AR features overlaid onto the natural world (Kamarainen et al. 2013) and just-in-time information to supplement the object of investigation (Cahill et al. 2010; Rogers et al. 2005). Such features can distract the learner from attending to the natural elements in front of them (Cahill et al. 2011; Hsi 2003; Lyons 2009). Unfortunately, in the current iteration of NatureCollections, younger children with lower language and device literacy found text entry challenging to use. Future work on NatureCollections is needed to design for a wider range of literacy skills.

Additionally, parents engaged with their children’s nature-based explorations might have influenced their children’s close attention and observation of natural elements in their surroundings beyond the app design. Prior learning sciences research emphasized the role of parents in supporting their children’s sense-making and observation in outdoor settings (Eberbach and Crowley 2017; McClain 2018). In the next study, I’ll evaluate the app with a group of children at a school setting.

4.2 OBSERVATIONAL STUDY WITH A COMPARISON GROUP

In the following observational study, we recruited a comparison group of children that used a basic Photo app, to ensure the effects of using NatureCollections that we observed in the *in situ* child-parent dyads study were not due to parental guidance or simply using a smartphone to photograph one's natural surroundings, and to rule out the novelty effect of using a smartphone—since most of the children in the study didn't own a smartphone. The Photo app—also titled NatureCollections with the same icon—consisted of two main features: (1) a camera feature with only a single shot (no other photo capture modes, filters, or video capabilities), and (2) a photo



Figure 4.3: a. Student taking a close-up shot of a flower b. One student pointing a nature element to her peers c. Students waling and scanning their surroundings

gallery.

4.2.1 *Method*

Our purpose in this evaluation study was to assess whether the interest-centered design framework facilitates the emergent behavior of personal interest, and to understand if and how the NatureCollections app design succeeds in triggering children's situational interest in nature. Although the design framework used to develop NatureCollections addresses all four phases of interest development, we chose to focus this initial evaluation study on the first phase, a triggered situational interest. A necessary precursor to the other three phases of interest development, a triggered situational interest incorporates the core dimensions of interest

development that pervade the entire model. Moreover, a triggered situational interest can be witnessed over the short-term, which was a practical consideration for this study. We operationalized interest by focusing on behavioral indicators of the four core dimensions of a triggered situational interest. This strategy is consistent with other work that uses proximal behavioral indicators as evidence of complex constructs (such as interest) (Moller et al. 2017).

4.2.1.1 *Participants*

Participants were 57 sixth graders aged 11-13 years ($M = 11.5$ years) attending a private middle school located in an affluent suburb in the city of Seattle. Students were predominantly White/Caucasian (73.5%) and lived in households with a high annual income (see Table 4.1 for complete demographic details). In a pre-survey, 100% of parents reported that their children use a tablet or phone daily, and 98% of parents reported their children own their own device. Prior to the study, we asked students about their general interests, hobbies, and favorite outdoor and nature-based activities and found no notable differences between the NatureCollections app and the Photo app groups. Students in both groups were far more likely to identify organized sports as a favorite activity than a nature-foregrounded activity.

Table 4-1. Demographic characteristics of participants, who shared their data (n = 49, across all classrooms).

Gender	Female (51%), Male (49%)
Age	Mean (SD) = 11.5 (0.54) Age 11 ($n=26$), Age 12 ($n=22$) Age 13 ($n=1$)
Race	White (73.5%), Asian/Pacific Islander (16.5%), Hispanic (4%), African American (2%), Middle Eastern (2%), Mixed (2%)
Household Income (US\$)	Less than 25K (2%), 25k-49K (2%), 50k-74k (4%), 75K-99K(4%), 100K-125K (14.5%), Over 150K (73.5%)

4.2.1.2 Procedures

We conducted the study with four different classrooms over a two-day period during their regular science class period. Since the study took place over two consecutive days and to account for weather and time of day effects (e.g., energy levels may vary before and after breaks), we used controlled random cluster assignments to assign the NatureCollections app and the Photo app to classrooms on both days. Two classrooms used the NatureCollections app (15, 16 students in each classroom, total = 31), and two classrooms used the basic Photo app (13 in each classroom, total = 26) (see **Error! Reference source not found.**). All four classrooms were told they were using a beta version of the NatureCollections app. Beyond introducing the researchers to the students, classroom teachers did not help the researchers run the study. They did, however, stay to observe their students and direct their questions to a researcher.

Table 4-2 App Class Assignment

App	Camera App	NG App
Day-1 Students Class Time	Class 1 13 Afternoon	Class 2 15 Afternoon
Day-2 Students Class Time	Class 3 13 Morning	Class 4 16 Morning

After explaining the study purpose, we divided the students randomly into small groups (4–5 students, 1 researcher per group). We obtained student assent, gathered parental consent forms, and administered a pre-activity questionnaire (described above). Researchers then led students in an outdoor icebreaker activity before introducing them to the photo-taking activity and handing out the phones with the app.

The photo-taking activity took place at a nearby urban community garden. Students in both groups were invited to explore their surroundings and take photos using the app for approximately 25 minutes. Researchers were careful not to prime children by discussing details

of the research project; rather, we asked them to help us try and give feedback on the nature app and reinforced that there were no right or wrong ways to use the app. In addition to videotaping the students' activity using chest-mounted GoPro cameras, researchers followed small groups of students to take observational field notes and ask them questions about their photo choices and app functionality. Following the activity, students returned to the classroom to participate in a semi-structured focus group discussion led by the researcher within their small groups. In this debrief discussion, we asked students about what pictures they took and their rationale for taking them, what they liked and disliked, and if they had suggestions for additional features.

4.2.1.3 *Data Analysis*

We used the video recordings of the sessions to examine triggered situational interest “moments” in detail across the two groups. The video recordings were central to our analysis; they included 18 total videos of the outdoor activity ranging from 25 to 29 minutes each. The recordings of the post-activity small-group discussions were secondary in our analysis; they included 18 debrief videos lasting approximately 15 minutes each. We analyzed our data thematically using both etic and emic codes (Boyatzis 1998; Maxwell 1996). Etic codes represented behavioral evidence of the core dimensions associated with a triggered situational interest: (1) personal relevance, (2) focused attention, (3) social interactions, and (4) opportunities for continued engagement. Due to the short-term nature of a triggered situational interest (and of our study), we did not expect to see robust evidence relating to continued engagement. Instead, we considered indicators that students were open to re-engage with the NC app if given future opportunities. Although we focused centrally on these etic coding categories, we also used a grounded theory approach to coding (Glaser and Strauss 1967) that allowed for emic themes to emerge directly from the data (Maxwell 1996).

We used interactional analysis and video research techniques to analyze the video data (Derry et al. 2010; Jordan and Henderson 1995). The 6 researchers who led the analysis were not involved with the NC app design process. Researchers individually created a content log for the GoPro video they captured, and conducted an initial coding based on the four design principles contained in the design framework. While logging, researchers flagged segments for more intense analysis and other salient emergent themes based on alignment with the interest development model (Hidi and Renninger 2006). After indexing the video data, the research team collectively viewed each video alongside its respective content log, stopping for group discussion at the identified flagged segments. Researchers resolved disagreements and came to consensus on the appropriate coding before moving to the next segment (Derry et al. 2010; Jordan and Henderson 1995). During this process, researchers highlighted “hotspots” representing triggered situational interest moments and examples of the emergent salient themes (Jordan and Henderson 1995). After the group viewing, three researchers repeatedly viewed the identified hotspots to document the triggered situational interest moments in detail.

We used the codes from the community garden activity analysis to code the video data of the post-activity focus group discussions. Two researchers viewed one video from each app assignment and coded it together to establish agreement. One researcher then coded the remaining videos and transcribed students’ responses for each small group. We chose not to analyze the content of children’s photos, as photo content itself does not offer deep insight into students’ attention, intent, or experience. Instead, we focused on qualitative observational and interview data to gauge children’s interactions with the app and their interest in nature.

4.2.2

Results

I present results from our analysis exploring the relationships between our etically derived interest development themes: *Personal Relevance*, *Focused Attention*, *Social Interactions*, and *Opportunities for Continued Engagement* and the students' interactions with the assigned app and their natural surroundings. In addition, I discuss two related themes that emerged emically: *Science Discourse* and *Mobility*. I include vignettes from the video data (outdoor activity and focus group debriefs) to illustrate how NatureCollections features supported specific dimensions of a triggered situational interest, followed by our observations of the Photo app group. **Error! Reference source not found.** shows an overview of the relationships between the emergent themes from our data analysis and examples of specific NatureCollections app features for each of the four dimensions of situational interest.

4.2.2.1 *NatureCollections App Group*4.2.2.1.1 *Personal Relevance*

We observed several instances where the students verbally indicated a connection between the NatureCollections app and their existing interests (**Error! Reference source not found.**, top left). NG features allowed students to choose the nature photos they wanted to collect, as one student expressed aloud while selecting her interests on the onboarding screen, “*Oh my god, I forgot about rocks, rocks are like my favorite things. I had so many rock pets when I was younger*”.

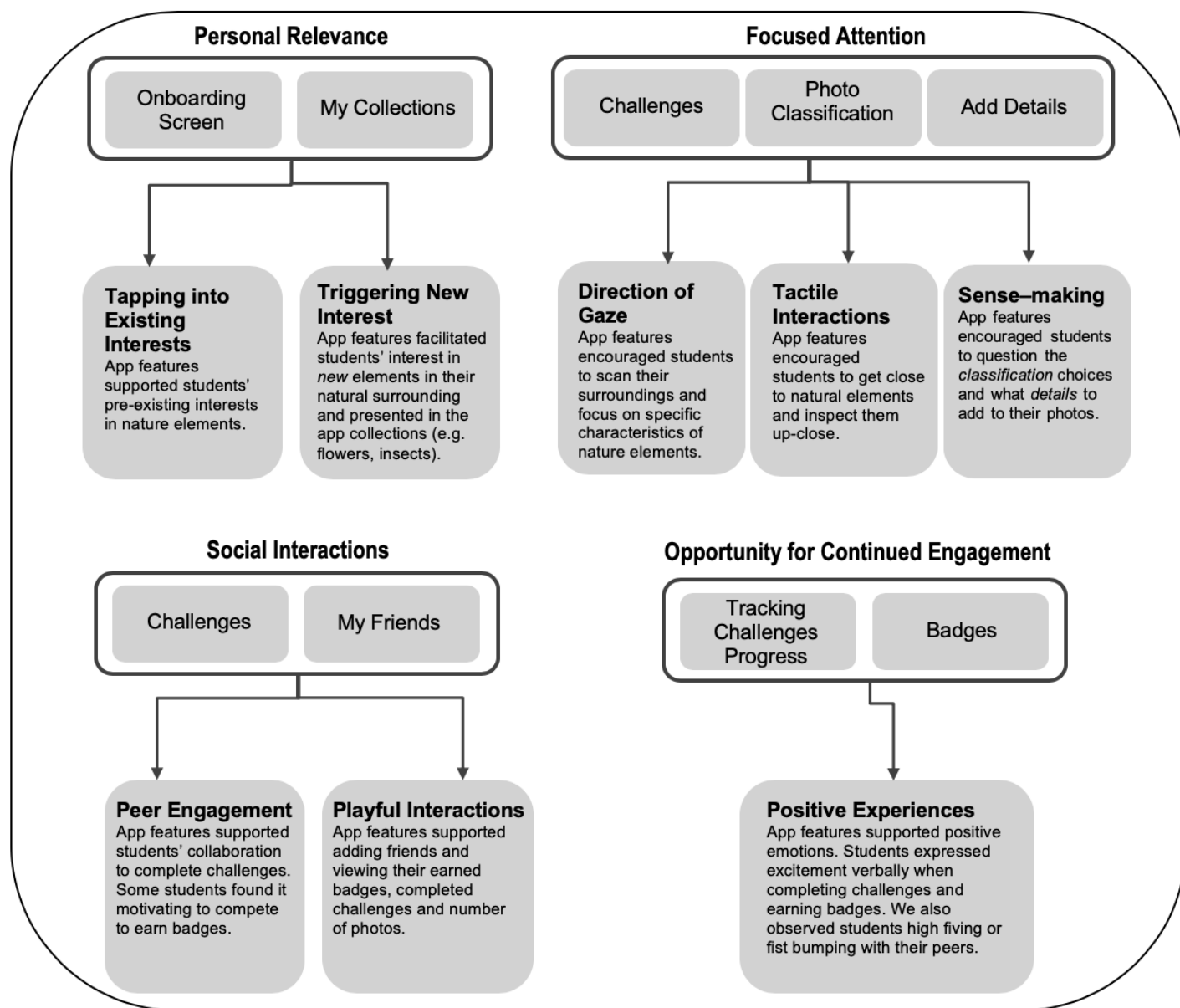


Figure 4.4:The relationship between individual dimensions of situational interest, examples of specific NatureCollections app features, and themes from our data analysis.

We also noticed that the NatureCollections app features, such as “My Collections,” prompted students to notice and take interest in unexpected and unsought elements in their surroundings (**Error! Reference source not found.**, top left). One student described to a researcher the

pictures he was taking, *“I’m just finding insects for my collection, that’s all.”* He then said, *“I lost it!”* and pointed his phone up in the air and said, *“Oh, there! I see it”* while another student crouched down next to him and lifted his phone up higher and exclaimed, *“They’re too small”* (referring to the insects). The first student then pointed to the area where the insects were and said, *“Yeah most of them, they’re right there.”*

During the small group debriefs, several students mentioned that their choice of photos was driven, in part, by things they were already interested in, such as rocks and flowers. For example, one of the students explained, *“I took photos of flowers because I like flowers,”* and she continued saying, *“I got excited when I found flowers to take pictures of.”* Another student said *“I took a photo of Winston”* When the researcher asked, *“Who is Winston?”* she replied, *“It’s my pet rock, I named it”* showing the researcher and her peers the photo of the rock.

Students across the small groups noted that they liked the Collections feature. They observed that it helped them to organize their photos based on their interests, as this student explained, *“I took pictures because it was a collection of photos, so I was not just taking random photos...and I like small plants, so I took photos of them.”* Students also indicated they liked being able to create their own custom collections.

4.2.2.1.2 Focused Attention

Direction of Attention: Students in the NatureCollections app sessions appeared considerably more focused on their surroundings than their device (**Error! Reference source not found.**, top right). The teacher in attendance remarked to a researcher, *“For a person who experiences them daily, this is what ‘focused’ is.”* When students did look at their device, their gaze alternated

between the app and the nature element. This typically happened when they were photographing, entering captions, or completing a classification for a nature element.

We observed that specific app features prompted students to focus on their surroundings. For instance, the “Challenges” encouraged students to search for specific nature elements, which led them to focus much of their gaze on scanning the community garden as opposed to observing objects through their device screen. One student mumbled while looking closely at several garden plots, *“I need two more photos of flowers.”*

Sense-Making: When students classified a photo using the “Classification” feature, the prompts encouraged them to focus on specific characteristics of a nature element. In one instance, three students looked at the ground, having finished photographing a pale spaghetti squash and now trying to classify it. Moving their gaze between the ground and their app, these students discussed which details and classification to assign to the photo (**Error! Reference source not found.**, top right). One said, *“That’s an egg,”* another responded, *“I know it’s an egg,”* and a third student said, *“No it isn’t, it’s a plant, it’s a squash, can’t you see the stem?”* The second replied, *“Oh yeah, it is,”* and the third continued, *“That has to be like an ostrich egg.”*

Tactile Interactions: Students also interacted tactilely with particular elements while photographing them (**Error! Reference source not found.**, top right). We observed students, while adding details or classifying their photos, move closer to plants to touch leaves or kneel to feel the grass. For instance, one student, when trying to determine whether a plant was cabbage,

moved closer to touch its large leaves. Several other students knelt to get closer to the ground to touch and take photos of an insect they had spotted. (See Fig 3-1 for the classification screen).

4.2.2.1.3 Social Interaction

Peer Engagement: Social interactions started immediately upon engaging with the NatureCollections app, with students helping peers discover new app features (**Error! Reference source not found.**, bottom left). Throughout the activity, students engaged in robust social interactions that involved not only showing each other their photos and earned badges, but also copying each other by photographing nature elements that their peers showed interest in or had photographed. They also provided suggestions to each other on which nature elements would be interesting to photograph, and helped each other find photos to complete challenges. In one instance, a student ran up to her friend, who was crouched down taking a photo of a plant, and excitedly told her, *“I found a purple flower!”* Her friend asked where, and she gestured for her friend to follow her. They both walked quickly to a garden bed where she pointed to a flower close to the ground. Her friend immediately crouched down to take a close-up photo of the flower and then she checked her friend’s progress with the flower challenge.

NatureCollections app students were often exploring together and engaged in collaborative discussions about what they found and how to name or categorize their photos as with the example of the *“ostrich egg, spaghetti squash”* above. In another instance, a student took a photo of the same shrub as his friend and asked, *“Oh, what should I put in here? [referring to the Detail screen],”* to which his friend responded *“shrub, I guess.”* The first student exclaimed, *“Oh snap! Yeah, I earned a new badge!”* and his friend replied, *“It looks like I earned a badge, too.”*

We also observed more competitive interactions between students, such as comparing their total number of photos, completed challenges, and earned badges. One girl remarked, “*You made it a competition,*” while another responded, “*If it is a competition that means I won [referring to their badge counts].*” Students seemed to find competing to earn badges motivating to find new types of nature elements to photograph.

Playful Interactions: Students seemed to be having fun with each other when they were using the NatureCollections app, showing excitement when they were sharing what they noticed. In one instance, a student excitedly called to his friends, “*Oh come here! Come here! I wonder what this is!*” kneeling to get close to a plant, “*this is so cool!*” His friend responded, “*It’s a spiky broccoli*” following his friend to take a photo of it as well. Students had fun exchanging ideas about what captions to add to their photos. While photographing a stone figure, for instance, one student referred to it as a “*fat snail*” and both giggled. The other said, “*Put it in the Stones and Amphibians collections*” and continued to laugh. Students also celebrated with each other when they earned a badge; for example, we observed three students high fiving each other when they earned a badge for taking a photo of a rock.

4.2.2.1.4 Opportunities for Continued Engagement

Due to the short duration of the study, we did not anticipate that our analysis would uncover substantial evidence relating to opportunities for continued engagement with the app. Nevertheless, we did identify several indicators that we believe increase the chances of students’ re-engagement with the NC app (**Error! Reference source not found.**, bottom right). For example, students’ evident engagement in the activity and their positive emotions—both described above—suggest they would be inclined to use the app again in the future.

Students expressed verbally in the post-activity discussion that they would use the app if they had it on their own devices. Several students said they were motivated by the challenges and desired to earn badges. One student in the NC app session explained, “*Getting [the] Aspiring Botanist badge makes me want to earn more badges.*” He continued “*I’ll probably do the challenges...I think this would get me outside more...like Facebook draws you in.*” This positive desire for continued engagement frequently manifested in the post-activity discussions, as students talked about the many ways they were interested in continuing to use the app beyond the session to document nature on hikes, while camping, and even in their own home gardens.

4.2.2.1.5 Science Discourse

Certain features of the NC app appeared to facilitate discussions between students about the natural elements in the surrounding area of the activity. Students engaged in science discourse as they collaborated to categorize their photos in collections and when choosing the classification options (**Error! Reference source not found.**, top right). For instance, one student asked his friend, “*Are humans mammals?*” while trying to classify the photo he took of his friend. Another student pointed out to his friend, “*Did you see the hummingbird?*” then added as he was trying to classify the photo he took, “*Is it a songbird?*”

Several other students asked their science teacher repeatedly about the plants they did not recognize. At one point, two students were asking the teacher questions about plants when a student, crouching on the ground, exclaimed to get his teacher’s attention, “*Wooo! Is it a broccoli?*” At the same time, another student moved close to touch a plant and asked the teacher, “*Is it a cabbage?*” The teacher pointed to the plants in sequence and explained, “*We got kale,*

chard, and this, I don't know what this is, but I have seen it at the grocery store.” Then another student said *“Is it rainbow choy?”*

Students also discussed the influence of seasons and geographical location on the nature elements they observed, noticing that some plants grow in certain seasons, as illustrated by the earlier example of one student who wondered how she could find a flower in winter. Students also discussed animal behavior. As one student searched for an animal to complete the mammals challenge, another student said to him, *“There’s no animals out in the rain.”*

4.2.2.1.6 Mobility

Across all of the NatureCollections app sessions, we observed students moving at a slower speed and scanning their surroundings more carefully as they searched for natural elements to photograph in the community garden (**Error! Reference source not found.**, top right). We hypothesize that this intentionality of movement supported their focused attention on nature. Students were also more likely to kneel down and position themselves closer to the natural elements they saw while using the NatureCollections app.

In addition, we noticed that students in the NG sessions showed distinct patterns of movement in small groups as they explored their natural surroundings together. Compared to the Photo app groups, NatureCollections app students were more likely to move in clusters and stay closer to friends, whether to compete or collaborate on completing challenges and identifying the elements in the community garden (**Error! Reference source not found.**, bottom left). We suggest that this spatial mobility was also critical to how students influenced each other’s photo

choices, as they were more likely to point out and discuss natural elements in their surroundings when they moved together.

4.2.2.2 Basic Photo App Group

Compared to students using the NC app, students in the Photo app group displayed notably different patterns of behavior in each of our four etic and two emic themes, as described below.

4.2.2.2.1 Personal Relevance

Overall, we documented less evidence of students forming a personal connection to the activity when using the Photo app. When we did see a personal connection, it tended to be around photography rather than nature. In one of the sessions, for example, a student uttered, *"I love photography,"* and a fellow student responded, *"I know, same"* while they were both capturing photos using the Photo app. This finding is not surprising when one considers that the two main features of the Photo app were the photo capture and photo gallery; nothing in the app prompted students to connect personally with nature beyond the name of the app (NatureCollections) and the researcher's initial prompt to take pictures of nature during the activity.

4.2.2.2.2 Focused Attention

In the Photo app sessions, students' interactions with their surroundings appeared to be mediated primarily through the device. The majority of the students looked through their phone screens to frame potential elements they considered photographing. For instance, one student mumbled while focusing the photo on a specific shrub, *"Let's take some more pictures of this."* Throughout the interaction, his gaze remained on the screen; he never looked directly at the bush. Students' attention seemed to be focused on the aesthetic aspects of nature elements when deciding what to photograph. When asked in the post-activity focus group sessions, students

explained that vivid colors, light patterns, and unique shapes were things they were interested in capturing. One student explained, *“Anything that’s brightly colored or seems unique,”* and another replied, *“Really colorful stuff, colorful plants, colorful step stones, or yeah, like plants.”* Students also mentioned the composition of elements, experimenting with different camera angles when framing photos. For instance, one student showed a researcher a photo he had taken of a small plant, noting, *“Look, I sorta make it look like a tree... I took it from underneath.”* We did not observe students articulating observations of specific non-aesthetic characteristics (e.g., identifying the type of plant), as we did in the NC groups. We also did not observe students in this group move closer to or touch the different nature elements they photographed.

4.2.2.2.3 Social Interaction

Students in the Photo app groups displayed notably different patterns of peer interaction, engaging in fewer app-related, nature-focused interactions with their peers. The interactions were more likely to be mediated through the phone screen as students took photos of one another and played offline games. For instance, we observed a group of students walking around the community garden together. They slowed down together in three different areas and spent no more than 5 seconds in each area. They had little interaction with each other while taking photos, which were often of different things. There was little discussion among them about their photos. The playful interactions we observed in this group typically consisted of posing for or taking photos of and with their peers rather than nature. During the post-activity debrief, students were excited to share with researchers the photos they had taken of themselves and their peers.

4.2.2.2.4 Opportunities for Continued Engagement

Overall, during the Photo app session, we did not observe the same level of excitement among students using the app. On the contrary, many students appeared to be disengaged from the photo-taking activity. Nearly two-thirds of the students in one session turned to an offline game on the device's default browser (the phones had no data plans and were not connected to WiFi) out of self-reported boredom.

4.2.2.2.5 Science Discourse

Similar to the NC app groups, we did observe some students discussing what counts as nature. However, these conversations appeared to be prompted primarily by the title of the app (NatureCollections). For instance, one student yelled when his friend tried to take a picture of a garden trellis grid, "*That's not nature enough!*" In fact, one group of students thought that the Photo app could only take photos of nature. They quickly abandoned this idea (and their focus on their natural surroundings) when they tried to take a selfie and the photo appeared in their gallery.

4.2.2.2.6 Mobility

During the Photo app sessions, students appeared to be more aimless and wandering in their movements. We observed students move faster through different parts of the environment, snapping pictures in a seemingly haphazard way. In these sessions, students displayed a tendency to search alone for things to photograph, and they gave photos only momentary focus before moving on. This led to students being scattered and spread out in different directions during the activity.

4.2.3

Discussion

In the second observational study, we investigated whether and how the NatureCollections app as a whole succeeded in triggering children's situational interest in nature in comparison to the basic Photo app. Our analysis of sixth-grade students' interactions with NatureCollections showed that the app's features collectively supported the four behavioral elements of personal interest that we investigated: *personal relevance*, *focused attention*, *social interaction*, and *positive experiences for continued engagement* (See Figure 4-4 for details on the relationships between the app features and the individual dimensions of situational interest). In addition, we documented two emergent themes in the NC app group: children's distinct patterns of *mobility* around the community garden and their engagement in *science discourse* with peers. Both of these behaviors related to and supported the four dimensions of interest development. Our findings point to the effectiveness of the interest-centered design framework used to design NatureCollections (Kawas et al. 2019). We conclude that, collectively, the design strategies embodied in the NatureCollections app hold promise for solving the problem of children's decreased time spent and interest in nature (Clements 2004; Holt et al. 2015; Lohr and Pearson-Mims 2004), with implications for supporting interest-driven learning about nature (Klemmer, Waliczek, and Zajicek 2005; Louv 2008).

The video analysis revealed how the design features of NatureCollections supported specific dimensions of the interest development model (Hidi and Renninger 2006). Moreover, our analysis of the students in the comparison Photo app group showed that the *absence* of these design features produced notably different behaviors in children. For instance, the NatureCollections app succeeded in supporting children's *focused attention* on the natural

elements in their surroundings through features such as “Challenges,” which prompt children to search for specific elements in nature, and “Photo Classification,” which requires children to focus on specific characteristics of an element in order to identify it. Although children in the basic Photo app group also focused their attention on natural elements in their environment, the Photo app’s limited palette of features, both of which emphasized taking pictures rather than exploring nature, resulted in focusing children’s attention on the act of setting up and taking aesthetically pleasing photographs rather than on the characteristics of the nature element they were photographing. In this way, the Photo app functioned much like prior outdoor mobile learning technologies, which have consistently faced challenges associated with focusing children’s attention on their device at the expense of engaging with their surroundings (Cahill et al. 2010; Kamarainen et al. 2013; Sobel et al. 2017).

Similarly, the “Onboarding” and “My Profile” features, among others, supported children’s self-directed, *personalized exploration* of nature. Lacking such features, children in the Photo app group tended to connect personally to the act of photography, if they formed a personal connection at all. Self-guided, personalized exploration also had the effect of drawing children’s attention to surprising elements in their surroundings, which they experienced as enjoyable, particularly when they shared them with their friends. Children using the NatureCollections app displayed excitement engaging with their environment and with their peers, and they conveyed their interest in *continued engagement* with the app beyond the study session. In contrast, children using the basic Photo app quickly lost interest in both the app and the activity. These differences suggest that it was the NatureCollections app and its unique set of design features,

rather than the mere novelty effect of using a smartphone to take photographs of nature, that succeeded in triggering children's situational interest in nature.

Although our analysis focused on teasing out individual design features and tying them to specific behavioral indicators of interest development, we underscore that it is the system *as a whole* that supported the emergent behavior of a triggered situational interest in nature. To help make this point, consider the findings related to *social interaction*. Children in both the NatureCollections sessions and the Photo app sessions engaged in social interactions with their peers during the activity. However, features such as “My Friends,” “Challenges,” and “Badges” shaped children's social interactions in distinct ways compared to the basic Photo app group. Importantly, the distinct quality of social interactions we observed in the NatureCollections sessions appeared to support other key dimensions of Hidi and Reninger's interest development model. For example, children helped each other discover the app's various features, such as how to use the “Photo Classification” and “Challenges” features to tailor a *personally relevant* and meaningful app experience that involved *focused attention* on nature. They further supported each other's focused attention by exploring their environment together, giving each other suggestions about what to photograph, and helping each other to classify the nature elements in their pictures. In addition, their playful interactions around collecting, classifying, and earning badges contributed to their engagement in and enjoyment of the activity, which we interpret as increasing their likelihood to *re-engage in the activity in the future* (Azevedo 2013; Hidi and Renninger 2006).

By contrast, the social interactions we documented among children in the Photo app sessions were centered to a greater degree on taking photos of each other rather than exploring and taking photos of their natural surroundings. These social interactions were neither nature-oriented nor were they supportive of the other dimensions of interest development. This example highlights the novel contribution of this work: we have provided empirical evidence that embodying the design strategies of the interest-centered design framework in a complete system (NatureCollections) can support children's development of interest in nature.

4.2.3.1 *Study Limitations*

This study included students from an affluent school, limiting the generalizability of the results. Moreover, although the participants' racial diversity was reflective of the city of Seattle in which the study was conducted, it is not representative of the broader US population. As prior research has shown, attitudes and experiences with nature are influenced by demographic variables (Lohr and Pearson-Mims 2004; Louv 2008). Therefore, it would be useful to evaluate the NatureCollections app with students from diverse backgrounds to determine whether they respond differently to the app. Further, the current study was conducted as part of a school-based science class and took place in a natural setting (i.e. community garden). Students' behaviors with the app and the outdoor activity might be different in other contexts (e.g. urban settings) when they are not surrounded by nature and when they are not being observed by their teacher.

4.3 SUMMARY OF CONTRIBUTIONS

These studies provide empirical evidence to evaluate T1 by examining the question of how, and to what extent, do the interest-centered design principles and strategies embodied in the NatureCollections (NC) app trigger children's interest in nature (RQ1.2). By identifying the

relationship between individual dimensions of interest development, specific NC app designs, and the themes of children's behaviors that emerged in our data analysis, I document the design opportunity of incorporating theory into applicable design recommendations to facilitate the responsiveness of design to aid in children's positive developmental tech-mediated experiences. The studies' findings demonstrate that the NC app succeeded in triggering children's situational interest in their natural surroundings. This evidence supports the effectiveness of the interest-centered design framework that we used to design NatureCollections. In addition to showing how the app's features supported specific dimensions of the interest development model (e.g., children's focused attention and personalized exploration of nature), our analysis also uncovered emergent themes related to children's scientific discourse and distinct patterns of movement through nature while using the NC app, in comparison to the Photo app group. These emergent themes complement the interest development framework and provide insight into its specific instantiation through the NatureCollections app.

CHAPTER 5. NATURECOLLECTIONS APP FIELD DEPLOYMENT STUDY

In the previous observational studies, I presented how the interest-centered design framework embodied in the design of the NatureCollections app succeeded in triggering children’s interest-driven explorations— a critical component of positive developmental experiences in children. However, to determine whether the NatureCollection app succeeds at encouraging children to go outside and providing opportunities for continued engagement with nature-based explorations over a longer period of time, I deployed the NatureCollections app in a three-week experimental field study. Prior research emphasizes repeated direct nature interactions and positive experiences during childhood in fostering a long-term connection with nature, and establishing pro-environmental behaviors in adulthood (Giusti et al. 2018; Ives et al. 2017; Tam 2013). In this study, I conducted a mixed-methods investigation with several collaborators to examine children’s longer-term engagement with NatureCollections, focusing specifically on how the app impacted children’s time spent outside and influenced children’s connectedness to and positive interactions with nature. I ask the following research questions (RQ1.3): Does the NatureCollections app succeed at getting children to spend more time outside? And does the app impact their connectedness to nature? This work was peer-reviewed and published in the ACM conference on Interaction Design and Children (Kawas, Kuhn, et al. 2020)⁵.

⁵ Kawas, Saba, Nicole S. Kuhn, Mina Tari, Alexis Hiniker, and Katie Davis. 2020. ““Otter This World’: Can a Mobile Application Promote Children’s Connectedness to Nature?” Pp. 444–57 in *Proceedings of the Interaction Design and Children Conference, IDC ’20*. New York, NY, USA: Association for Computing Machinery.

Additionally, in this study, I explore the design needs for joint family nature-based explorations with the NatureCollections app. One of the main components of the positive technological development (PTD) model to foster children’s developmental needs is to consider children’s situated tech-based experiences in various social contexts (Bers 2012). Particularly, the PTD model emphasizes designing to consider the dynamics of parent-child interactions and shared play experiences among children peers. During the *in situ* case study with child-parent dyads in Chapter 4, we observed the likelihood that the app’s design is positioned to encourage nature-based interactions between children and their parents due to the app’s emphasis on engaging children in personally relevant activities, encouraging social interactions (including with parents and siblings), and providing opportunities for continued joint engagement with nature. To distill design implications for an app to engage children and their parents in a joint family nature-based explorations, I examined parents’ and children’ shared experiences using NatureCollections over two-week period of app use through a transitional period of parent-child relationships (RQ1.4) This work was peer-reviewed and published in the ACM conference on Human Factors in Computing Systems (Kawas et al. 2021)⁶.

Exploring these scoped questions (RQ1.3 and RQ1.4) provided me with empirical data that is relevant to evaluating the broader implications of T1, by determining the long-term NC app interactions effects in promoting positive development in children, and whether examining

⁶ Kawas, Saba, Nicole S. Kuhn, Kyle Sorstokke, Emily Bascom, Alexis Hiniker, and Katie Davis. 2021. “When Screen Time Isn’t Screen Time: Tensions and Needs Between Tweens and Their Parents During Nature-Based Exploration.” Pp. 1–14 in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. New York, NY, USA: Association for Computing Machinery.

parents' and children's shared experiences could inform the design of joint family nature-based explorations.

5.1 NATURECOLLECTIONS AND CHILDREN'S TIME IN NATURE

5.1.1 *The Three-Week Experimental Study Design and Method*

We recruited 32 children between the ages of 9 and 12, and one of their parents (one child-parent pair per family) to participate in the study. Twenty-eight families (15 = NC app; 13 = Photo app) completed all the procedures and were included in our final sample. Of the families who dropped out of the study, one (Photo app) did so in the first week before the child received the phone. The second family dropped out after receiving the phone and the child never used the app (Photo app). The last two families (Photo app, NC app) did not complete the final interviews and dropped out in the last week of the study after their children used the app (Table 5-2).

5.1.1.1 *Recruitment*

We recruited families that had at least one tween child between the ages of 8 and 12 years. We attempted to recruit a diverse sample with respect to race, household income, and education level using a variety of recruitment strategies. We distributed flyers at local libraries, schools, and community centers throughout the metropolitan region where the study took place. We also posted the study announcement via a campus-wide news post and shared it in a local magazine. Authors used their personal social media accounts to share the study and we posted it on local parent Facebook groups. We had 164 qualified families interested in the study. We divided the children's families into two groups based on whether they reported that tween owned a handheld smart device (e.g. smartphone or iPod touch) or not.

Table 5-1. Demographic characteristics of participants

Demographic Variable		NC	Photo
		N	N
Gender	Female	9	9
	Male	6	4
Age	Age 9	8	3
	Age 10	5	5
	Age 11	0	2
	Age 12	2	3
Race	White or Caucasian	8	8
	Black or African American	1	0
	Asian / Pacific Islander	1	1
	Mixed	5	4
Household Income (US\$)	Less than \$25,000	1	0
	\$25,000 to \$49,999	0	0
	\$50,000 to \$74,999	2	5
	\$75,000 to \$99,999	1	1
	\$100,000 to \$149,999	4	2
	\$150,000 or more	7	5
Parent's Education	High school graduate	1	0
	Trade /Vocational	3	1
	Associate's degree	2	0
	Bachelor's degree	5	8
	Graduate degree	4	4
Child Lives with Parent	Yes, Full-Time	14	13
	Yes, Part-Time	1	0

We then emailed equal numbers of families from each group based on the order they had signed up for the study to schedule the initial interview for the deployment study. We contacted a total of 151 families to schedule the initial interviews, and it took 3 weeks to complete the recruitment and the initial interviews. We gave families the option to meet us on campus, located in the center of the city, or at their neighborhood library to encourage the participation of lower socioeconomic families. Our final sample skewed towards upper- and middle-class families; however, it mirrors the race distribution of the urban city where the study took place. Families also reported living in neighborhoods that were distributed across the city metropolitan area. Table 5-1 shows participants' demographics. Families received a \$25 gift card after completing

the initial interview and the first week of the study, and a \$50 gift card once they completed the final interviews.

5.1.1.2 *Study Design*

We conducted a three-week experimental study in which we used a stratified random sampling approach to assign an equal number of participants to one of two conditions: (1) the intervention group, who received the NatureCollections (NC) app (NC condition), or (2) the active control group, who received a basic Photo app (Photo condition). Within each condition, children were equally distributed based on the following factors: (1) whether they had their own handheld device; (2) whether they were an only child or had siblings; and (3) their birth order in the family. Of the participants who finished the study, 15 were in the NC condition and 13 were in the Photo condition. We chose to include an active control group to determine whether the novelty of being given a smartphone and being prompted to take pictures of nature would, on its own, impact children's time outside and interactions with nature (Jake-Schoffman et al. 2017).

To eliminate any recorded changes or differences between app conditions due to chance, we used a multiple baseline experimental design, where the start date of the three-week study was staggered over two weeks across three groups of families (10, 10, and 8 families who completed the study in each group). The app condition was randomly assigned to equal numbers of families within each of the three groups. See Table 2 for details on condition assignment and group start dates.

The experiment was a 2x2 mixed factorial design with the following factors and levels:

◆ *Condition: NC, Photo* ◆ *Intervention: Pre, Post*

The between-subjects factor was the app condition (either NC or Photo), and the within-subjects factor was the intervention period, as both groups submitted journal entries during baseline and intervention phases. We also collected three measures of children’s behaviors during both baseline and intervention periods: (1) time spent outside, (2) time spent on technology (both measured by self-reported diary entries from parents (Ross et al. 2007)), and (3) during the intervention period, we collected time spent on the assigned app (measured by app log data from children’s devices).

Table 5-2. Group start dates

Group	NG N	Ph N	W N	Total N
Week 1	5	4	2/Ph	12
Week 2	5	5		10
Week 3	4	4	1/Ph, 1NC	10
Total	15	13	4	32

Note. NC: NatureCollections, Ph: Photo app, W: Withdrew.

5.1.1.3 Study Procedures

Parent diary entries: During the first week, we asked parents, with the help of their child, to fill out a daily journal of their child’s total time outside and type of outdoor activities, as well as time spent using screen-based technologies, and type of tech-based activity. The goal was to establish a stable baseline of these activities for each child in our sample before introducing the app condition. In the second week, families received (either in person or in the mail) a phone with either the NatureCollections or the Photo app installed. Parent-child pairs were asked to continue filling out the daily journal throughout the second and third weeks. In addition to

recording children's total time outdoors, they were asked to report instances of using the NatureCollections/Photo app, including time, location, and a brief description of the context of use. We collected 21 diary entries per parent-child pair, for a total of 588 entries from all participants. Five parent-child pairs missed a total of 25 entries.

Log data: Both the NC app and the Photo app logged all of the children's interactions and input into the phone. These data included time on app, features used, and geo- and time-stamped photos taken by each child. Our NC app has a backend server to store user data once the device is connected to WiFi. We used Firebase to store the data from the Photo app.

Ecological momentary assessment (EMA): EMA involves repeated sampling of participants' *in situ*, real-time behaviors and experiences (Ross et al. 2007). Over the two-week period, children were asked to periodically complete two short surveys, detailed below, using the study phone at specific times: after their first app use, then twice during the two-week app use period and one final time on the last day of the study. We used the Snap Mobile Anywhere Survey app, which captures audio responses to questions and does not require cell phone data to submit. The two surveys we administered were:

(1) *audio reflections:* The first survey had three audio reflection questions asking children to (a) describe what photos they had taken and why; (b) things they liked about the app; and (c) things they disliked.

(2) *outdoor experiences:* The second survey asked children about their outdoor time using the app. We asked (a) if they feel happy or less happy to go outside, (b) if they'd like More time or Less time in nature, and (c) if they feel very excited or not excited to

use the app in nature. For each of these questions, children had the option to record an audio reflection further explaining their answers.

Children's post-experiment outdoor activity: After completing all experimental procedures, parents and children were invited to participate in a final, audio-recorded interview held at the university campus. Parents were asked about their family experiences having their child use the assigned app and clarifying questions about their daily journal entries. While parents were being interviewed, children participated in an outdoor activity in which they showed a researcher how they used the app and shared their thoughts and experiences around their app engagement. Those activities were audio- and video-recorded. The final interviews were completed within a few days of the experimental phase of the study and over a total period of 5 weeks due to participants' staggered start dates and to accommodate families' commitments and travel dates.

5.1.1.4 Data Analysis

Parent diary entries & log data: We used the parent diary entries and phone usage logs to construct a dataset of app use for each child. We used these datasets to conduct an analysis of children's total time spent outside during the baseline and intervention periods (pre- and post-app use). For the missing data entries (discussed above), we utilized multiple imputations using the expectation-maximization algorithm to substitute those data points (Molenberghs and Verbeke 2005). Because the data were not normally distributed, we first performed a log transformation. We used block ANOVA to account for non-independence of our data points (multiple data points per child across the study period), with condition (NC and Photo app) as the independent variable and intervention period (pre- and post-app use) as the blocking factor.

Children's post-experiment outdoor activity: We completed 28 post-child outdoor activities and interviews that were video- and audio-recorded (ranging from 25 to 45 minutes). One researcher transcribed 4 post-child activity videos from each app condition verbatim and added descriptions of the non-verbal actions of the child with their surroundings (total of 8 post-child activity videos). Using a grounded theory approach (Charmaz and Belgrave 2015), two researchers then openly coded two transcripts from each app condition (total of four transcripts) to identify emergent themes. The researchers came together to review their coding, combine themes where appropriate, and come to a consensus on an initial list of themes (e.g. nature captures child's attention; child demonstrates curiosity about nature; child-directed nature exploration). They applied this consensus list of themes to the remaining four transcripts (2 from each group) and checked whether any new themes emerged. The researchers came together once more to discuss and come to consensus on the newly identified themes. They divided the remaining videos and coded them separately, checking in regularly to ensure the consensus was maintained (Smagorinsky 2008).

