ABSTRACT

Title of Document:	COOPERATIVE DESIGN, COOPERATIVE SCIENCE: INVESTIGATING COLLABORATIVE RESEARCH THROUGH DESIGN WITH FLORACACHING
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This dissertation presents a case study of collaborative research through design with Floracaching, a gamified mobile application for citizen science biodiversity data collection. One contribution of this study is the articulation of collaborative research through design (CRtD), an approach that blends cooperative design approaches with the research through design methodology (RtD). Collaborative research through design is thus defined as an iterative process of cooperative design, where the collaborative vision of an ideal state is embedded in a design. Applying collaborative research through design with Floracaching illustrates how a number of cooperative techniques—especially contextual inquiry, prototyping, and focus groups—may be applied in a research through design setting. Four suggestions for collaborative research through design (recruit from a range of relevant backgrounds; take flexibility as a goal; enable independence and agency; and, choose techniques that support agreement or consensus) are offered to help others who wish to experiment with this new approach. Applying collaborative research

through design to Floracaching yielded a new prototype of the application, accompanied by design annotations in the form of framing constructs for designing to support mobile, place-based citizen science activities. The prototype and framing constructs, which may inform other designers of similar citizen science technologies, are a second contribution of this research.

COOPERATIVE DESIGN, COOPERATIVE SCIENCE: INVESTIGATING COLLABORATIVE RESEARCH THROUGH DESIGN WITH FLORACACHING

By

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Dedication

To Dana, as a second leaf on the same tree.

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Chapter 1: Introduction to the Study

The goal of understanding how to design new interactive technologies lies at the heart of Human-Computer Interaction (HCI) research. This goal is problematic in the sense that there are no universal principles that apply to all designs; rather, design "is about creating something in the world with a *specific* purpose, for a *specific* solution, for a *specific* client… design is about the unique, the particular, or even the *ultimate particular*. (Stolterman, 2008, p. 59)." In other words, it is difficult to generalize design knowledge in the same sense that knowledge in (for example) the hard sciences is generalized, because the goal of design is to produce particular, as opposed to universal, truth (Gaver, 2012).

In lieu of universal truth, what researchers can offer one another are contributions that support the practice of design and design research. In the context of art and design, Christopher Frayling famously delineates different design research contributions as research *into* art and design, research *through* art and design, and research *for* art and design (Frayling, 1993, emphasis original). HCI researchers have adopted these categories, in slightly modified forms, to discuss design contributions within HCI (Zimmerman, Forlizzi, & Evenson, 2007). For example, research about design is described as research about the human process of design, including philosophies and historical perspectives (Zimmerman, Stolterman, & Forlizzi, 2010). Research for design advances the practice of design by offering new frameworks, recommendations, methods or techniques, and implications. A third type of research, research through design, involves “the process of iteratively designing artifacts as a creative way of investigating what a potential future might be” (Zimmerman, Stolterman, & Forlizzi, 2010, p. 313).

The present study investigates how cooperative design (e.g., Sanders & Stappers, 2008) may be applied to research through design. The resulting approach, collaborative research through design (CRtD), is explored through a case study of Floracaching, a gamified mobile application for citizen science biodiversity data collection. A description of collaborative research through design, grounded in a case study of implementing CRtD with a university community, is one contribution of this study. A second contribution is the annotated design artifact (Zimmerman, 2007), which consists of a new prototype of Floracaching, along with associated framing constructs. Together, the prototype and framing constructs illustrate how mobile technology may be designed to support place-based citizen science on a university campus.

Introduction to research through design

Research through design (RtD) is a framework that uses the process of design to address difficult research questions, or “wicked problems” (e.g., Buchanan, 1992; Zimmerman, Stolterman, and Forlizzi, 2010). Research through design produces contributions in two forms. Design artifacts take the form of prototypes, or completed applications. These artifacts are accompanied by annotated portfolios, which reference key features of a design, and explain why these features were implemented based on research uncovered through the iterative process of design (Lowgren, 2013).