Following this open coding process, researchers organized the emergent codes into hierarchical themes aligned with Giusti et al.'s framework. We focused in particular on themes related to abilities and qualities associated with the first phase of being IN nature. (Giusti et al. 2018). For example, emergent codes that focused on child-initiated app use in nature aligned with the "child-driven" quality of significant nature-based activities.

Ecological momentary assessment (EMA): Children completed a combined total of 198 audio surveys with a total of 534 individual audio files, with a response duration ranging from a few seconds to 2.6 minutes. In 50 surveys (115 audio recordings), the participant IDs were not

captured, and one audio file was corrupted. However, we were able to identify the app condition (NC or Photo) for 34 of these 50 surveys (67 recordings). 56% of the total surveys came from the NC app condition, and 43% came from the Photo app condition.

We transcribed all audio clips before analyzing them. Two researchers individually coded the same 30 audio clips selected randomly from each app condition (a total of 60 audio clips) using the same coding scheme developed for the post-experiment outdoor activity. We met to discuss and achieve consensus on code definition and application, resolve disagreements of any coded clips, and assess inter-rater agreement. Inter-rater agreement was satisfactorily high ($\kappa = 0.81$) (Landis and Koch 1977). After this process, one researcher coded the remaining 474 audio clips.

5.1.2 *Results*

Here, I describe our study results to answer the sub-questions about the ways NatureCollections impacted children's time spent outside, RQ1.2 (*Does the NatureCollections app succeed at getting children to spend more time outside?*), and their connectedness to and interactions with nature, RQ1.3 (*Does the NatureCollections app impact children's connectedness to nature?*)

5.1.2.1 Children's Time Spent Outside

During the first week of the study, before receiving the app (pre-intervention), children in the NG app group spent an average of 2 hours 7 minutes outside per day (sd = 105.38 mins). Children in the Photo app group spent an average of 2 hours 4 minutes outside per day (sd = 129.15 mins). This difference was not statistically significant ($p = .482$), see Figure 5.1.

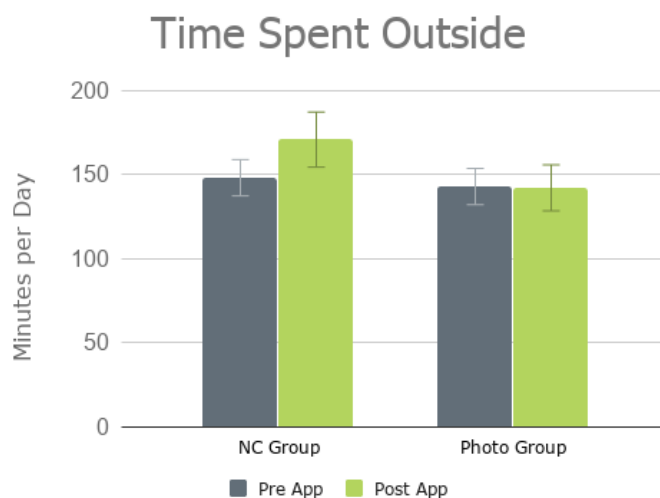


Figure 5.1 Average minutes spent outside per day for NC and Photo groups during *Pre* and *Post* app use

We used block ANOVA to account for the non-independence of our data points (multiple data points per child across the study period), with condition (NC and Photo app) as the independent variable and baseline and intervention periods (pre- and post-app use) as the blocking factor. Children in the Photo app group averaged 2 hours 6 minutes per day outside during the intervention period. This amount of time did not differ to a statistically significant degree from the average amount of time this group of children spent outside during the baseline period ($F(1,193) = 10.551, p = .657$). However, there was a statistically significant difference in the average amount of time that children in the NC app group spent outside between the baseline and intervention periods (mean = 2h 48min, $sd = 132.67$, $F(1, 389) = 12.153, p < .001, \eta^2 = .026$). In other words, the NC app group spent more time outside, on average, after they received the app.

During the post-intervention outdoor activity, children in the NC app group explained that having the app encouraged them to go outside more often. One 12-year-old girl reflected on her experience using the NC app: “*It’s pretty fun to use, it really gets you outside, too.*” Another

child, when asked how often he went outside during the study, responded: “*Every day actually, yes this app brought me outside more*” (boy, age 10). In the NC group, 86% of the children used the app frequently over the two-week intervention period, particularly at the beginning of the study and at the end.

In contrast, the Photo app group did not express similar motivation to spend time outside during the intervention period. Approximately 75% of the children in this group stopped using the app after the first couple of times. One ten-year-old girl described her experience with the Photo app: “*Usually I would spend about three hours a day outside without even using the app. The app didn't really help me spending more time outside.*”

5.1.2.2 NatureCollections Impact on Children’s Connectedness to Nature

I present the results of our qualitative analysis of children’s *in situ* audio responses during the two-week period of app use, as well as children’s responses during the post-intervention outdoor activity. Results are organized thematically, for each app condition, around children’s HNC-related abilities and qualities from Giusti et al.’s framework that we identified in our data (Giusti et al. 2018). We focus on the first phase of the framework, *being IN nature*. The abilities in this phase include *being curious about nature* and *feeling comfortable in natural spaces* (e.g., with dirt, mud or bugs). We include discussion of the specific qualities of nature-based experiences that supported each of these abilities.

5.1.2.2.1 Being IN Nature: Showing Curiosity About Nature

NatureCollections app group. In addition to encouraging children to go outside, the NC app sparked children’s curiosity about natural spaces and motivated them to learn about and explore nature. One 12-year-old boy explained: “*I like using the app because it motivates me to go*

outside and learn more about what I'm taking photos of.” With respect to the qualities of children’s nature-based experiences that supported their curiosity, the NC app succeeded in *drawing children’s attention to nature* and encouraging them to engage in *child-driven explorations of nature*.

The NC app helped draw children’s attention to the natural elements in their surroundings. For instance, one 10-year-old boy reflected on his app experience during the post- intervention outdoor activity: *“I notice things differently since I started using the app, like types of animals and trees.”* NC app features like “Add Details,” “Classifications,” and “More Information” drew children’s attention to different types of nature elements. One 10-year-old girl reflected on her connection to nature while using the app: *“When I use the NC app, I feel pretty connected to nature because I’m taking pictures of nature and identifying them and placing them into groups and learning more about the plants. Because I have to observe it and really try to understand more about it.”*

During the post-intervention outdoor activity, one 9-year-old girl noted that she liked how the classification feature drew her attention to details in nature: *“I like the classify part, like what type is it, how many pairs of wings does it have [referring to bug classification], what do the leaves look like.”* Another 10-year-old boy commented: *“I look at things more and notice more things, like animals, bugs and stuff.”* In a similar manner, one 9-year-old girl excitedly shared her app experience: *“It was pretty great, I liked how you were trying to get kids to nature...to..to figure out what it is more.”* When we asked her what she meant by *more*, she explained: *“How I*

was trying to figure out what leaves that tree had. I wouldn't have looked really close at the leaves before.”

In addition to drawing their attention to nature elements, the NC app sparked children’s interest in learning more about nature. For instance, while showing us the photos he took during the post-intervention outdoor activity, one 10-year-old boy explained enthusiastically: *“I feel like I know more like that tree is called a pine tree, that tree has like this kind of shape. It makes me want to like show my friends, like, take a picture of this and show them, ‘Oh you see that shape in the tree? That means it’s this tree. See this bird of this? That’s a song bird. This is a bird of prey.’”*

Children in the NC group expressed a desire to learn more about nature even after being outside. Children initiated conversations with their parents and siblings around different nature photos they had taken, and some even searched online to learn more about nature elements they observed. One 12-year-old boy explained: *“I would go on the computer or the phone and be like what’s a cedar bark tree [referencing the app tree classification option]?”*

Photo app group. In contrast, the Photo app did not appear to draw children’s attention to natural elements or motivate them to interact with nature. Instead of focusing on the specific details of a nature element (e.g., leaf type), their photos were more likely to be driven by a focus on the aesthetics of the photo composition (e.g. shape, color). For example, one 10-year-old girl was asked during the post-intervention outdoor activity: *“What are you normally thinking of when you take pictures?”* The girl explained *“Just how it looks, like that [points to a spider web near the building entrance]: I like how spider webs look. It captures the water droplets, it keeps it like that, it doesn't spread out, when it catches it like the ground, it doesn't disappear.”*

Children in this group mentioned taking photos for personal relevance, like their backyard, pets, or selfies of themselves and their peers for fun. When asked to explain why he took the photos he did, one 9-year-old boy said: *“Anytime I wanted to see our frontyard without having to walk away from my show or my toys.”* He went on to show some of his photos and commented: *“I also really like this selfie by the beach...I think this one’s funny.”*

5.1.2.2.2 *Being IN Nature: Feeling Comfortable With Natural Elements*

NatureCollections app group. Enjoying one’s time in nature is one indication of feeling comfortable in nature. We therefore looked for evidence that children were engaging in nature-based activities that they found *fun and joyful*. Both the NC and Photo app children reported feeling happy and enjoying nature when they were outside with their app. Children in the NC app group reported being more excited and passionate about nature after using the app. One 9-year-old girl described her feelings about nature during the post-intervention activity interview: *“I’m more passionate about nature now, just by using the app and being outside more.”* Similarly, another 12-year-old girl explained her experience using the app: *“I also think it’s easy and it works its goal of using technology to help you appreciate nature. I kind of noticed a trend in my audio recordings: at first, I was simply talking about what I took a photo of and why, and later when I was using the app I started talking more about how I feel about nature in general and why I took a photo in more detailed reasoning.”*

Beyond simply enjoying nature, children in the NC app group expressed *amazement and awe*, which appeared to heighten their connection to nature during their outdoor exploration with the

app. One 10-year old boy explained his surprise upon learning that trees are living things: *“Before, I thought that trees were pretty boring cause they're just trees. But then when I started taking pictures with them, they're not just trees, they're actually living! So they're like us, but they're not moving around. They're staying put. They don't have faces, but they're alive and we have to take care of them... like trees are living things!”* Similarly, a 9-year-old girl expressed her wonder about nature while showing us a photo of close-up leaves: *“I think nature is really really fascinating, like skeletal leaves: those are really really cool.”*

Lastly, *interacting with animals* is another indication that children feel comfortable in nature. In our analysis, we found that children who used the NC app were more likely to describe interacting with wild animals. For example, one 9-year-old girl narrated the story behind a close-up photo she took of baby birds: *“I took a photo of a bird, a bird and its mama and babies at my grandma's house. There's a mama bird nest. And so, my grandma tried to take care of it and told me to get water and I tried to get close to the birds. But sometimes it's weird when they open their mouths, the babies! Cause it's black and looks like a little hole.”*

Photo app group. Children who enjoyed using the Photo app told us that they liked photography, or that they took pictures of things that were personally meaningful to them. For example, one boy explained while showing us the photos he had taken: *“I like trees cause I can climb them. ... these are the trees I've climbed before.”* He also talked about liking how the trees looked at certain times of the day, for example, during sunset: *“I'm not sure what trees those are. [They are the] tallest trees in neighborhood. I like their colors [referring to the sunset lighting].”*

Unlike children in the NatureCollections group, children in the Photo app group did not exhibit evidence that the app facilitated their direct interaction with nature, and they did not express amazement related to nature elements. When we asked these children if the app helped them notice things differently in their surroundings, one 11-year-old girl said: *“I don’t think so, it was the same before and after. I don’t really pay attention to how much I notice and how much I don’t.”* Although children in the Photo app group were often drawn to aesthetic qualities of their natural surroundings, this focus was not typically accompanied by an expressed interest in or enjoyment of nature. One 10-year-old girl explained: *“Sometimes I see something and think ‘Oh, that’s pretty,’ but I’m never like ‘I want to take a picture of that or get close.’”*

5.1.3

Discussion

In light of the critical role of nature exposure during childhood, researchers and educators are increasingly motivated to creating nature-based experiences for children that promote nature exploration, curiosity, and direct engagement with natural elements. Nature kindergartens and school programs that focus on direct child-nature interactions have increased markedly in recent years. In the United States alone, such programs increased from around 25 programs in 2012 to more than 250 programs spanning 43 states in 2017 (Education (NAAEE) 2017; Turtle, Convery, and Convery 2015). In this work, we explored the potential for using mobile technologies to encourage children to spend more time outside and engage directly with nature.

The primary contribution of this work is empirical evidence from an *in situ*, three-week experimental deployment of the NatureCollections app, showing that the app significantly increased the time children spent in nature, compared to children in the Photo app group. Prior

research has found that direct nature interaction and spending time in nature play a pivotal role in children's nature connectedness and willingness to perform pro-environmental behaviors during adulthood (Giusti et al. 2018; Ives et al. 2017; Louv 2008; Mayer and Frantz 2004; Tam 2013). In this study, we observed key qualities of children's nature interactions, suggesting that the NatureCollections app promotes and supports the development of children's abilities of Human-Nature Connection (Giusti et al. 2018).

Our results showed that for children in the NatureCollections app group engaged in positive developmental related behaviors and experiences, the app succeeded in promoting child-driven exploration and attention to natural elements, in contrast to children in the Photo app group. Specifically, we observed evidence that, while using the NatureCollections app, children *directed their attention* to their natural surroundings, such as pointing to birds, bunnies and bugs, and they engaged in tactile interactions with nature elements, such as feeling tree trunks, reaching for tree leaves, and touching dirt. They also interacted with nature in a way that was *child-driven*, even seeking to extend their learning after their time in nature by engaging their parents in conversations about what they had seen and photographed with the app. These observed qualities of significant nature-based experiences in the NatureCollections app group supported children's *curiosity about nature*, one of the HNC abilities associated with *being IN nature* described in the Giusti et al. framework (Giusti et al. 2018).

Children in the NatureCollections group also showed indicators of *feeling comfortable in nature*—another HNC-related ability associated with *being IN nature* (Giusti et al. 2018). Children in this group expressed being *happy, excited, and passionate* about nature after using

the NatureCollections app during their outdoor experiences. Those experiences were often accompanied by a sense of *awe and amazement*. During our post-intervention outdoor activity, children who used the NatureCollections app recalled positive nature memories about their nature experiences as they showed us the photos they had taken during the study. Children also felt comfortable *interacting with wild life* while using the NC app, getting close to animals and bugs in order to photograph them. Taken together, the NC app promoted critical behaviors for positive development in children (Bers 2012). In contrast, the children in the Photo app group engaged considerably less with their natural surroundings, taking photos indiscriminately with no clear subject or purpose beyond the aesthetic composition of the photograph. Although these children showed excitement about being outdoors and engaged in play, these interactions rarely centered on direction interaction with nature elements.

Several features of the app contributed to these results. First, children's experiences with the app were highly child-directed experiences. Children could choose what to photograph, which collections to build, and which challenges to pursue. Features such as "Add Details," "Classifications," and "More Information" also facilitated children's direct nature interactions and enjoyment of their time in nature. For example, in the process of making classification decisions for a nature element, children often expressed amazement and drew their attention to a natural element while making close observations of its details. Similarly, the "Add Details" feature of the app allowed children to reflect on their choices of what they had photographed and articulate in their own terms how to describe the nature element. When children engaged with this feature, they showed curiosity and inspected the natural element closely, especially when attempting to classify it. After learning more about the different species using the "More

Information” feature, several children reported feeling comfortable getting closer to a variety of natural elements, such as bugs and other animals, in order to photograph them. Children who used the NatureCollections app also engaged in conversations with peers and parents about the nature elements that they photographed.

5.2 NATURE-BASED EXPLORATIONS FOR FAMILIES

In the prior evaluative studies, the NatureCollections app successfully promoted children’s curiosity of and connectedness to their natural surroundings (Kawas, Kuhn, et al. 2020; Kawas, Sherry-Wagner, et al. 2020). The app succeeded at engaging children in enjoyable, meaningful interest-driven nature explorations and social learning experiences with their peers. Taken together, these behaviors reflect a healthy and positive development among children. Additionally, the developmentally responsive app design is positioned to encourage nature-based interactions between children and their parents due to the app’s emphasis on engaging youth in personally relevant activities, supporting focused attention on nature, encouraging social interactions (including with parents and siblings), and providing opportunities for continued joint engagement with nature (Kawas et al. 2019). As part of the previous app deployment experiment study, we were interested in understanding parents’ experiences, perspectives, and their family needs around using NatureCollections to support joint family engagement with the app in the context of children’s nature-based explorations and ways to increase family time spent outdoors. Informed by the critical role of parent-child tech-related tensions in prior research in family technology adoption, described in detail in chapter 2 (2.2.4), part of the study investigates the nuanced interactions in parent-child relationship dynamics in the adoption of mobile applications such as NatureCollections by children and their families. This study extends our understanding

of families' Joint Media Engagement needs (Chapter 2, 2.2.3) by considering child-parent interactions in a new context: nature-focused exploration. This work was peer-reviewed and published in the ACM Conference on Human Factors in Computing Systems (Kawas et al. 2021).

5.2.1 *Method*

One of the key aspects of designing developmentally responsive digital experiences for positive child development is the emphasis on the situated social contexts, particularly, the dynamics of parent-child relationships (Bers 2012). In the following study, we examined parents' and children's shared experiences using NatureCollections. We recruited 23 children (including eight sibling pairs), ages 8-12, from 15 unique families to use NatureCollections for a two-week period. Participant demographics for this group are shown in Table 5-3.

5.2.1.1 *Study Procedure*

For this study we examined parent-child experiences in the context of children's NatureCollections app use by analyzing: (1) parent self-reported descriptions of their experiences during exit interviews, and (2) children's and their families' real-time interactions when using the app, recorded using the Anchored Audio Sampling method (AAS) (Hiniker et al. 2019). During the parent interviews, we used a semi-structured protocol and asked them about their family's and children's experiences with the NatureCollections app during their nature-based explorations. The length of these interviews ranged from 37 to 51 minutes ($M= 43$). All interviews were audio recorded and transcribed for data analysis. In-app AAS recordings were 3 minutes long and were captured during children's NatureCollections app use. AAS is a remote audio recording technique that is triggered seamlessly in response to a specific interaction to

extract qualitative audio snippets during field deployment with children. These AAS recordings capture how children make sense of technologies and how they use them in their everyday life (Hiniker et al. 2019). Each audio recording was randomly triggered either at the start, middle, or closing of a NatureCollections session to sample the full spectrum of a children’s app use experiences. The app displayed a notification on the app user interface that audio was being recorded. Recordings were stored locally on the device and then uploaded to our university servers once the device was connected to WiFi.

Table 5-3. Demographic characteristics of families and their children.

Demographic Variable		NC App*
Gender	Girl	12
	Boy	11
Age	Age 6	1
	Age 8	2
	Age 9	8
	Age 10	9
	Age 11	0
	Age 12	3
Race	White or Caucasian	13
	Black or African American	1
	Asian / Pacific Islander	1
	Mixed	8
Household Income (US\$)	Less than \$25,000	1
	\$25,000 to \$49,999	0
	\$50,000 to \$74,999	2
	\$75,000 to \$99,999	1
	\$100,000 to \$149,999	4
	\$150,000 or more	7
Parent’s Education	High school graduate	1
	Trade /Vocational	3
	Associate’s degree	2
	Bachelor’s degree	5
	Graduate degree	4
Birth Order of Primary Tween in Sibling Pair	Older than sibling	5
	Younger than sibling	3
	Single tween participating	7

15 Families : *n = 23 total children, 15 primary participants and 8 siblings

At the end of the study, families had the option to delete some or all of the app recordings, though none of the families chose to delete any recordings. We captured a total of 704 recordings across all 23 children during the two-week period ($M= 29$ files per tween, $SD= 19$). Seven of the audio files were empty, indicating the participants did not say anything during the audio samplings. All audio files were transcribed verbatim.

5.2.1.2 Data Analysis

We took a joint inductive-deductive analysis approach to our qualitative data sets (Corbin 2015), the parent interviews and the app AAS recordings. Two researchers independently open coded 20% of the parent interviews following an inductive approach, and both researchers met regularly to discuss emerging themes and iterate on the codes for consistency (Braun and Clarke 2006). Next, three researchers, including one who participated in coding the parent interviews, read through 20% of the transcribed AAS recordings from the phones, a total of 137 files. Following a similar inductive approach, the researchers coded the transcripts while writing memos on any new emerging themes, and discussed these themes in team meetings. Finally, following a deductive approach, all researchers looked through similarities across themes in both the parent interviews and the AAS recordings while iterating on the themes and adding any new codes to the codebook. We used Dedoose⁷ to code both qualitative data sets, with one researcher coding the remaining parent interviews and the other researchers splitting the audio recording and coding them separately. The researchers met regularly to discuss the emerging themes and excerpts from the data.

⁷ Dedoose (<https://www.dedoose.com/>) is a web-based research application for analyzing qualitative data in a collaborative asynchronous environment.

5.2.2 *Results*

Two overarching themes emerged from our data sources: (1) families' experiences of tweens' NC app use during nature-based explorations, and (2) concerns and tensions surrounding tweens' technology use during their transitional period of development.

5.2.2.1 Families' Experiences of Tweens' App Use during Nature Exploration

5.2.2.1.1 *How tweens engaged their parents and siblings around app use*

Tweens engaged with their parents and siblings in joint nature-based explorations during their NC app use, often sharing their app activities and achievements with them. Tweens' app use increased their parents' attention to and engagement with nature elements in their surroundings. Additionally, tweens and their families worked together to make sense of nature elements. Some parents incorporated their pre-existing interests in nature activities and, at times, their knowledge around plants and other species while their tweens used the app.

Tweens shared their app photos, activities, and achievements with both parents and siblings during and after their app use. We heard one tween tell his mother:

“Can I show you my favorite picture? I wanna show you my favorite picture. It’s amazing, okay. ... I’m doing a night tree series” to which she responded encouragingly, *“I like that one, it is a really good picture. Oh, that’s a pretty one. Yeah, very good.”* AAS [T7 (boy, age 10)].⁸ T7’s father commented, *“He was super jazzed about it. He was showing me every single picture he took that evening that he first tried it out. He had actually some really good pictures. It was cool.”* P7 [T7 (boy, age 10)].

⁸ T refers to tween, P refers to parent, S refers to sibling

Tweens sought their parents' and siblings' help in taking photos for the app, with one tween who asked his father: *"Right before you go to bed, do you think you could wake me up and take me outside, cause I wanna take a picture of the moon, cause one of my categories is moons?"* AAS [T7 (boy, age 10)].

Sibling pairs were each provided with phones for the study and engaged with one another, sharing photos and achievements while using the app collaboratively. A brother-sister pair talked about their photos and helped each other find nature elements:

S5: "There's a lot of types of birds." And her brother asked "T5: Do you have a lot of birds [photos]?"

S5: "No. There is a lot of types of birds. Stop."

T5: "Let me see." Then the brother pointed to his sister:

T5: "There was a bird over there, look." AAS [T5 (boy, age 10), S5 (girl, age 8)].

Many parents noticed that their tweens engaged in outdoor activities differently when using the app, with one mother, P8, sharing:

"He never said anything to me, but he said, 'Oh, I need to take a picture of this marigold.' That was really hard to, but he had never, ever mentioned the marigold that we've had for six years, since before. Yes, it did actually help him interact and verbalize what he's seeing, definitely." P8 [T8 (boy, age 9), S8 (girl, age 12)].

Tweens' app use during regular family activities like going on walks, heading to the grocery store, and going out to dinner prompted an increase in their siblings' and parents' attention to nature and encouraged them to slow down, observe their natural surroundings, and engage in discussions about the photos they were taking. We heard a conversation between one tween and her mother:

T12: "There's a snail right here."

P12: "Where? I don't want to step on him!"

T12: "He's right there. I'm taking a photo of it."

P12: "It's here? Let [your brother] get a picture of it." AAS [T12 (girl, age 12), S12 (boy, age 10)].

This same mother shared with us about her two tweens:

"I remember there was this bird on the fence that they were trying to get a picture of, and I remember we were just all sitting around for a while waiting for this bird to come back because it was flitting around. They were just super focused trying to get a picture of this bird. I can't remember if they actually got it [chuckles]." P12.

Another parent, P14, mentioned:

"There was a day when we were coming home from her grandma's house and we were driving through the neighborhood. Then she yelled out, 'Oh, there's that bush! I remember that bush. I took a picture of that bush for the NatureCollections app and then I recorded it, why it was important to me.' I was like, 'Oh, I've never really noticed that bush.' [laughing] She was like, 'I know, now I'm always going to remember because I took a picture with it'." P14 [T14 (girl, age 9)].

In some families, tweens' joint app engagement also supported family time outdoors. One mother noted: *"We definitely just took more random [family] walks, that the kids initiated just to take photos of nature."* She further explained that her daughter and son do not often play together, but since they had the NC app: *"They were definitely interacting because of the app and with the app."* She also observed her younger son develop an interest in something other than video games, like photography and nature (*P12 [T12 (girl, age 12), S12(boy, age 10)]*).

Tweens worked with their parents and siblings to make sense of nature elements, inspiring togetherness as they named plants in their photos, engaged in app activities, discussed nature elements in detail, and looked up nature-related app content. One mother, P2, shared:

“We were both arguing about what we can define, what the plant looks like, [laughs] ... so we would both go back and forth all the time about what we would call this...because we don't really know what plant [it is].” P2 [T2 (girl, age 9)].

We heard one tween, T15, and her mother working together to classify a tree using the app:

T15: “Mom, those trees back there are ferns, right?” ...

P15: “Fir. Douglas fir. There’s some fir trees back there, and apple trees. A whole bunch of trees back there.” And the mother continues:

P15: “Needle. Fir trees have needles.” ...

T15: “Fruit, fleshy berry-like things. So juniper is a tree?” ...

P15: “It is a type of tree. It’s a bush tree.” ...

T15: “I put it as a shrub.” ...

P15: “Shrub, actually that’s a better way to put it.” AAS [T15 (girl, age 9)].

Another parent mentioned how her tweens' app use: *“caused us to talk about things that maybe we wouldn't have talked about, leaves and the color of flowers and things like that” P3 [T3 (girl, age 9), S3 (girl, age 10)].*

While some tweens competed with their siblings for the highest number of photo collections, badges earned, and challenges completed, many tween sibling pairs also supported each other with other app activities like choosing photo names, adding photo details, and making sense of nature elements to classify photos. For instance, these two sisters helped each other describe a photo of a pine tree and figure out the tree type while going through the classification scheme in the app:

T4: *“How would you describe the pine tree?”*

S4: *“The pine tree is spiky but soft.”*

T4: *“Spiky but soft. Spiky but elegant.”*

S4: *“I got half of it. T4 I was alright typing “spiky but,” but ok.”*

T4: *“Spiky but elegant. On a walk. I’m just going to type on a walk for where we found it.: It’s a tree. Conifer. Is it needle or scale type?”*

S4: *“Needle.”*

T4: *“Needle, yeah. Woody cones? Yeah, woody cones. Needles.”*

S4: *“No that one.”*

T4: *“Fir, spruce...Hemlock? Don’t touch it.”*

S4: *“I won’t. I’m not touching it.” AAS [T4 (girl, age 10), S4 (girl, age 9)].*

Parents shared that the NC app brought families together during nature activities. For instance, one parent shared how she would regularly go on walks with her tween, but he would usually be scootering a couple blocks ahead of her. When he was using the NC app, in contrast, they walked together, looking at plants, talking about animals and even the crevices in the sidewalk. *“We were actually having a conversation, usually we don’t” P1 [T1 (boy, age 10)].*

Parents’ nature-related interests such as gardening, walking, and hiking regularly provided context for tweens’ NC app use. Some tweens also incorporated their parents’ love of nature into their photos, with one parent, P13, describing:

“It was so pretty like just a sunset and how the trees were. It was just so pretty. He knows that my favorite part of the day is the sunset. He’s like, ‘I’m going to take this picture, mom.’” P13 [T13 (boy, age 10)].

Parents also shared with their tweens their interest in specific nature elements, like teaching their tweens about different flower names and sharing details about their favorite flower as their tween

took photos of it. One mother reported how she often visited their local P-patch with her tweens, noting how they engaged differently in these outings while they were using the NC app:

“It was the first time they had really looked around and asked specific questions about the plants around them considering, ‘Hey, what are other people growing? What is this?’” P12 [T12 (girl, age 12), S12 (boy, age 10)].

5.2.2.1.2 Parents’ needs for engagement

After spending two weeks engaging and observing their tweens’ NC app use, parents provided their insights on additional app features that would increase both their tweens’ app engagement and their joint family nature-based explorations. Three main areas of need emerged: (1) app features to increase access to information about nature; (2) app activity sharing to support parent-tween engagement; and (3) new opportunities for family collaboration and competition.

Many parents expressed a strong interest in having more app-supported opportunities for their tweens to increase their knowledge about nature. One parent, P7, suggested access to nature information via the app would be a key element for her to support her tween’s use of the app:

“Having as much information about whatever you take a picture of, would be the most important thing that would get me to download [the app].” P7 [T7 (boy, age 10), S7 (boy, age 6)].

Parents often shared that their tweens wanted the app to help them more as they were choosing names, classifying photos, or working on challenges. Many parents also wanted to use this additional information themselves to engage with their tweens in information seeking about nature and to support nature-focused family conversations. As one mother, P9, suggested:

“If it’s a beetle, some parents might not know much about beetles but have casual like facts or research about it and you can have a conversation point.” P9 [T9 (girl, age 9), S9 (girl, age 8)]

Parents shared a common desire to see how their tweens used the app and the photos they took, either through automatic activity reports or through tweens selecting photos to share. One mother, P8, shared her ideas for a reporting feature:

“...like having some kind of a little report card. This is what your kid did today, or this week. This is how many pictures he took, very little synopsis of what kind of pictures they were; were they all plants? Were they all animals? ... I think it'd be interesting to know what interests him, is it all flowers.. animals..mountain scenes..?” P8 [T8 (boy, age 9), S8(girl, age 12)].

Parents largely expected this reporting to be facilitated electronically through the app, emails or text messages rather than by viewing the information on their tweens' phones. They also wanted the app to prompt their tweens to interact with them. As one parent, P3, suggested that tweens could: *“...get a notification that they've taken so many pictures and ... see a notification like, 'Oh, you've taken 20 pictures. Go share them with the parent,' or, 'Let's talk with somebody about it.’” P3 [T3 (girl, age 9), S3 (girl, age 10)].*

Further, parents wanted to keep engaging their tweens by sharing comments on photos, titles, and classifications, and through a chat feature that would allow them to prompt their tween with questions. As one parent observed, this additional engagement through the app could serve as family conversation starters: *“...there's at least little bits I can pull out to have bigger conversations or uncover things I should know that otherwise if I was like, 'Tell me about your day,' I'd never get anywhere.” P14 [T14 (girl, age 9)].*

Numerous parents wanted even more app-facilitated, family-focused activities, with many expressing a desire for parents and extended family members to participate in collaborative and

competitive activities with their tweens. Some also felt that having the app offer these challenges would more effectively engage their tweens in family activities:

“I know some kids that would have an issue with something being forced upon them from a parent, like, ‘Go do this,’ rather than the game actually prompting you to do it ... a kid would be much more inclined to follow whatever incentive it is that the game actually promoted it, rather than the parent.” P7 [T7 (boy, age 10), S17 (boy, age 6)].

Parents shared many ideas for activities that would increase their tweens’ family and app engagement, including daily goal setting and competitions for taking a specific number of photos. One parent, P1, shared how she envisioned competition with her tween:

“He’s old enough now where he doesn’t want me butting in on his challenges. He doesn’t want me helping him. He wants to do everything himself, so he would never ask me, ‘Go try to find a deciduous tree.’ He would want to do it, and then show me that he found more than I did.” P1 [T1 (boy, age 10)].

5.2.2.2 Tweens’ Transitional Tech Use

5.2.2.2.1 How the NC app fit into parents’ screen-time rules

All parents indicated they have screen-time rules for their tweens, including rules about total screen time allowed per day, when and where tweens could use devices, parental screening of apps before downloading, and restrictions around chatting with friends on apps. Parents described the tensions they face around screen-time rules as their tweens transition between childhood and adolescence. A mother, P5, shared her experience with this tension:

“I’m kind of trying to just keep the 30-minute lockdown right now, for as long as I can, and that’s all he knows. But I feel like that his being in fifth grade next year, the junior high kids start

getting phones and there's less limitations on it, so I don't know, it's gonna be a whole different thing to kind of deal with." P5 [T5 (boy, age 10), S5 (girl, age 8)].

Parents reported making exceptions to screen-time limits when technology use facilitated a valued family activity. They explained that they positively viewed technology engagements that support spending time outdoors, connecting with and learning about nature, social interactions with family, and creative activities over mindless tech use. One parent, P3, told us:

"It would be nice to be able to have something on a device, an activity that was more educational or help them see the world in a different way. Not just sit there. That's my biggest issue with the devices and the TV. You're just sitting there being a zombie. You're plugged in, and that's it." P3 [T3 (girl, age 9), S3 (girl, age 10)].

Parents mentioned that they did not count their tweens' time on the NC app as screen time, and the app use therefore did not impact the amount of regular screen time their tween had on other devices. When we asked parents if this was due to participating in the study, they explicitly said it was not due to the study but rather because the NC app encouraged their tweens to go outside. One parent, P14, even suggested the NC app could be successfully marketed to parents with the tagline: *"Help balance your child's screen time, help your child spend more time outdoors with their technology."* This parent further explained: *"They are not even going to have to read much further, they'll just be like, 'I'll spend the US \$3.99.'"*

Parents also identified other aspects of the NC app that they felt set it apart from the typical screen time they try to regulate:

(1) Connecting with and learning about nature: Parents expressed strong values associated with supporting their tweens' ability to connect with and learn about nature. One mother, P11, shared:

“I think all families, anybody that you ask, will tell you that the struggle is real, trying to push them away or pull them away from this video game, anxiety of winning competition, and having this relationship with people that you don't even see or know or have, there's no real connection. And I think given the alternative to have this connection with nature, I think it goes a long way.”
 P11 [T11 (boy, age 12), S11 (boy, age 10)].

(2) Family interactions and activities: Parents often remarked positively on the social interactions they observed when they had two children using the app together. A parent of a 12-year-old girl and a 10-year-old boy shared:

“Most of the screen time they use is a personal thing. They sit with YouTube or whatever, and it's just them and the screen. The NatureCollections app just encouraged more sharing, especially between the two of them. They would go out together, and they would just talk about what they were going to take pictures of. They would show each other their pictures, so that was definitely different.” P12 [T12 (girl, age 12), T12 (boy, age 10)].

(3) Creative engagement: Additionally, parents related other valued interactions to their tweens' NC app use such as creativity. A mother, P12, shared about her two children:

“They had a lot of fun taking pictures with the app. I thought that was good because-- Photography is a creative outlet, so I thought that was the positive use for technology to use it in that kind of way.” P12 [T12 (girl, age 12), S12 (boy, age 10)].

Parents also noticed that NC app features had prompted their tweens' imagination while interacting with natural elements. One parent, P2, shared an instance where she and her daughter spent some time in a garden and she noticed her tween:

“...had a whole different look of imaginations of how the fruits and the vegetables and the pictures. That was kind of fun to see, watch her imagination be a little bit- something that we normally wouldn't do. That she's using her imagination calling, labeling, and trying to describe flowers and things. That was kind of fun.” P2 [T2 (girl, age 9)].

Despite these valued outcomes, tensions still arose around phone use and the NC app. For instance, a few parents had family rules that restricted technology use outdoors. One mother shared:

“Because she's 9 and she doesn't have a phone, her go-to attitude about electronics is not to take them outside. As a family, she's not allowed to really take her iPad outside. It's like if you're going to go outside, part of why you're going outside is to disconnect from electronics, not take them with you” P14 [T14 (girl, age 9)].

Another parent affirmed the general lack of familiarity among parents with the concept of tweens using technology outside. When she was asked about her child's use of technology outside during the study, she responded:

“I would always be confused by that question, because to me, spending time outside and technology don't go together, just because devices can get damaged. 'Cause when my kids play outside, it's all about being in motion.” P11 [T11 (boy, age 12), S11 (boy, age 10)].

When tweens took the phone to new outdoor spaces, they were often challenged with taking responsibility for it. One mother shared how she did not want to carry both of her tweens' phones for the study:

“I'm not carrying it, because I already have the dog's stuff, my own stuff, my own water .. they decided they wanted to take it and ... I remember my husband ended up carrying them.” P5 [T5 (boy, age 10), S5 (girl, age 8)].

5.2.2.2.2 *Negotiating independence in phone and app use*

Some parents shared that they did not spend much time helping their tween learn how to use the app after its initial setup. One parent commented:

“To be honest, I didn't really look at the app too much. I just let him do his thing. I didn't want to suggest too much to him, what he should do with this. I stayed away from that. He showed me pictures often of what he took, but that's about all I saw of the app.” P7 [T7 (boy, age 10), S7 (boy, age 6)].

Many parents mentioned that they and their tweens preferred this level of independent app use, with one parent stating her daughter's preference for independence using the app:

“She likes to do it mostly on her own. The only time we really had interactions if she had a question about something ...Then she was wanting a lot of interaction to try to help her figure out and that was towards the beginning. I think it was still fairly new to her, but after that she didn't ask for a lot of guidance with it. She just likes to do it on her own.” P10 [T10 (girl, age 9)].

At the same time, many parents also voiced concern about the safety measures that would be available to parents to monitor and manage tweens' social interactions. Numerous parents stated a desire to manage their tweens' friends on the app, with one father commenting:

“I think the ability to have a lot of control I think as a parent that's, I think, important. If she were to have her own device, we would want control over who she actually makes friend relationships with and it wouldn't be her decision alone. I would expect that to be on the other side as well.” P6 [T6 (girl, age 9)].

Parents also expressed concerns about their tweens' activities with friends on the app, including messaging and sharing photos: *"It's a double-edged sword. It would be nice to have, but then I can also see it getting out of hand, and maybe they start sharing pictures of all kinds of stupid random things...There would have to be some kind of parental control."* P7 [T7 (boy, age 10)].

The same parent suggested parental controls to limit the number of chats being sent to friends and regular reports to parents with the photos shared between friends. Additionally, numerous parents wanted to receive regular updates on their tweens' NC app use, including the amount of time they spent using the app. Several parents also voiced concerns over privacy:

"I would just not want any public online account sort of thing. If you could not do that, that would definitely be a plus" P12 [T12 (girl, age 12), S12 (boy, age 10)]. Some parents expressed a desire to limit their tweens' online presence: *"I am very concerned about their online presence. The trail, I don't want pieces of their address. Sometimes if they asked you where do they go to school? ... I don't want my kids to put their real names."* P9 [T9 (girl, age 9), S9 (girl, age 8)].

Another dimension of negotiating independence in phone and app use related to the geographic limitations experienced by the tweens in this study, which impacted where they could use the NC app and their ability to venture out to new spaces without their parents. Parents reported that their tweens mostly used the app in their own yards and in their neighborhoods, close to their homes. When tweens used the app farther from home, they were largely accompanied by a parent, often going on walks, riding bikes, walking their dog, and running errands. One mother shared her tween's limited access to nature spaces: *"We don't have a neighborhood where he can go out on his own. It's our backyard or when I was close with him."* P1 [T1 (boy, age 10)].

Two siblings in the study discussed their geographic limits:

T12: “Okay, are we going? Okay, well bye!” ...

P12: “Don't go farther than, you know, don't go far” ...

T12: “What did she say our limit was?” ...

S12: “She didn't say what [our] limit was. I think our limit is up to the fence back there” ...

P12: “Geezz, I think the limit is any parking lot. Whoops! We just crossed one! L-O-L X-D.”

[T12 (girl, age 12), S12 (boy, age 10)].

Sometimes, tweens tried to negotiate with their parents to go to new places, such as the zoo, a nearby beach, or on family hikes to explore and take photos of new nature elements.

5.2.3

Discussion And Design Implications

In this study, we describe how parents experienced their tweens’ NatureCollections app engagement in outdoor exploration and uncover family needs around app use. Our results showed that the NC app succeeded in engaging tweens in positive developmental related behaviors and experiences with their parents, such as promoting creativity, curiosity, and connecting with and learning about natural elements during family joint nature explorations. Our results also indicate the app encourages tween’s agency, family bonding, and positive social interactions with parents and siblings. We also found, however, that the digital experiences intended to connect tweens to nature and enrich their outdoor explorations were influenced by parents’ screen-time rules and parent-tween negotiations around technology use. In our discussion, we draw from our empirical insights and prior work to present recommendations for designers to support family joint nature explorations. We also identify several opportunities to reduce parent-tween screen-time tensions during tweens’ transitional period of development.

Joint nature-based exploration: Our results showed that the NC app facilitated Joint Media Engagement (JME) (Takeuchi and Stevens 2011), by supporting family togetherness during nature-based activities and promoting behaviors that aligned with family values. This work extends our understanding of JME by considering these interactions in a new context: nature-focused exploration involving tweens who are experiencing a transitional stage of technology use. We uncovered families' needs that highlight parents' desire to support their tweens' autonomy while maintaining connection and shifting some of the burden of guiding their tweens to the app. Similar to prior JME research (Ferdous et al. 2016; Yu et al. 2017), we found that tweens' app activities sparked meaningful family interactions with nature. Parents, however, also expected the NC app to support deeper conversations with their tweens by providing access to nature-related knowledge and by sending them contextual information about their tweens' photos and app activities. Like Sobel et al., our results show that the NC app encouraged families to create more family bonding experiences, including spending more time together outdoors (Sobel et al. 2017). Parents and their tweens worked together while using the NC app to identify and learn about nature, consistent with prior insights about parents taking on new facilitation roles to support family social learning experiences (McClain 2018). Yet, parents in our study also wanted to take on this new role through their own parent version of the NC app, allowing them to remotely share photos, collaborate on activities, and complete family challenges. Additionally, parents wanted the app to facilitate a variety of joint family outdoor activities such as scavenger hunts and time- or location-based challenges.

NC app use during a time of transitional tech use: Tweens are in a transitional period of development, seeking to re-negotiate parental boundaries as they establish greater personal

autonomy (Collins and Steinberg 2006; Wrate 1986). These dynamics can lead to tension between tweens and parents related to technology ownership and use (Davis, Dinhopf, and Hiniker 2019; Kim and Davis 2017). On one hand, parents appreciated how the app encouraged their tweens' independence to initiate time outdoors without parental nudging, and they believed their tweens would be more willing to engage in these activities if they were suggested by the app rather than by them. On the other hand, tensions emerged around the integration of the NC app into parents' existing screen-time rules. Parents indicated that they normally enforced screen-time limits for their tweens' technology use. However, they made exceptions to these rules for the NC app, citing how the app supported and valued family activities that engaged their tweens with positive outcomes like spending time outdoors, connecting with and learning about nature, family bonding activities, and creative activities over passive media consumption. Additionally, tweens negotiated geographic boundaries that determined where they could go without parental supervision, defining the limits of their outdoor app use. These struggles are similar to prior work examining parent-teen tensions related to the phone (Blackwell, Gardiner, and Schoenebeck 2016; Davis et al. 2019), but shaped in distinct ways by the specific context of outdoor nature exploration.

In addition to the needs identified for family joint nature-based engagement, parents expressed concerns about parental controls and safety concerns, including privacy, safety, and social connections with non-family members through the app. Parents desired a range of engagement options to address these concerns, mirroring parental mediation styles (Clark 2011; Livingstone et al. 2017). Some parents wanted to restrict who their tweens could connect with on the app and their level of social engagements; other parents wanted to monitor their tweens' overall app

activity; and still other parents wanted to become co-users with their tweens with a parents' version of the app that integrated with their tweens' NC app. With these empirical insights in mind, we offer the following design recommendations:

5.2.3.1 *Facilitate Digital Experiences that Mind the Context Gap*

Our findings demonstrate that parents felt they were missing context around their tweens' NC app engagement, including app-related nature knowledge. Parents explained that lacking this context impacted how and to what extent they reacted and engaged with their tweens' nature-based experiences. Parents' engagement needs spanned the desire to learn what interested their tweens about the photos they were sharing with them, the type of nature element in focus (e.g., plant or bug), and the number of photos and badges their tweens collected. Parents expressed needing access to contextual nature information to increase their knowledge to be able to support their tweens in identifying the species in their photos and surroundings. Parents also desired nature prompts and questions to facilitate sense-making and deeper conversations about nature with their tweens.

Previous research in the learning sciences field has found that when parents support their children's observations and sense-making during family nature-based explorations, it facilitates children's development of scientific thinking and shapes their problem-solving skills (Eberbach and Crowley 2017; McCLAIN and Zimmerman 2014). These findings provide a design opportunity to facilitate digital experiences that bridge the context gap around app interactions and nature information to increase joint family nature-based engagement. Designers could consider supporting in-app audio and visual snap features to collect the context of tweens' app use. This data could be displayed alongside the photo metadata, such as location and photo details, entered by the tween. The app could incorporate just-in-time features to recall photo-

related nature information and nature prompts to support family conversations during their joint nature explorations.

5.2.3.2 *Support Co-Located and Remote Family Activities*

In our study, parents expected to jointly interact with their tweens' app activities both while being together and when being apart. Parents had competing demands and responsibilities, yet they desired the app to support continued engagement with their tweens' nature explorations, even when they were physically separated. Other parents desired features to support family activities during outdoor trips and even suggested having a parent version of the app, where parents and their tweens work together on family collections and challenges. Parents felt that these additional features would increase their joint family engagement around nature and facilitate meaningful family and nature interactions.

Prior research found that when parents and children engage in meaningful nature-based experiences together, it advances their children's connection to nature and supports their conservation values and environmental stewardship development (Ernst 2018). Our work suggests that families can share nature-based experiences both when they are physically together and also when they are apart. These insights provide a design opportunity to combine co-located and remote digital family activities to support family togetherness in nature-based explorations. Designers could consider facilitating parent-tween remote connection and interactions around nature by supporting features for parents to engage digitally with their tweens' shared photos. For joint family activities, the app design could include co-play features that support collaborative and competitive nature-based challenges to increase family engagement and interactions with nature.

5.2.3.3 Create opportunities for technology to reduce screen time tensions

In addition to design needs to increase family joint nature-based engagement, we found that tweens' experiences with the NatureCollections app were influenced by how parents and tweens negotiate screen-time and technology-use tensions. Prior work identified that the sources of parent-tween tensions are influenced by the transitional period of development that accompanies tweens' technology use (Collins and Steinberg 2006; Steinberg and Silverberg 1986; Wrate 1986). We found that tweens explored their autonomy and independence from their parents when using the NatureCollections app. Tweens negotiated geographic boundaries that limited their outdoor explorations of where they could go without parental supervision. We also observed in our study that parents' roles to mitigate their concerns about their tweens' privacy, safety, and social interactions with technology use matched the parental mediation roles of restrictive, active, and co-use (Clark 2011; Livingstone et al. 2017).

Recent work investigating parental mediation roles has found that parental mediation roles are not discrete but fall on a spectrum that parents employ in different contexts (Jiow, Lim, and Lin 2017). These findings provide design opportunities to create technology that reduces screen-time tensions by supporting the diversity of parental mediation approaches and augmenting them with strategies that support tweens' autonomy needs. Facilitating tweens' sense of choice is central for tween autonomy development and proper separation from their parents on the path to adolescence and adulthood (Collins and Steinberg 2006; Wrate 1986). Designers could consider supporting parent-tween negotiations around screen time by facilitating features that: (1) guide clear limit setting; (2) elicit a meaningful rationale for limits; (3) mitigate conflict by acknowledging tweens' perspectives; and (4) provide choices and options. Designs could support

features for tweens to self-direct boundary setting, in agreement with their parents, around which apps to use on their device and for how long by providing easy app drag-and-drop or feature selection options. In the context of nature-based exploration, the app design could support parents and tweens in jointly establishing geographic boundaries where tweens can explore. The app might send a notification to tweens when those boundaries are approaching. Additionally, designs could provide guiding prompts to parents to support conversations with tweens around their family's shared values and explanations for technology restrictions. These prompts could also engage tweens in reflective practices that encourage them to take ownership of their actions. In these ways, technology designs could promote meaningful input from both parents and their tweens and enable tweens' involvement in decision-making around their technology use.

5.3 SUMMARY OF CONTRIBUTIONS

The studies' results demonstrate that the NatureCollections app significantly increases children's time spent outdoors, and fosters positive family joint nature-based experiences that promote nature exploration, curiosity, and direct engagement with natural elements—critical indicators that the app design supports optimal child development. Here, I contribute a generative theory and design guidelines that expands the joint media family engagement (JME) in a new context of nature-based explorations. Accounting for the dynamics of parent-child interactions in tech-mediated experiences facilitates children's developmental growth. Together with the findings presented in Chapter 4, this empirical evidence addresses the broader implications of T1, by determining the long-term NC app interactions' effects in promoting positive development in children and examining parent-child app shared experiences to distill design recommendations for joint family nature-based explorations.

CHAPTER 6. TRANSLATING CHILD-COMPUTER INTERACTION RESEARCH

Reflecting on my work in incorporating child development theory to enhance the developmentally responsiveness of mobile technology designs (Chapter 3-5), led me to ask RQ2: What are the research contributions, values, and developmental needs the CCI community aims to support when advocating for developmental responsive designs for children? Yarosh et al. (2011) paper reported on the explicit values inherent in children's design and research published at IDC from 2002 to 2010. The paper examined the children's developmental qualities supported in the IDC research, the role of the child in the design process, and the theories and models that guided the design choices of child technologies. The findings of this systemic review and other CCI reflective published work (discussed in Chapter 2) identified that despite the abundant research on child development and educational theories, a small portion of the research explicitly references those theories to ground design choices in children's technologies (Antle 2013; Read and Markopoulos 2013; Yarosh et al. 2011). However, since the publication of this review study over a decade ago, we have seen an explosion in children's use of touch-screen, wearables and conversational agents technologies, younger children having access to easier-to-use technology, and an increasing role for parents. Thus, an updated look at IDC research practices and the imbued values is valuable for the CCI research and the design practice communities.

In order to support the broader context of T1 by examining current CCI research in incorporating child development theories to inform their children's technology design, and to explore T2 by identifying Child Computer Interaction (CCI) research to include in the designer's toolkit, I set out, in collaboration with a team of researchers from three different universities, to examine the

developmental needs and behaviors the CCI researchers seek to support in children, the theories that inform the CCI research, and the criteria that guide the design choices in the research published in the Interaction Design and Children (IDC) conference between 2011 through 2019 (220 papers). IDC is the ACM's primary annual international conference series for CCI researchers and educators to publish and share the latest peer-reviewed research findings, new technology innovations, and methodologies of inclusive child-centered design and interactions. The IDC published research from the last two decades has been committed to participatory design experiences and discussions on how to create better interactive experiences with and for children (Giannakos et al. 2020). This study provided a foundational work to synthesize evidence-based research and summarize actionable design recommendations for the Interaction Design and children designer's toolkit described in detail in Chapter 7. This work was peer-reviewed and published in the ACM conference on Interaction Design and Children (Kawas, Yuan, et al. 2020)⁹.

6.1 METHOD AND ANALYSIS

In collaboration with a group of researchers from three different universities, I led a qualitative systematic literature review of the full content of published research papers in the IDC conference between 2011 through 2019 (220 papers). We replicated the analysis conducted by (Yarosh et al. 2011) for IDC papers published from 2003-2010 and expanded that work by identifying new value categories and considerations. We also sent a survey to the first author of

⁹ Kawas, Saba, Ye Yuan, Akeiyah DeWitt, Qiao Jin, Susanne Kirchner, Abigail Bilger, Ethan Grantham, Julie A. Kientz, Andrea Tartaro, and Svetlana Yarosh. 2020. "Another Decade of IDC Research: Examining and Reflecting on Values and Ethics." Pp. 205–15 in *Proceedings of the Interaction Design and Children Conference, IDC '20*. New York, NY, USA: Association for Computing Machinery.

each paper to better understand the values and ethical considerations that authors imbue in their work that might not be explicitly expressed in the paper due to space limitations. We also reflected on how IDC research has changed between 2010 and 2019. Our work is driven by the following questions:

1. What developmental qualities and behaviors does IDC research aspire to support in children?
2. What types of research contributions do IDC papers make?
3. What are the roles of the children and other stakeholders in the design and research process?
4. What theories, models, and frameworks inform IDC research?
5. What criteria inform IDC's technical design choices?
6. How has 2011-2019 work seized on the opportunities for IDC presented in (Yarosh et al. 2011)?

6.1.1 *Review and Coding Process*

Three teams at three different universities (3 faculty and 5 PhD, 4 Masters, and 2 undergraduate students) participated in reading, coding, and conducting a content analysis of the full text of 220 papers. Team leads (faculty and PhD candidates) from all three universities developed the coding scheme. We developed initial codes based on our research questions and the findings presented in (Yarosh et al. 2011), examining the values in the IDC published papers in the first decade. All team leads then applied these codes to one paper and discussed revisions and clarifications. Team leads then led their teams in applying the codes to four randomly selected papers and met to finalize the codebook. Next, pairs of researchers coded a random sample of 20% of the papers. Inter-rater reliability (IRR) for these papers was calculated with Cohen's kappa coefficient for

each pair of responses within the sample. The resulting IRR value across 146 categories of codes 41 papers was 0.543, suggesting moderate agreement (McHugh 2012). We discussed all disagreements to ensure accurate coding, we coded the remaining papers using a consensus process where two researchers on the same university team individually coded each paper and then met to reach consensus for the final codes. To facilitate communication and consistency across teams, team leads met weekly over video conferencing throughout the coding, analysis, and writing process.

In total, we applied 146 individual codes to identify the following: children's behaviors and developmental qualities supported by the research (e.g.; learning, social interactions); the contribution(s) of the paper (e.g.; design artifact, empirical study); the role of the child (e.g.; co-designer, user), researcher, and other stakeholders in the design process; co-design values explicitly described in the paper; consideration of children with special needs or abilities; the relationship of the approach to current practices; the theories, models, and frameworks informing the work; the technical design choices; and whether the paper responded to specific opportunities posed by (Yarosh et al. 2011). In addition, the research team could add additional "other" codes throughout (e.g., behaviors encouraged by the designs, technical design choice, and stakeholders and their roles) and were asked to provide specific details on particular codes, which included: theories, frameworks, and models identified in the paper; the relationship of the research to current practices; whether children with special needs or abilities were included; and how papers responded to opportunities from (Yarosh et al. 2011). These open-ended responses were qualitatively analyzed by pairs of researchers using data-driven thematic analysis (Braun and Clarke 2006) to identify new emerging themes discussed in the results. We also obtained the data

set from Yarosh et al.'s work, which we used to analyze patterns over the two decades (2002-2019). We used Pearson correlation to analyze the trends over years for all the codes during 2011-2019, and for the codes used for both decades (2002-2019).

6.1.2 *Author Survey*

Our qualitative analysis could only identify values explicitly expressed in each paper. For deeper insights into the values and ethics that drove IDC papers, we conducted a survey sent to the first authors of papers published between 2011 and 2019. We used a Qualtrics survey tool and asked open-ended questions about: values authors described as inherent in their work, what motivated them to conduct their research, the impact they would like for their work to have in the world and the ethical considerations central to their work with children. We received responses for 44 papers (20% of the papers published at IDC between 2011-2019). Through data-driven thematic analysis (Braun and Clarke 2006), two researchers identified emerging themes reflecting authors' motivations (e.g., creating positive outcomes for children), values (e.g., reflecting on the role of technology), desired impact (e.g., raising awareness in applied practice) and ethical considerations (e.g., protecting children's privacy and safety from participating in research). Initially, two researchers independently coded survey responses for 10 papers and then met to discuss the coding themes, define inconsistencies, and create a codebook. Both researchers coded the remaining survey responses for consensus and met to discuss agreement and refine codes based on new emerging themes.

In the following sections, I first discuss children's behaviors and developmental qualities the IDC research aspires to support, then report our findings addressing the other five questions above. Finally, I discuss the author's survey response.

6.2 CHILDREN'S SUPPORTED DEVELOPMENTAL QUALITIES AND BEHAVIORS IN IDC RESEARCH

Researchers expressed their motivation, in their designs and investigations, to support children's developmental needs through their interaction with technology and the world around them across several domains (See Table 6-12).

6.2.1 *Social Interaction & Connectedness*

Researchers aimed to support children in developing social skills, collaborating with their peers to share knowledge and design, and cultivating environments where peers could freely interact with one another (e.g. facilitating effective group work). In this decade, 41% of papers were tagged as supporting social interaction, 35% of papers were tagged as supporting collaboration, and only two papers aimed at supporting competition. While many of these papers focused primarily on social interaction within peer groups, 7% of papers explored social interaction between children and their families. Researchers have persisted with their motivation to support collaborative behaviors in children, with an increase in papers that supported collaboration (see Table 6-1).

6.2.2 *Learning*

IDC continues to value behaviors related to learning, including literacy, inquiry and reflection. Many researchers designed technologies and conducted investigations concerned with understanding how these factors can contribute to children's learning. Researchers examined reflection (12% of the papers) as an opportunity to facilitate learning and developed technologies that supported children in their ability to reflect on events and situate their reflections within the broader context. Researchers also investigated learning as an opportunity to support cognitive

development in children, increasing from 7% of papers in the last decade to 16% of papers in the current decade. Broadly, researchers aimed to support children in their exploration of the world and ability to grasp age-appropriate academic concepts. Exploration (in both academic and non-academic contexts) rose as a supported behavior, growing from 15% of papers in the last decade to 30% of papers this decade. Several researchers utilized theories related to exploration (e.g., Inquiry-based Learning) to inform the design of technologies, and support knowledge inquiry across a variety of contexts.

Table 6-12. Codes addressing developmental qualities IDC aspires to support in children, the percent of papers that were tagged with this code, and trends over time.

Social Interaction & Connectedness						
Code	2002-2010		2011-2019		2002-2019	
	%	Trend	%	Trend	%	Trend
Social Interaction	41	0.45	41	0.77	41	0.29
Collaboration	28	0.44	35	-0.21	32	0.38
Family Connectedness	4	0.56	7	0.19	6	0.39
Competition	4	0.06	0.5	0	2	-0.24
Learning						
Learning	14	-0.11	56	-0.32	40	0.66
Exploration	15	-0.17	30	-0.52	24	0.26
Fluency with Technology	9	-0.12	17	0.16	14	0.37
Support Cognitive Development	7	0.72	16	0.25	13	0.72
Inquiry	7	-0.03	14	-0.42	11	0.23
Programming/Coding	12	0.17	12	-0.08	12	-0.04
Reflection	7	0.06	12	0.15	10	0.35
Literacy	9	-0.51	8	-0.03	8	-0.31
Learning Real World Skills	6	-0.36	7	0.69	7	0.09
Expression						
Self-Expression	18	-0.62	20	0.05	20	-0.01
Creativity	17	0.01	20	0.43	19	0.15
Narratives	18	-0.02	11	0.46	14	-0.35
Imagination	7	0.52	7	0.50	7	0.22
Play						
Playfulness	10	0.36	31	-0.09	23	0.75
Physical Activity	9	0.57	11	0.12	10	0.34
Personal Growth						
Attitude & Motivation	4	-0.07	16	0.35	11	0.65
Equity of Participation	5	-0.46	12	-0.31	9	0.31
Autonomy	-	-	12	0.63	-	-
Identity	-	-	4	0.62	-	-
Morality & Ethics	3	-0.41	3	-0.50	3	-0.17
Autonomy & Identity	7	-0.59	-	-	-	-
Health & Well-being						
Health/Well-being	-	-	12	0.59	-	-
Other						
Have Children Buy Products	1	-0.13	0	-	1	-0.35

6.2.3 *Expression*

Researchers also aimed to support more generative behaviors, like the ability to construct narratives, creativity, and imagination. As in the first decade review, researchers were motivated to support children when expressing their personal ideas, beliefs, and motives and all three of these categories continued to be well-represented between 2011 and 2019 (see Table 6-1).

6.2.4 *Play*

Compared with 2002-2010, more 2011-2019 papers aimed to support students in play and playfulness (10% vs. 31%). Additionally, 11% of papers examined physical activity as an opportunity to engage students in play events (Table 6-1).

6.2.5 *Personal growth*

Several papers in this decade of research intended to support personal growth in children. Compared to the prior decade (7%), 16% of papers explored the benefits technology can afford when supporting children as they develop their own identities and sense of autonomy in the world. For example, papers tagged with “equity of participation” increased from 5% to 12%. Additionally, more papers aspired to support children’s “attitude and motivation” (4% vs. 16%).

6.2.6 *Health and well-being*

While this category did not emerge in the first decade review, “health and well-being” was a significant category in the 2011-2019 literature (12% of the papers, Table 6-12). Future IDC research may explore health and well-being further and support children through their experiences.

6.2.7 *Emerging Categories of Supported Behaviors and Developmental Qualities*

Several categories of ‘other’ child behaviors emerged alongside the preexisting child behavior codes. These categories varied across facets of executive function, connectedness with the community and design for privacy and security. Specifically, 14 new qualities and behaviors emerged from the ‘other’ codes in 64 papers. For example, 7% of all papers promoted the value of supporting executive functions including self-regulation, planning, attention, and memory. Many of the papers also pursued supporting healthy emotional development. 9% of papers aspired to support social and emotional skills through emotion regulation and supporting positive (affect) emotion states. Fewer papers (5%) aimed to support mental health and therapy. Alongside explicitly supporting autonomy, we also observed 6% of papers aimed to support children’s self-advocacy and empowerment. In contrast, direct mention of inclusive practices within the research was uncommon. Only 2% of papers presented work that explicitly upheld inclusive practices (e.g. inclusive learning or inclusive play).

Researchers also championed children’s design skills and fabrication of new technologies instead of simply generating ideas to design for existing ones. In 5% of papers, researchers encouraged fabrication activities (e.g. making, crafting, tinkering) for children. While papers did encourage engagement with different technologies, no papers involved in this analysis encouraged children to purchase products or asserted advertising to children.

6.3 RESULTS

6.3.1 *IDC Research Contributions*

We developed a research contribution coding scheme based on prior work in HCI (Wobbrock and Kientz 2016) and coded each paper with one of the seven primary research contribution types. To compare primary contributions between the first decade (2002–2010), and the second decade (2011–2019), we matched categories that shared similar definitions (Table 6-3). In Yarosh et al., authors reported contributions that emerged from open coding, thus we assume that in the 1st decade there might not have been methodological or theoretical contributions, see Table 6-3.

Table 6-3. Codes addressing primary contributions, the percent of papers that were tagged with this code, and trends over time.

Paper Primary Contribution						
Code	2002-2010		2011-2019		2002-2019	
	%	Trend	%	Trend	%	Trend
Contributes an Empirical Study	45	-0.14	61	0.34	55	0.46
Contributes an Artifact	43	0.64	23	-0.36	31	-0.51
Contributes a Method	-	-	6	0.28	-	-
Contributes a Theory	-	-	5	0.10	-	-
Contributes a Research Review	-	-	4	0.02	-	-
Contributes a Reflection	12	-0.38	1	0.02	5	-0.59
Contributes a Dataset Corpus	-	-	0	-	-	-
Paper Contribution Values						
Design and Evaluate in Context	7	-0.66	40	0.005	27	0.73
Understanding Children's Models	18	-0.12	39	-0.11	31	0.43
Examine our Methods	21	-0.73	17	0.17	18	-0.37
Makes an Explicit Appeal to IDC	11	-0.70	15	0.02	13	-0.09
Conflict between Goals and Methods	8	-0.34	8	0.23	8	-0.10

Most papers published in the second decade (2011–2019) (61%) emphasized contributing *empirical* knowledge from both qualitative and quantitative studies. 23% of papers contributed a novel *artifact* (e.g., a new innovation or system). Only 1% of the papers from the second decade focused on *reflection and discussion* as their primary contribution. Although *empirical* study and *artifact* contributions remained as the most common primary contributions in the second decade, there was a moderately increasing trend for *empirical* contributions compared to the first decade

(see Table 6-3). Fewer papers focused on designing novel systems in the second decade, and thus the *artifact* category seemed to show a strong declining trend over the past two decades.

When examining papers' values contributions, we found more papers consistently valued designing and evaluating technologies in authentic contexts in the second decade (40% of the papers, as opposed to 7% in the first decade). Papers focusing on understanding children's models (39% in the first decade versus 18% in the second decade) showed a rising trend over the past two decades. 17% of papers from 2011-2019 explicitly discussed reflecting and examining methods used to work with children, and 6% of the papers emphasized creating new knowledge on how the IDC community does science or designs with children. Although IDC still values discussion and improvement of methods, it seems that there is a moderate decline in "examining our methods" over the past two decades.

We also examined where IDC work was carried out between 2011 and 2019 to understand who is represented by the IDC community. IDC authors listed their affiliations in 28 countries and reported conducting research in 30 countries. In general, the research was conducted in the same location as the author's institution with only 5% of research conducted in a different location. IDC papers are mostly from institutions in the US (49%), European countries (38%), the UK (10%) and Canada (4%). In contrast, the number of papers with authors from countries in Africa and South America is extremely small, with only one paper from Africa and two papers from South America. IDC authors from Asia and Oceania constitute 6% and 1% of papers respectively.

6.3.2

The role of the child and other stakeholders in the design process

IDC researchers still value children's participation in the technology design process. More papers ensure that designs reflect children's voices from 2011-2019 (20%, as opposed to 14% from 2002-2010). When specifically examining children's role in the design process, we found more papers involved children as informant (13%) in the second decade, where children inform the design process at various stages (e.g., being observed with existing technologies, asked to sketch new ideas). There seems to be a moderate trend indicating the increase of children as informants in the recent decade as well as over the two decades (Table 6-4).

Table 6-4. Codes addressing for whom IDC designs, the percent of papers that were tagged with this code, and trends over time.

Role of Child in Design						
Code	2002-2010		2011-2019		2002-2019	
	%	Trend	%	Trend	%	Trend
Tester	39	0.86	35	-0.11	37	0.06
User	-	-	29	-0.31	-	-
Informant	8	0.08	13	0.37	11	0.36
Design Partner	29	-0.82	12	0.25	18	-0.70
None	-	-	9	0.14	-	-
Role of School						
Including Teachers	5	-0.42	18	0.01	13	0.60
Curricular Integration	14	-0.05	15	-0.13	15	-0.01
Balance Multiple Stakeholder	9	-0.50	13	0.15	11	0.14
Whole Class Activities	2	0.67	12	-0.37	8	0.73
Codesign Values						
Reflect Children's Voices	14	-0.79	20	0.39	18	0.12
Children as Active Agents	20	0.07	15	0.18	17	-0.12
Equalize Power btw Child & Researcher	9	-0.67	6	0.21	7	-0.30
Diversity Values						
Design for Special Needs	12	0.75	15	-0.02	14	0.28
Engaging the Underserved	7	0.17	12	0.27	10	0.39
Gender Awareness	11	-0.39	8	0.48	9	-0.27
Design for Multiinteraction Styles	15	-0.24	5	-0.22	8	-0.59
Culturally-Appropriate	4	0.01	5	0.63	5	0.22
Design for All Genders	6	-0.65	2	-0.45	3	-0.52

However, fewer papers explicitly discuss the value of children as active agents in the design process in the recent decade (15% of the papers, as opposed to 20% of the papers from 2002-2010). Only 12% of the papers involved children as design partners in their design process, compared to 29% of the papers from the first decade. Children as design partners shows a strong

decline trend over the two decades (Table 6-4). This might indicate a shift in children's role in IDC, where researchers see children beyond co-designers in their studies (e.g., child as protagonist (Iversen, Smith, and Dindler 2017)). Despite this declining trend, IDC authors reported valuing child-centered research process. According to the author survey, authors emphasized creating a positive experience when having children participate in research and advocated for making sure children's perspectives are represented in the desired outcome (e.g., artifact or intervention).

We also examined adult stakeholders' roles in the design process. 52% of the papers from the 2011-2019 includes adult stakeholders in their investigations. Among these papers, 49% of these papers include parents, 31% of these papers include teachers, and 16% of these papers include other professionals (e.g., therapist, doctors, administrators) in their studies. Researchers mostly include parents as users (33%), and testers (30%). In 19% of papers, parents were informants. In several investigations, parents were design partners (7%) and test facilitators (7%). One potential explanation for parents' role in the design process might be that IDC as a community often designs for both children and their families.

When examining the role of school in the design process, we found including teachers seems to have a strong increasing trend over the two decades. Also, there seems to be a strong increasing trend in designing for whole class activities in the two decades. When teachers are included in investigations, the majority (53%) of studies included the teachers as informants. Other roles for teachers include users (20%), design partners (20%), testers (13%), test facilitators (13%), and evaluators (7%). The emphasis on roles that directly affect designs suggest that researchers

leverage teachers' expertise in children's learning and development when designing technology systems.

IDC authors continue to support children with different abilities and needs and engage the underserved communities in their investigations. Compared to the first decade, *designing culturally appropriate interventions* seems to be a strong increasing trend in the second decade. Both *designing for multiple interactions styles* and *design for all genders* seem to decline strongly over the two decades, which might indicate less explicit discussion about these diversity values that may be assumed in the design process.

6.3.3 *Theories, models and framework that inform IDC research*

Yarosh et al. identified “more widespread and more explicit use of theories and models” as an opportunity for IDC (Yarosh et al. 2011). Our results suggest the community has embraced this directive (Table 6-7). 75% of 2010–2019 papers identified theories that informed the research, and the breadth of theories used appears to be much broader (Table 6-5). 5% of papers make a specific theoretical contribution (Table 6-3).

Yarosh et al.'s analysis identified developmental theory, the cognitive theory of Embodiment (cognition is entwined with the body's interactions in the environment), Piaget's Constructivism (children's knowledge is self-constructed from their experiences), and Papert's Constructionism (based in Constructivism, learning occurs while constructing artifacts) as the key theoretical trends from 2002–2010. They also looked specifically at approaches used in learning papers and identified “learning through play” (15% in 2002-2010, 3% in 2011-2019), “games for learning” (1% in 2002-2010, 4% in 2011-2019), “*in situ* learning” (9% in 2002-2010, 2% in 2011-2019),

and “learning through embodied interaction” (9% in 2002-2010, 10% in 2011-2019 (along with the specific theories of Constructivism and Constructionism), as trends informing the designs. Comparative analysis is detailed in Table 6-5.

Table 6-5. Codes addressing theories and models, the percent of papers that were tagged with this code, and trends over time.

Theories						
2011-2019 Code	2002-2010		2011-2019		2002-2019	
	%	Trend	%	Trend	%	Trend
Developmental Theory	15	0.71	14	-0.45	14	0.10
Constructionism	15	0.25	11	0.21	13	-0.17
Constructivism	24	0.28	10	-0.49	15	-0.38
Embodiment	22	0.40	6	-0.75	13	-0.43
Learning Theories	-	-	17	0.17	-	-
Social Theory	-	-	15	-0.04	-	-
Design/Interaction Theories	-	-	14	-0.18	-	-
Humanities	-	-	5	-0.15	-	-
Other	-	-	16	0.55	-	-
Learning Philosophies/Approaches						
Learning through Embodied Interaction	9	0.12	10	-0.73	10	-0.07
Games for Learning	10	0.26	4	-0.22	6	-0.34
Learning through Play	15	0.11	3	-0.73	8	-0.60
In Situ Learning	9	0.16	2	-0.06	5	-0.35

Our analysis identified a much broader array of theories. As part of our coding process (described above), we had researchers list any theories authors used to explicitly inform the research, and then two researchers further analyzed and categorized the identified theories. Authors still cited staged and other general developmental psychology theories (14%, compared to 15% in 2002-2010). Constructionism (11%, vs. 15%), Constructivism (10%, vs. 24%), and Embodiment (6%, vs. 22%) are still specific theories central to the community. We also identified a number of theories that we categorized as “learning theories” (those that discuss pedagogy or how learning occurs) or “social theories” (e.g., Vygotsky or socio-cultural theories). Though our results could be interpreted as indicating a decreasing trend with respect to Constructivism and Embodiment, many of the new theories we identified have roots in these theories, further specifying how children construct knowledge and engage their environment.

We also saw authors using design theories and frameworks to inform their work. For example, Horn et al. (Horn, AlSulaiman, and Koh 2013) use Lee's "cultural modeling design framework" (Lee 2003) to inform their design process. Some authors discuss Participatory Design, a method for working with users, as a theory or framework informing their work. In addition, we noted emerging use of theories from the Humanities, such as feminist theory, theories on cultures, and literary theories. These critical theories are an interesting complement to IDC's traditional social science lens. Finally, our "Other" category encompassed a range of other theories that did not fall into those above, such as additional cognitive (e.g., cognitive load, memory), communication, behavior change, or computational theories.

In summary, social science theories related to how children learn and develop is central to IDC work, and researchers are using more specific theories to understand designs for children. The community is also applying non-social science theoretical lenses. Future work could look in more detail at *how* theory is being used to inform IDC work, such as motivation, design features, and evaluation.

6.3.4 *Criteria that inform the design choices*

Similar to papers from 2002-2010, IDC continues to view intrinsic motivation and engagement as important design criteria for new technologies. In the second decade, 20% of the papers valued enjoyment of their designed technologies and 36% of the papers discussed engagement with the technology in their system design (Table 6-6). Although we observed a higher percentage of technology engagement discussion in the papers from the second decade, the discussion was decreasing in recent years. One reason for this decrease could be that researchers have moved beyond engagement and want to support a wider range of attributes.

IDC papers increasingly value designing for learner's experience in new technologies, with 21% of the papers emphasizing learner-centered design and 15% of the papers mentioning designing for the experience in their technology design criteria. The discussion about learner-centered design and designing for the experience seemed to increase over the past two decades (Table 6-6). Unlike typical technology evaluations, IDC papers focus less on efficiency, task completion, or cost effectiveness when designing technologies. Fewer papers appear to discuss these criteria in the second decade.

Table 6-6. Codes addressing values in the technical design, the percent of papers that were tagged with this code, and trends over time.

Attributes Valued						
Code	2002-2010		2011-2019		2002-2019	
	%	Trend	%	Trend	%	Trend
Engagement	24	0.69	36	-0.51	32	0.57
Learner-Centered Design	4	0.27	21	-0.10	14	0.65
Enjoyment	24	-0.30	20	0.23	22	-0.21
Designing for the Experience	4	-0.18	15	-0.28	10	0.46
Feedback	9	0.12	14	0.06	12	0.31
Customizability	4	0.42	10	-0.67	8	0.56
Simplicity	4	0.29	10	0.01	8	0.42
Desirability	14	-0.55	8	-0.07	10	-0.44
Multiple Senses	4	0.08	6	0.53	5	0.12
Naturalness (Intuitive)	20	0.12	5	-0.08	11	-0.55
Challenge	7	0.17	5	-0.43	5	-0.19
Efficiency or Task Completion	6	0.50	5	-0.80	5	-0.08
Cost Effectiveness	3	0.50	4	-0.16	4	0.19
Engagement in the Long Term	3	0.24	3	-0.40	3	0.01
Aesthetics	3	0.15	2	0.02	2	-0.14
Technical Choices						
Tangibles	26	0.30	20	-0.18	22	-0.28
Bridging Physical and Digital	11	0.54	15	-0.61	14	0.28
Innovate and Explore Novel Technologies	8	-0.51	7	-0.30	8	-0.23
Mixed Reality	15	0.58	5	0.02	9	-0.17
Platform						
Tangibles & Smart Objects	-	-	20	-0.21	-	-
Mobile Technologies	-	-	19	-0.25	-	-
Personal Computer	-	-	13	-0.76	-	-
Shared interactive surfaces, tabletops	-	-	8	-0.70	-	-
Sensor-based and Wearable	-	-	6	0.16	-	-
Virtual & Augmented Reality	-	-	4	0.71	-	-
Multisensory Environments	-	-	2	0.06	-	-
Natural User Interfaces	-	-	2	0.63	-	-
Robotics	-	-	0	-	-	-
Relation to Current Practices						
Leverage Current Practices	12	-0.29	49	0.09	34	0.76
Transform Current Practices	2	0.07	23	-0.38	15	0.51
Concerns about Technology Negatives	5	0.22	6	0.48	6	0.23

IDC shares some similar design criteria with the broader HCI community: papers from the 2011-2019 emphasized feedback (14%), customizability (10%), engaging multiple senses (6%) and naturalness (i.e., intuitiveness) (5%) in their designs (Table 6-6). However, the discussion on intuitive or natural technology design seemed to decrease over the past two decades.

This decrease could be due to several factors: (1) increased rigor of IDC research that is published; (2) the shift in the goals of the designed technologies as the IDC aims to support other behaviors and qualities; and (3) an emphasis on involving children in the design process for new technologies, which ensures the intuitiveness of the designs.

Bridging the physical and digital still attracts IDC's interest compared to other technical choices (15 % of the papers), though there is a decreasing focus in recent years. Tangibles remains the most popular form of technologies researchers leveraged in their designs in the second decade (20% of the papers) and 5% of the papers encouraged mixed reality. As IDC aims to design for a larger variety of ages, researchers are leveraging more mobile and ubiquitous platforms: 19% of the papers designed with mobile technologies, 6% with sensor-based technologies and wearables, and 2% with natural user interfaces (e.g., gestures and speech) in the second decade. Design for personal computers seems to show a strong declining trend in the second decade (Table 6-6). This decline might be due to the wide spread of mobile technologies and smart devices (e.g. wearables).

IDC researchers often consider novel or innovative technology solutions as opportunities to support and transform activities that are not traditionally technology mediated. When examining the relation between technology and current practices, we found an increasing number of papers discussing technology designs that leverage current practices (49%, Table 6-6). Researchers also

emphasized the importance of leveraging current research practices in the author survey, for example, following current participatory design techniques for having children involved in the design process. Papers that focused on transforming current practices have increased in the second decade as well, with 23% compared to 2% of papers in the first decade.

As in the first decade, IDC papers in the second decade rarely addressed concerns about technology negatives (only 6%). However, those that did covered a variety of concerns, such as online safety and privacy (Kumar et al. 2018), problematic app designs (Fitton and Read 2019), datafication (Zaman, Van Mechelen, and Bleumers 2018), and use of intelligent systems, AI, and voice agents (e.g., (Pantoja et al. 2019)).

6.3.5 *How has IDC research seized on the opportunities presented in Yarosh's paper?*

We specifically coded each paper from 2011–2019 based on the five opportunities (bolded in the text below) that Yarosh et al. proposed in their IDC 2011 paper. Many authors ground their research in **theories or models** on how children learn, think and relate to others. While fewer than half of papers from 2002-2009 used theory, 75% of the 2011-2019 made explicit references to theories or models. Moreover, we identified 5% of IDC papers where theory is the primary contribution (Table 6-3), which was not a noted contribution category at all in the first decade.

More researchers in recent years investigated **children younger than 5 or older than 12**. Although papers from 2011-2019 still mostly target children between 7-12 years old, 53% of

papers include wider range of older children (below 5 and over 12 years old) and children younger than 7 in their investigations (Figure 6.1).

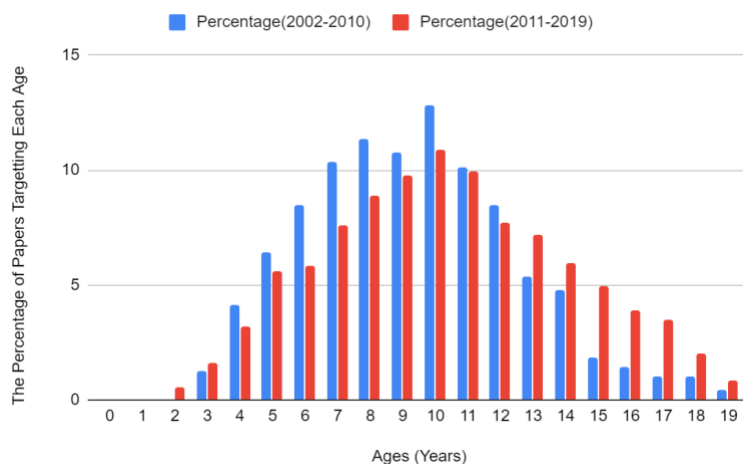


Figure 6.1 The percentage of papers that involved studies or systems intended for children of each age (when an age range is given, each year in the range is counted).

However, still relatively few papers specifically target teenagers (13-19 years old) (e.g., (McRoberts et al. 2016)) or include 2- and 3-year-old children), which might be due to the medical community discouraging screen time by children under the age of two (Brown and Council on Communications and Media 2011).

Three other opportunities from Yarosh et al. received moderate or low uptake. Papers in our review gave more attention to children’s **broader socio-cultural systems** rather than only focusing on the children and the technology—23% of the papers explicitly discuss a broader ecology. Researchers also **explicitly discuss the values** that drive their work (44%), though not necessarily in a formal “values” section as recommended by Yarosh et al. A few researchers (15%) focused on **long-term evaluations** rather than single-session studies (e.g., usability),

though that number is still fairly low. Finally, we found papers with **miss-alignment between stated goals and measured outcomes** (e.g., designing a system to support learning only measuring engagement) at the same rate of 8% as the original review (Table 6-7).

Table 6-7. Opportunities for IDC proposed in the IDC 2011 paper, the percent of papers that were tagged with this code, and trend over time.

Opportunities for IDC proposed in the IDC 2011 paper		
Code	%	Trend
Explicit Use of Theories and Models	75	-0.34
Design for a Larger Variety of Ages [child < 5 or > 12]	53	0.60
Explicitly Reveal Values that Drive the Work	44	-0.18
Designing for the Entire Socio-Cultural System	23	0.58
More Long-Term Evaluations	15	0.14
Miss-alignment of Motivation and Evaluation	8	0.23

6.4 AUTHOR SURVEY RESULTS

Authors of 20% of IDC papers published between 2011-2019 responded to our survey regarding the values that drove their work, motivations for conducting the research, the kind of impact authors intend from their research, and the ethical considerations central to their work.

6.4.1 *Values Informing Author's IDC Work*

Researchers shared their values reflecting desired outcomes for children and research practices.

Affording child agency and empowerment: Authors emphasized their desire to provide agency to and empower children through participation in research. Authors achieved this by providing children with opportunities to choose freely, considering the power dynamics prevalent in the research, and prioritizing the child's needs. Researchers valued empowering children to express their lived experiences. Authors also reflected on the role of technologies in addressing children's needs and called for awareness of technology serving to augment children's experiences and not replace them.

Child-centered research process: Similarly, authors highlighted the importance of putting the child first in the research process. Many emphasized creating positive experiences for children's participation in research and ensuring equity in partnership in the design process (e.g., by ensuring each child's contributions are visibly represented in the design).

Encouraging broad participation: Furthermore, authors reported valuing making their research more inclusive and diverse, by working with a wider range of demographics and abilities. Some researchers particularly pointed out the value of basing their research on the diverse lived experience of children and the necessity of creating appropriate research methods.

Striving for research quality: As IDC matures as a scientific community, many specifically reflected on research quality as a value. This included establishing scientific rigor, integrating relevant outside expertise in the research process, and adhering to ethical guidelines.

6.4.2

What Motivated IDC Researchers to Conduct Their Work

IDC reported four motivations that guided them in selecting a particular research topic: (1) *achieving a specific desired outcome for children* (e.g. social-emotional skills); (2) *seizing opportunities by capitalizing on research gaps or available calls for funding*; (3) *bridging the research-practice gap* – researchers desired to make research insights available to practitioners and bring theories and IDC methods to influence industry design practices; and (4) *reflecting on methodological needs* – researchers are motivated by providing theoretical foundations and methodological concepts which can inform research and design practices.

6.4.3 *Intended Research Impact on the World*

Authors reported three main ways they hoped their research would have impact: (1) *Raising awareness* – to promote opportunity for more research to impact practice and advocate for cultural awareness; (2) *Supporting IDC community* – to promote new models, methods or theories for future research in child interaction design; and (3) *Reaching beyond the research community* – to impact policymakers, parents and educators of their research outcomes.

6.4.4 *Ethical Considerations of IDC Researchers*

Researchers value adherence to ethical considerations that are explicit in nature (*e.g.*, consent process) as well as implicit in the structure of their research (*e.g.*, agency).

Beyond the Institutional Review Boards (IRBs): Researchers mentioned the importance of adhering to explicit guidelines such as creating equal opportunities in the recruitment process, extending transparency of the research aims, and, in addition to obtaining assent from the child and consent from the child’s guardian (required by IRB), putting efforts into explaining consent to the child. Some called to extend ethical considerations beyond those required by IRB to consider the child’s context-dependent needs currently not captured within IRB standards. One researcher described ethics as being a “moving target” since they experienced a gap between formal ethical requirements and what they had to consider in the field, especially when designing in sensitive design spaces.