Traditionally, RtD is a tool for trained designers: it is valued in part “because it allows designers to do what they do naturally (to design), and to create a stepping-stone to theory.” (Zimmerman, Forlizzi, & Evensoon, 2007, p. 313). But, the value of RtD – an approach that draws on established theory, user research, and creative iteration to attack a difficult problem from numerous angles—suggests that this method may be useful for others in HCI and beyond. The potential for a broader implementation of this approach leads to important questions, such as: What types of problems is research through design suited for? Who may use research through design? How can people who are not trained as designers participate in and benefit from this approach?

Introduction to the citizen science problem space

Citizen science is a form of collaboration where members of the public contribute to scientific research (Bonney et al., 2009). As a historic tradition, citizen science pre-dates the professional practice of science (Silvertown, 2009). When Charles Darwin made his historic journey on the HMS Beagle and collected observations to inform the theory of evolution, he acted as a citizen science volunteer.

Today, citizen science is growing and changing. There are thousands of projects in fields ranging from astronomy, to ecology, to public health (the Scistarter database[1] offers one list of active and completed projects). Citizen science projects involve the public in different types of research activities (Shirk et al., 2012; Haklay, 2013). Some projects, including those in the Zooniverse suite,[2] engage volunteers in large-scale data analysis or interpretation. Other projects, like the Delaware Bay Horseshoe Crab

[1] http://www.scistarter.com. Retrieved March 2015.
[2] http://www.zooniverse.org. Retrieved March 2015..

Spawning Survey,[3] ask volunteers to collect data through naturalistic observations analyzed by professional scientists. The current research is designed to support the later type of citizen science, by designing a mobile application to facilitate biodiversity data collection for Project Budburst, a place-based citizen science project. [4]

Project Budburst

Project Budburst (PBB) summarizes their mission with the following haiku:

People watching plants
Contributing to research
Join Project Budburst

To achieve this mission, Project Budburst asks volunteers to monitor plants and collect *phenology* data. Phenology is a scientific term that refers to the timing of lifecycle events. Phenology does not always refer to events—such as birth or death—that occur a single time in an organism's life. Rather, phenology often designates cyclical events, such as the spring emergence of leaf buds for some plants, that occur at predictable times across an organism's lifecycle. Project Budburst is one of a handful of citizen science projects that collect phenology data. Three projects are summarized in table 1.

Project Budburst supports two types of observations: single reports, where volunteers submit an independent observation; and, regular reports, where volunteers visit and observe the same plant many times over the course of a year. For both types of

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[3] http://www.dnrec.delaware.gov/coastal/DNERR/Pages/DNERRHSCSpawningSurvey.aspx. Retrieved March 2015.

[4] http://www.budburst.org. Retrieved March 2015.

Table 1

Three citizen science projects that collect plant phenology data

	Project Budburst	Nature's Notebook	AMC Mountain Watch
Participation	Volunteers submit independent observations, or monitor a plant over time.	Volunteers designate a site of interest, and submit observations of organisms observed at that site.	Volunteers in the Northeast United States collect observations along hiking trails.
Target species	Plants.	Plants and animals.	Plants.
Sample goals	Project Budburst seeks to advance ecological research. PBB also publishes educational resources to support K-12, informal, and higher education, and professional development.	Nature's Notebook "gathers information…to be used for decision-making on local, national, and global scales to ensure the continued vitality of our environment.[5]"	AMC scientists collect phenology data as indicators of climate change. Information is also used "for public education, to raise media attention, and advocate for appropriate environmental policy to address climate change.[6]"

reporting, data submission is the same. Volunteers share information including the genus and species of a particular plant, the location of that plant, and the plant's current phenological state (for example, "First flower: Date the first flowers are fully open"). Volunteers share this information in one of three ways. They may fill out paper and pencil data sheets, and mail these in. They may also share data through a web form, or upload data directly from the Budburst Mobile Android application.

5 https://www.usanpn.org/nn/about. Retrieved March 2015.

6 http://www.outdoors.org/conservation/mountainwatch/mtplant.cfm. Retrieved March 2015.

Project Budburst volunteers are driven by factors such as “knowing that data collected was environmentally important” (Han, Graham, Vasillo, & Estrin, 2011, p. 1447). But research suggests that alternative mechanisms, such as tracking one’s observations or incorporating the motivational affordances of games, may also motivate Project Budburst volunteers (Graham et al., 2012; Han et al., 2011). The present study builds on this work by investigating how technology design may motivate a new user group of citizen science volunteers, members of a university campus, to collect and share plant phenology data.

Motivation and technology in citizen science

Research on citizen science as a tool, or “the science of citizen science” (Shapiro, 2014), is growing. One important research agenda is understanding the factors that motivate volunteers to participate in citizen science. Motivation designates reasons for initial participation, or factors influencing *recruitment*, and factors supporting *retention*, or continued participation. As motives for initial participation are not identical to motives for continuing participation (Rotman et al., 2012; Rotman, 2013; Rotman et al., 2014), recruitment and retention are distinct topics. In addition, volunteers hailing from different national cultures experience motivation differently (Rotman, 2013; Rotman et al., 2014). Finally, motivation differs within a single culture, as different types of volunteers express different motivations (Bowser et al., 2014). Thus, motivation in citizen science is a complex question that varies in regard to individual, cultural, and temporal differences.

Yet, there are some commonalities. Volunteers may be motivated by interesting technologies or different elements of design (Newman et al., 2012). For example, one group of researchers observed that visitors to a natural park were attracted to an attractive tabletop display (Preece, et al., 2014). Others suggest that gamification, or the use of elements of game design in non game contexts, may draw new user groups into citizen science (Iacovides, Jennett, Cornish-Trestrail, & Cox, 2014; Newman et al., 2012; Prestopnik & Crowston, 2012). Yet, despite promising early research on motivation in *virtual* or online citizen science (Eveleigh, Jennett, Blandford, Borham, & Cox, 2014; Iacovides et al., 2014; Prestopnik & Crowston, 2012; Prestopnik, Crowston, & Wang, 2014), there is a dearth of knowledge on how to apply gamification to *place-based* citizen science, which is constrained by a specific geography. In addition, more work is needed to understand the value of specific elements of gamification, for example by considering how missions, badges, and points are valuable in a place-based context.

Researchers see a need to engage new types of volunteers in citizen science (Newman et al., 2012). However, little is known about how to design specifically for different user groups, such as a university community. In addition, designing technologies to support citizen science is a difficult task (Tinati et al., 2015). Designing citizen science technologies requires negotiating the needs of conflicting stakeholders. For example, scientists may require rigorous protocols to support research goals, while volunteers wish for lightweight and interactive experiences (Bowser et al., 2013a). Other tradeoffs include the need to collect precise data and metadata on one hand, and the need to support volunteer privacy on the other (Preece & Bowser, 2014). Finally, designers must consider organizational constraints, such as limits to resources including time, money, and expertise (Wiggins, 2013), and natural constraints of the problem space, such as the need to conduct research in remote environments or areas with low wireless connectivity. Like many other design problems, the question of how to design Floracaching to motivate members of a university campus is thus considered a *wicked problem*, defined as a problem with incomplete or changing requirements that may be difficult to recognize (in line with Buchanan, 1992). This, makes designing Floracaching ideal for a research through design approach (Zimmerman, Forlizzi, and Evenson, 2007).

The process of cooperative design empowers users as key stakeholders and active participants in technology development, while helping designers understand tacit procedural knowledge in order to create better technologies (Sanders & Stappers, 2008). Therefore, taking a cooperative approach to research through design could produce technologies that represent an ideal state created not just by a designer, but an entire community, while ensuring that these technologies are more likely to be used. In addition, cooperative technology design builds on a growing tradition of cooperative project design in citizen science (e.g., the "co-created" projects of Shirk et al., 2012). For these reasons, a cooperative design approach was applied to research through design in the present study.