Being aware of responsibility: Respondents further reflected on ethical guidelines to create an awareness of responsibility in providing longstanding benefits to participating children. Others

called for considering potential sources for negative experiences during participation, such as research artifacts (*e.g.*, robots) prompting adverse reactions. Respondents further expressed surpassing the traditional standards of ethical research. For instance, when working in classroom settings, researchers found ways to engage students without guardian consent to avoid harm from exclusion during entire class activities. This topic was examined with regards to research designs and constant review of the ethics underlying their research practices.

Protecting privacy and safety: Upholding privacy and safety for children, both during and after research participation, was a particularly salient theme across responses. This was expressed in relation to the use of sensitive data as well as safeguarding children's wellbeing when participating in the research process.

6.5 CONCLUSION AND FUTURE WORK

My results indicate that the CCI research community, in the past decade, has shifted to employ child development theories and models to inform the research and designs of child technologies. Furthermore, CCI researchers are more likely to design systems in service of promoting children's developmental growth, rather than to capitalize on technical novelty. My results also indicate that the published research continues to support children's social interactions, learning, expression, creative and personal growth, and increasingly values play and children's overall health and well-being. In terms of technologies, CCI continues designing systems that bridge the physical and the digital with new technologies leveraged for that purpose. Additionally, the CCI research community remains reflective and innovative in the use of methods to include children's voices, ideas and experiences in the design process.

These changes over the past decade suggest that the CCI has solid core values and practices to build developmentally responsive designs for children, while still learning and adapting as new knowledge is generated, which is a sign of a healthy research community. Though CCI have been creating and evaluating developmentally responsive designs for children, future work could look in more detail at *how* theory is being used to inform their work, such as motivation, design features, and evaluation. Additionally, these findings show a design opportunity to reduce the CCI research-practice gap and create evidence-based design resources that can benefit industry designers. In the next chapter I explore how to reduce the research-practice gap by (1) investigating how designers' current practices, barriers and needs to use the CCI research and (2) designing an evidence -based toolkit for children's technology designers.

6.6 SUMMARY OF CONTRIBUTIONS

The analysis of the published Child Computer Interaction research at Interaction Design and Children conference in the recent decade shows that researchers employ theories and models of child development to ground their design decisions and choices in children's technologies. CCI research primarily is motivated by fostering positive children's developmental needs, including cognitive, physical, social, and emotional growth. Additionally, CCI researchers innovate design artifacts that support children's social interactions, learning, expression, creative growth, and increasingly value play and children's overall health and well-being. I build on these findings in Chapter 7 by designing a toolkit for children's technology designers to bridge the CCI research-practice gap. This work contributes to our empirical understanding of the imbued children's developmental needs in CCI published research and addresses T1, by providing broader empirical evidence of incorporating child development theory to enhance the developmental

responsiveness of children's technologies. By extension, these findings support T2, in identifying the research to synthesize evidence-based research and actionable design recommendations for the Interaction Design and Children designer's toolkit described in Chapter 7.

CHAPTER 7. INTERACTION DESIGN & CHILDREN DESIGNER'S TOOLKIT

My formative analysis on the published Interaction Design and Children research over the past two decades (Chapter 6), with the CCI community researchers focusing on children's learning and developmental growth, led me to ask RQ3: *What are industry designers' practices, barriers, and needs related to using CCI research in their design work for children's technologies?*

The IDC research resulted in a wealth of evidence-based and theoretically driven research findings that can provide insights to design practitioners to understand how children behave when using technologies and potential ways to support children's cognition, physical and social-emotional growth through their products. Despite the value of this research on improving children's technologies, industry designers and design researchers (herein referred to collectively as practitioners) do not use academic research to its full potential to inform children's products. As described in the related work in Chapter 2, this is known as the research-practice gap (Bansal et al. 2012; Buie et al. 2013; Hörig et al. 2005; Sas et al. 2014). Often, practitioners are unable to access academic research hidden behind paywalls and hard-to-identify search terms (Colusso et al. 2017). Even when practitioners are able to access academic papers, the research is often not presented in a format that is readily applicable to new products (Colusso et al. 2017; Sas et al. 2014). Conversely, academics feel that when their research is applied in industry, it is misinterpreted (Carroll and Rosson 1992; Colusso et al. 2017; Sas et al. 2014). This research-practice gap limits industry products when design decisions are not informed by evidence and impedes the advancement of academic research that is missing out on opportunities to evaluate actual products in real use (Buie et al. 2013; Colusso et al. 2017).

To address the research-practice gap in the IDC community, and to answer RQ4: What are the design considerations for a designer’s toolkit that can best support designers in accessing and applying child-computer interaction research to their design work? I designed, developed, and evaluated an Interaction Design and Children Designer’s Toolkit. The toolkit synthesizes research and presents it in an actionable format. It distills and translates the research findings of individual IDC papers and CCI Journal articles into a digital “card” format. The cards are then organized for industry practitioners to search and browse. I worked with a team of collaborators¹⁰ to conduct two co-design workshops with eight industry designers and researchers working on children’s products to better understand industry practices using academic research and to evaluate the toolkit content and design. The findings from this study supported T2 by helping answer RQ3 and RQ4 and provided key implications for the re-design of the Interaction Design and Children designer’s toolkit navigation, organization, and content that can best support industry designers’ practices. Additionally, I discuss ways the CCI community can better meet industry practitioners’ needs in translating research to actionable recommendations.

7.1 IDC TOOLKIT DESIGN

To facilitate the translation of CCI published research studies into a digestible format that can be easily accessed and used by children’s product researchers and designers, I designed the online Interaction Design and Children Toolkit that distilled research findings and practical insights from CCI research papers into actionable design recommendations and guidelines onto a “card”

¹⁰Saba Kawas, Andrea Tartaro, XueYan Sue Chen, Jacob Laxton, and Julie A. Kientz. “Connecting the Silos: A Designer’s Toolkit for Bridging Interaction Design and Children Research With Industry Practice.”

for each paper. Below, I describe the process of developing the toolkit content and the design of the toolkit.

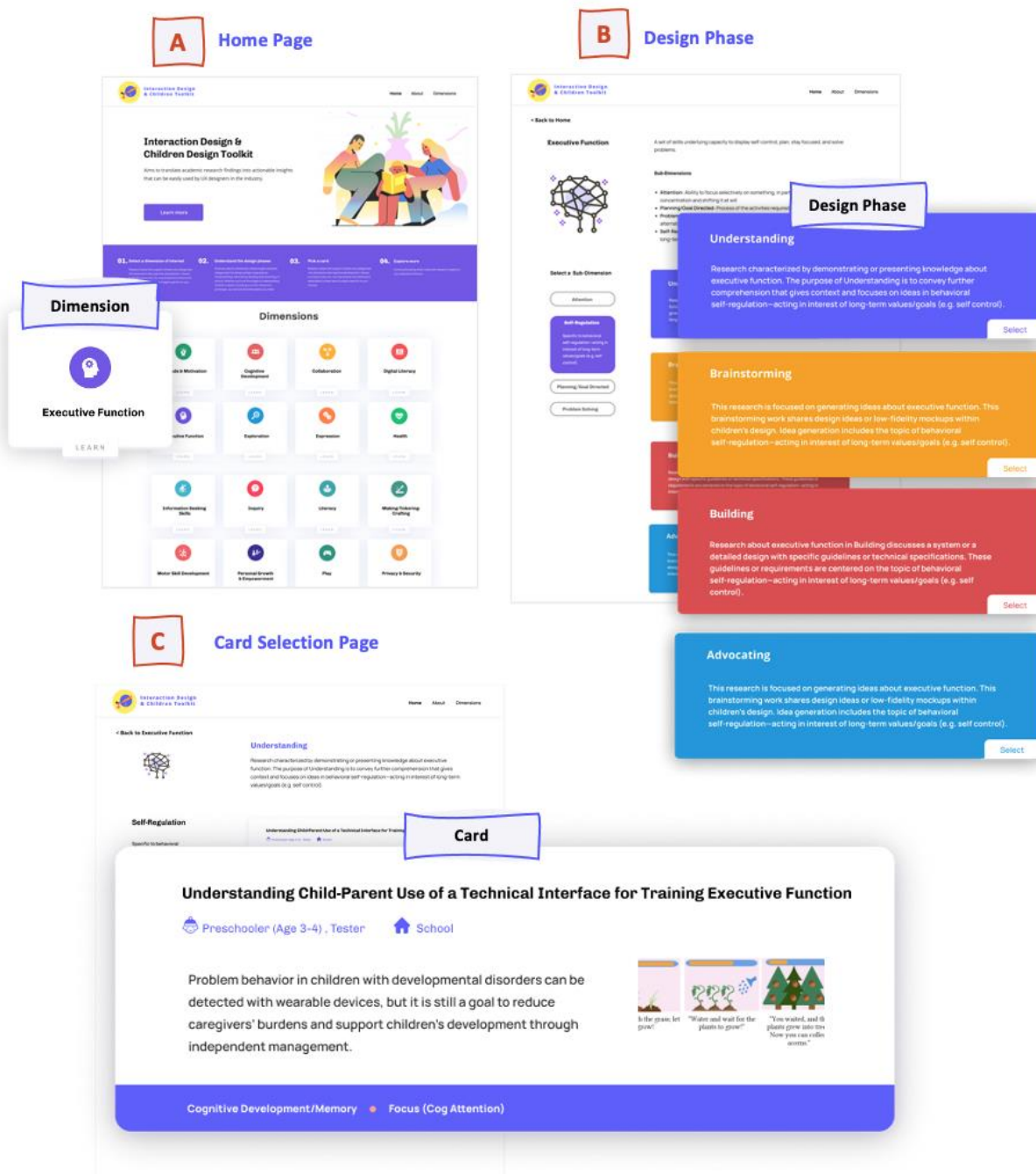


Figure 7.1: IDC Online Designer's Toolkit

7.1.1

Developing the Toolkit Content

As part of the prior study (Chapter 6), we reviewed papers from the IDC digital library from the past decade, organizing them based on the type of research contribution (Wobbrock and Kientz 2016) (including empirical studies with children, artifact, theoretical, and methods to design with children), the key developmental dimensions and qualities the research aims to support, and the design phase. To establish the dimensions and domains, we began with the values established in previous work published in the two primary venues of CCI, the IDC conference (Kawas, Yuan, et al. 2020) and the International Journal of CCI (Giannakos et al. 2020). We then used an iterative process of detailed qualitative coding of the children's behaviors and developmental qualities the CCI research papers aimed to support and organized the dimensions using affinity diagramming (Lucero 2015).

We created a series of stepped questions to support and guide the translation of empirical findings into actionable tips and recommendations to inform product design. These questions examined core research content including the problem space, main outcomes of the contribution, notable findings, and actionable design recommendations for designers (See Figure 7.2). A group of graduate and undergraduate researchers then summarized and then translated the research content into an accessible digital card format to prioritize key insights for practitioners. Through this translation process, the toolkit aims to bridge CCI research to practice with actionable design recommendations.

Card in Detail

Understanding: Self-Regulation

Understanding Child-Parent Use of a Technical Interface for Training

Executive Function

Preschooler (Age 3-4), Tester
 School

Problem Space

Executive function (EF) is a composite set of skills that collectively enable an individual to engage in goal-directed behavior. Researchers have worked on training programs to help children develop EF skills, including computer-based training. Although there are research prototypes train EF, these studies have not yet looked at EF training through commercially available apps for children, giving opportunity on how interaction design could support EF training.

Design Recommendations

They found strategies that effectively support completion of executive function related tasks. This included reinforcing directions, physical positioning to prepare for task, intentional near-misses, and recognition of difficulty.

01. It is useful for apps for young children to differentiate between successful strategies that are likely to be obvious to adults (e.g., telling children to count the number of arms on a monster before deciding which shirt to give it) and those that are likely to be obscure (e.g., telling children to distract themselves as the pig walks across the screen).
02. When strategies are obvious, the app can stay out of their way and allow the parent to provide scaffolding.
03. But when strategies are non-obvious, the app might need to provide more direct support to the parent.
04. Games can also embed scaffolds for parents, such as on-screen text describing effective in-the-moment strategies

Notable Findings

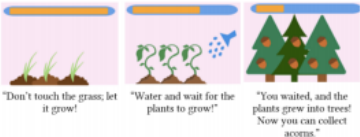
01. Children used systematic strategies to engage with the game. Some of these strategies align with known ways for successfully drawing on EF, while others undermine it.
02. Parents engaged in a common set of behaviors as they worked to support their children, using some techniques that are known to improve EF but neglecting to try other known strategies.
03. These behaviors suggest mechanisms by which designers might guide child users and the adults who support them toward productive techniques for developing EF.
04. With thoughtful design, it may be possible for digital experiences not only to avoid negative effects on children's attention but also to promote positive ones.

Methods Not Evaluated With Children

01. Children completed an assessment for the Minnesota Executive Function Scale (MEFS), a comprehensive measure of executive function.
02. Children in the experimental group played Cookie Monster's Challenge for 15 minutes next to their parents. Parents could play together with the child and were free to help the child if they wanted. After 15 min, children completed the MEFS a second time.
03. Children in the control group engaged in all of the same procedures, except they played Explore Daniel Tiger's Neighborhood in place of CMC.

Limitations

This work was conducted primarily with 37 middle-class families, larger, more representative sample would be more accurate. Future work should also consider children's baseline executive function skills, and how it could influence their play and interaction with parents.



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Translational Questions

- What is the state of the world?
- Briefly explain the main outcome of this design contribution. (e.g., technical system, non-technical system or design requirement.)
- What are the notable findings from this paper that might benefit the designers?
- Provide a short overview of what the researchers did.
- List the steps on how the researchers carried out the study.

Figure 7.2: Card detail and Stepped Translational Research Guide

7.1.2

Toolkit Design

We used Figma¹¹, a web-based graphic editor and interactive prototyping tool, to create an interactive prototype of the toolkit to share with participants during the workshops with design practitioners. We used the dimensions identified during our development process to organize the cards (e.g., cognitive development, learning, or social interactions (**Error! Reference source not found.A**)) and sub- dimensions within these dimensions (e.g., memory, STEM learning, and communication skills).

Browsing by key dimensions enables practitioners to easily search for topics within their area of interest. With the guidance from prior research that describes how designers search for academic resources (Colusso et al. 2017), we further organized our cards to align with the design process phases: understanding, brainstorming, building, and advocating (**Error! Reference source not found.B**). Users interact with the toolkit by first selecting from a set of dimensions introduced on the homepage (**Error! Reference source not found.A**). They can then read an overview of the dimension definitions, filter a particular domain within the dimension, and choose the design phase. The toolkit then presents a list of card previews that include overview information of the research, children's ages, technology platform, and context of use (e.g., home, school) (**Error! Reference source not found.C**). Once they choose a card, it expands to reveal the content synthesized and translated from an IDC research paper (Figure 7.2).

¹¹ Figma: a collaborative interface design and prototype tool. Figma <https://www.figma.com/>

7.2 TOOLKIT EVALUATION WORKSHOPS

I led two online co-design workshops with practitioners to understand their current practices, barriers and needs related to using research on interaction design and children in their products, and to evaluate our toolkit design. I examined how the toolkit features and content supports or hinders industry design practices.

7.2.1 *Participants*

We recruited practitioners from across the United States through posts on LinkedIn and relevant Facebook interest groups. Of the 16 respondents who completed the study interest form, we invited 14 participants that met our recruitment criteria: a minimum of one year of industry experience working on children’s media products. To accommodate for time zones and participants’ schedules, we ran two workshops, one in the morning and one in the evening. Eight participants attended our online workshops. Participants were all women, had between 2 years to more than 7 years of experience, and worked in a range of roles including children product designer, kid’s user researcher, interaction design and research consultant, and director of design research for children’s products.

7.2.2 *Procedure*

We had three participants attend the morning workshop and five attend the evening workshop. We used Zoom¹², a cloud-based platform for video and audio conferencing, to connect and share

¹² Zoom: a remote video conferencing, and web-based screen sharing tool. Zoom: <https://zoom.us>

our screens with the participants, and Miro¹³, a visual whiteboard for team collaborations, to facilitate the co-design workshop activities. Each workshop lasted 2 hours and consisted of two goals: (1) understand industry practices of using academic research, and (2) derive design ideas and feedback on our toolkit content and toolkit system design. All sessions were audio and video recorded.

We used a co-design approach (Sanders and Stappers 2008), to integrate our participants' expertise with our design team. We paired each participant with a facilitator and split into two breakout rooms during the workshop activities. We structured the workshop around four co-design techniques: (1) Affinity clustering (Lucero 2015); (2) Visualize the vote (Dalton 2019); (3) Ideation and Schematic diagramming (Sturdee and Lindley 2019); and (4) Think Aloud (Eccles and Aarsal 2017). Each of the workshops followed the same format, as follows:

(1) *Introductions* (~10 minutes): participants and facilitators socialized and met everyone.

(2) *Design ice-breaker* (~10 minutes): we presented participants with a prompt to design and invent superpowers to support children's growth, to get participants comfortable using the Miro whiteboard tool, and focus on the workshop; We then introduced the co-design workshop activities during which participants and facilitators divided into breakout rooms.

(3) *Affinity clustering* (~15 minutes): Facilitators asked participants about their current practices, barriers and needs of using academic research in industry, and collaboratively

¹³ Miro: a free online collaborative whiteboard platform. Miro <https://miro.com/>

added post-it notes on the Miro whiteboard while clustering emerging themes. Then, for the last 5-8 minutes, we left the breakout rooms to discuss the key themes as a large group.

- (4) Visualize the vote (~20 minutes): We presented the participants with synthesized examples of IDC research papers and asked them to assess the content by casting their votes with one of the following colored tokens for each section: *Influential* (green): “Important information to include. I’d definitely use it in my work.” *Interesting* (yellow): “Interesting information to include but not essential. I might refer to it in my work.” *Unnecessary* (red): “Extraneous information to learn. It’s highly unlikely I’ll use it in my work.” Then we invited participants to discuss their votes.
- (5) Ideation and Schematic diagramming (~20 minutes): We originally intended for participants to collaboratively create digital sketches in Miro using a library of drawing elements, but due to the short time allocated for this activity, we ended up asking participants to talk about their ideas. We asked them to think about form factors (e.g., physical cards, web-based tool, or mobile app) and best ways to organize and prioritize academic research content in a toolkit.
- (6) Think Aloud (~30 minutes): We asked participants to share their screens when using the interactive design toolkit Figma prototype while they “thought aloud” about the toolkit design, features, and content. In a few of the cases, when participants had connectivity issues, the facilitator shared their screen with the prototype and asked participants to guide

them. We asked participants how they would prioritize the research content and how to make it relevant to their design process. We also asked them to reflect on the current features and what they would like to add.

7.2.3

Analysis

All workshops' video recordings, including the recordings of the breakout rooms used for the small group activities, were transcribed. We began our analysis by examining the initial affinity clustering themes generated during the workshops. We took a joint inductive-deductive analysis approach to our data sets to identify key themes (Corbin 2015). First, a group of researchers viewed the videos and discussed additional observations and added post-hoc notes for the first activity (affinity clustering practices, barriers, and needs). Then, following an inductive approach, two researchers read all the transcripts for the remaining workshop activities separately and coded them for new themes. Finally, to inform a codebook, two researchers met to discuss and organize all the notes taken during the workshops as well as the codes from the videos and transcripts. Following a deductive approach, researchers looked for similarities across the emerging themes to iterate the codebook and add new codes. Two research assistants used Dedoose, a web-based software for analyzing qualitative data sets, to independently code all the workshop transcriptions. Then researchers met with the RAs to discuss disagreements for each of the workshop transcripts, reach consensus, and refine codes based on emerging themes.

7.3 RESULTS

7.3.1 *Using Academic Research in Industry*

Our participants identified some key practices of using academic research in their design work, common barriers to using research, and specific needs for using research in their projects.

7.3.1.1 *Current Practices*

Our participants had diverse roles in their design firms. While many were designers, some were researchers who share research with design teams and give design recommendations. The industry researchers reported needing to be able to both look things up quickly as well as stay up-to-date: the design team wants them to weigh in on broad topics related to child developmental stages and ages, some not even necessarily related to the project, and quickly. *“Oftentimes you’re the only person in the room with the knowledge of... children’s background development. So you get thrown so many different questions.”* Another participant is a designer, but her company is working towards integrating more research into their work, especially from the learning sciences.

Academic research is often consulted at the beginning of a product lifecycle in the planning phase, particularly when there is not time to run a study. The planning phase is often given limited time, restricting practitioner’s application of academic research to less than they would prefer. Once designers move to iterating tangible products, research is consulted infrequently. One participant reported that consulting research especially makes sense when a project is focused on education. Industry practitioners will use research to find things they can build off of related to their project. They may look for examples of how kids accomplish a product goal

without technology and how that could inform product features. If they cannot find information related to a specific product they are working on, they will look for general developmental research and see how they can apply it. Practitioners look for foundational information then create more insights off of research findings. One participant, who is a researcher working with designers, described identifying theories related to a project goal and then translating the relevance for the team. She posed a hypothetical example of how tech could help children complete chores. She described that she might look up research on how to motivate children which would lead her to specific theories such as self-determination theory or autonomy, and then she would consider what this means in terms of kids and devices. *“So let’s say it’s autonomy, ok, maybe it’s we have a family meeting where kids can pick their own chore.”* Kawas et al (Kawas, Yuan, et al. 2020) found that IDC research is increasingly theory-based, and this example suggests theoretically-grounded findings are valuable for designers because they enable them to generalize to new products. However, not all designers have access to a researcher who can translate theory to a product.

The need for “translation” came up repeatedly through this phase of the study. Industry researchers working with design teams frequently described their role *“trying to translate [research] into something that’s really actionable and relevant for designers...how do we then turn that into something that doesn’t lose the heart of what the research is with the nuances that are in that research, and then are also super approachable.”*

A critical use of research is to advocate for children’s views and developmental needs. For example, one participant reported that she was working on a language-based project where one

syllable was described as one sound, while the participant believed this contradicted what 3-4 year-olds need to know about phonemic awareness, “*cat is a word with three sounds*” but one syllable. This need to advocate may come from the pressure in industry to monetize design. This same participant worked at a company that had success developing a series of products for different ages and wanted to create one for babies. However, the participant could not “*in good conscience*” design a product for babies, “*babies don’t need to be sitting and interacting with a screen, they need to be interacting with people.*” Thus, she used research to successfully advocate for a design to support parent-child interaction that she viewed as a success based on research.

The content and presentation of research differs from what designers need in meaningful ways. While as researchers we are interested in methods of a study to evaluate the reliability and validity of the results, practitioners think about how to implement the research findings into products. Research papers are often long and not necessarily the desired source of information. Instead, practitioners turn to the New York Times, the Nielsen UX Training, Consulting, & Research (Nielsen Norman Group 1998), KidsScreen (Brunico Communications 1996), industry newsletters, and university press releases. Other examples of resources practitioners use include: self-made developmental charts, pdfs saved on their computers, company-wide repositories of research, a Slack channel dedicated to emerging research, a book club on research topics, and simply relying on what they know from previous experience and education. These reports from practitioners on their current practices suggest research is found somewhat haphazardly, and that practitioners prefer a different language that is more in line with popular press than academic writing.

7.3.1.2 *Barriers*

A clear message came across that our participants did not use research as much as they'd like. They identified a number of barriers to incorporating research into their design practice, chief among them: Time. As described above, research is often relegated to the beginning of the product lifecycle, the planning phase is short, and decisions are made quickly. *“There’s not enough time to do research, period full stop. Let alone research that can lead to ideas before we even get into design.”* Questions that arise during the design of products must be answered quickly. Participants felt pressure to *“keep the rigor while... being agile for the development process.”*

Some of this time pressure comes from company priorities and goals other than products based on academic research, and undervaluing of research in terms of both time and budget across industry. *“But I think it’s... every place I’ve worked. [Academic research] has not been.. supported or promoted as much as I would like.”* Participants also felt organizational barriers – that there were numerous groups across the company doing relevant research, but no communication across groups. *“The silos are out of control in, in our companies... there are so many relevant teams doing relevant research but it’s in different places.”*

In addition to barriers with academic writing styles, practitioners reported that language is a significant barrier to finding applicable research. Research and industry use different terms, for example, research on conversational agents would be relevant to a digital assistant product, but *“I’m not searching ‘conversational agent’ because that’s not my lexicon.”* One participant expressed frustration that different fields use different words to mean the same thing or,

conversely, the same word means different things in different fields. Academic papers are long: *“I probably never again am going to read a full study. So if someone could give me the like the New York Times article version of it, that would be great.”* Our industry researchers repeatedly returned to the idea of translating research for the designers they work with.

Academic research is often narrowly focused while industry needs to be informed by a broader context such as child development, play, learning, and cognitive abilities. Some topics relevant to products, such as voice assistance, do not have much available research yet. Yet for other topics, the content is overwhelming and understanding requires connections across research areas. Research archives yield too many results. Practitioners felt research moves much slower than industry. Yet staying up-to-date and finding the “new” research is challenging. Our participants wanted to know what newsletter they should be subscribing to for the latest insights. Finally, paywalls and access remain a barrier for industry. While as students they had access to databases, often they can only now access abstracts.

7.3.1.3 *Needs*

Our participants recognize the value of evidence-based research and the impact it can have on products. They communicated specific needs in order to reap those benefits. Practitioners need company investment in research to address both time and budget barriers. They need a means for staying up-to-date and research presented as “digestible tidbits” that are easy to understand and find quickly, *“The keyword to all of this is actionable. Yeah... if you could have that... all in caps and bold as a takeaway... that’s gigantic.”* Practitioners need help synthesizing across research areas, for example *“bridging data analytics, learning analytics, qualitative findings, consumer insights, design research... efficacy research”*: *“taking the silos down from different forms of*

research and having them meaningfully weave together.” Practitioners also need support bridging research and design, for example matching curricular goals from learning sciences research with interaction patterns. They also emphasized that their work often requires foundational information about children that can apply broadly to products: development, communication, peers, and learning. One designer mentioned wanting strategies for collecting data with children – she noted *“some teams already have specific methods and protocols, but that is not the case broadly across industry”* especially when working with children. Practitioners also want collaborative spaces with other designers and academics for communication about research.

7.3.2 *Toolkit Design Feedback*

During the second part of our workshop, participants gave us feedback on the toolkit content and design. We also asked them to share design ideas for the toolkit features to support their practices in using academic research. All participants were enthusiastic about a resource to access IDC research insights and design implications, *“I’m just so excited there might be a resource, so excited”*. Our participants shared detailed feedback on the content and the usability features of the toolkit.

7.3.2.1 *Content*

During the visualize the vote activity, participants unanimously agreed that the most **influential** information presented was the list of design recommendations and strategies, children’s ages, the developmental goals for the design, the context of use, description of the problem space, whether children were involved in the design or evaluation of the system, and the notable findings from

the study. Participants pointed out the importance of including the study year and location and, when possible, a link to the full papers. Participants identified information that was **interesting** but not necessarily relevant to their process, such as the description of the research procedures, the role of the child in the design process, or the number of participants. They identified **unnecessary** information such as the study motivation, limitations, and any illustrations or images of the study. Participants found many of the research terms and language confusing. They pointed out critical missing information such as a detailed description of the system design and features and how kids interacted with the technologies.

Through the ideation and think-aloud walk-through of our prototype, participants revealed additional influential, interesting, and unnecessary content, as well as additional needs.

Influential: Participants found the inclusion of the theoretical background of the dimensions essential to support their understanding, *“I think for me it just gives me a quick understanding of what I’m gonna be learning about in this paper, and I think when my team comes to me and says, ‘Hey we want to understand if kids can control themselves’ you know, I know that’s executive function and this just tells me like, this paper will help me dig into that. I often put in my research proposals a background of why I’m digging into this and I could copy and paste this background. I’m digging into this because it’s important.”*

For individual papers, participants wanted full and detailed descriptions of all applicable strategies that support the developmental goal of a system, not just an example, *“[here is] Example one two three. But... all the examples is what I want. What are the successful*

strategies... I want every single one laid out because that's what I'm going to apply to my work and into my product." Participants were also interested in the underlying developmental theories and prior research that informed the design implications and wanted to understand the rationale for design recommendations. Participants noted that they want an understanding of study findings, particularly what was successful and not successful about a design with respect to the developmental goals of the research and how children reacted to the design. However, they did not want analysis and discussion of specific study results. Including the intended context of use for a system is relevant to designers *"I think context would matter like whether, it's going to be school or home or whatever."*

Interesting: Although participants stressed the importance of indicating children (and other stakeholders) involvement in the research and what *type* of research study (e.g. participatory design, evaluation study), they had lukewarm reactions to including the study method details. *"We start with [design strategies], but we then don't want to know the methodology and the participants and all of the things before we actually get to findings."*

Unnecessary: Participants did not find the inclusion of any illustrations or images of the study necessary or relevant to their work. Most participants found the summarized information of the study motivation and the study limitations unnecessary to include on the "Card" details, and suggested to link to the full paper or the authors' websites.

Additional Needs: Participants pointed out a critical piece of information that was missing: the cards do not include how children actually interact with the system. *"what were specific*

examples of things kids said, like show me the design of the app that the kids were reacting to?”

They wanted specific information about the kinds of interaction children engage in and how those interactions are related to developmental goals. *“I’m always searching for things like that and it’s really hard to find less so than like academic research to be honest. It’s like what are kids doing at different ages and how does that relate to technology.”* Additionally, practitioners wanted additional information that describes how to generalize actionable design strategies and recommendations beyond the system presented *“I felt like, if the findings are powerful that have to do with the way kids engage with something, then I don’t care where it happened, I’m gonna find ways to have crossovers and learnings that can impact lots of different setting”*. Some wanted references to design principles that are based on children’s ages and abilities that are applicable in different contexts and technical systems. *“I draw on a lot of research that happens in classrooms about transitions, so it doesn’t matter if this is designed for schools, if there are theories or takeaways or strategies I can use and implement in tech, [that is] most important.”* They envisioned rubrics for different ages and what’s useful/appropriate when designing interactive technologies. Participants indicated their knowledge gaps and described a need for developmental information as it relates to technology interaction abilities, for example, *“can a kid at three drag and drop an item on an iPad?”*

Participants wanted content to be presented in digestible tidbits (e.g., bullet points rather than paragraphs) that cover the key influential information: what did the children do with the system and what were the details of the design and features used.

7.3.2.2 Toolkit Features

Participants liked the overall design of the toolkit and appreciated the clarity of the content hierarchy and the successful use of visual design and color schemes as a guidance for the toolkit organization. *“I like this design. There’s something about the hierarchy that’s nice”*. However, they made a number of valuable suggestions for organization and navigation of the system.

Homepage: Participants found the instruction overview of how to use the toolkit (Figure 1 A) unnecessary and instead suggested relying on a responsive design that prompts users with what they can do for each step. *“I guess I’m wondering how important that... big purple section where we have the steps. Like select a dimension of interest, understand the design phase, and pick a card explore more. I guess I’m wondering how necessary it is to spell that out.”*

Participants found the dimensions (e.g., executive function) presented on the homepage to be too broad and often not in designer’s language *“I think these are much too broad. I mean would designer even know what cognitive development means. Let alone whether working memory is cognitive development or executive function or is it part of information seeking skills. I mean I think you might need a finer grained level [for the dimension’s language]”* Participants preferred to de-emphasize the dimensions as the main way to navigate the toolkit as it might pose a barrier to designers to find related research *“I mean the designer isn’t necessarily going to know where a concentration game fits or where a jigsaw puzzle game fits. Okay I’m making a jigsaw puzzle. Where does that go? Is that cognitive development or digital literacy or I have no idea.... you know... you see what I mean?”* However, they liked the granularity of the domains

presented (e.g. self-regulations, planning, goal setting) once a dimension was selected and appreciated that definitions and the descriptions of the underlying theories.

Participants were confused about the design phases presented under each domain and expressed that it was unclear what the purpose was of grouping the cards under the described design phase in the research paper. Participants explained that they usually use academic research in the initial phase of any project and found the explicit indication of the design phases of the research irrelevant to their work. Instead, they wanted to know if the research paper described system design, included a study with children, or reviews literature. These categories mirror the HCI contributions types (Wobbrock and Kientz 2016).

Card Selection Page: Participants liked the summary of the research presented on card previews to give them an overview of the content before clicking on the “Card” details. Additionally, participants found the use of icons to represent study details of children ages, technology platform, context of use (Figure 1 C) helpful. However, they proposed that instead of summarizing the research study details, the preview should include who were the target children, what did they do with the system, and what was the developmental goal.

Additional Needs: Practitioners wanted the toolkit to match their use of academic research to provide understanding of the intended problem space for their design. They want to focus on the developmental needs for different children’s ages. Participants desired a simplified interaction design with fewer steps and clicks to get to the key information (i.e. the card preview and the card details). They proposed de-emphasizing the use of dimensions and instead presenting the

domains that “were hidden” (i.e. shown after a dimension was selected) as an optional filter selection on the homepage. Participants wanted to search using keywords or specific tags and to sort and filter the research cards based on children ages, technology platforms (e.g. tablet, wearables), context of use (e.g. school, home, museum), and subjects or topics (e.g. math, exercise). Participants also suggested that instead of having the preview card summaries shown on a separate search result page, have them update dynamically on the main homepage when filtered and sorted to narrow the search results.

7.4 DISCUSSION

7.4.1 *Toolkit Redesign*

Our results have implications for both the design of the navigation and organization of the IDC Toolkit, and the detailed “card” content. We used Figma to create the re-designs and we describe them in detail here.

7.4.1.1 *Navigation and Organization*

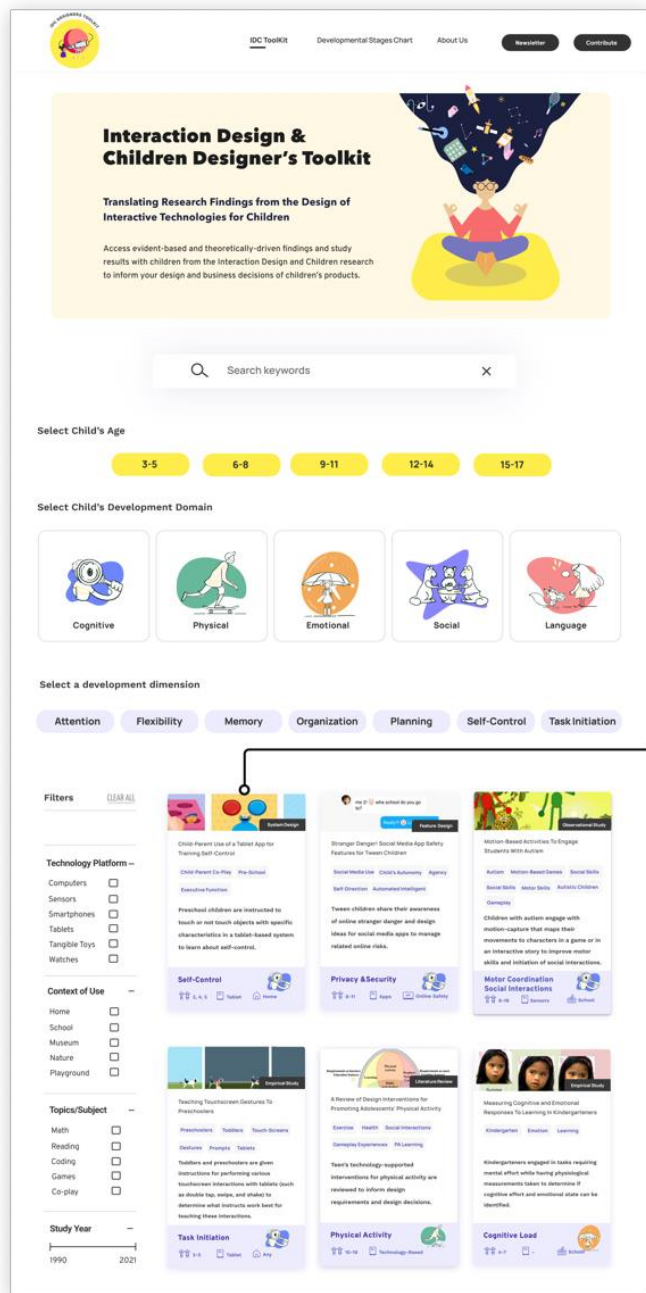
In our new Toolkit design, the homepage decreases the number of steps to viewing actual research content and focuses on displaying “card overviews” that can be clicked to view a “card”—the synthesized details about an IDC paper. The homepage enables users to search for content via their own chosen terms in a search bar across the top of the page, or filter content in a number of ways (Figure 7.3 A). Below the search bar, users can select criteria based on our results reflecting how practitioners conceptualize their products. They can select an age range (3-5, 6-8, 9-11, 12-14, 15-17), and a color-coded category of development: cognitive, physical, emotional, social, and language. These categories are based on key areas of human development

(Keenan, Evans, and Crowley 2016) and are similar to those used in the Developmentally Situated Design Cards (Bekker and Antle 2011). The categories also map to the behaviors and qualities IDC research aims to support in children (Kawas, Yuan, et al. 2020). When a category is selected, dimensions within that category appear, for example, in the cognitive category, attention, memory, and self-control, among others. Thus, we have decreased the importance of dimensions as the main way to navigating the toolkit. Future work will further refine those dimensions that are most meaningful to designers (described below). We added a column along the left-hand side to filter by technology platform (e.g., computers, smartphones, tablets), context of use (e.g., home, school), and topics (e.g., science, reading, coding). Each time content is filtered, the overview cards adjust to fulfill the selected filters. If the applied filters narrow such that no research is available, users see a form where they can make a request to IDC researchers suggesting a topic and area of research (Figure 7.3b).

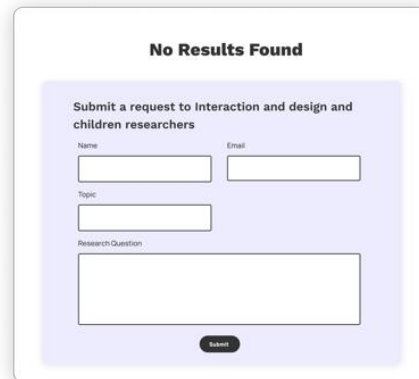
The card overview (Figure 7.3b) provides a title for the card, which may be based off of the title of the paper, but may be translated or shortened. Under the card title we added research keywords or tags relevant to designers. Below that is one summarizing sentence about the research specially formatted to convey the “who,” “what,” and “why” of the card – Who is the target audience of the system or other research? What do they do with the system or what is explored? Why are they doing that, in other words, what is the development or educational goal? For example, for *No Touch Pig* (Sobel et al. 2019): “Preschool children {who} are instructed to touch or not touch objects with specific characteristics in a tablet-based system {what} to learn about self-control {why}.” Finally, the bottom of the card overview lists the *domain(s)* and summarizes key characteristics of the research with icons: ages, technology, and (intended)

context of use. The very top of the card lists the type of research contribution such as system design or literature review.

(a) Home Page



(c) Request Form



(b) Card

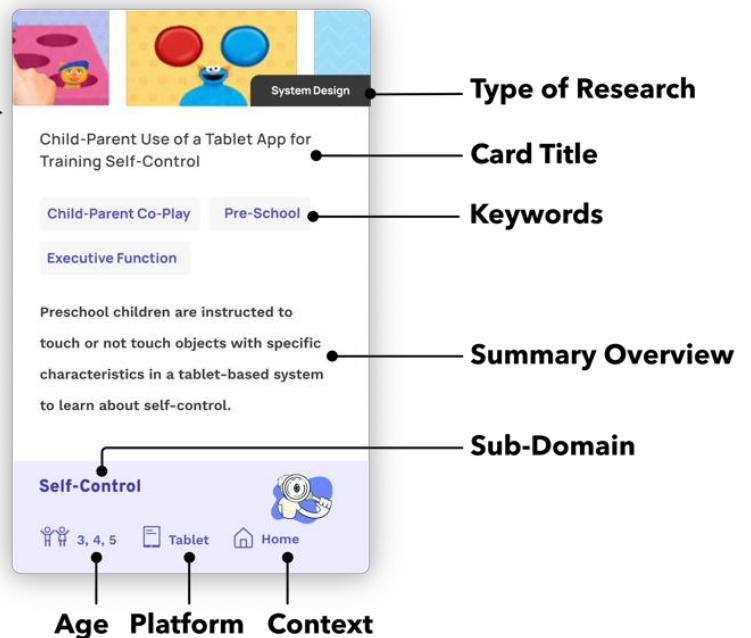


Figure 7.3: IDC Toolkit Re-Design (a) Homepage (b) “Card” Overview detail (c)Research Request Form

7.4.1.2 *Detailed Card Content*

Each card includes a set of icons representing age range, platform, and intended context below a header identifying the category and dimension. The content is then divided into specific sections chosen based on suggestions and feedback from our workshop participants. The card identifies the “Developmental Goal” and provides a bullet-pointed description of that goal. This is followed by the “System Description” that specifically describes the activities children engage in with the system, how those activities support the developmental goal, and what specific interactions children use (e.g., touching objects that appear and move on the screen). The next section of the card highlights “Actionable Strategies” designers can use, including practical insights generalizable to other systems and guidelines that support design decisions. This section uses a different background color to call out its importance. “What was successful” and “What was not successful” follows Actionable Strategies, and the card concludes with a “Key Takeaway” that is once again highlighted with a different background color. For example, for *No Touch Pig!* (Sobel et al. 2019), the key takeaway could be: “Design systems that encourage collaborative interaction between parents and preschool children and provide on-screen support for parents on successful strategies to guide their child’s behaviors.” The updated card composition addresses content our participants identified as most helpful during our workshops: actionable advice that can be applied to diverse products, specific descriptions of systems and the types of interactions involved, how those systems address specific goals, what was successful and what was not successful. Figure 7.4 provides a complete example of a Card.

7.4.2 *Implications for IDC Authors and Future Directions*

A key finding of our research is the desire for translation and accessible, actionable guidance. Industry researchers described their practices for translating their research for the design team.