While the potential benefits of cooperative research through design are promising, there is little guidance on how a cooperative approach to research through design should actually be implemented. This leads to the first research question, explored through a case study of Floracaching: *How can cooperative design techniques be effectively integrated into the research through design methodology*?

Answering this question requires applying the method of collaborative research through design to assess its value. Through this process, a new prototype of Floracaching is designed with the goal of motivating a university community to participate in citizen science. Thus, the second research question asks, *How might a gamified mobile application for citizen science biodiversity data collection be designed to engage a place-based citizen science community?* The methodology for addressing both questions is described below.

<u>*Research design*</u>

This study does not represent initial research or design with Floracaching, but builds heavily on previous work (Figure 1). Early prototyping efforts utilized a cooperative design approach, where the research team worked closely with users in co-design workshops (Bowser et al., 2013b) or through evaluation (Bowser, et al., 2013a). These efforts yielded a method for prototyping location-based apps and games named the PLACE approach,[7] which was an early precursor to research through design (Bowser et al., 2013b). It also led to a number of low-fidelity, mid-fidelity, and high-fidelity prototypes of the Floracaching app.

By building heavily on previous research, the present study offers a detailed description of four co-design workshops, held at the University of Maryland (UMD) and Brigham Young University (BYU) in spring of 2015. The goal of these workshops was to investigate how a cooperative research through design approach could be applied to Floracaching. Data were collected through observations made by the research team and

[7] PLACE is an acronym for **P**rototyping **L**ocation, **A**ctivities, and **C**ollective **E**xperience over time

by co-designers, prototypes created during each workshop, and focus group discussions. Data were analyzed first through an inductive approach similar to grounded theory (Glaser & Strauss, 1967) and thematic analysis (Braun & Clark, 2006). The results of early data analysis were then synthesized with relevant theory during the iterative