Designers expressed a desire for the “New York Times” version of the research. They also emphasized different aspects of the work than is emphasized in academic writing. For example, in (Sobel et al. 2019) “*No Touch Pig: Investigating Child-Parent Use of a System for Training Executive Function*,” the example we used in the design toolkit during our study, the abstract (which summarizes key information for researchers) does not describe children’s actual interactions with the system—a critical piece of information for designers. For researchers to contribute directly to the toolkit, they will need guidance on how to provide actionable advice generalizable to various products. We envision creating a survey for authors similar to the translational tools our research team used to develop our initial prototype, but focused on the new important content we distilled from our research with industry practitioners. This will include MadLib-style¹⁴ questions that focus on the “who,” “what,” “why” of their research (Bauer, J., Kientz, J. 2013), for example, as is displayed on our new ‘Overview Card’ described above, and guides them towards designer-friendly language and actionable bullet points. We also envision creating workshops for supporting authors in translating research findings for design practice or training research trainees to summarize findings for a large number of papers, a practice followed by the Center for Scholars and Storytellers¹⁵. These are next steps for the future work of this project. In addition, since industry practitioners often do not have access to publication databases, it would be helpful if IDC authors add key system interactions, developmental implications of technical features, and actionable advice for designers to the abstract of papers. Allowing for slightly longer abstracts in IDC would facilitate this recommendation and help expand the impact of the publishing venue.

¹⁴ MadLibs is a phrasal word template prompting for a list of words to substitute for blanks in sentence.

¹⁵ Our Work. Center for Scholars & Storytellers: <https://www.scholarsandstorytellers.com/our-work>

We also found that the dimensions and domains that we used in the initial toolkit design of the toolkit, adapted from IDC value analysis research (Kawas, Yuan, et al. 2020), were not meaningful to industry practitioners. Primarily, the language used to refer to children's developmental qualities was not the same language designers use. As described above, we de-emphasized this feature as the navigational focus of the toolkit. In addition, our future work includes establishing dimensions that are meaningful to industry through analysis of how existing commercial products are categorized and surveys of practitioners. If IDC authors become aware of these meaningful dimensions and speak to them in their work, their articles will be more readily applicable to industry designs.

Practitioners often found that research was too narrowly focused to fit the problems they faced creating products. Yet underlying theories, albeit described in layperson's terms, can help generalize findings (Bekker and Antle 2011; Rogers 2004). Thus, conveying the underlying concept of a theory, and how it plays out in the specific design studies, could help in designing new products.

Our findings also suggest directions for future IDC research. Designers wanted more basic research on the abilities of children at specific ages such as the types of interactions with different platforms they can understand. IDC authors and other CCI researchers have done some work in this area; an example is Hiniker et al.'s IDC paper (Hiniker et al. 2015) that analyzed apps to determine what types of touchscreen prompts preschool children might encounter, and then evaluated children's ability to follow prompts at different ages between 2 and 5 years old.

Soni et al. (Soni et al. 2019) created a framework of Touchscreen Interaction Design Recommendations for Children (TIDRC). While potentially useful to design practitioners, these recommendations and evidence-based practices are rare and scattered throughout the academic literature, making them inaccessible to designers.

The image shows a research card detail page with a white background and blue accents. The card is titled "Investigating Child-Parent Use of a System for Training Self-Control" and includes a "Download the Card" and "Request Paper" button. The card is divided into several sections: "Cognitive/ Self-Control", "Developmental Goals", "System Descriptions", "Actionable Strategies", "What was successful", "What was NOT successful", and "Key Takeaway".

Home Page/Search Results

Investigating Child-Parent Use of a System for Training Self-Control

No Touch Pig! Investigating Child-Parent Use Of A System For Training Executive Function

2019 Kiley Sobel, Kate Yen, Yi Cheng, Yeqi Chen, Alexis Hiniker

Cognitive/ Self-Control

3, 4, 5 Tablet Home

Developmental Goals

- Preschool children are developing "executive function" skills which include remembering information to complete a task, directing attention to complete a task, and self-control. These skills are related to successful learning, careers, health, and well-being.
- This study focuses on designing systems for developing self-control skills.

System Descriptions

- What do children do with the system:**
Children and their parents play with a commercially available tablet-based app called "Cookie Monster's Challenge," specifically 3 games within the app:
 - clicking objects with particular characteristics while avoiding objects without those characteristics (ex. Dogs with hats vs. dogs without hats)
 - clicking a red or blue button when they see objects with particular characteristics
 - clicking an object (a pig) when instructed to do so while not clicking the pig when told not to click the pig.
- How does the system support the developmental goals:**
These games ask children to remember and distinguish particular characteristics of objects and use self-control to avoid clicking certain objects.
- Interaction:**
Clicking objects that appear and move on the screen or buttons.

Actionable Strategies

01. Practical insights generalizable to other system designs:

For preschool children, design systems that encourage collaborative interaction between parents and children, and provide in-system support for parents on successful strategies to guide their child's behaviors.

Provide a background story to explain why children should exhibit self-control. For example, do not touch a new plant until it is grown.

02. Support for design decisions:

Principles and guidelines for design

Provide text-based on-screen supports for parents to guide child behaviors.

Provide interventions when ineffective strategies are detected, such as hovering above or clicking around something that should not be clicked.

What was successful

- Some children used strategies described in previous research to encourage self-control and following the rules: repeating the rules outloud or moving their hands to avoid clicking when they weren't supposed to.
- Some parents supported their children to complete the games successfully by repeating instructions.
- Unlike children who used a control system, those who used the app improved their score on a test of executive function skills after using the app compared to before using the app.

What was NOT successful

- Some children used an ineffective strategy: tempting themselves to click objects they were supposed to avoid by holding their fingers above the object or clicking around the object. This often led to failure to complete the task.
- Some parents did not know how to provide support to their children: some interfered before a child could attempt a task, some did not provide support even when their child struggled, and some provided support that research suggests undermines success, for example, focusing on tempting aspects of the tasks.
- No parents suggested distraction techniques which research suggest is the most effective strategy for self-control (not clicking the pig).
- Parents had trouble motivating why children should not click the pig because the task provided no narrative context.

Key Takeaway

Design systems that encourage collaborative interaction between parents and preschool children and provide on-screen support for parents on successful strategies to guide their child's behaviors.

Figure 7.4: Example of A Card Detail Page

While additional research in this area is needed, designers also need links to existing resources. For example, Bekker and Antle's Developmental Situated Design Cards (Bekker and Antle 2011) break down physical, cognitive, social, and emotional abilities of children at three different age ranges, though do not specifically address abilities as they relate to interactive technology. Practitioners are also interested in work that bridges different forms of research such as data analytics, qualitative findings, consumer research, and efficiency studies.

Our research supports the need for an IDC Design Toolkit, but it also reveals other tools that would be beneficial to industry designers but are beyond the scope of this toolkit. Designers expressed interest in a community space for connecting on research related to design for children. Additionally, practitioners expressed interest in better understanding methods and techniques for designing and evaluating with children. Finally, our research also suggests that a newsletter synthesizing the key research from IDC could be valuable for industry practitioners to engage with IDC research communities. This could become part of the tasks taken on by the organizing committee or student volunteers of our annual IDC conference.

7.5 SUMMARY OF CONTRIBUTIONS

Today's children are surrounded by digital experiences that were not available a decade ago. Technology has the potential to foster children's learning and developmental growth. While there are evidence-based benefits of research applications, the vast majority of children's apps available in app marketplaces do not incorporate child development, learning, or literacy knowledge. Children's technology designers seldom use theoretically driven design considerations and evidence-based research to account for children's developmental needs due to

a variety of barriers, including accessing and translating academic research. Additionally, designers are rarely educated in children's key developmental needs. I address these challenges by answering RQ3 and RQ4. Here, I contribute a design artifact and show in support of T2 that an Interaction Design and Children (IDC) designer's toolkit can provide evidence-based resources for designers to create developmentally responsive technology designs for children. Additionally, these findings contributed to our understanding of designers' practices, barriers, and needs related to using theoretical driven research in their design work for children's products. The evaluation study with designers provided key implications for the re-design of toolkit navigation, organization, and content that can best support industry designers' practices and reduces the research-practice gap. I also discuss opportunities for the CCI community to better meet industry practitioners' needs, including translating research to actionable recommendations and directions for future studies.

CHAPTER 8. DISCUSSION AND CONCLUSION

Across the studies in this dissertation, I investigated how to design developmentally responsive technologies for children. I designed the NatureCollections app to promote children's interest in their natural surroundings by incorporating child-development theory into the design consideration to guide the developmental responsiveness of children's mobile applications. Then I examined child-computer interaction (CCI) research that could support the developmental needs of children, which served as the foundational research for the content presented in the Interaction Design and Children designer's toolkit. Through this body of research, I have sought ways to support children's technology designers to enhance the developmental responsiveness of their designs. To do this, I have offered considerations and resources to bridge the CCI research and practice gap, including concrete examples that simultaneously support children's development and design practices.

In this chapter, I revisit my thesis statements in the context of the results from this dissertation's formative studies and deployments. First, I discuss cross-cutting themes that emerged across the results of the projects described here, starting with the central role of children and their developmental, psychological, and social needs in designing technical systems. I then reflect on the challenges to incorporating theory into practice, describing considerations for developmentally responsive designs and future opportunities for the Interaction Design and Children toolkit beyond the design process. Finally, I summarize the theoretical and empirical contributions I make in this dissertation. I also discuss the artifacts I created in the process of doing this work and how they might be used by other researchers and designers. In conclusion, I identify areas for future work, describing how I intend to extend what I have done here.

8.1 INCORPORATING THEORY INTO DESIGN

8.1.1 *Developmental Responsive Design*

Developmentally beneficial tech-based experiences are most likely to occur when designs incorporate child development theories and models to support children's tech-mediated behaviors and carefully consider situated social contexts appropriate for the child developmental stage (Bers 2012; Hirsh-Pasek et al. 2015). Although my focus with the NatureCollections app design was to support children's interest development, I repeatedly observed the app fostering several positive developmental-related behaviors in children across the research studies. The app promoted children's sense of autonomy and competence through facilitation of creating experiences, creatively experimenting, and interacting with others—critical conditions for children's positive technological development (Bers 2012). Results in Chapter 4 and Chapter 5 show that the app fostered child-driven nature explorations and sensory inspection of the nature elements in their surroundings (e.g., direct children's attention to their surroundings and fosters tactile interactions). Additionally, parents valued the app supporting their children's autonomy by taking on some of the burden of guiding their children's outdoor explorations while maintaining a sense of family connection and fostering family bonding experiences. The app activities also sparked meaningful family nature interactions and conversations. This work expands the developmental responsive design in the contexts of joint family engagement (JME) in nature-based explorations.

Similarly, across the Interaction Design and Children published research (Chapter 6), CCI work primarily aimed at exploring the affordances of technology in facilitating positive developmental-based behaviors in children. The CCI research is driven to design technologies

with and for children’s optimal developmental growth. In addition to leveraging theories to design tech-based experiences that correspond to children stage of development and encourages interactions and behaviors that fosters developmental growth, the CCI research community is committed to empowering children and value inclusive child-centered methodologies in the design and evaluation of children’s technologies (Giannakos et al. 2020; Kawas, Yuan, et al. 2020). Together, my results show that creating developmental responsive design depends on incorporating child development theories and models. While today’s technology may be constantly changing, children’s developmental needs do not (Bers 2012). I look forward to evolving this design space and engaging with the CCI research community to support children’s technology designers and practitioners to focus on the kinds of developmental tasks that technology can facilitate—rather than user engagement—creating digital experiences that promote positive developmental growth.

8.1.2 *Challenges to Distilling Theory-Driven Design Considerations*

The current landscape of children’s market applications and technologies are guided largely by commercial purposes and not by children’s developmental concerns (Papadakis et al. 2018; Vaala et al. 2015) although CCI published research is motivated to inform the design practice (Chapter 6). Prior work on research-practice gap reports that designers rarely use academic research findings due to barriers to accessing and understanding the academic work that seems abstract, complex, and not presented in a format that fits the design process used in industry (Chapter 2). My work reveled new barriers to implementing academic research; designers pointed out that CCI research lacks critical information, such as a detailed description of the system design and features and a description of how children interacted with the designed system. Another critical barrier is that research studies are often narrowly focused while

designers need to be informed by a broader context of child development abilities and how to generalize the actionable design strategies and recommendations beyond the system presented (Chapter 7).

During my work on designing the NatureCollections app, I faced similar challenges to industry designers. To situate the app design in child development theory, the process required domain expertise and time and recourses to collaborate with children—all are often in short supply in industry contexts (Colusso et al. 2017). In addition to collaborating with child development researchers, as an HCI designer and researcher with no former training in child development practices, I had to learn about interest development theories and study child developmental needs in general prior to starting this project. Although child development research has a wealth of evidence to benefit positive technological development, it does not describe potential means for design practice (Bers 2012; Colusso et al. 2017). Additionally, in my survey of prior CCI research of mobile technologies to support children’s outdoor explorations, practical design considerations and strategies were described at a high level and were scattered across multiple publications (see Chapter 2.3.3).

To start the process of incorporating theory into design consideration, I first distilled key design principles that adhere to the underpinning characteristics of all phases of interest development theory. These principles include (1) engaging children in personally relevant activities, (2) supporting their focused attention on their surroundings, (3) encouraging social interaction and (4) provide opportunities for continued engagement. These design principles provide an overview of the desired outcome from tech-based experiences but do not describe actionable

design recommendations (Chapter 3 describe the process in detail). Guided by HCI translational research recommendations to reduce the research-practice gap (Colusso et al. 2019), I collaborated with children as co-designers to identify specific design strategies and app features to implement for each of the design principles to design a nature-focused children's application. (See Table 3-1 for the full interest centered design framework.) The app evaluation results (Chapter 4 and 5) suggest that providing designers access to theory-based design frameworks and actionable research-based design recommendations can facilitate the design of developmentally responsive technologies for children. However, the process of distilling actionable design strategies from child development theory to build tech-based solutions in CCI research projects are described at high level and miss critical details and examples needed for design practice (Chapter 7).

Additionally, my results revealed that a small percentage of published papers make a theoretical contribution in Interaction Design and Children (Chapter 6). This suggests a research opportunity for the CCI community to broaden research contributions to generative theories with a focus on design frameworks to support children's positive developmental experiences with tech-based interactions. In addition to contributing new knowledge about current designer practices, barriers, and needs in incorporating research in design practice, in this dissertation I explore how an evidence-based designers toolkit, that focuses on actionable design recommendation, can reduce the research-practice gap in Child-Computer Interactions. Furthermore, I am excited to envision future translational tools, practices, and training to support CCI researchers to share their research and design recommendations in a meaningful way for design practice.

8.2 TOOLKIT BEYOND THE DESIGN PROCESS

The online IDC designer's toolkit is aimed to guide designers in evidence-based app developmental responsiveness in children's technology design. The toolkit also provides guidance for child-computer researchers to make child-specific interaction design research accessible to designers. However, my hope is that the IDC designer toolkit content can be leveraged beyond supporting the design process of children's technology design. In the following section, I discuss two potential future uses of the toolkit. First, the toolkit could be used as a comprehensive resource on interaction design and children in educational courses for designers. Second, researchers and educators can use the toolkit to create an evidence-based guide for evaluating the developmental appropriateness of existing children's apps.

8.2.1 *Toolkit for Educational Courses*

Designers of child-focused mobile applications are rarely educated in children's developmental needs or trained in child-centered methods to include children in the product design cycle. Additionally, designers face barriers to accessing relevant academic research due to hard-to-identify search keywords and articles hidden behind paywalls. Even when designers can access academic papers, the research is often presented in a format that does not match their design needs.

The IDC design toolkit offers opportunities for User Experience Design and Human-Computer Interaction educators to incorporate CCI research of tech-based systems for children in their courses. The CCI research in the toolkit advocates for children's views and developmental needs and speaks to designers in meaningful ways. The synthesized research in the toolkit matches

designers' needs and includes key system interactions that describe how children used the design features, the developmental implications of technical features and design choices that support children's developmental goals, and actionable advice for designers such as how to generalize the actionable design strategies and recommendations beyond the system presented.

8.2.2

Toolkit to Guide the Assessment of the Developmental Responsiveness of Existing Children's Application

The IDC toolkit aims to support designers in evidence-based children's app development. However, the evidence-based toolkit could guide the creation of developmental standards to evaluate the effectiveness of existing children's apps. The toolkit content focuses on how design choices presented in the research align and facilitate children's developmental growth. A comprehensive analysis of the research shared in the toolkit could aid in developing a set of principles that can be used to evaluate the developmental responsiveness of current children's apps in the app store. While there is no way to assess every app on the market, this set of development-based principles can be used to evaluate popular apps for children. This work can be in conjunction with popular parent-oriented app rating services like Common Sense Media and Children's Technology Review. For example, Common Sense Media uses a 5-point scale to rate "educational value," "ease of play," "violence & scariness," "sexy stuff," "language," "consumerism," and "drinking, drugs, & smoking." Reviews could also include whether the app is grounded in evidence-based research and matches the developmental needs of the targeted children's age range.

8.3 CONTRIBUTIONS

The first contribution of this work is a theory-based interest-centered design framework for children's technologies to promote interest development in a topic and document the framework design process. To date, much of the design and research space for learning mobile technologies focused on either supporting motivation or providing external structured support to guide scientific inquiry in and out of school. The evaluative approach of the design framework was in the context of interest development in nature, but I hope the set of design principles and strategies can serve in other domains.

Similarly, my second contribution is a generative theory that extends joint media engagement (JME) in the context of nature-based explorations, taking into consideration the parent-child relationship tensions around technology use during a transitional period of childhood. I discuss how designers can facilitate digital experiences that (1) bridge the context gap around technology interactions and nature information to increase joint family engagement with nature; (2) support a family's sense of togetherness during co-located and remote nature-focused activities and promote behaviors that align with family values. In addition to the design needs of family joint nature-based engagement, technology design decisions can reduce screen time tensions.

The third contribution of this dissertation is two design artifacts, the NatureCollections App and the Designer Toolkit. These design artifacts facilitate new explorations, draw new insights, and imbue new possible futures (Wobbrock & Kientz, 2016).

NatureCollections: In this case, the app's features embody interest-centered design strategies and show how mobile technologies can facilitate children's interest development.

IDC research-based designer's toolkit: With a purpose of enabling generative design-driven activities to help us understand the needs of designers who work on children's technologies. Based on these insights, I redesigned the toolkit. In this dissertation, I show two iterations of the design toolkit functional prototype.

The fourth contribution of this dissertation presents a generative, empirical understanding of the current state of children's interest-driven nature explorations and informs the design of mobile technology for children. I conducted several research studies that evaluated multiple dimensions of the NatureCollections app design and by extension the ICD framework. Through a mixed-method approach, I demonstrated the app succeeded at sparking children's interest and engaging them in enjoyable, meaningful nature explorations. Additionally, the empirical insights provided an understanding of parents' experiences, perspectives, and family needs, informed by the critical role of parent-child tech-related tensions, using NatureCollections to support joint family engagement in nature and increase family time spent outdoors.

Lastly, the fifth contribution of my dissertation gives a generative, empirical understanding of the current state of the child-computer interaction research-practice gap and evaluates the research-based designer's toolkit. This focused analysis on current practices and needs of designers that work on children's products has revealed new barriers to using academic research, which is often narrowly focused on study research questions, while designers need to be informed by a broader context of child development goals and abilities. The evaluation of the

toolkit also uncovered additional implications and opportunities for transitional CCI research practices, including how the children used the design system, explicitly describing how the design choices assisted children's developmental growth and how to generalize the actionable design strategies and recommendations beyond what the technical system presented.

I hope all these contributions extend our current understanding of designing developmentally responsive technologies for children and help both designers and researchers incorporate theory-driven and research-based insights in their design decisions for children's technologies.

8.4 FUTURE WORK

There are several areas of future work that build on the research I presented in this dissertation. First the two investigations I conducted here provide designers with theory-driven design framework and resources of actionable design recommendations that focus on specific context intended with the CCI translated research (e.g., promoting interest in nature). However, my formative work suggests the need to derive a broader design applicable guidance of positive developmental-related behaviors in children for each developmental stage. What are the actionable design strategies to support critical positive developmental tasks for each developmental stage? How does the context for which we are designing impact the design implications of technical systems? Additionally, future research should examine the ethical consequences of possible use of the framework in creating malicious design patterns or designs that are corrosive to family and societal values.

While my work on the NatureCollections app focuses on promoting children's interest development in their natural surroundings, future research could investigate the use of the

interest-centered design framework to design for children's interest development in other learning contexts. How can the design of technical-based solutions promote interest in topics like STEM, or nurture creative skills and design thinking? Additionally, a clear next step for the app would be to tailor the current app design to meet joint family nature-based engagement needs, to investigate how technical systems may be able to bear some of the burden of parental mediation of children's technology use, supporting children's independence while maintaining their connections to their family. Future work could also study long-term app use to foster children's well-developed personal interest and its effect on their connection to nature.

Regarding the IDC designer's toolkit, first I plan to deploy the re-designed web-based prototype to evaluate the toolkit navigation UI features, the organization and content of the toolkit with industry designers that work on children's technology products. This research study would closely mimic the use of the toolkit in the real world, as I plan to explore how the toolkit fits within current design practices, and how the translated research can meet designers' needs in rapid industry product cycles. Additionally, future research could investigate the longitudinal effects of children's products that implemented the translated research and evaluate the values imbued in these products. Second, I plan to evaluate the current lightweight stepped process of translating the CCI research for the toolkit with authors of IDC and CCI research papers, and to investigate their needs in translating research findings for design practice. Moreover, future studies could explore using a series of professional development resources, like creating asynchronous training workshops for authors to summarize and synthesize their research. Additionally, future research could investigate the types of infrastructure needed to maintain the toolkit over time, and ways to scale it to support research beyond system designs.

Finally, the work done in this dissertation has explored how to support developmentally responsive technology designs within western contexts. Future research could consider cultural ideologies, values, and its discourse in impacting the designs of developmentally responsive technologies for children. Additionally, future iterations could investigate how developmentally responsive designs are tailored for children with disabilities. Moreover, there are additional opportunities to study design considerations across all the key children-developmental areas, to create a comprehensive guiding design theory of a developmentally responsive framework across different parts of children's lifespans. I am excited to investigate this further in my future research.

8.5 CONCLUSION

Children and teenagers are prolific users of digital technologies unavailable a decade ago. With tablets and smartphones, children have increasing access to various mobile applications and games. Although popular wisdom depicts the potential dangers of screentime, emerging academic research across multiple fields from educational technologies and medical to child-computer interaction provides clear evidence of the learning and developmental benefits of interactive app use by children (Griffith et al. 2020; Hirsh-Pasek et al. 2015; Papadakis et al. 2018). Today, the vast majority of self-proclaimed children's educational applications available on the app store do not meet the developmental needs of children (Papadakis et al. 2018; Vaala et al. 2015), and designers are seldomly trained in child development, literacy, or educational theories, to incorporate this knowledge when designing children's technologies. Additionally, the implemented interface design features are often inappropriate for the intended children's

developmental skills (Hiniker et al. 2015; Soni et al. 2019). Designing developmentally responsive technologies for children depends on designs that consider the child's developmental stage, and the situated social contexts when formulating the content and activities of children applications and employing an interaction design appropriate to the child's cognitive and motor skills (Bers 2012).

In this dissertation, I begin to examine ways to support children's technology designers in creating developmentally appropriate digital experiences for children. First, I show that incorporating child-development theory into mobile technologies design recommendations to promote children's interest-development in a topic. This work is the first to contribute an interest-centered design framework for children's mobile technologies. I present the design of the NatureCollections app that embodied the interest-centered framework principles and strategies to support children's personal interest-development in nature. Children's interest in nature is an important dimension to support nature-based science learning and encourage children to become responsible stewards of the environment. My findings show that children's designers can support children's developmental growth when integrating evidence-based insights into their designs. Second, this work contributes to the first empirical study that investigates children's designers' needs of transitional CCI research and points to specific design implications when designing research resources, such as the IDC designer toolkit, to support the design of developmentally responsive children's technologies.

More research is needed to evaluate the potential of children's applications to support their development and their limitations. I prompt other researchers and designers to consider how their

design decisions help or hinder children's developmental needs. How can we derive a generative theory for design implications that guide children's development over their childhood span? What impacts imputed values in specific design features on children's development growth? How do these design artifacts work within family systems and socio-technical contexts? How might we prevent the use of developmentally responsive designs in a harmful way? Who might be responsible for guiding the ethical use of evidence-based research resources?

My aim is to draw attention to the influential position designers and researchers have in designing developmentally responsive applications for children. I argue that incorporating child development theories into design considerations for children's mobile technologies, and providing actionable, evidence-based resources for designers can enhance children's developmental growth with digital technologies.

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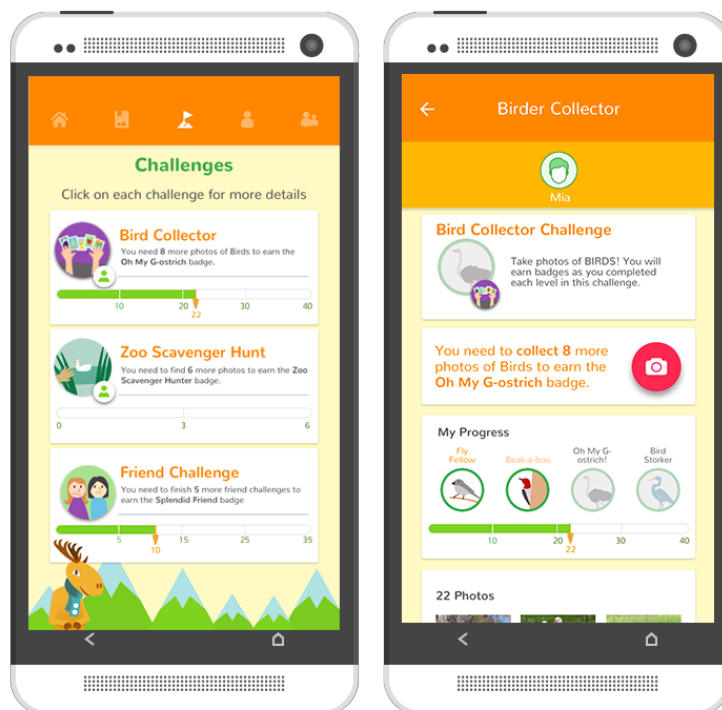
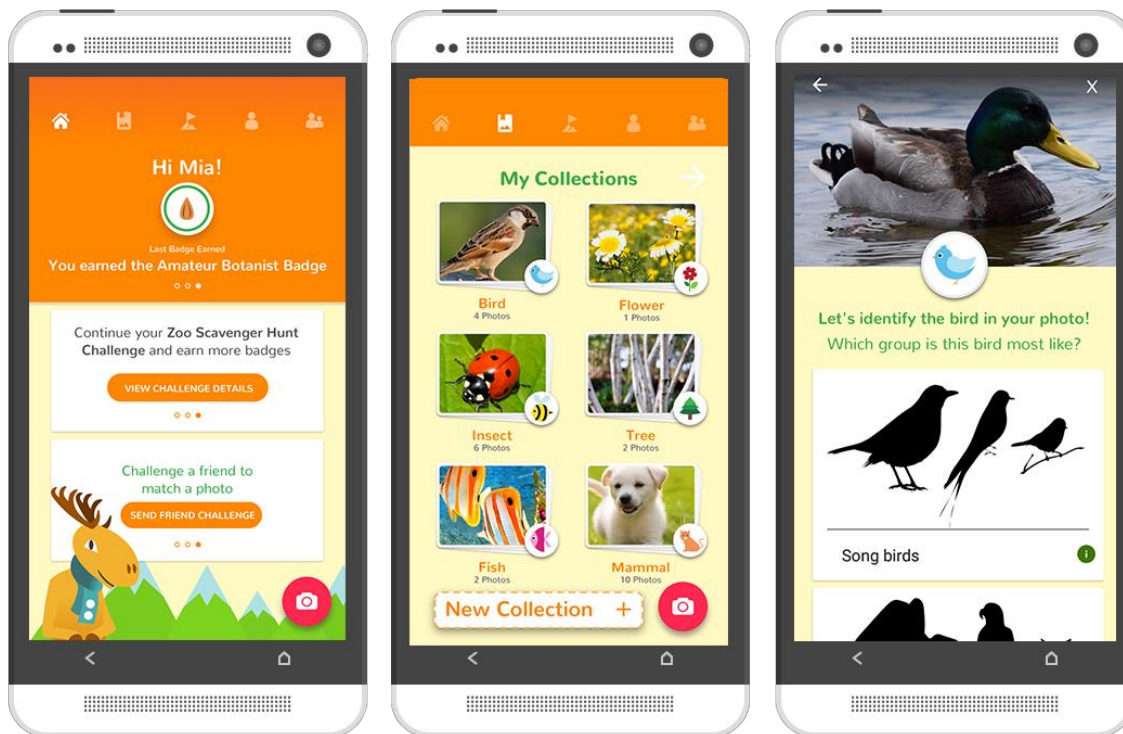
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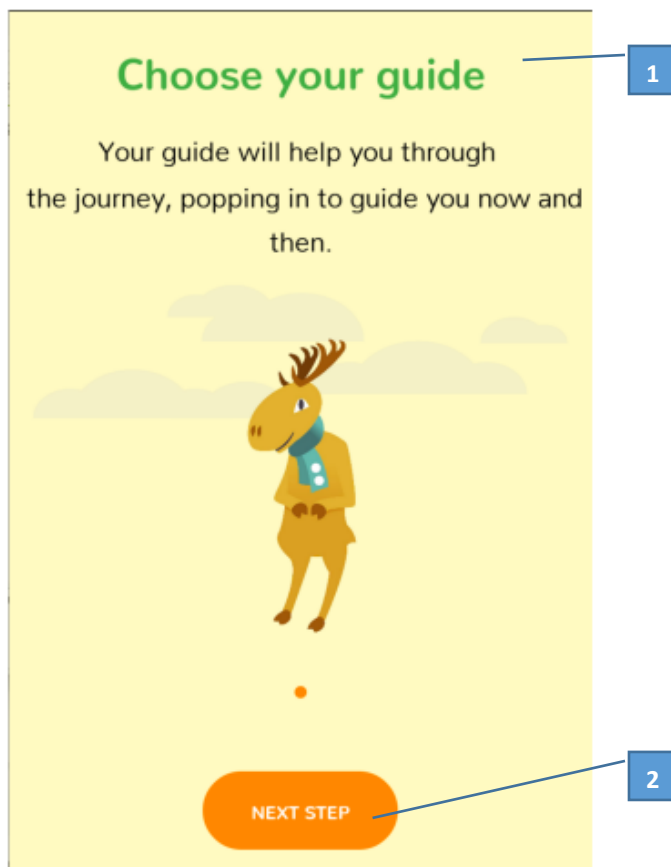
APPENDIX A: NATURECOLLECTION APP DESIGN SPECIFICATIONS



Design Specifications

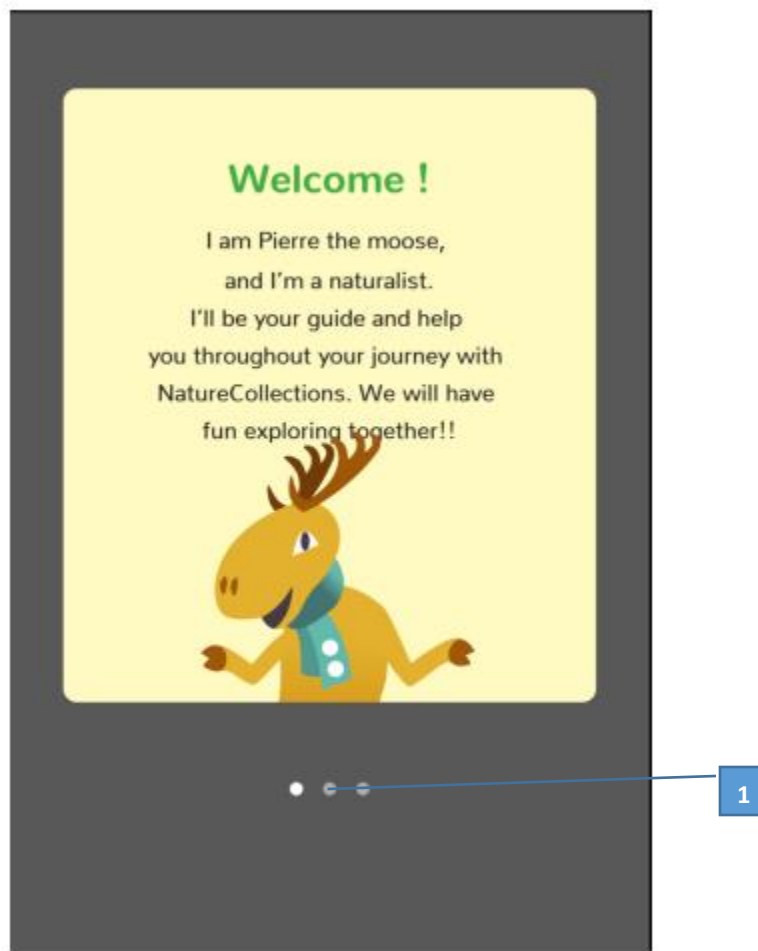
Onboarding and Tutorial Screens

Choose Your Guide screen



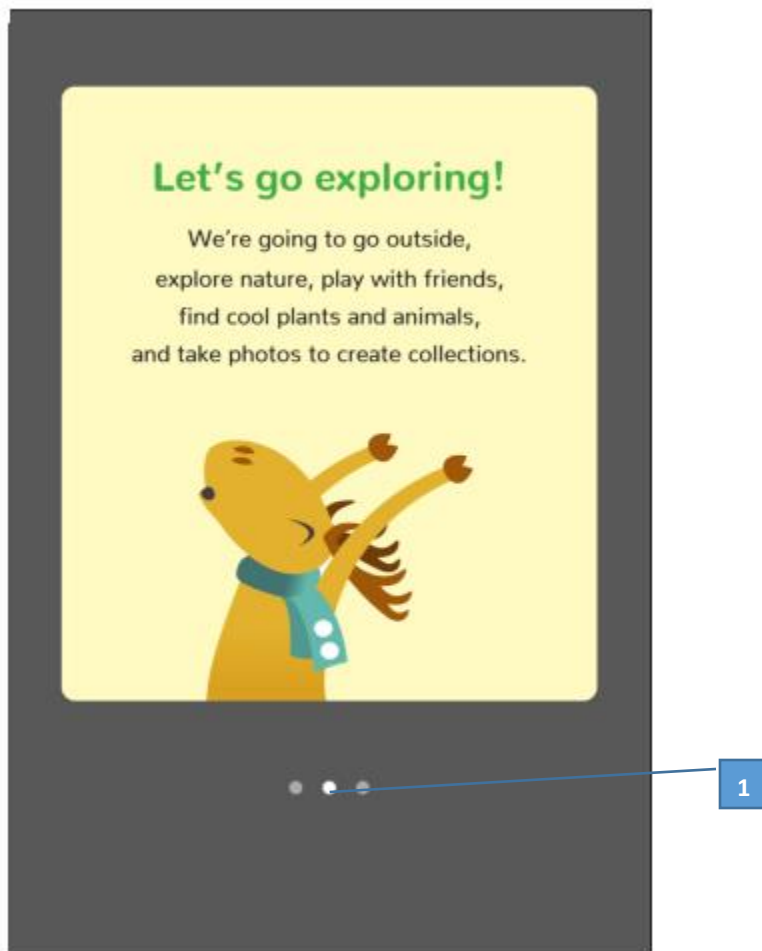
#	Label	Description
1	Choose a guide	Until additional functionality has been implemented allowing the user to choose between multiple guide characters, change the text to, This Is Your Guide
2	Next step button	On tap, user goes to Onboarding Screen 1

Onboarding Screen 1



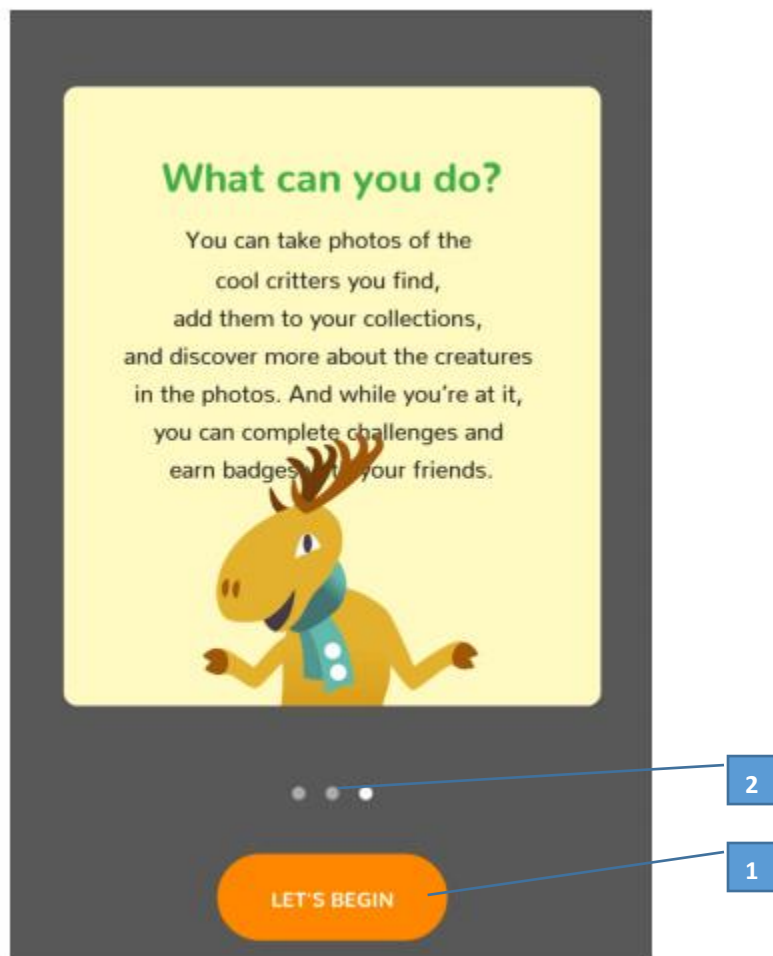
#	Label	Description
1	Swipe to next screen	User must swipe left to scroll to Onboarding Screen 2. User cannot scroll to previous screen.

Onboarding Screen 2



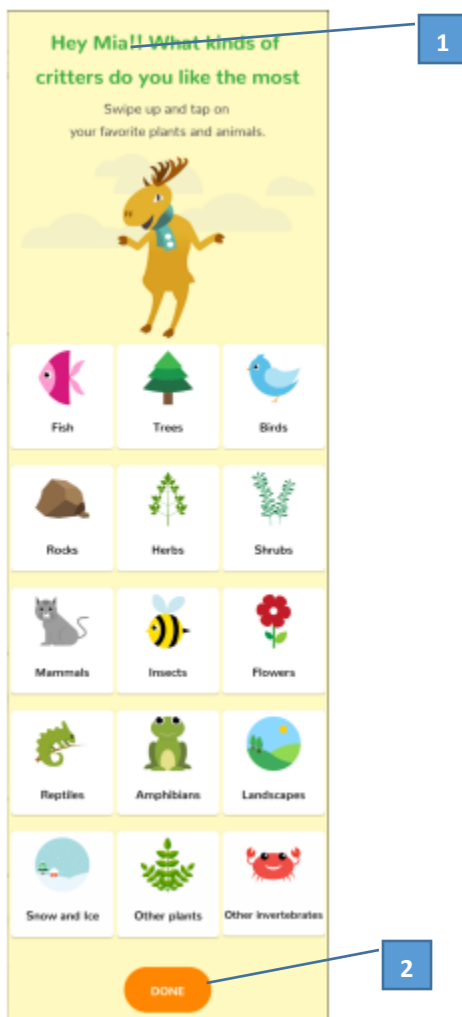
#	Label	Description
1	Swipe to next screen	User must swipe left to scroll to Onboarding Screen 3. User can also scroll to previous screen.

Onboarding Screen 3



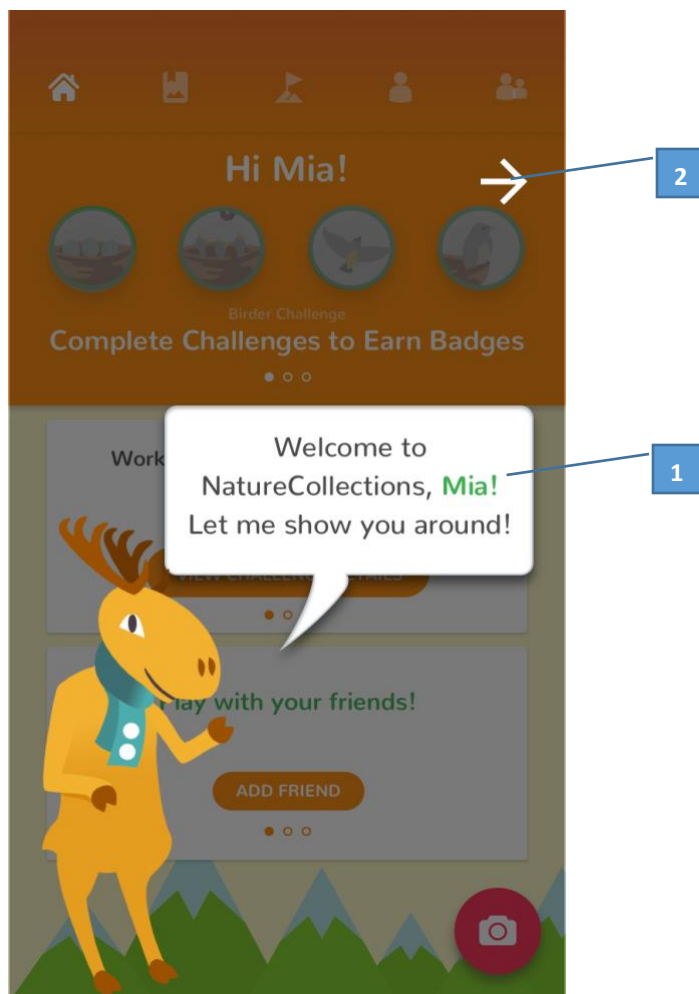
#	Label	Description
1	Begin button	On tap, user goes to Select My Interests Screen.
2	Scroll to previous page	User can scroll to previous screen, but cannot scroll to next screen.

Select My Interests Screen



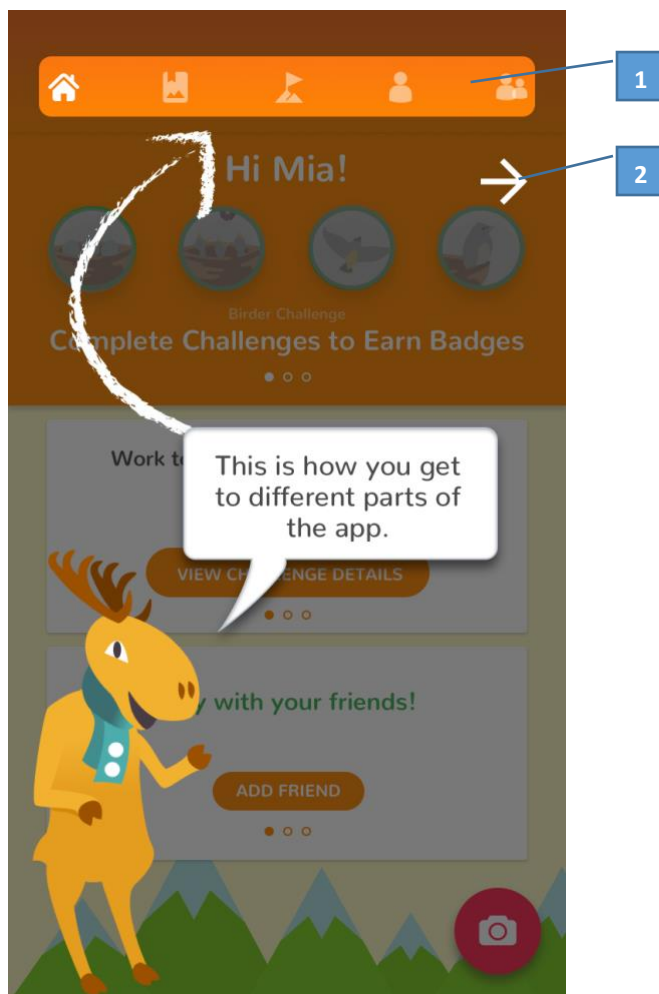
#	Label	Description
1	Personalized greeting	Greeting should be dynamic: Hey [username]!!
1	Done button	On tap, user goes Tutorial Screen 1. User may select as many options as they choose. User is not required to select an option before moving to next screen.

Tutorial Screen 1



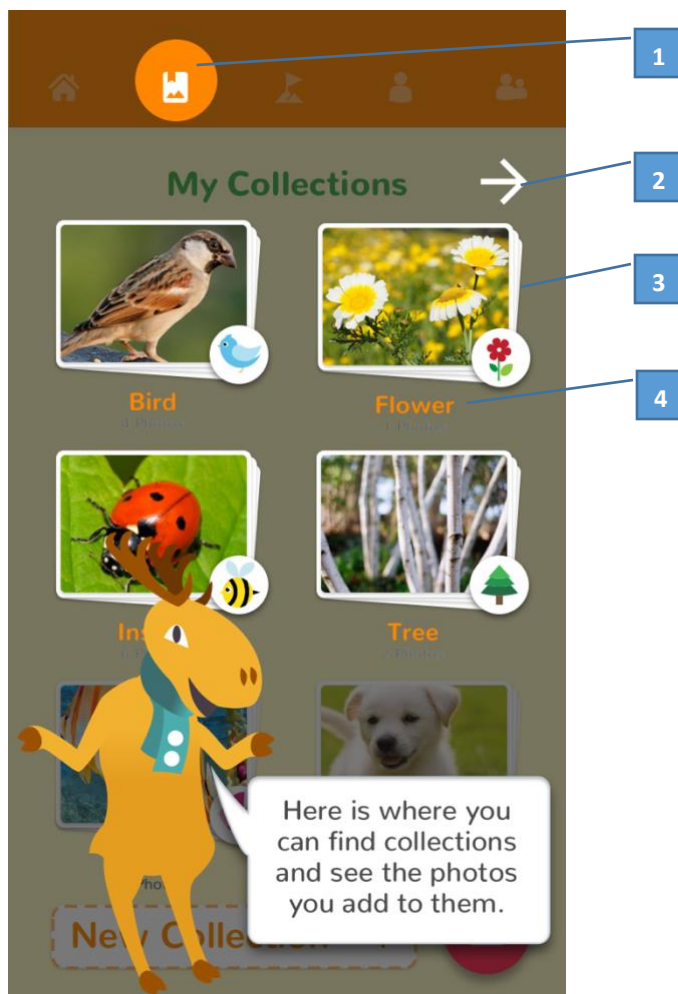
#	Label	Description
1	Personalized greeting	Text should be dynamic: Welcome to NatureCollections, [Username]! Let me show you around
2	Next arrow	On tap, user goes to tutorial screen 2

Tutorial Screen 2



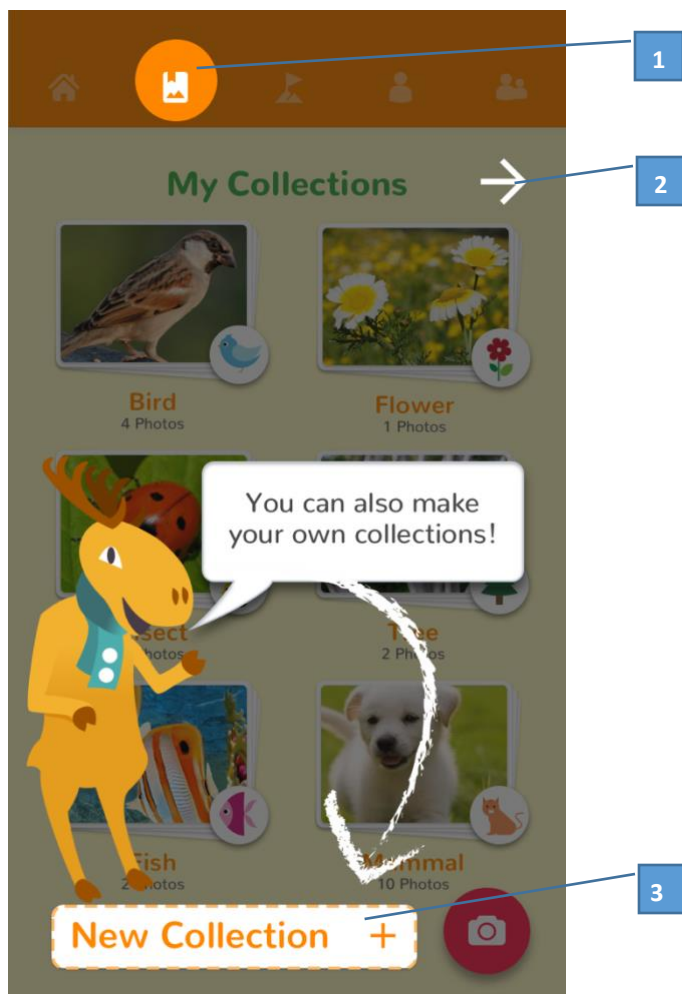
#	Label	Description
1	Highlighted navigation bar	Navigation bar is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 3

Tutorial Screen 3



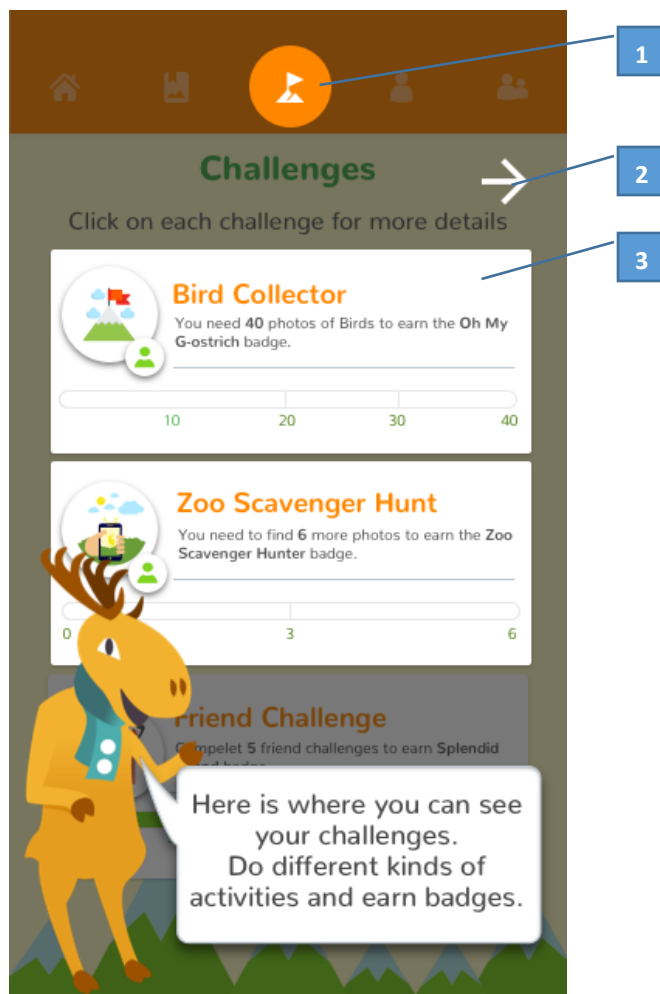
#	Label	Description
1	My Collections tab	My Collections tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 4
3	Collections	Top 4 collections are highlighted. They are populated with stock photos, not the empty state icon.
4	Collections title	Top 4 collections titles are also highlighted.

Tutorial Screen 4



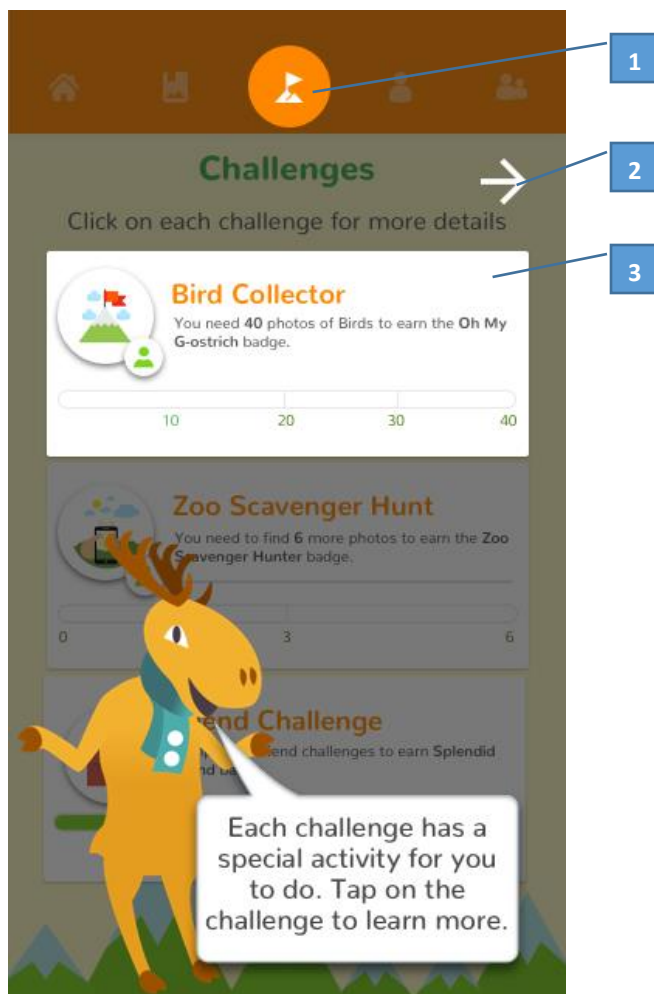
#	Label	Description
1	My Collections tab	My Collections tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 5
3	Custom Collections	Create a custom collection button is highlighted, but not clickable

Tutorial Screen 5



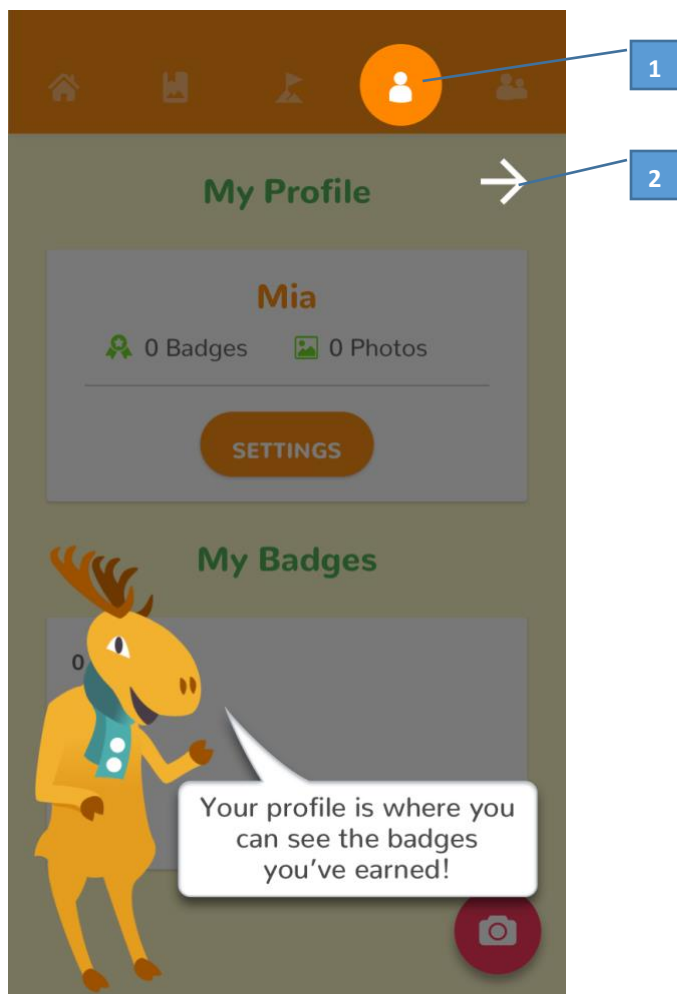
#	Label	Description
1	Challenges tab	Challenges tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 6
3	Challenge cards	Top 2 challenge cards are highlighted, but not clickable

Tutorial Screen 6



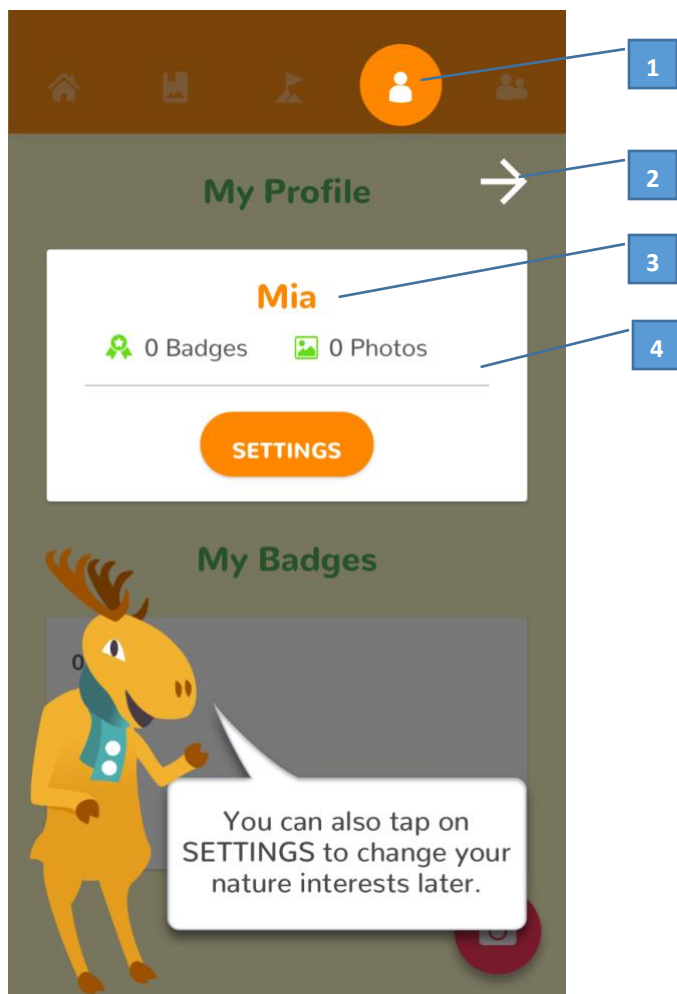
#	Label	Description
1	Challenges tab	Challenges tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 7
3	Challenge cards	Top challenge card is highlighted, but not clickable

Tutorial Screen 7



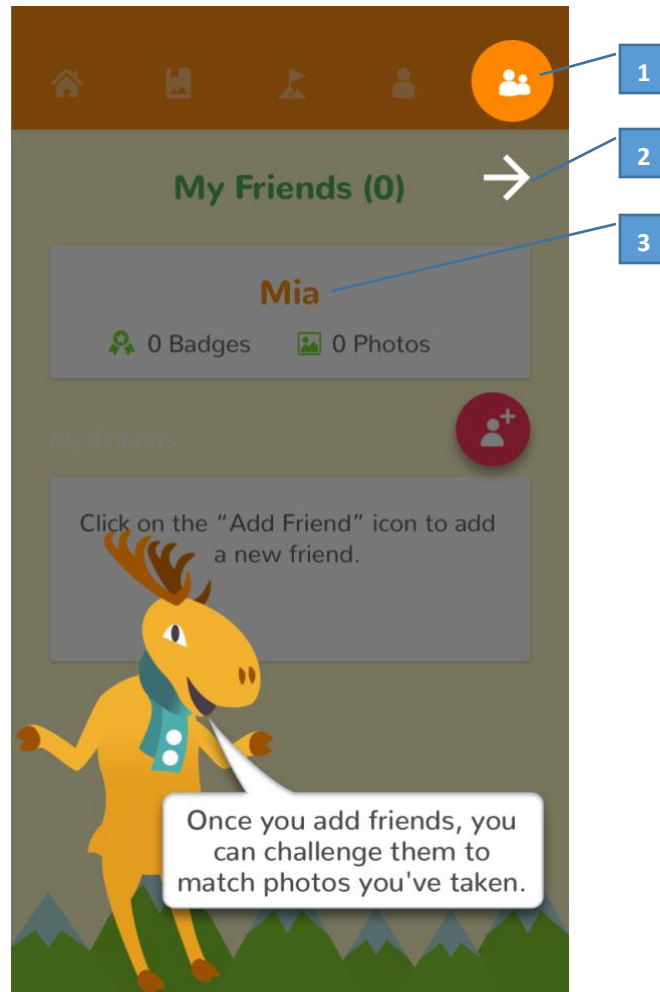
#	Label	Description
1	My Profile tab	My Profile tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 8

Tutorial Screen 8



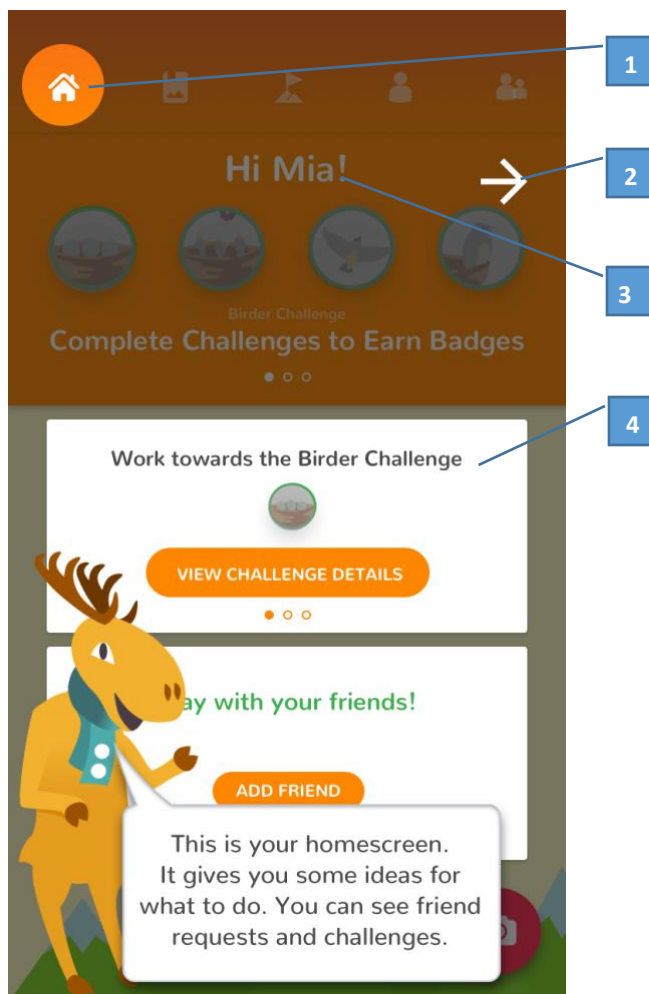
#	Label	Description
1	My Profile tab	My Profile tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 9
3	Personalized profile	Username on My Info card should be dynamic: [Username]
4	My Info card	My info card is highlighted, but the Settings button is not clickable

Tutorial Screen 9



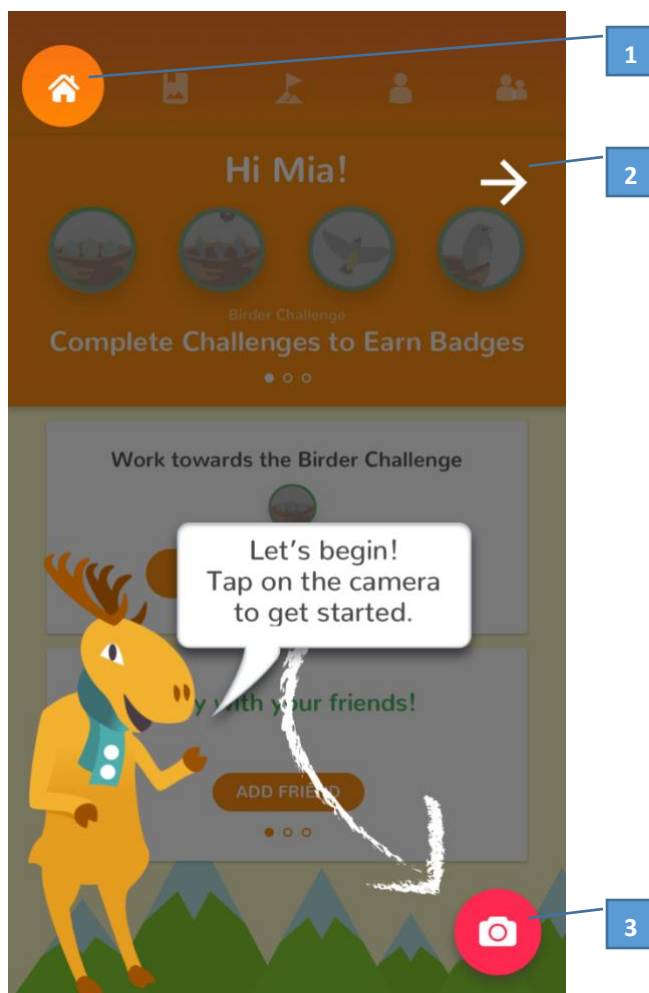
#	Label	Description
1	My Friends tab	My Profile tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 10
3	Personalized card	Card text should be dynamic: [Username]

Tutorial Screen 10



#	Label	Description
1	Homescreen tab	Homescreen tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Tutorial Screen 11
3	Personal greeting	Text on dashboard card should be dynamic: Hi [Username]!
4	Cards	The Suggestion and Notification cards should be highlighted, but not clickable. They should be the empty state card content

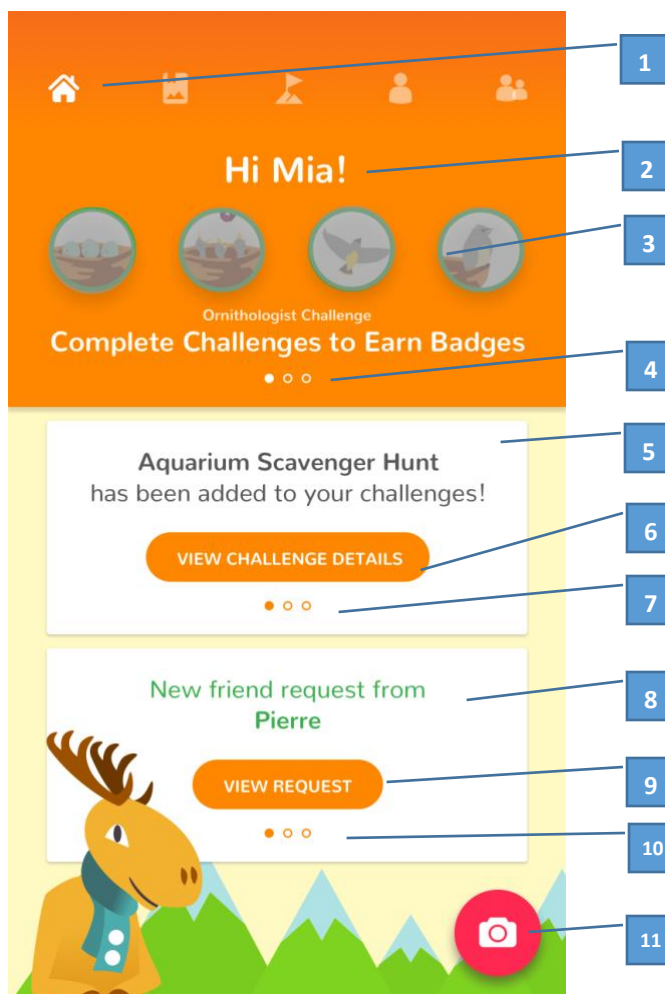
Tutorial Screen 11



#	Label	Description
1	Homescreen tab	Homescreen tab icon is highlighted, but not clickable
2	Next arrow	On tap, user goes to Homescreen (empty state)
3	Camera icon	Camera icon is clickable. On tap, user goes to android camera

Homescreen Screens

Homescreen layout



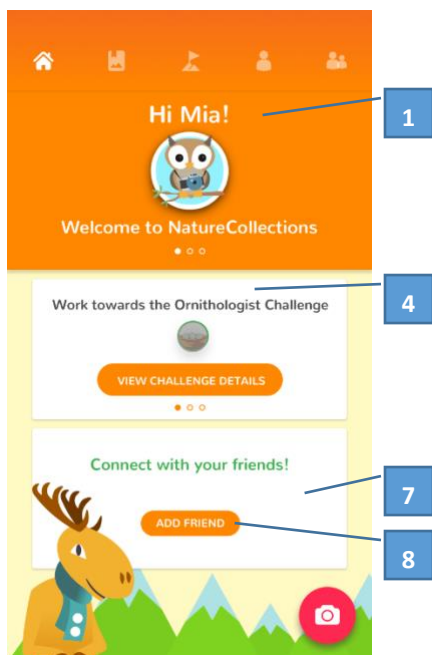
#	Label	Description
1	Home Tab	Homescreen appears when user taps on Home tab
2	Personal Greeting	Greeting should be dynamic: Hi [username]
3	Dashboard card	Dashboard cards are not clickable. See below for content for dashboard cards. Content should be refreshed every time the user opens the app and when the app is connected to the Wi-Fi/network (this should not require the user to log off and log back on)

4	3 scrollable Dashboard cards	There are at least 3 scrolling cards, which automatically toggle through on a set time interval. The user may also swipe in either direction to manually scroll through the cards. This will be circular (when user gets to the last card, and swipe right, they go back to the first card)
5	Suggestions Card	Suggestion cards have a clickable button. See below for content for each card. Content should be refreshed every time the user opens the app (this should not require the user to log off and log back on).
6	View detail button	On tap, user goes to Challenge Details screen for the challenge.
7	3 scrollable Suggestion Cards	There are 3 scrolling cards, which automatically toggle through on a set time interval. The user may also swipe in either direction to manually scroll through the cards. This will be circular (when user gets to the last card, and swipe right, they go back to the first card)
8	Notification Card	Notification cards have a clickable button. Show all notifications that are pending (require user action) See below for types of notification cards. Notification cards should be refreshed every time the user returns to the homescreen.
9	Respond to Notification button	This button is clickable, and is how the user responds / takes action on the notification. See below for notification content and anticipated functionality of this button depending on notification type
10	Scrollable Notification cards	This will have a dynamic number of scrolling cards. Each pending notification will receive a card, so it depends on how many notifications the user must take action on. Cards will automatically toggle through on a set time interval. The user may also swipe in either direction to manually scroll through the cards. This will be circular (when user gets to the last card, and swipe right, they go back to the first card)
11	Camera button	On tap, user goes to the android camera.

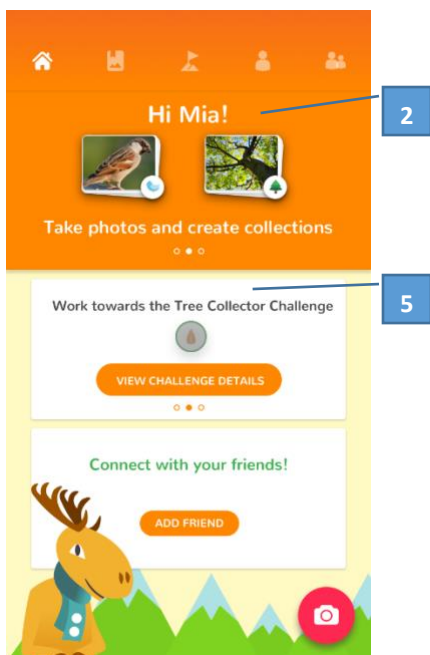
		If camera is accessed from the homescreen, photos taken will only count towards Collect or Identify challenges (not Team or Scavenger Hunt challenges)
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Homepage - Empty State Card Content

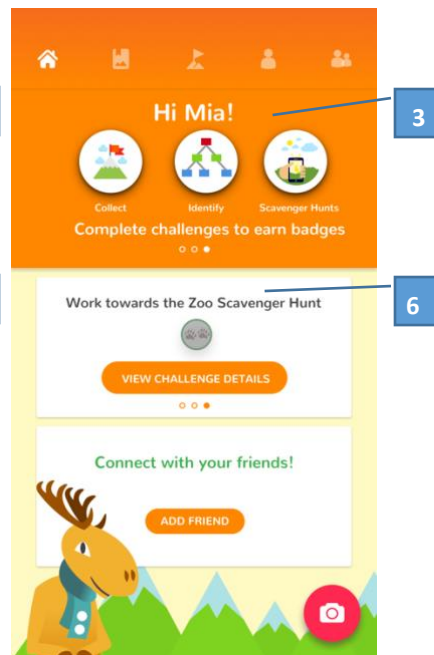
Empty State 1



Empty State 2



Empty State 3

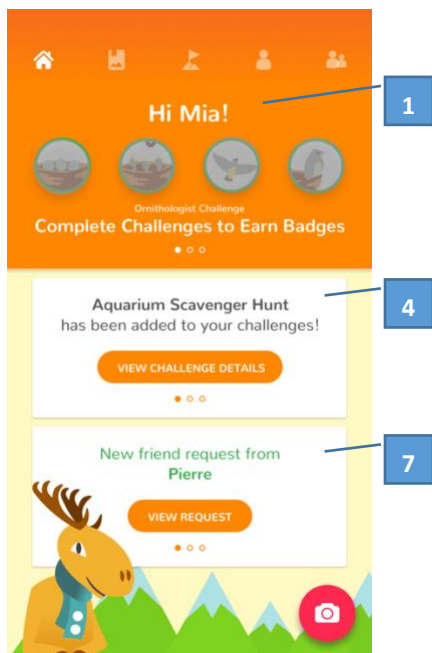


#	Label	Description
1	Dashboard Card Empty State 1	This is the first of the 3 scrollable dashboard cards for the empty state (when user first logs on)
2	Dashboard Card Empty State 2	This is the second of the 3 scrollable dashboard cards for the empty state (when user first logs on)
3	Dashboard Card Empty State 3	This is the third of the 3 scrollable dashboard cards for the empty state (when user first logs on)

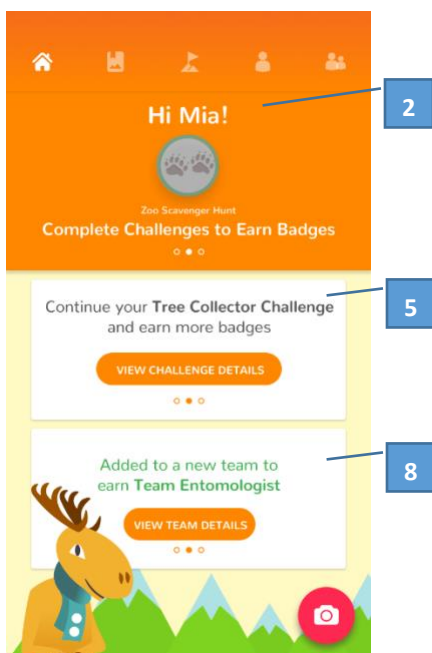
4	Suggestion Card Empty State 1	Suggestion for a Identify challenge selected based on user’s My Interests settings (see below for logic details).
5	Suggestion Card Empty State 2	Suggestion for a Collect challenge selected based on user’s My Interests settings (see below for logic details).
6	Suggestion Card Empty State 3	Suggestion for a Scavenger Hunt challenge, randomly selected (see below for logic details)
7	Notification Card Empty State - if no friends	If there are no notifications requiring user action, and the user as not added any friends, this notification should appear
8	Add Friend button	On tap, user is taken to My Friends screen.

Homepage – Card Content & Logic

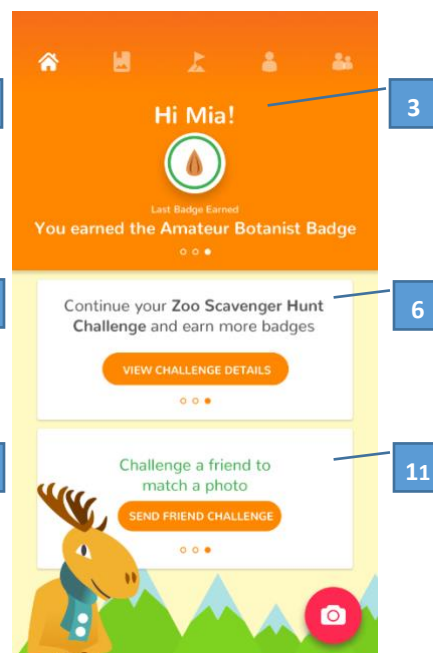
State 1



State 2



State 3

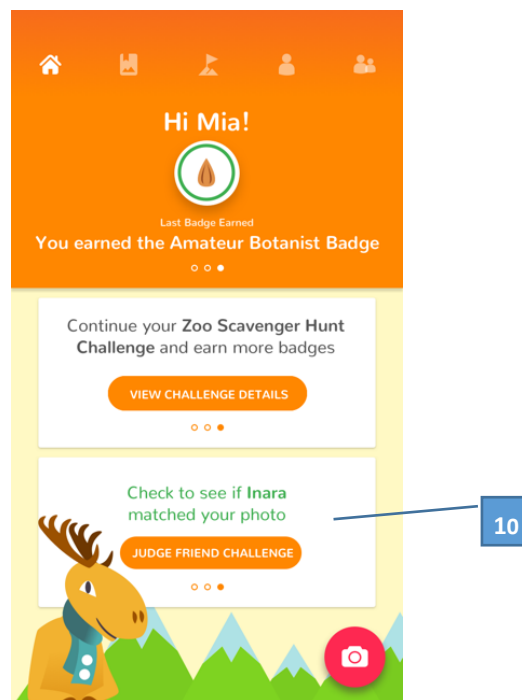
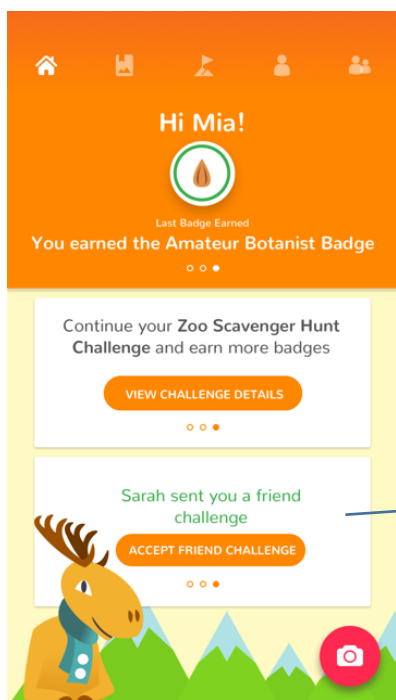


#	Label	Description
1	Dashboard Card State 1 (Progress on Collect or Identify)	<p>Dashboard Card State 1 should show progress on the Collect or Identify challenge they worked on most recently.</p> <p>Logic: Most recently worked towards Collect or Identify challenge (i.e., which challenge most recently had the photo count increased).</p> <p><i>If no progress has been made towards any Collect or Identify challenge, show Dashboard Card Empty State 1</i></p> <p>Badge icons should reflect progress on the challenge, and the badges currently earned (unearned badges have grey overlay)</p> <p>Small text (dynamic): [Challenge title]</p> <p>Large text: Complete Challenges to Earn Badges</p>
2	Dashboard Card State 2 (Progress on Scavenger Hunt)	<p>Dashboard Card State 2 should show the progress on the Scavenger Hunt challenge the user worked on most recently.</p> <p>Logic: Most recently worked towards Scavenger Hunt challenge (i.e., the challenge with the most recently increased photo count)</p> <p><i>If no progress has been made towards any Collect or Identify challenge, show Dashboard Card Empty State 2</i></p> <p>Badge icon should reflect progress on the challenge, and if the badge was earned. (unearned badges have grey overlay).</p> <p>Small text (dynamic): [Challenge title]</p> <p>Large text: Complete Challenges to Earn Badges</p>
3	Dashboard Card State 3 (badge earned)	<p>Dashboard Card State 3 should show the most recently earned badge.</p> <p>Logic : Most recently earned badge</p> <p><i>If no badges have been earned, show Dashboard Empty State 3</i></p> <p>Small text: Last Badge Earned</p> <p>Large text (dynamic): You earned the [badge name] badge</p>

4	Suggestion Card State 1 (new challenge added)	<p>Suggestion Card State 1 should show recently added Collect, Identify, and Scavenger Hunt challenges (pushed after app instillation).</p> <p>Logic: (1) Most recent Collect, Identify, or Scavenger Hunt challenge pushed from the admin panel that (2) has not been completed.</p> <p><i>If no challenges have been added, show State 2 or 3. Randomly select a challenge that is not already suggested on Cards 2 or 3.</i></p> <p><i>If all Collect, Identify, AND Scavenger Hunts have been completed, don't show this card (there will only be 2 cards in this scenario)</i></p> <p>Bold text (dynamic): [Scavenger hunt title] OR [Challenge title]</p> <p>Unbolded text: has been added to your challenges!</p>
5	Suggestion Card State 2 (Collect or Identify challenge)	<p>Suggestion Card State 2 should show a suggestion for a Collect or Identify challenge based on user's "My Interests" settings.</p> <p>Logic: Selected randomly from the possible challenges that meet the following criteria: (1) Challenge has not been completed (user can still earn at least 1 badge), and (2) the challenge is associated with user's "My Interests" settings.</p> <p><i>If all challenges associated with "My Interests" settings have been completed, or there are no challenges associated with "My Interests" settings, select based on a prioritized list of challenges, excluding completed challenges.</i></p> <p><i>Example prioritized list: Bird, Tree, Insect, Flower, Mammal, then random selection from all other challenges, both pre-set and those pushed from admin panel</i></p> <p><i>If all Collect and Identify challenges have been completed, show a second scavenger hunt suggestion (duplicate Card 3 with a second suggestion), that is NOT shown on cards 1 or 3.</i></p> <p><i>If all Collect, Identify, AND Scavenger Hunts have been completed, show "Take photos and add them to your collection" with a button that takes them to My Collections</i></p> <p>Text (dynamic): Continue your [Challenge title] Challenge and earn more badges.</p>

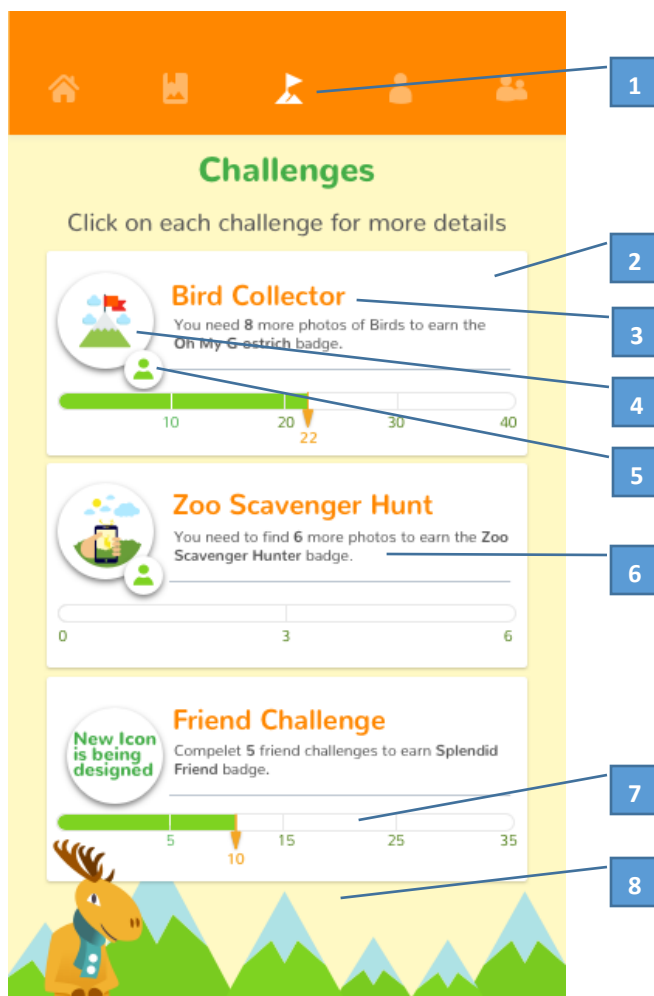
6	Suggestion Card State 3 (Scavenger Hunt challenge)	<p>Suggestion Card State 3 should show a suggestion for a Scavenger Hunt challenge.</p> <p>Logic: Selected randomly from all scavenger hunt challenges that have not been completed (badge has not been earned).</p> <p><i>If all scavenger hunts have been completed, show a second Collect or Identify challenge suggestion (duplicate Card 2 with a second suggestion), this should not be the same suggestion as Cards 1 or 2.</i></p> <p><i>If all Collect, Identify, AND Scavenger Hunts have been completed, show “Send a Friend Challenge!” with a button that takes them to Friend Challenge details screen</i></p> <p>Text (dynamic): Continue your [Challenge title] Challenge and earn more badges.</p>
7	Notification Card – Friend request	<p>This notification appears when another user sends a friend request, requires approval or denial</p> <p>Expected button function: When tapped, user will go to Friend Request Approval pop-up</p> <p>Criteria from removing notification from homepage: User must approve or deny friend request</p>
8	Notification Card – Added to a team	<p>This notification appears when user is added to a team challenge</p> <p>Expected button function: When tapped, user will go to the team challenge details screen</p> <p>Criteria from removing notification from homepage: Team must earn the badge</p>
9	Notification Card – Accept friend challenge (example shown below)	<p>This notification appears when a friend has sent user a Friend Request</p> <p>Expected button function: When tapped, user will go to “Accept Friend Challenges” screen</p> <p>Criteria from removing notification from homepage: User must complete the friend challenge (send a photo back to their friend) OR report the photo</p> <p>NOTE: We are not implementing the “Report a Photo” feature at this point, but logic should allow for this functionality in the future.</p>

10	<p>Notification Card – Judge friend challenge</p> <p>(example shown below)</p>	<p>This notification appears when a friend has sent back a photo match (friend completed the friend challenge) and the user needs to verify it</p> <p>Expected button function: When tapped, user will go to “Judge Friend Challenges” screen</p> <p>Criteria from removing notification from homepage: User must judge/verify the photo match OR report the photo</p> <p>NOTE: We are not implementing the “Report a Photo” feature at this point, but logic should allow for this functionality in the future.</p>
11	<p>Notification Card – Empty State (with Friends)</p>	<p>If there are no notifications requiring user action, and the user has added at least one friend, this notification should appear. If user taps on button, user goes to Friend Challenge details screen</p>





Challenges & Challenge Details Screens

Challenges screen

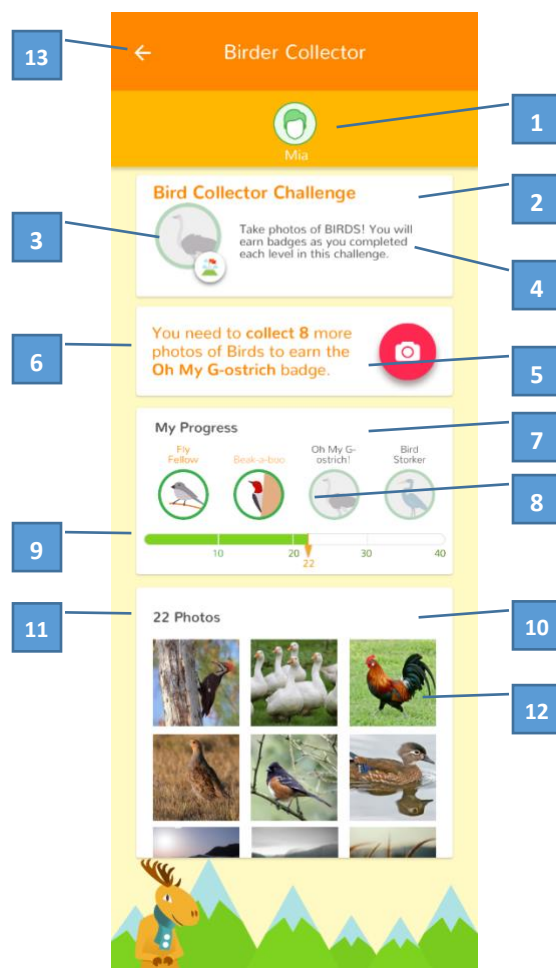


#	Label	Description
1	Challenges tab	When Challenges icon is tapped, the user is taken to the Challenges screen
2	Challenge Card	Each Challenge has a card. When challenge card is tapped, the user should go to the Challenge Details card

3	Challenge Title	This is dynamic text, and reflects challenge title (set up from the admin panel)
4	Challenge Icon	The large icon should reflect the challenge (See Challenge Types and Logic above)
5	Individual/team Icon	<p>For Collect, Identify, and Scavenger Hunt activates, there will be a small icon that whether it is an individual or team challenge. <i>NOTE: At this phase, ONLY Collect activates can be team activities.</i></p> <p><u>Individual:</u> </p> <p><u>Team:</u> </p>
6	Dynamic Instruction Text	<p>This should be dynamic text, based on challenge type, and reflect the progress needed to earn the next badge.</p> <p><u>Individual Collect:</u> You need to collect [#] more photos to earn the [badge name] badge.</p> <p><u>Individual Identify:</u> You need to identify [#] more photos to earn the [badge name] badge.</p> <p><u>Scavenger Hunt:</u> You need to find [#] more photos to earn the [badge name] badge.</p> <p><u>Team Collect:</u> Your team needs to collect [#] more photos to earn the [badge name] badge.</p> <p>Friend Challenges: You need to complete [#] more friend challenges to earn the [badge name] badge.</p> <p><i>If the highest level badge has been earned, text should be:</i> Good job! You completed the [Challenge name].</p>

7	Progress Bar	The progress bar should reflect the user's progress towards the Challenge.
8	Challenge Cards	There should be as many challenge cards as there are current challenges, and is scrollable. Order of challenges cards alphabetical. New challenges pushed from the admin panel appear integrated in this list based on alphabetical order. New challenges pushed from the admin panel will be highlighted with a green border until the first time the user taps on the card to view challenge details.