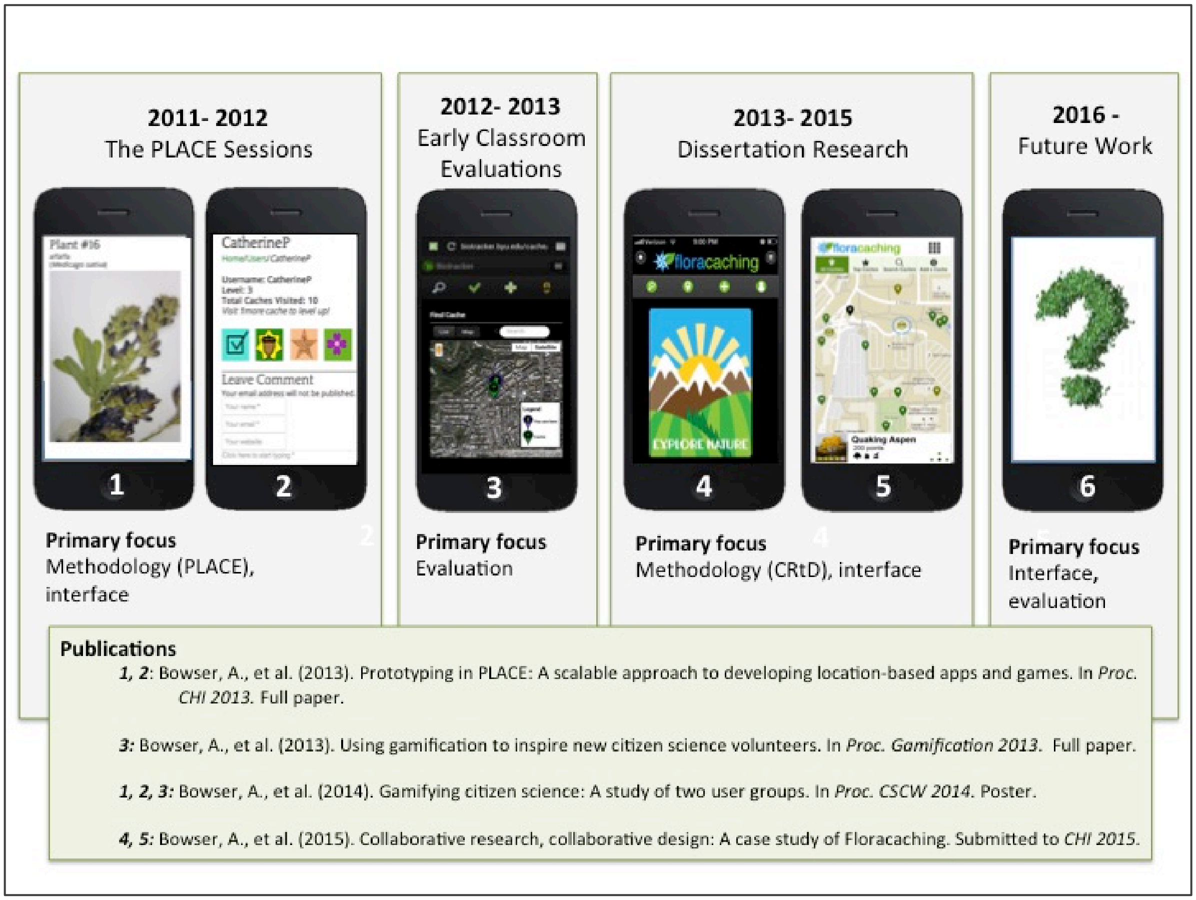

Figure 1. An overview of research with Floracaching.

process of design, in line with the research through design methodology (Zimmerman, Forlizzi, & Evenson, 2007).

Initial analysis revealed seven themes related to the second research question, namely how to design a gamified app to engage a university community in citizen science. Additional theories, such as experiential learning (Kolb, 2014) and a sense of place (Gustafson, 2001; Ramkissoon, Weiler, & Smith, 2012), illustrate how these themes converge into a holistic understanding of motivation for Floracaching. During this analysis, the author simultaneously re-designed the Floracaching app based on the prototypes created by co-designers and her evolving understanding of the data.

This process was evaluated by the author, by other members of her research team through field notes and debriefing, and by a few co-design participants. This evaluation generated a list of suggestions for conducting co-design with a university community, and a description of a new approach to the research through design methodology, namely collaborative research through design (CRtD). The value of CRtD is explored through a case study of Floracaching development, and also through applying standards from research through design (Zimmerman, Forlizzi, & Evenson, 2007) and participatory design (Spinuzzi, 2005). Key tenets of the CRtD methodology are described in detail, so that others can implement this method in citizen science and in other contexts.

In Floracaching, collaborative research through design was conducted with members of a university community. While others have explored how to conduct cooperative design with user groups such as children (e.g. Druin, 1999) or the elderly (e.g., Demirbilek & Demirkan, 2004), this user group is under-represented in the cooperative design literature. This, the contribution associated with research question one also includes a list of suggestions for conducting cooperative design with a university community.

This research draws on previous work (Bowser et al., 2013a; Bowser et al, 2013b; Crowston & Prestopnik, 2013; Eveleigh et al., 2014; Prestopnik & Crowston, 2012) to investigate how gamification can be applied to place-based citizen science. Specifically, this study offers seven framing constructs—nature is everywhere; contribution; socialization; topical knowledge; local knowledge; and, the self in place—that illustrate and suggest how a mobile app for place-based citizen science may be designed. This research also explores how the theoretical concept of a sense of place can be used to understand citizen science participation, expanding other research (Haywood, 2013; Wiggins, 2012). Thus, the second main contribution of this study is understanding how to design technology for a specific type of citizen science activities.

Key terms

The following terms describe core components of this study.

Citizen science is a form of collaboration, where members of the public contribute to scientific research (Bonney et al., 2009; Shirk et al., 2012). Some projects are designed around scientific research goals. Foldit, a citizen science game, identified the structure of a protein crucial to the reproduction of HIV (Khatib et al., 2011). Citizen science may also be designed to support formal or informal education, and participation linked to improvements in testable topical knowledge (Jordan, Gray, Howe, Brooks & Ehrenfeld, 2011). Citizen science is also used as a mechanism to influence public policy. For example, the Big Butterfly Project uses species abundance data to assess the effectiveness of conservation policies and influence new programs (Haklay, 2015).

Different models of citizen science allow volunteers to play a variety of roles. Volunteers may be responsible for collecting field data in contributory projects, or pose research questions in co-created projects (Shirk et al., 2012). In all forms of citizen science the term *practitioner* designates a researcher who organizes or implements a project. *Volunteer* designates an individual who contributes to practitioner-led projects.

Motivation is a force or influence that causes somebody to do something. Without understanding motivation, citizen science practitioners may not be able to recruit enough volunteers to meet project goals. ***Recruitment*** is the process of soliciting volunteers to participate in citizen science by appealing to different motivations. ***Retention*** designates a volunteer's continued participation in citizen science activities.

Reader-to-leader is a framework for understanding membership in online communities (Preece & Shneiderman, 2009). The reader-to-leader framework presents a spectrum of participation in online communities, and describes how initial contributors, or readers, may evolve to contributors, collaborators, or leaders. This framework is used to analyze motivation in Floracaching.

Gamification is the use of motivational elements from game design in non-game contexts (Deterding, Dixon, Khaled, & Nacke 2011). A program or application is "gamified" when it incorporates select elements from games, but does not form a complete and independent game. For example, Salesforce[8] is a platform for customer relationship management that allows an organization to keep track of key relationships to find business opportunities. Salesforce is designed to support marketing goals, and

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[8] http://www.salesforce.com/. Retrieved March 2015.

implemented in business settings. Yet, it incorporates elements of games—including points, badges, leaderboards, and missions—to motivate employees (Hamari, Kivisto, & Sarsa, 2014). Note that the people who use gamified apps are called users, or players. Numerous elements of gamification are now explored in turn.

Points, or numerical indicators of progress that accumulate through the use of a system over time, are the most common element in gamified apps (Zichermann & Cunningham, 2011). Points motivate players through feedback, by signaling desired activities. They also enable players to mark their status compared to other users, motivating through competition (Werbach & Hunter, 2012).

Leaderboards are ordered lists that rank users on a given metric. One function of leaderboards is to provide users with feedback regarding how successfully they are engaging with a system (Costa, Wehbe, Robb, & Nacke, 2013). Leaderboards also facilitate social comparison.

Badges are virtual rewards earned by completing certain game activities. Badges motivate players by signifying competence or achievement, or by marking similarities between like-minded players (Antin & Churchill, 2011; Denny, 2013).

Missions, also called achievements, quests, or clear goals, direct a player's action towards a desired end state. In some cases, missions are designed as interventions to encourage players to spend more time with an application (Eveleigh et al., 2014). Missions may also link in game actions to real world motivations and goals (Decker & Lawley, 2013).

New Volunteers. There is a common perception that traditional citizen science volunteers "tend to be almost exclusively white, highly educated, fairly affluent people, and people in their late 40s and up" (Caren Cooper, quoted in Tomley, 2015). According to Newman et al., new technologies may "broaden participation in citizen science in ways that were not previously possible and, if used appropriately, will allow data collection by communities who traditionally remained uninvolved in scientific projects" (2012, p. 301). Some researchers find new volunteers in communities that are geographically isolated and/or historically underserved. The Extreme Citizen Science (ExCiteS) group uses "a situated, bottom-up practice that takes into account local needs, practices, and culture and works with broad networks of people to design and build new devices and knowledge creation processes that can transform the world."[9] Other researchers and practitioners depart from the community perspective, and focus instead on how to engage new user groups. Prestopnik and Crowston introduced a series of web-based classification platforms to study questions including the motivations of different volunteers including a new group, *gamers* (2012). The proposed research focuses on recruiting members of a university community as a new user group to participate in citizen science through the Floracaching app.