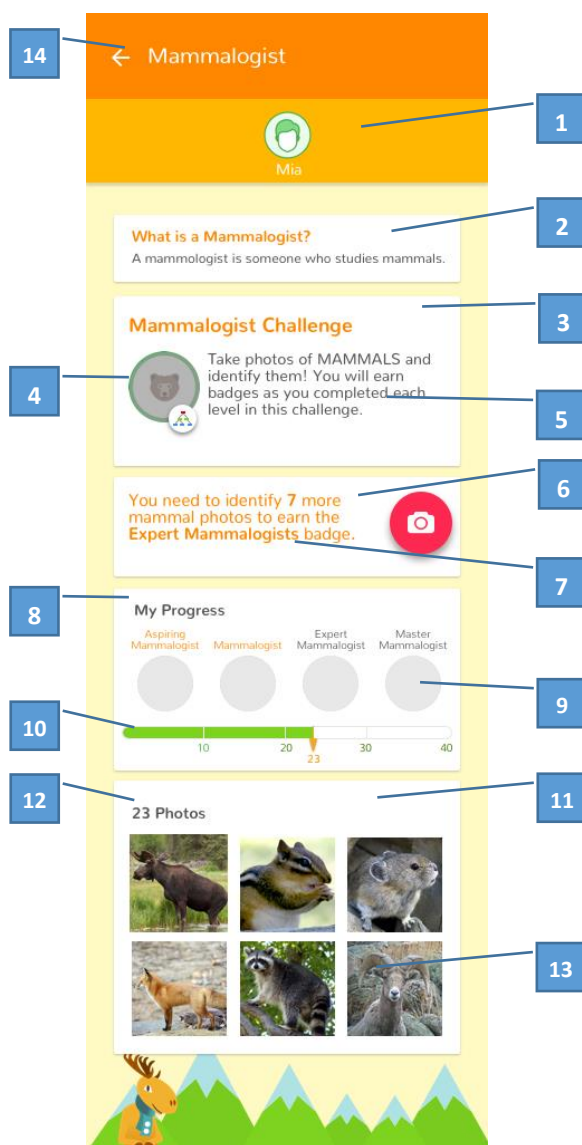
Individual Collect Challenge Details Screen



#	Label	Description
1	Individual vs. Team banner	For individual collect challenges, this should just contain a profile icon and username. The banner is not clickable.
2	Description card	The first card should have the Collect Challenge Title, along with dynamic descriptive text that is entered from the admin panel. This card is not clickable.
3	Next badge and challenge icon	Individual Collect should have a badge and a small challenge type icon. The badge shown should be the next badge the user can earn (not earned yet) and greyed out <i>unless</i> the user completed the last level of the challenge. Then the badge shown is the badge for the highest level and is not greyed out.
4	Descriptive text	This text should describe what the user has to do to work towards this challenge. This text should be entered from the admin panel when a researcher or teacher sets up the challenges
5	Challenge prompt card	This card contains the camera icon and dynamic text telling the user how many photos they still need to collect to earn the next badge. The card is not clickable, but the camera icon is clickable and takes you to the camera feature.
6	Dynamic text	This should be dynamic text and reflect the progress needed to earn the next badge. You need to collect [#] more photos of [Album] to earn the [badge name] badge. <i>If all badges have been earned, text should say:</i> Good job! You completed the [Challenge name]
7	My Progress card	This card contains the badges, and a dynamic progress bar
8	Badges	There may be 1-4 levels for Individual Collect challenges, so there may be 1-4 badges. Each badge should be greyed out until the set

		<p>number of photos have been collected. Once the required number of photos are collected, the user earns a badge – it is no longer greyed out on the Individual Collect details screen, and it appears among the badges on My Profile screen.</p> <p>Titles for unearned badges are black, while titles for earned badges are orange</p>
9	Progress bar	<p>Progress bar should reflect user’s progress, including a specific photo count. The bar is marked based on each level/badge and the number of photos needed to earn the next badge.</p>
10	Challenge photo card	<p>This card contains photos counted towards this challenge, along with dynamic photo count text.</p> <p>The card is not clickable, but the photos are.</p>
11	Dynamic photo count	<p>This text should be dynamic and based on the number of photos taken. This should match the progress bar photo count.</p> <p>If 0 photos OR 2+ photos: [#] Photos</p> <p>If 1 photo: [#] Photo</p>
12	Challenge photos	<p>Photos that count for this challenge should appear here, as well as in the collections the photos were added to.</p> <p>The photos are clickable, the same interaction as when a user clicks on a photo in My Collections (they can edit “Add Details” info and delete any photos from the challenge).</p>
13	Back button	<p>If user taps back button, the go back to “Challenges” screen</p>

Individual Identify Challenge Details Screen



#	Label	Description
1	Individual vs. Team banner	For individual collect challenges, this should just contain a profile icon and username. The banner is not clickable.
2	Explain Card	This card includes an explanation of the scientific term (Which is used in the title of the identify challenges)
3	Description card	The card should have the Identify Challenge Title (a scientific title), along with dynamic descriptive text of the identification challenge.

		The text is entered from the admin panel. This card is not clickable.
4	Next badge and challenge icon	Individual Identify challenges should have a badge and a small challenge type icon. The badge shown should be the next badge the user can earn (not earned yet) and greyed out <i>unless</i> the user completed the last level of the challenge. If all levels are completed, the badge shown is the badge for the highest level and is not greyed out.
5	Descriptive text	This text should describe what the user needs to do to work towards this challenge. This text should be entered from the admin panel when a researcher or teacher sets up the challenges
6	Challenge prompt card	This card contains the camera icon and dynamic text telling the user how many photos they still need to identify to earn the next badge. The card is not clickable, but the camera icon is clickable and takes you to the camera feature.
7	Dynamic text	This should be dynamic text and reflect the progress needed to earn the next badge. You need to identify [#] more photos of [Album] to earn the [badge name] badge. <i>If all badges have been earned, text should say:</i> Good job! You completed the [Challenge name]
8	My Progress card	This card contains the badges, and a dynamic progress bar
9	Badges	There may be 1-4 levels for Individual Identify challenges, so there may be 1-4 badges. Each badge should be greyed out until the set number of photos have been identified. Once the required number of photos are identified, the user earns a badge – it is no longer greyed out on the Individual Identify details screen, and it appears among the badges on My Profile screen. Titles for unearned badges are black, while titles for earned badges are orange

10	Progress Bar	Progress bar should reflect user's progress, including a specific identified photo count. The bar is marked based on each level/badge and the number of photos needed to earn the next badge.
11	Challenge photo card	This card contains identified photos counted towards this challenge, along with dynamic photo count text. The card is not clickable, but the photos are.
12	Dynamic photo count	This text should be dynamic and based on the number of photos identified. This should match the progress bar photo count. If 0 photos OR 2+ photos: [#] Photos If 1 photo: [#] Photo
13	Challenge photos	Photos that count for this challenge should appear here, as well as in the collections the photos were added to. The photos are clickable, the same interaction as when a user clicks on a photo in My Collections (they can edit "Add Details" info and delete any photos from the challenge).
14	Back button	If user taps back button, the go back to "Challenges" screen

Individual Scavenger Hunt Details screen



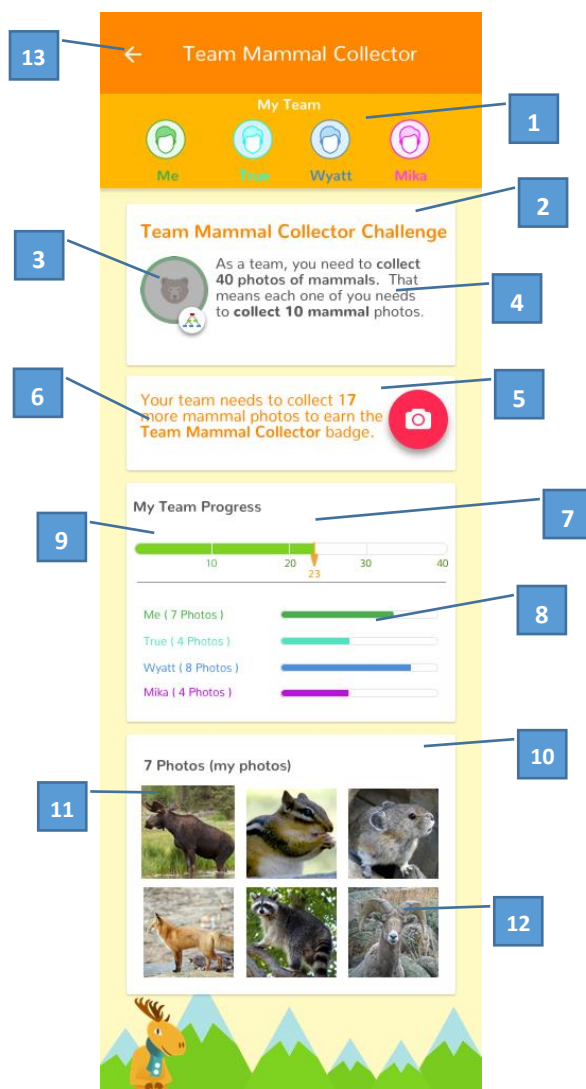
#	Label	Description
1	Individual vs. Team banner	For individual scavenger hunts, this should just contain a profile icon and username. The banner is not clickable.
2	Description card	The first card should have the Scavenger Hunt Challenge Title, along with dynamic descriptive text that is entered from the admin panel. This card is not clickable.
3	Badge and Challenge icons	Scavenger hunts should have the badge and a small scavenger hunt icon (challenge type icon). The badge shown greyed out <i>unless</i> the user completed the challenge.

4	Descriptive text	This text should describe what the user needs to do to work towards this Scavenger hunt challenge. This text should be entered from the admin panel when a researcher or teacher sets up the scavenger hunt
5	My Progress card	This card contains the progress bar and badge for the scavenger hunt. It is not clickable.
6	Badge	There is only one level for Scavenger Hunts, so there is only one badge. This badge should be greyed out until all items on the list are collected. Once all items are collected, the user earns a badge – it is no longer greyed out on the scavenger hunt details, and appears among the badges on My Profile screen. There should be an option in the admin panel to verify the photos before the badge is earned.
7	Progress bar	Progress bar should reflect user's progress.
8	Scavenger Hunt List card	This card contains the camera icon, dynamic text telling the user how many items they still need to collect, and cards for each item on the list. Scavenger hunt list are entered in the admin panel when the researcher or teacher sets up the scavenger hunt. Each item on that list have a small item card. The large card isn't clickable, but the small item cards and the camera icon are clickable.
9	Dynamic progress text	This should be dynamic text and reflect the progress needed to earn the badge. You need to find [#] more things on this list to earn the [badge name] badge. <i>If all photos have been collected, text should say:</i> Good job! You completed the [Challenge name]

10	Camera Icon	<p>When user taps on the camera icon, they go to the camera. When user gets to “what is in your photo” screen, no items on the list are pre-selected. The user is required to manually select an item.</p> <p>The user must either access the camera from this icon, or from the item cards in order for the photo to go through the scavenger hunt screen flow and have it count towards this scavenger hunt.</p>
11	Item cards	<p>If an item card is tapped, the user goes to the camera. When user gets to “What is in your photo” screen, the item that was clicked is pre-selected on the list (user can change selection manually).</p> <p>The user must either access the camera from this icon, or from the item cards in order for the photo to go through the scavenger hunt screen flow and have it count towards this scavenger hunt.</p> <p>Once the user has collected a photo towards an item, the card turns green and the camera icon is replaced with a check mark. The completed item card is no longer clickable. Users may still collect photos towards this item through the camera icon.</p>
12	Challenge photo card	<p>This card contains photos taken for the scavenger hunt, along with dynamic photo count text.</p> <p>The card is not clickable, but the photos are.</p>
13	Dynamic photo count	<p>This text should be dynamic and based on the number of photos taken. NOTE that this number may be more than the number of items on the list (there may be duplicate photos for a single item)</p> <p>If 0 photos OR 2+ photos: [#] Photos</p> <p>If 1 photo: [#] Photo</p>
14	Challenge photos	<p>Photos taken for the scavenger hunt should appear here, as well as in the collections the photos were added to.</p> <p>The photos are clickable, the same interaction as when a user clicks on a photo in My Collections (they can edit “Add Details” info as well as see what item the photo was collected for. They cannot change which item it was collected for. The user can delete any photo in the list- this will add the item back to the list that needs to be collected. For example, if the user took a panda photo, and then deleted it later, the panda icon would turn orange again</p>

		indicating that the user needs to collect the photo of a panda again),
15	Back button	If user taps back button, the go back to “Challenges” screen

Team Collect Challenge Details Screen



#	Label	Description
1	Individual vs. Team banner	For team collect challenges, this should contain a profile icon and username for all team members. The banner is not clickable.
2	Description card	The first card should have the Collect Challenge Title, along with dynamic descriptive text that is entered from the admin panel. This card is not clickable.
3	Badge and challenge icon	Team Collect should have a badge and a small challenge type icon. The badge shown should be greyed out <i>unless</i> the team completed the challenge. Then the badge shown and is not greyed out.
4	Descriptive text	This text should describe what the each team member has to do to work towards this challenge. This text should be entered from the admin panel when a researcher or teacher sets up the team collect challenge
5	Challenge prompt card	This card contains the camera icon and dynamic text telling the user how many photos they still need to collect to earn the next badge. It is not clickable, but the camera icon is clickable.
6	Dynamic text	This should be dynamic text and reflect the progress needed to earn the next badge. Your team need to collect [#] more photos of [Album] to earn the [badge name] badge. <i>If all badges have been earned, text should say:</i> Good job! Your team completed the [Challenge name]
7	My Team Progress card	This card contains team badge, and a dynamic progress bar for the team.
8	Each team member progress bar	There may be several members for the Team Collect challenges, so for each member there is there individual progress par that display how many photos they've collected and how many they still need.

		<p>Once the required number of photos are collected by each team member and this is verified in the admin panel, the team earns the badge – it is no longer greyed out on the Team Collect details screen, and it appears among the badges on My Profile screen.</p> <p>Title for unearned badges is black, while the title for earned badge is orange</p>
9	Team Progress bar	Progress bar should reflect all team member’s progress, including a specific photo count
10	Challenge photo card	<p>This card contains ONLY the user’s photos counted towards team challenge, along with dynamic photo count text.</p> <p>The card is not clickable, but the photos are.</p>
11	Dynamic photo count	<p>This text should be dynamic and based on the number of photos taken only by the user. This should match the progress bar photo count.</p> <p>If 0 photos OR 2+ photos: [#] Photos</p> <p>If 1 photo: [#] Photo</p>
12	Challenge photos	<p>Photos that count for the team challenge taken only by the user should appear here, as well as in the collections the photos were added to.</p> <p>The photos are clickable, the same interaction as when a user clicks on a photo in My Collections (they can edit “Add Details” info and users can delete photos which will affect the number of photos towards their progress).</p>
13	Back button	If user taps back button, the go back to “Challenges” screen

Friend Challenge screen



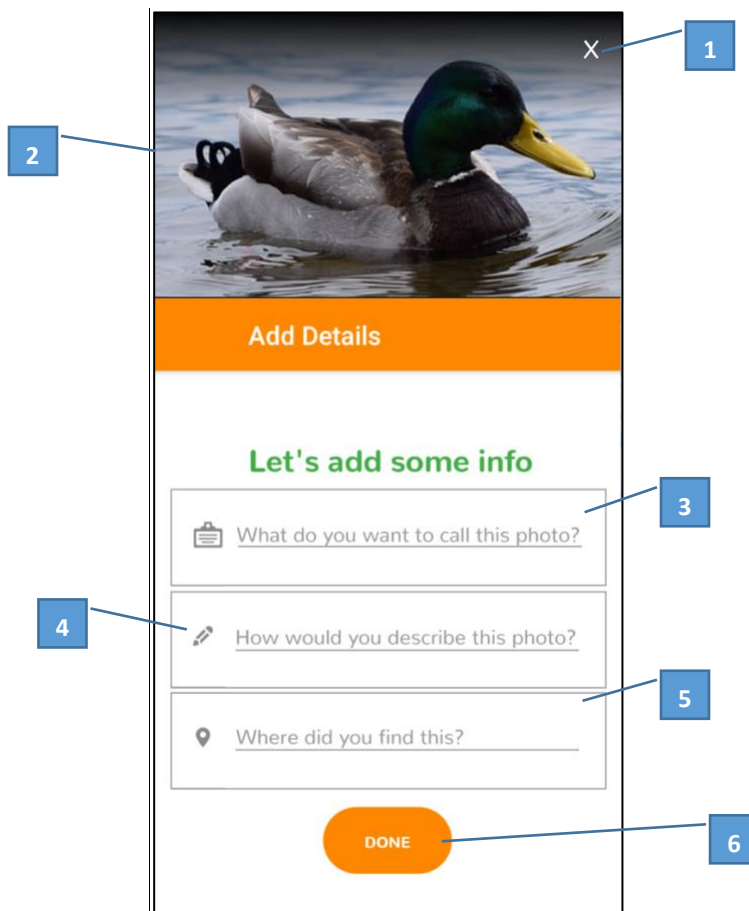
#	Label	Description
1	Individual banner	For Friend Challenge, this should contain a profile icon and username. The banner is not clickable.
2	Description card	The first card should have the Friend Challenge Title, along with dynamic descriptive text that is entered from the admin panel. This card is not clickable.
3	Next badge and challenge icon	Friend Challenges should have a badge and a small challenge type icon (match friend challenge icon). The badge shown should be the next badge the user can earn (not earned yet) and greyed out <i>unless</i> the user completed the last level of the challenge. Then the

		badge shown is the badge for the highest level and is not greyed out.
4	Descriptive text	This text should describe what the user has to do to work towards this challenge. This text should be entered from the admin panel when a researcher or teacher sets up the friend challenge.
5	Send a Friend Challenge button	When tapped, user is taken to camera and follows Send a Friend Challenge process flow to challenge a friend to match a photo they've taken
6	Accept a Friend Challenge button	When tapped, user is taken to the Accept Friend Challenges screen, where the user can accept to match a friend challenge or complete it at a later time or reject the challenge.
7	Judge a Friend Challenge button	When tapped, user is taken to the Judge Friend Challenges screen, where they view what their friend's photo and decided if it matches their photo or not.
8	My Progress card	<p>This card contains the badges, dynamic text, and a dynamic progress bar</p> <p>The dynamic text reflects the progress needed to earn the next badge.</p> <p>You need to complete [#] friend challenges by sending or accepting a challenge from a friend to earn the [badge name] badge.</p> <p><i>If all badges have been earned, text should say:</i></p> <p>Good job! Your team completed the [Challenge name]</p> <p>Users are still able to accept and send Friend Challenges even when they've earned all the available badges.</p>
9	Badges	There may be 1-4 levels for Friend challenges, so there may be 1-4 badges. Each badge should be greyed out until the set number of challenges have been completed. Once the required number of challenges are completed (whether sent or accepted) , the user earns a badge – it is no longer greyed out on the Friend Challenge

		<p>details screen, and it appears among the badges on My Profile screen.</p> <p>Titles for unearned badges are black, while titles for earned badges are orange</p>
10	Progress bar	Progress bar should reflect user's progress. A challenge is counted towards both the sender's and receiver's progress once the sender judges the challenge.
11	Back button	If user taps back button, the go back to "Challenges" screen

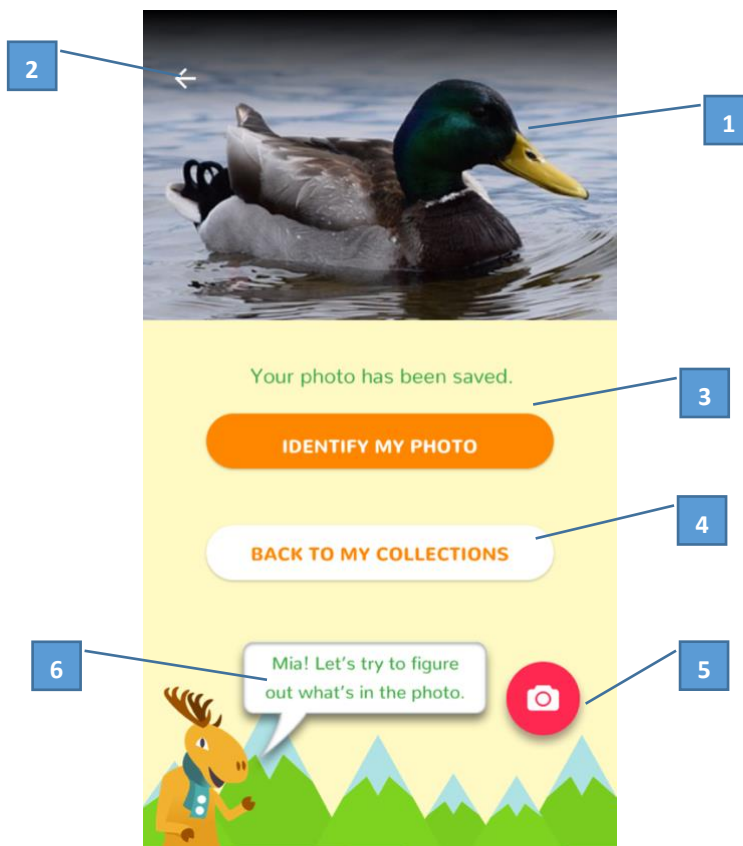
Key Mid-Flow Screens

Add Details Screen



#	Label	Description
1	Exit button	<p>If tapped, there should be a pop-up notification asking the user if they want to delete the photo and exit. If they exit, user's details are not saved, and the photo is deleted.</p> <p>User lands back on the Android camera to take a new photo.</p>
2	Photo	User should see the photo they took (same as top portion of screen for Identification Scheme flow)
3	Add Details text fields	Allows the user to enter text. Text is not required, and characters are not capped
4	Add Details icons	Graphics appear to the left of the text fields
5	Add Details prompts	Change prompt text to questions
6	Done button	Done button on this screen is always orange (because no action is mandatory for the user on this screen). When the user taps on the done button, where the user is taken depends on the specific screen flow (see High level process flows)

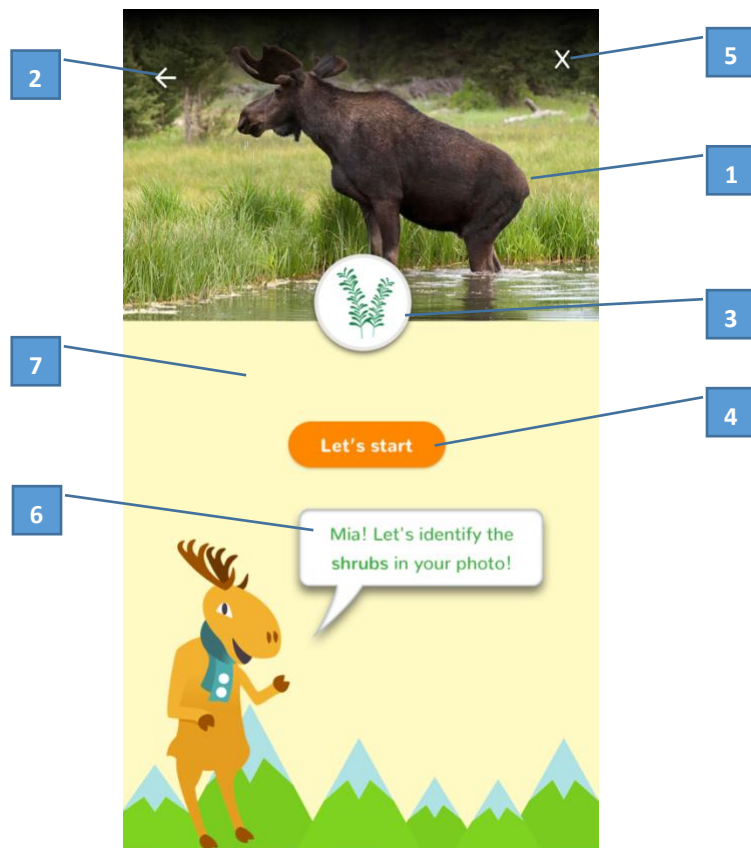
Activity Decision Screen



#	Label	Description
1	Photo	User should see the photo they took (same as top portion of screen for Identification flow)
2	Back button	If tapped, user should return to previous screen (“add to a collection”)
3	Identify Button	If tapped, user should go to Identification flow
4	My Collections button	If tapped, user should go to My Collections screen
5	Camera icon	Camera icon is clickable. On tap, user goes to android camera

6	In Context help	This text contains a dynamic username. [Username]! Let's figure out what's in the photo.
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Pre-Identification Screen



#	Label	Description
1	Photo	User should see the photo they took (same as top portion of screen for Identification flow)
2	Back button	If tapped, user should return to previous screen (the last screen in the previous identification scheme – in this example is the mammal identification scheme”

3	Collection Icon	This should be the icon for the following (2 nd ,3 rd or 4 th) collection, with a build in identification scheme, in which the photo was placed.
4	Let's Start Button	If tapped, user should go to Identification flow for that collection
5	Exit button	<p>If tapped, a pop-up notification will appear asking the user to confirm that they want to exit and message saying that their identification tags associated with this album/collection will be lost. If they exit, user's pervious identification tags that have been completed will be saved, but the tags for this album/collection will not be saved. Identification tags for each album/collection will be handled separately. The photo is saved to all collections and appears in "My Collections".</p> <p>User is taken to My Collections screen.</p> <p>If the user does not finish an identification for an album/collection, they are able to complete this at a later date by clicking on the photo in My Collection and adding identification tags then.</p>
6	In Context help	This text contains a dynamic username. [Username]! Let's figure out what's in the photo.
7	Pre-identification screen	This screen replaces the current pop-ups that appear between collections identification scheme [<i>Children disliked pop-ups and were frustrated whenever they appeared</i>]

Identification Screen – With Silhouettes

Let's identify the bird in your photo!
Which group is this bird most like?

Song birds

Birds of prey

Upland ground birds

Perching and tree climbing

Waterfowl and Marshland birds

9

NEXT

1

2

3

4

5


6

7

8

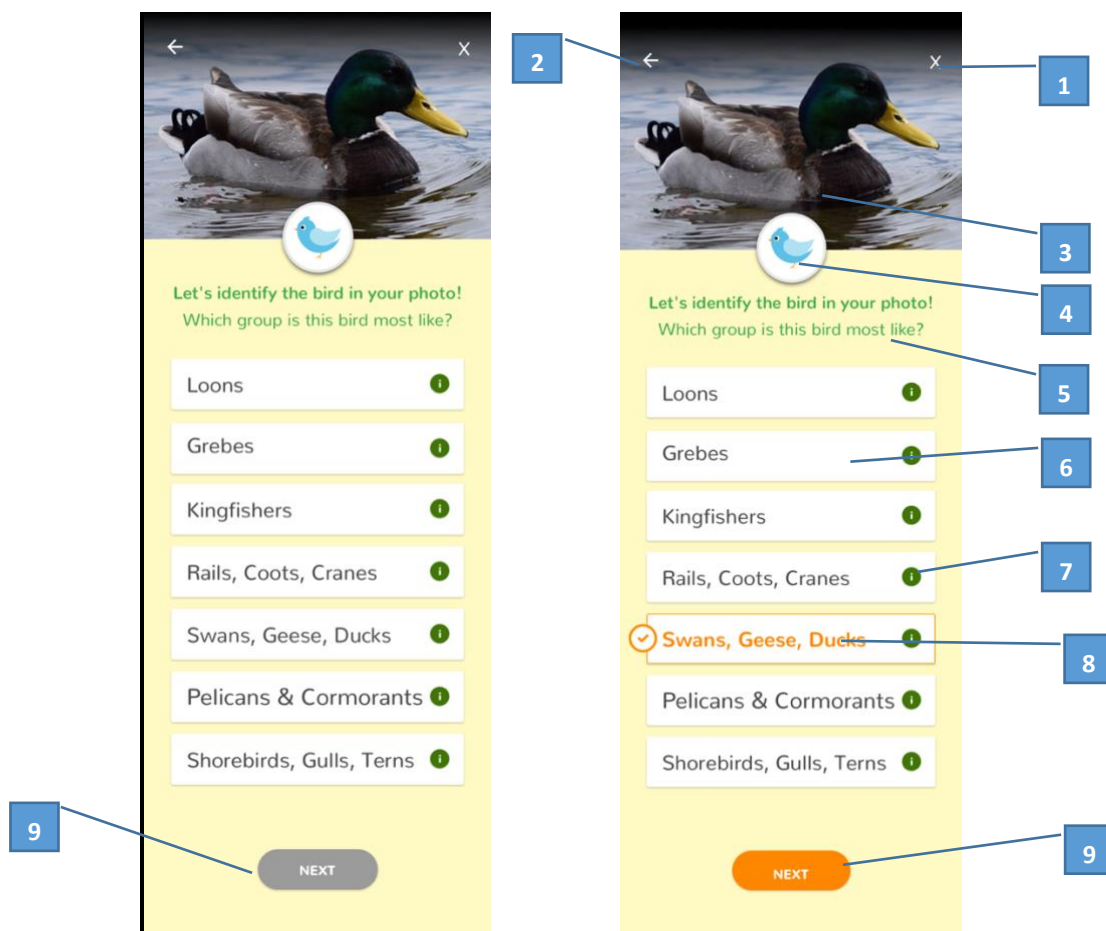
9


NEXT

#	Label	Description
1	Exit button	<p>If tapped, there should be a pop-up notification asking the user to confirm that they want to exit. If they exit, decisions/tags for this album/collection are not saved, but tags for previous album/collection are saved.</p> <p>User is taken to My Collections screen.</p>
2	Back button	<p>If tapped, user should return to previous screen and modify a previous decision choice. If this was the first screen in the identification scheme, when the user taps the back button they return to “Add to a Collection” Screen and will be able to modify their Collection choices.</p>
3	Photo	User should see the photo they took
4	Collection Icon	This should be the icon for collection in which the photo was placed. In this example it’s a bird collection.
5	Dynamic descriptive text	<p>The dynamic text describes what the user should be doing on that screen.</p> <p>Let’s identify the [Album name] in your photo!</p> <p>Which group is this [Album name] most like?</p>
6	Silhouette option cards	<p>This content of this card is uploaded from the admin panel, and has an image of the identification scheme + title (the silhouette image size should be following the recommended size & dimension in the admin panel. The title text should also have a recommended character limit to display correctly in the app).</p> <p>Card layout should be in one column—only one card per row.</p>
7	 More info icon	<p>On each of the silhouette cards a more info option is included and set up on the admin panel. The icon will appear if there is a “More Info” content.</p> <p>The icon color is green and it’s clickable.</p>

8	Silhouette Card Selected	When tapping on any of the Silhouette option cards it gets selected by highlighting the card with an orange border and a check mark icon appears. Only one card can be selected at time. Tapping on another card de-selects the pervious selected card and selects the new card.
9	Next Button	This button is grey until a card is selected. Once a card is selected the button turns orange. If the user taps on the grey button before making a selection an android notification text should appear telling the user to make a selection first.