A university community includes traditional and non-traditional students taking classes at a college or university within the United States, and also professors, administrators, and others. This group is considered a cohort, or a group of people united

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[9] http://www.ucl.ac.uk/excites/home-columns/full-what-is-extreme-citizen-science. Accessed March 15, 2015.

by a common trait. In this study, the key trait of this cohort is a common social, geographic, and educational community. Note that individuals will move in and out of this target group based on enrollment or employment status. For example, a senior undergraduate who helped co-design Floracaching in 2011 would be considered a target user during that time, but not after graduating, e.g. during research conducted in 2015. While somewhat obvious, this distinction is important because it informs the selection of participants, as explained later on.

Floracaching is a gamified mobile application that includes points, leaderboards, badges, and missions with the goal of engaging university college students in citizen science. At the time of this research, Floracaching is an HTML5 prototype available at http://www.floracaching.byu.edu.

Experiential learning is a method of learning from life experiences (Kolb, 2014). Experiential learning is a constructivist learning theory, which stresses how direct awareness and interaction with an environment leads to learning gains. This theory is applied to understand how learning may take place through Floracaching.

A sense of place is a collection of theories from phenomenological geography. Place attachment explores how people become attached to a place with unique social and geographic features. Place meaning is a similar concept, which demonstrates how places acquire significance in a person’s life. These theories are used to understand how co-designers see value in citizen science facilitated through Floracaching.

Cooperative design, also called co-design, is an approach to design that harnesses the “collective creativity” of a target user group across “the whole spectrum of the design process" (Sanders & Strappres, 2008, p. 6). Related approaches include participatory design (Mueller & Druin, 2010), contextual design (Holtzblatt, Wendell, & Wood, 2005), and coopeative inquiry (Druin, 1999). While differing on factors including the philosophical underpinnings, the types of users targeted, and the specific techniques employed, all of these methods involve participants in design to a greater degree than traditional user-centered design methodologies.

Collaborative research through design (CRtD) is the specific methodology used to prototype Floracaching. This is a new approach to research through design. CRtD illustrates how a problem can move from its current state to a preferred state by channeling the creativity of researchers, designers, and users to prototype a new technology. This methodology, which combined research through design (Zimmerman, Forlizzi, & Evenson, 2007) and cooperative / co-design methodologies (e.g., Sanders & Stappers, 2008), was refined over the course of this study and previous work. In short, collaborative research through design (CRtD) is a way to define and solve problems through the iterative process of cooperative design

Summary and chapters ahead

This chapter introduced the current study, explaining how the two research questions are situated within knowledge of design methodologies, and research on citizen science. It offered a short overview of research methods, established key contributions, and listed important nomenclature.

Chapter 2: Methodological Background provides important background on research through design, collaborative design approaches, and key research techniques.

Chapter 3: Problem Space reviews relevant literature, focusing on the question of motivation in the context of citizen science, and the design of gamified citizen science applications. This chapter presents early work co-designing Floracaching that offers important insights into the motivations of new users, the application of gamification, and the emerging collaborative research through design methodology.

Chapter 4: Research Methods begins by presenting the version of the Floracaching app accessed by participants in this study. It then offers a detailed description of the four co-design workshops, and data analysis. This chapter includes a discussion of the limitations of the research methods selected.

Chapter 5: Findings on Key Themes for Floracaching presents seven key themes that emerged through analysis of the four co-design sessions: personal relevance; design; gamification and reward; awareness and recognition; knowledge and learning; socialization; and, community and contribution. The analysis is a first step towards answering the second research question.

Chapter 6: A New Iteration of Floracaching synthesizes the key themes presented in Chapter 5. This chapter integrates the analyzed research with relevant theory through the creative process of design, to describe how a new group of volunteers may be motivated to contribute to citizen science through Floracaching. Chapter 6 concludes with a presentation of new prototypes for Floracaching and a short list of framing constructs. This design-driven analysis and integration fully answers the second research question, *How might a gamified mobile application for citizen science biodiversity data collection be designed to engage a place-based citizen science community?*

Chapter 7: Findings on Collaborative Research Through Design describes the CRtD methodology as it actually unfolded. This chapter offers an ethical stance on CRtD, and a procedural evaluation of three techniques valuable for conducting CRtD. Chapter 7 concludes with a list of key tenets of collaborative research through design, and also offers suggestions for designing with a university community. In this chapter, the first research question, *How can cooperative design techniques be effectively integrated into the research through design methodology*?, is answered.