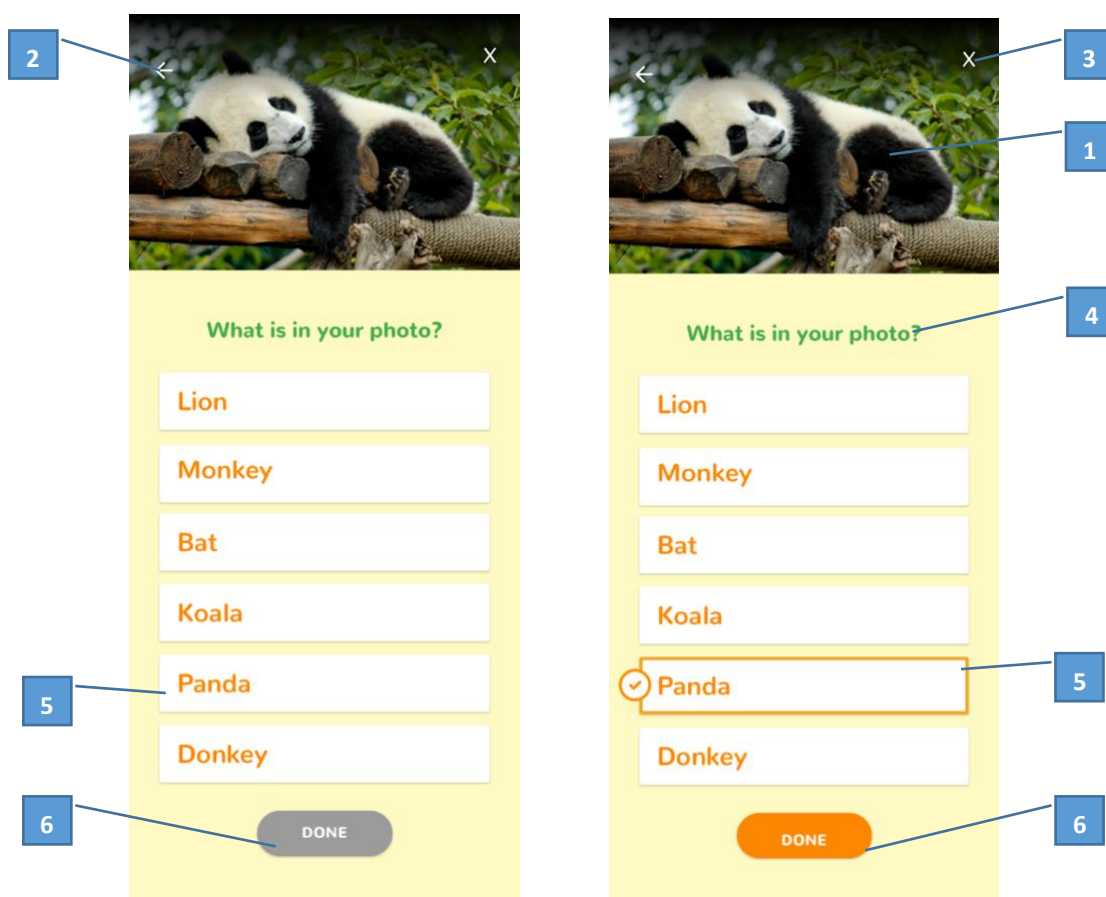
Identification Screen – No Silhouettes



#	Label	Description
1	Exit button	<p>If tapped, there should be a pop-up notification asking the user to confirm that they want to exit. If they exit, decisions/tags for this album/collection are not saved, but tags for previous album/collection are saved.</p> <p>User is taken to My Collections screen.</p>
2	Back button	<p>If tapped, user should return to previous screen and modify a previous decision choice. If this was the first screen in the identification scheme, when the user taps the back button they return to “Add to a Collection” Screen and will be able to modify their Collection choices.</p>
3	Photo	User should see the photo they took
4	Collection Icon	This should be the icon for collection in which the photo was placed. In this example it’s a bird collection.
5	Dynamic descriptive text	<p>The dynamic text describes what the user should be doing on that screen.</p> <p>Let’s identify the [Album name] in your photo!</p> <p>Which group is this [Album name] most like?</p>
6	Text option cards	<p>The title text of each card is setup from the admin panel. The title text should have a recommended character limit to display correctly in the app.</p> <p>Card layout should be in one column—only one card per row.</p>
7	 More info icon	<p>On each of the cards a more info option is included and set up on the admin panel. The icon will appear if there is a “More Info” content.</p> <p>The icon color is green and it’s clickable.</p>

8	Card Selected	When tapping on any of the option cards it get selected by highlighting the card with an orange border and a check mark icon appears. Only one card can be selected at a time. Tapping on another card deselects the previous selected card and selects the new card.
9	Next Button	<p>This button is grey until a card is selected. Once a card is selected the button turns orange.</p> <p>If the user click on the grey button before making a selection an android notification text should appear telling the user to make a selection first.</p>

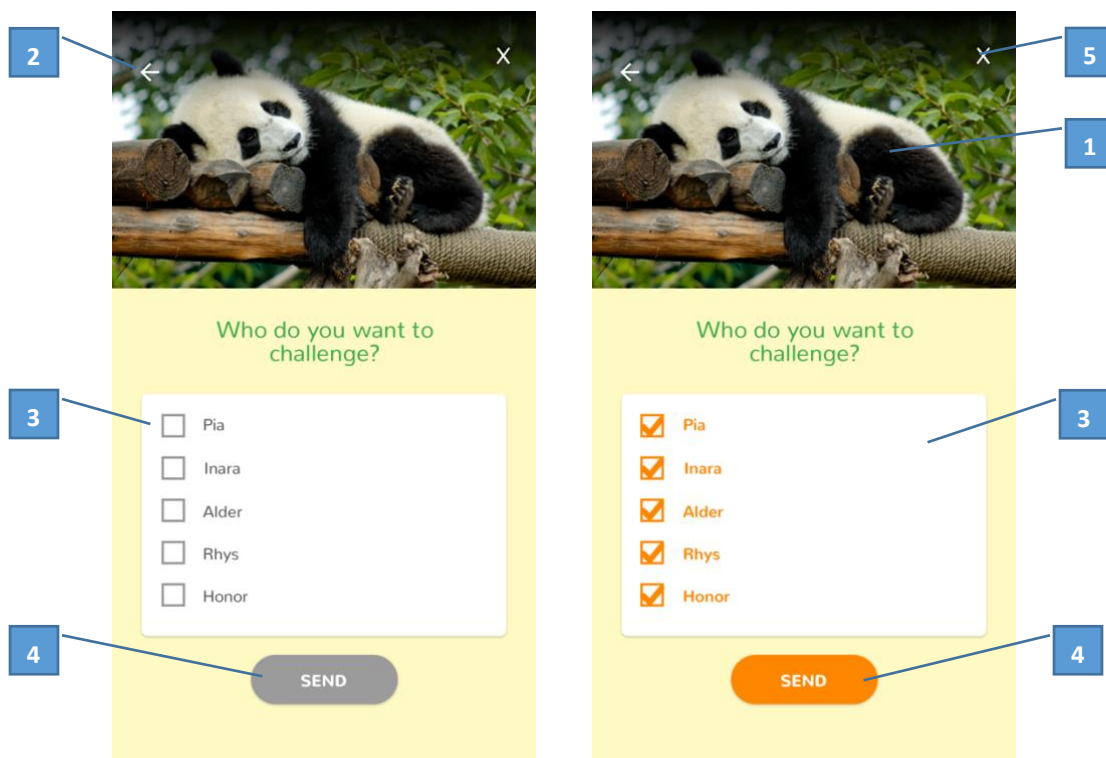
Scavenger Hunt - What is in your photo Screen



#	Label	Description
1	Photo	User should see the photo they took (same as top portion of screen for Identification flow)
2	Back button	If tapped, user should return to previous screen (“add to a collection”)
3	Exit button	If tapped, there should be a pop-up notification asking the user to confirm they don’t want the photo to count towards the scavenger hunt. If user confirms, and escapes from this screen, they go back to the Scavenger Hunt details screen. The photo is saved to collections and appears under “My Collections”, but is not saved towards the scavenger hunt and does not appear in the Scavenger Hunt Photos card.
4	Prompt Static text	What is in your photo?
5	Item cards	<p>Item cards, similar to cards in identification flow without silhouettes. If camera is accessed through an item card on the Scavenger hunt details page, this item is preselected.</p> <p>If camera is accessed through the camera icon, no item is preselected.</p> <p>User must select only one option</p> <p>User is allowed to select an item that has already been selected. (Example, collecting 2 photos of pandas). If the user selects an item that has already been collected, the photo count does not increase, but the photo does appear in the Scavenger Hunt Photos card</p>
6	Done button	<p>If no item is selected, the done button is greyed out and is inactive. Once the user has selected one item, the button turns orange and the user is allowed to move to the next screen.</p> <p>If the user taps on the grey done button an android message should appear prompting them to make a selection first.</p> <p>When the user taps on the done button, they are taken to the Scavenger Hunt details screen.</p>

Friend Challenge Flow Screens

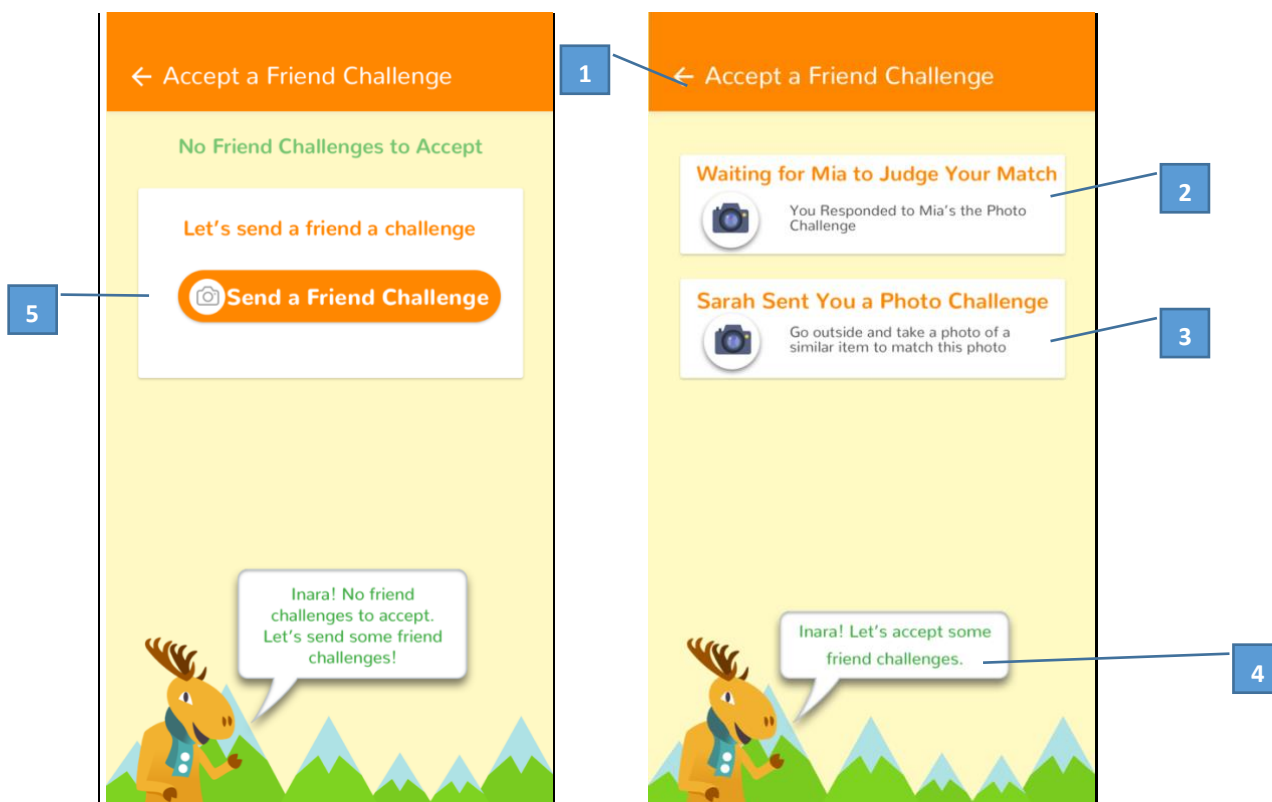
Friend Challenge – Choose Friends Screen



#	Label	Description
1	Photo	User should see the photo they took (same as top portion of screen for Identification flow)
2	Back button	If tapped, user should return to previous screen (“add to a collection”)
3	List of user’s friends	This list contains all the user’s friends. There is no length cap, the user must scroll down the list. User must select at least one friend, but may select multiple.

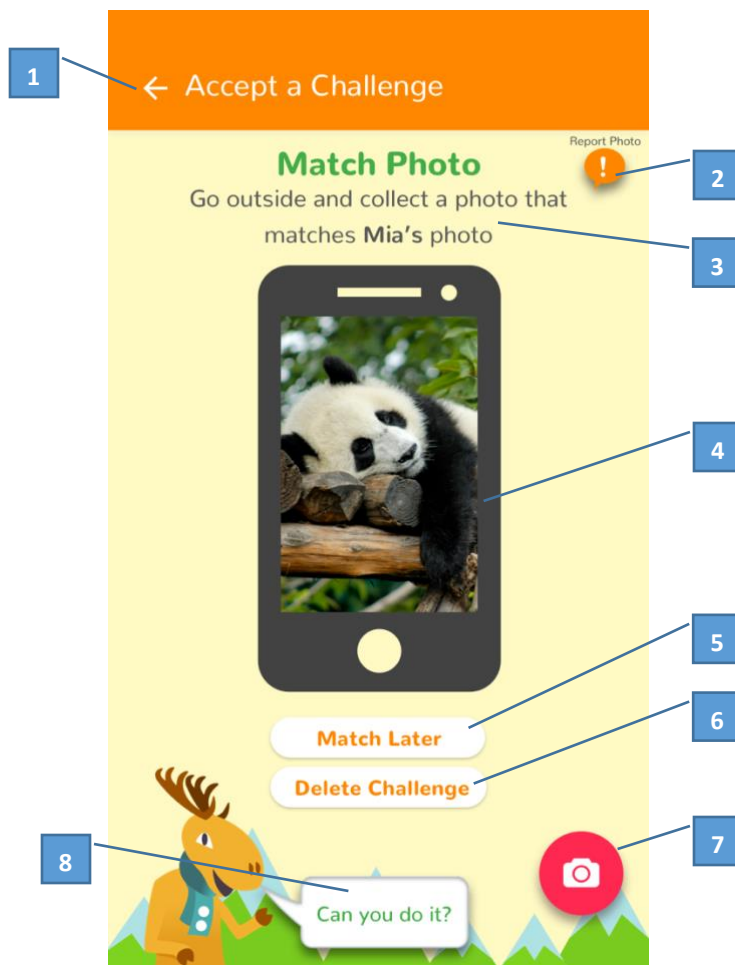
4	Send button	<p>If no friends are selected, the send button is greyed out and is inactive. Once the user has selected one friend, the button turns orange and the user is allowed to move to the next screen.</p> <p>If the user taps on the grey button an android message should appear to prompt the user to make a selection.</p> <p>When the user taps on the send button, a confirmation pop up appears before they are taken to the Friend Challenge details screen.</p>
5	Exit button	<p>If tapped, there should be a pop-up notification asking the user to confirm they don't want to send the photo challenge to any of their friends. If user confirms, and escapes from this screen, they go back to the Friend Challenge detail screen. The photo is saved to collections and appears under "My Collections.</p>

Friend Challenge – Accept Challenges Screen



#	Label	Description
1	Back button	If user taps back button, they go to Friend Challenge Details screen
2	“Pending Verification” Cards for User’s Friend Challenges	Once a user has sent photo back to the sender, the Friend Challenge card indicates that it is pending verification. It is not clickable.
3	“Needs a response” Cards for User’s Friend Challenges	Each Friend Challenge has a card. When the card is tapped, the user should go through the Accept Friend Challenge process flow for that challenge. Text for the photo should be dynamic: [User] Sent You a Photo Challenge.
4	In Context help	This text contains a dynamic username. [Username]! Let’s accept some friend challenges.
5	Empty State - No Challenges to Accept	When there is no Friend Challenges to accept- user will have a card prompting them to send a friend a challenge.

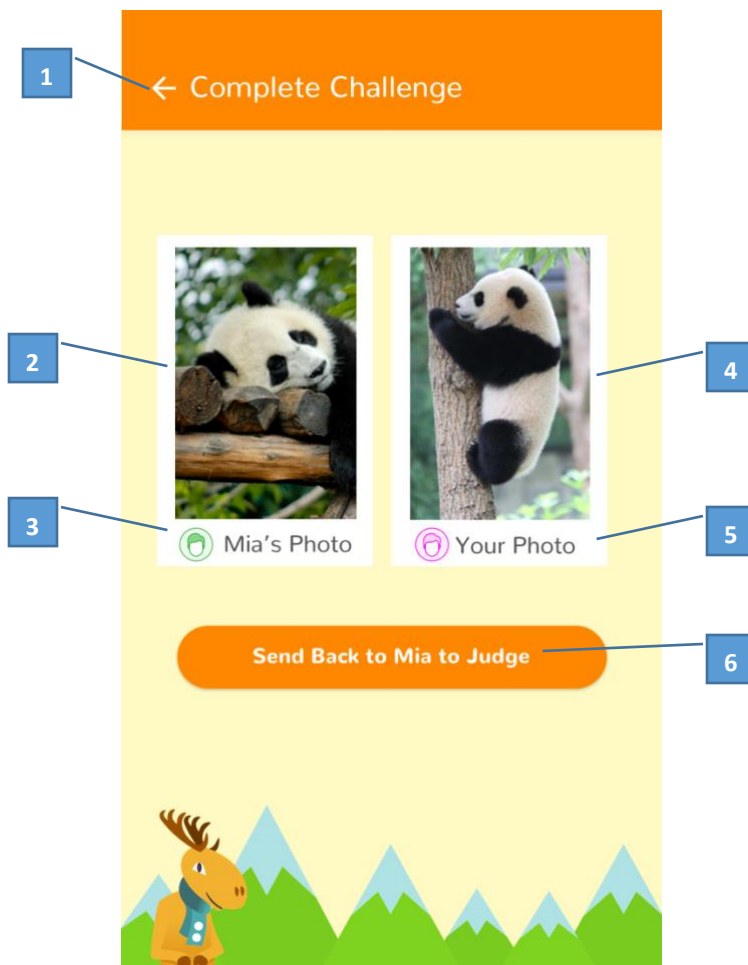
Friend Challenge – Match This Photo Screen



#	Label	Description
1	Back button	If user taps back button, they go to Accept Friend Challenges screen
2	Report a Photo	Note that we are not building this feature yet, but want to allow for it to be implemented at a later date.
3	Dynamic Prompt text	This text prompts the user to go outside and collect a photo that matches their friend's photo. Dynamic text is the [Friend Name]

4	Photo to match	This shows the user the photo that their friend sent and challenged them to match.
5	Match Later button	If tapped, user is taken back to Friend Challenge details screen
6	Delete Friend Challenge button	If tapped, a pop-up appears requesting user to confirm they want to delete the challenge. If they confirm, the challenge is removed from the Accept Challenge list. User is taken back to Friend Challenge details screen.
7	Camera Icon	When tapped, user is taken to android camera. Camera must be accessed from this screen for a photo to be counted towards this friend challenge.
6	In Context help	This text contains is static.

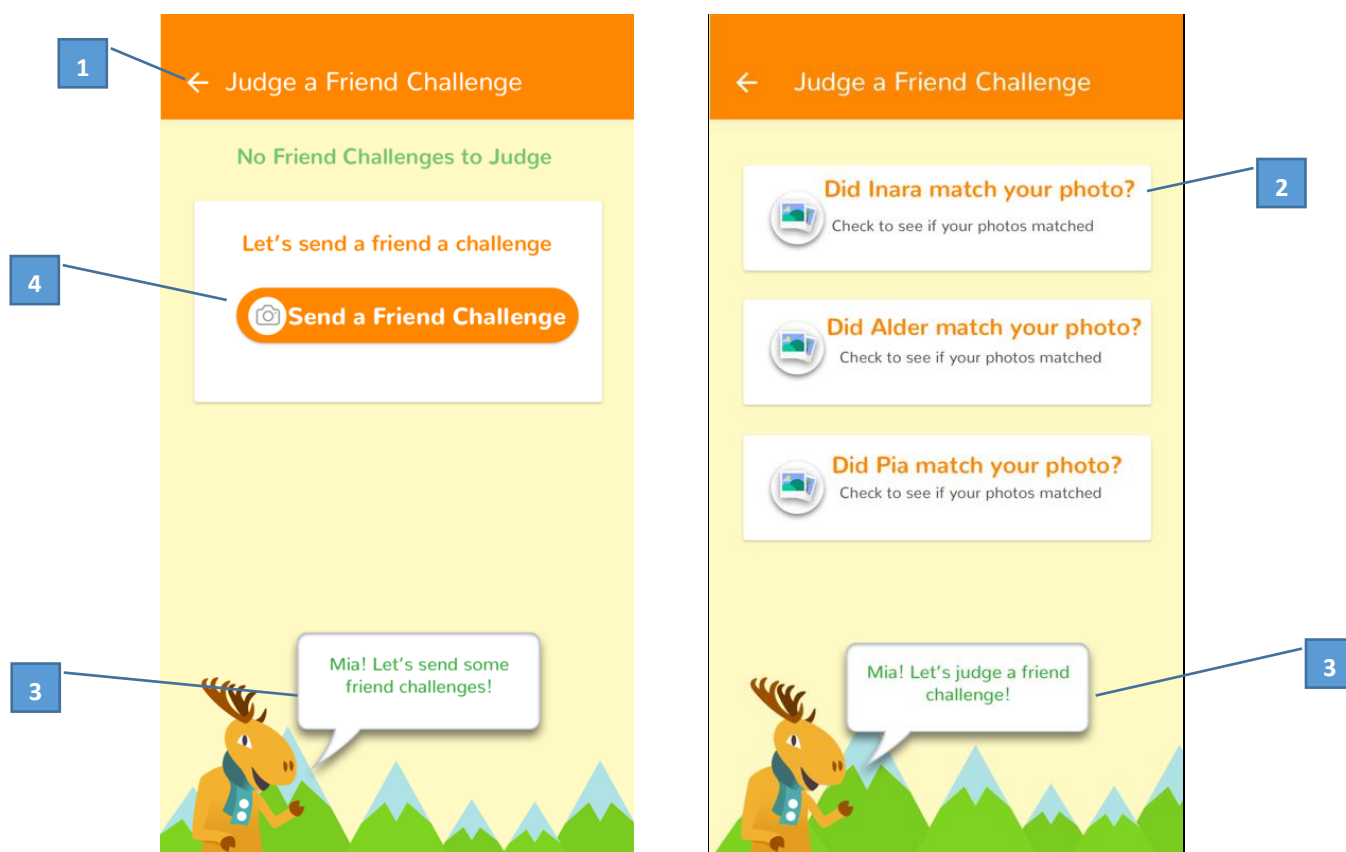
Friend Challenge – Complete Friend Challenge Screen



#	Label	Description
1	Back button	If user taps back button, a pop-up asked the user to confirm that they don't want to send their photo to their friend. If they confirm, they go to Friend Challenge Details screen (same as "I'll Match Later")
2	Sender's photo	Shows the sender's photo
3	Sender's profile icon and username	Profile icon and dynamic text: [Sender's Username]'s photo

4	User's photo	Shows the user's the photo they've taken
5	User's profile icon and username	Profile icon and dynamic text: [Username]'s photo
6	Send to [Friend] to Judge	This text contains a dynamic username. Send back to [Username] to Judge!

Friend Challenge – Judge Friend Challenges Screen



#	Label	Description
1	Back button	If user taps back button, they go to Friend Challenge Details screen

2	Cards for User's Friend Challenges	Each Friend Challenge that is pending verification has a card. When the card is tapped, the user should go through the Judge Friend Challenge process flow for that challenge. Text for the card should be dynamic: Did [User] match your photo?
3	In Context help	Dynamic text: [Username!] let's judge a friend challenge! Or in the empty state: [Username!] let's send a friend challenge!
4	No Challenges to Judge	When there is no Friend Challenges to Judge- user will have a card prompting them to send a friend a challenge.

Friend Challenge – Judge a Friend Challenge Screen

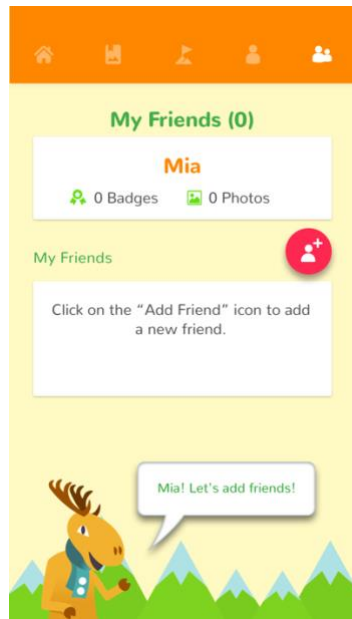


#	Label	Description
1	Back button	If user taps back button, they go to Friend Challenge Details screen. Challenge remains in their Judge Friend Challenges screen
2	Report a Photo	Note that we are not building this feature yet, but want to allow for it to be implemented at a later date.
3	User's photo	Shows the user's photo
4	User's profile icon and username	Profile icon and dynamic text: [Username]'s photo
5	Respondent's photo	Shows the respondent's photo
6	Respondent's profile icon and username	Profile icon and dynamic text: [Respondent's Username]'s photo
7	Photos Match button	If tapped, a pop-up appears, and user is taken back to Friend Challenge details screen. Challenge is "completed" and counts towards both user's progress.
8	Photos Don't Match button	If tapped, a pop-up appears, and the user is taken back to Friends Challenge details screen. Challenge in respondent's "Accept Friend Challenges" queue is switched from "pending judgement" to "needs a response". User is taken back to Friend Challenge details screen.
9	In Context help	This text is static: What do you think - Do they match?

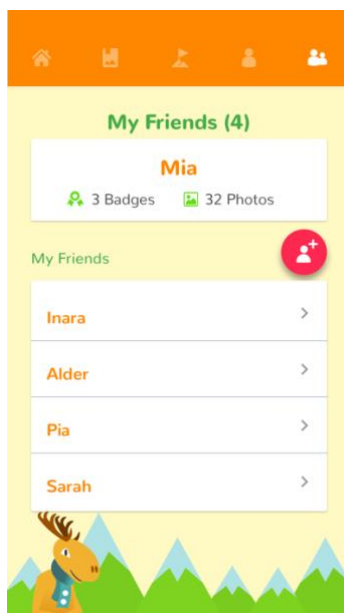
Other Key Screen Re-Designs

My Friends Screens

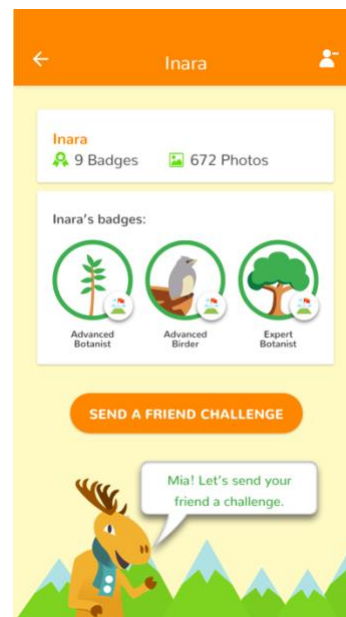
Empty State



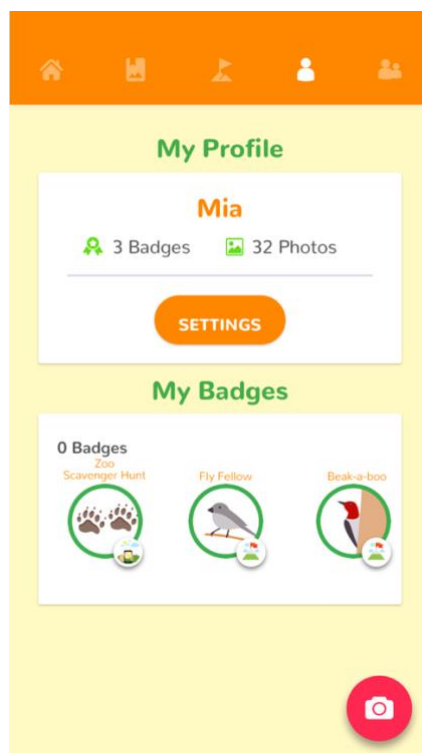
Friends Screen



Friend's Detail Screen

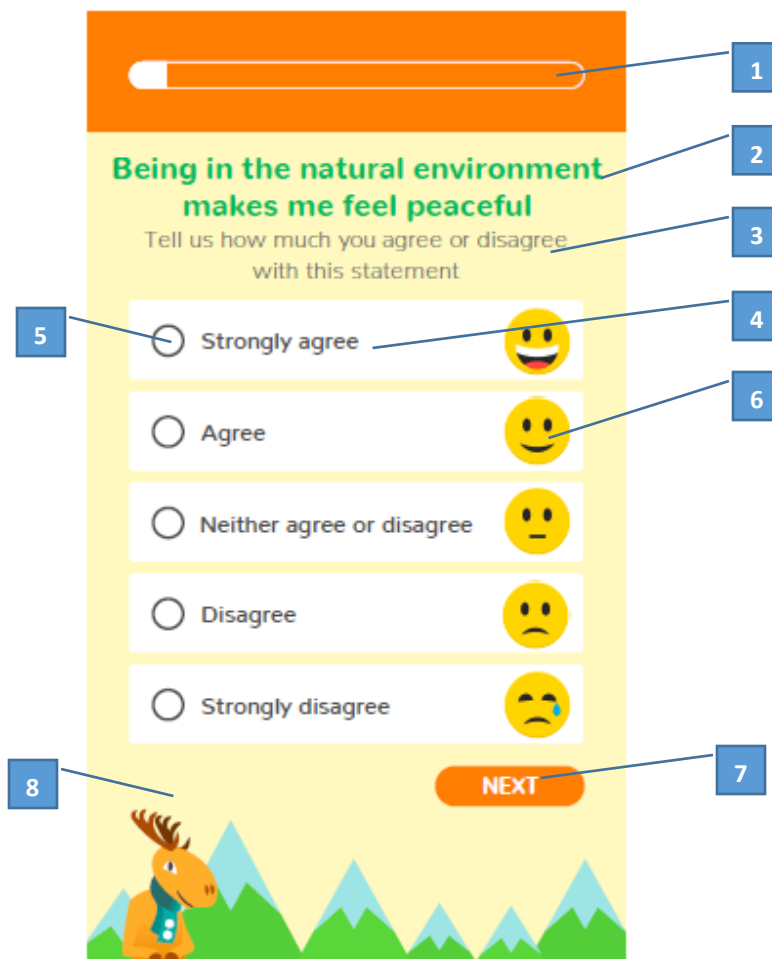


My Profile Screen



Survey Question Type Screens

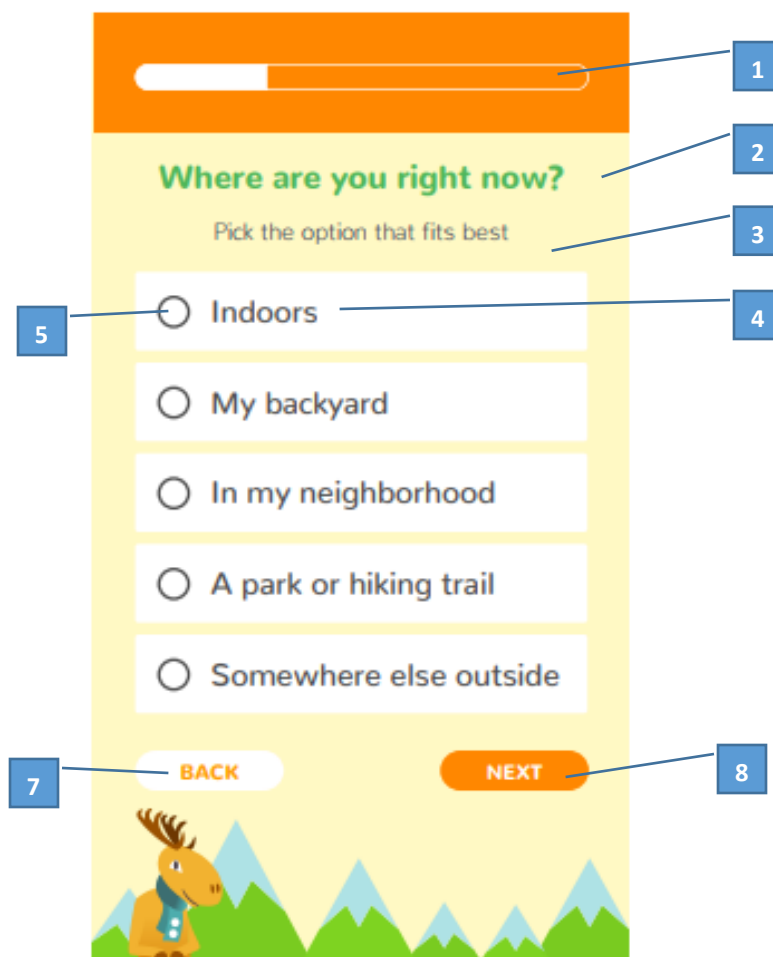
Question Screen - 5-point Likert with emojis



#	Label	Description
1	Progress bar	This reflects the user's position in the survey, and is dynamic based on Screen#/total screens
2	Question text	This is customizable when the survey is set up
3	Question instruction text	This is customizable when the survey is set up

4	Response options	For this type of question, there are exactly 5 options. Text for the response options is customizable when the survey is set up. Each response option has its own card.
5	Radio buttons	Radio buttons indicate that the user can only select one button
6	Emojis	Each of the 5 responses is paired with an emoji. These are static for all questions of this type.
7	Next button	If no response is selected, the next button is greyed out and is inactive. Once the user has selected a response, the button turns orange and the user is allowed to move to the next screen. When tapped, the user goes to the next question screen.
8	No Back button	Regardless of which question type appears first in the survey, no back button appears on the first screen (there's no "back" to go to)

Question Screen – Multiple Choice Single Response



#	Label	Description
1	Progress bar	This reflects the user's position in the survey, and is dynamic based on Screen#/total screens
2	Question text	This is customizable when the survey is set up
3	Question instruction text	This is customizable when the survey is set up
4	Response options	For this type of question, there is no limit for response options. Screen affordances should be designed to optimize 2-5 options, but allow for the possibility more (by allowing the screen to be

		scrollable). Text for the response options is customizable when the survey is set up. Each response option has its own card.
5	Radio buttons	Radio buttons indicate that the user can only select one button
6	Next button	If no response is selected, the next button is greyed out and is inactive. Once the user has selected a response, the button turns orange and the user is allowed to move to the next screen. When tapped, the user goes to the next question screen.
7	Back button	When tapped, the user goes back to the previous question screen. They may modify their previous answer.

Question Screen – Multiple Choice Multiple Responses

1

2

3

4

5

6

7

Which kinds of living things do you like the best?

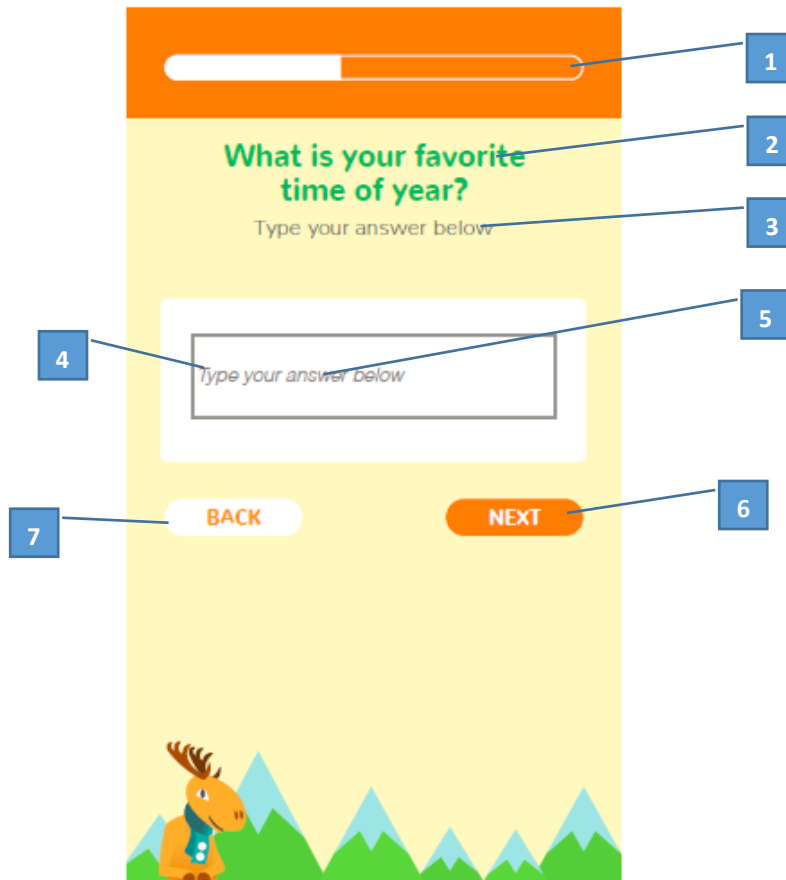
Pick all the options that fit

- Mammals
- Birds
- Trees and Shrubs
- Flowers
- Insects
- Reptiles and Amphibians
- Other plants
- None of these

BACK NEXT

#	Label	Description
1	Progress bar	This reflects the user's position in the survey, and is dynamic based on Screen#/total screens
2	Question text	This is customizable when the survey is set up
3	Question instruction text	This is customizable when the survey is set up
4	Response options	For this type of question, there is no limit for response options. Screen affordances should be designed to optimize 2-8 options, but allow for the possibility more (by allowing the screen to be scrollable). Text for the response options is customizable when the survey is set up. Response options are shown on a single list card.
5	Checkbox buttons	Checkbox buttons indicate that the user may multiple options
6	Next button	<p>If no response is selected, the next button is greyed out and is inactive. Once the user has selected at least one response, the button turns orange and the user is allowed to move to the next screen.</p> <p>When tapped, the user goes to the next question screen.</p>
7	Back button	When tapped, the user goes back to the previous question screen. They may modify their previous answer.

Question Screen – Short Open-Ended



#	Label	Description
1	Progress bar	This reflects the user's position in the survey, and is dynamic based on Screen#/total screens
2	Question text	This is customizable when the survey is set up
3	Question instruction text	This is customizable when the survey is set up
4	Text field	This should only be one line deep, but user's entry is not limited. User must enter at least one character to be considered completed.

5	Prompt	This prompt is static for all questions of this type. Text should say: Type here.
6	Next button	If no response is typed in the box, the next button is greyed out and is inactive. Once the user has entered at least one character, the button turns orange and the user is allowed to move to the next screen. When tapped, the user goes to the next question screen.
7	Back button	When tapped, the user goes back to the previous question screen. They may modify their previous answer.

Question Screen – Long Open-Ended



#	Label	Description
1	Progress bar	This reflects the user's position in the survey, and is dynamic based on Screen#/total screens
2	Question text	This is customizable when the survey is set up
3	Question instruction text	This is customizable when the survey is set up
4	Text field	This should be a larger box (signaling to the user that their response may be longer), but user's entry is not limited. User must enter at least one character to be considered completed.
5	Prompt	This prompt is static for all questions of this type. Text should say: Type here.
6	Next/done button	<p>If no response is typed in the box, the next button is greyed out and is inactive. Once the user has entered at least one character, the button turns orange and the user is allowed to move to the next screen.</p> <p>EXCEPTION – if this is the last question in a survey, there should be the option to make a response to this question optional when setting up the survey. If it is the last question in the survey, the button should say Done</p> <p>When tapped, the user goes to the next question screen.</p>
7	Back button	When tapped, the user goes back to the previous question screen. They may modify their previous answer.

Question Screen – Numeric Open-Ended

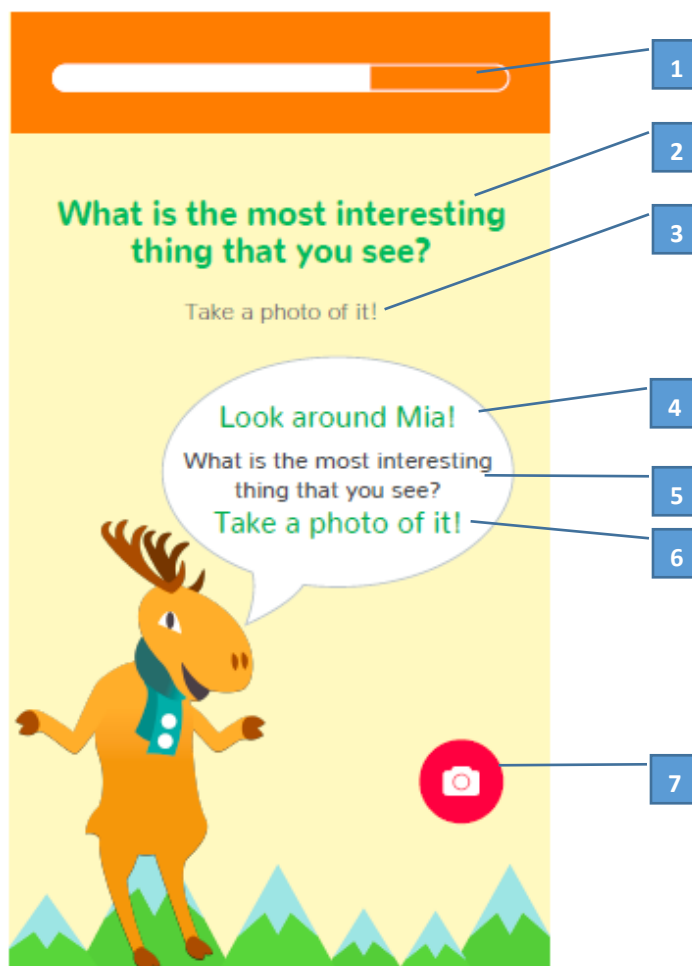
The image shows a mobile survey screen with the following components labeled with numbers 1 through 7:

- 1: Progress bar at the top.
- 2: Question text: "How many people are with you right now?"
- 3: Question instruction text: "Enter a number"
- 4: Text field for the user's answer, containing the placeholder "Enter a number".
- 5: "BACK" button.
- 6: "NEXT" button.
- 7: Decorative illustration of a moose and mountains at the bottom.

#	Label	Description
1	Progress bar	This reflects the user's position in the survey, and is dynamic based on Screen#/total screens
2	Question text	This is customizable when the survey is set up
3	Question instruction text	This is customizable when the survey is set up
4	Text field	This should only be one line deep, but user's entry is not limited. User must enter at least one character to be considered completed. Entry must be numbers.

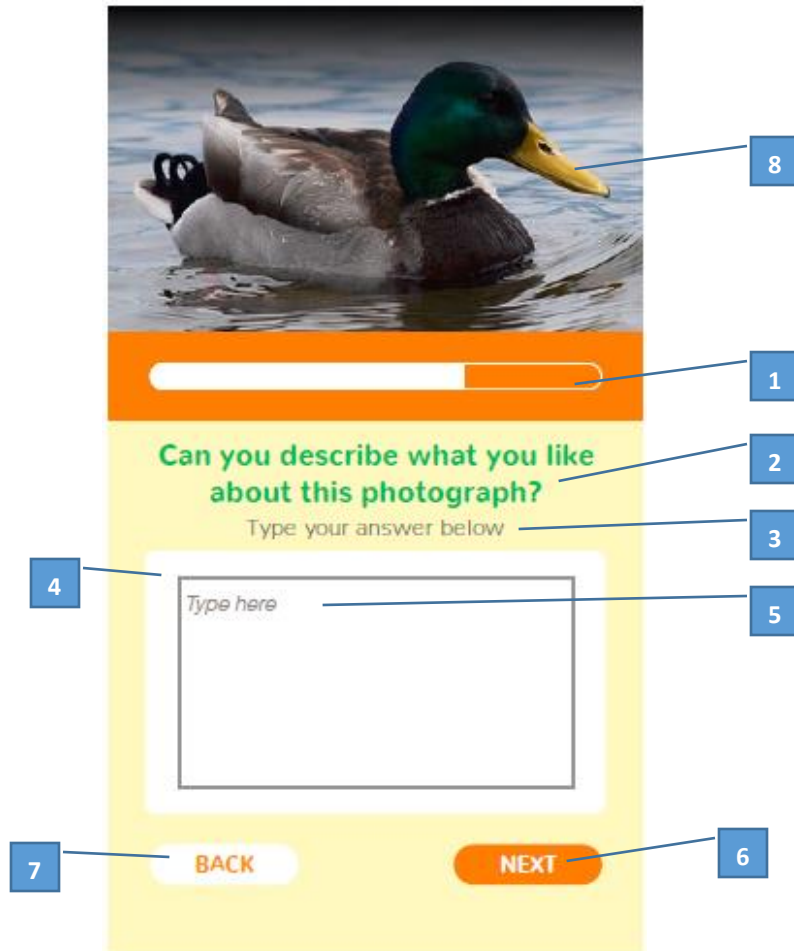
5	Prompt	This prompt is static for all questions of this type. Text should say: Enter a number.
6	Next button	If no response is typed in the box, the next button is greyed out and is inactive. Once the user has entered at least one character, and all characters are numbers, the button turns orange and the user is allowed to move to the next screen. When tapped, the user goes to the next question screen.
7	Back button	When tapped, the user goes back to the previous question screen. They may modify their previous answer.

Question Screen – Photo (first screen)



#	Label	Description
1	Progress bar	This reflects the user's position in the survey, and is dynamic based on Screen#/total screens
2	Question text	This is customizable when the survey is set up
3	Question instruction text	This is customizable when the survey is set up
4	Dynamic text	Dynamic text: Look around [Username]!
5	Customizable Prompt	This prompt customizable when the survey is set up
6	Static prompt	This text is static and should say: Take a Photo!
7	Camera Icon	When tapped, the user goes to the android camera, and then to the second Photo Question screen.

Question Screen – Photo (second screen)



#	Label	Description
1	Progress bar	This reflects the user's position in the survey, and is dynamic based on Screen#/total screens
2	Question text	This is customizable when the survey is set up
3	Question instruction text	This is customizable when the survey is set up

4	Text field	This should be a larger box (signaling to the user that their response may be longer), but user's entry is not limited. User must enter at least one character to be considered completed.
5	Prompt	This prompt is static for all questions of this type. Text should say: Type here.
6	Next/done button	<p>If no response is typed in the box, the next button is greyed out and is inactive. Once the user has entered at least one character, the button turns orange and the user is allowed to move to the next screen.</p> <p>When tapped, the user goes to the next question screen.</p>
7	Back button	When tapped, the user goes back to the previous question screen not the camera prompt screen. They may modify their previous answer.
8	Photo	User should see the photo they took (same as top portion of screen for Identification flow)

Pre-Survey Screen(s)



#	Label	Description
1	Pre-survey Screens	The number of pre-survey screens is customizable (1-3) when the survey is set up
2	Back and next buttons	The user may move between the pre-survey screens by tapping the next and back arrow buttons
3	Dynamic text	This should be dynamic: Hi [username]! We need your help!
4	Customizable text	This text is customizable when the survey is set up
5	Let's Start button	When tapped, the user goes to the first question screen. Once they go to the first question screen, the user cannot go back to these screens. We need a timestamp for when the user taps the button

Post-Survey Screen



#	Label	Description
1	Post-survey Screen	The screen will display a funny or a rare animal photo as the reward for completing the survey questions. [Question to the developers: How complex is it to use GIF photo?]
2	Okay button	When the user taps on the Okay button they go to “Add to a Collections” scheme. Once they are in the “Add to a Collection” screen, if they choose to exit before adding the photo to a collection, the photo will be saved in a new “Funny Photos” collection
3	Dynamic text	This should be dynamic: Thanks [username]!
4	Static text	Here is a fun photo. Let’s add it to your Collections.

APPENDIX B: IDC DESIGNER'S TOOLKIT DESIGN

Interaction Design & Children Designer's Toolkit

Translating Research Findings from the Design of Interactive Technologies for Children

Access evident-based and theoretically-driven findings and study results with children from the Interaction Design and Children research to inform your design and business decisions of children's products.



Select Child's Age

3-5

6-8

9-11

12-14

15-17

Select Child's Development Domain



Cognitive



Physical



Emotional



Social



Language