Chapter 8: Conclusions, Limitations, and Future Work summarizes key findings of this study, and identifies limitations of this research. It raises a number of open questions related to collaborative research through design, the research through design methodology, and research in citizen science, to inform future scholarship.

Chapter 2: Methodological Background

This chapter provides the background needed to understand the research question, *How can cooperative design techniques be effectively integrated into a research through design methodology*? This chapter begins with a description of the research through design methodology in which various cooperative approaches including participatory design (Spinuzz, 2008), contextual design (Holtzblatt, Wendell, & Wood, 2005) and cooperative inquiry (Druin, 2002) are explored.

<u>Research through design (RtD)</u>

Research through design is an aspirational design lens that "stresses design artifacts as outcomes that can transform the world from its current state to a preferred state." (Zimmerman, Forlizzi, & Evenson, 2007, p.310). Research through design produces a physical design artifact accompanied by designs annotations, which describe the theory and assumptions codified in a design. The process and outputs of RtD are introduced through the example of prayer companion, an artifact designed to support the activities of cloistered nuns (Gaver et al., 2010). The designers of prayer companion had two overarching goals. First, they hoped to create a tool to help cloistered nuns leverage their spirituality to support the outside world. Second, they wished to investigate four research themes: the balance between openness and specificity; the importance of a system's materiality; the challenges of designing for older people; and, the potential for computation to support spiritual behavior (Gaver et al., 2010). With these goals in mind, an iterative user-centered design process led to a device called prayer companion, a small, wooden, crucifix-shaped device.

Prayer companion displays headlines pulled from major news sites and social media to provide inspiration for nuns who seek timely and relevant communication with God (Gaver et al., 2010). A Prayer Companion prototype was installed in the Poor Clare cloister, and received positive reviews following early tweaks to the content displayed. By installing prayer companion in Poor Clare, researchers achieved their first goal of using technology to support spirituality, with the caveat that nuns believed the device would need prove its value over many years (Gaver et al., 2010).

Through the evaluation of Prayer Companion, researchers also achieved their goal of uncovering new knowledge. For example, they learned that in order to discourage stereotypes and create better designs, it is preferable to focus on a specific group of older people—in this case, cloistered nuns—instead of considering the elderly as a single user group (Gaver et al., 2010). Thus, this example illustrates how research through design may contribute an artifact (e.g., the Prayer Companion prototype) while supporting new knowledge through the process of reflection and annotation (e.g., the research published at the CHI conference).

Christopher Frayling articulated one version of research through design in the context of art and design (Frayling, 1993). Frayling differentiates between three related processes: research *into* art and design; research *through* art and design; and, research *for* art and design. The first category, research into art and design, describes research conducted to understand art and design—for example, taking a historical perspectives approach to understand impressionism, or writing a cultural critique.

Research through art and design unfolds in numerous ways (Frayling, 1993). It may involve materials research, where art pushes the boundaries of what a material can achieve. It may involve development work, for example by customizing an existing technology to achieve a new goal. It may also entail action research, where an artist annotates their design process through a research diary. Frayling compares both research into art and design and research through art and design to cognitive traditions in art, which require an artist to focus on "subjects which existed outside themselves and their own personalities" (Frayling, 1993, p. 3). In other words, practitioners consider an outside party the target or subject of research and design activities.

To contrast, in research for art and design thinking is *"embodied in the artifact,* where the goal is not primarily communicable knowledge in the sense of verbal communication, but in the sense of visual or iconic or imagistic communication." (Frayling, 1993, p. 5, emphasis original). Thus, research is codified in the artifact that design produces. Frayling compares research for art and design to expressive traditions in art, where an expression of the artist's experience is communicated through design.

Based on Frayling's model, Zimmerman, Forlizzi, & Evenson proposed a method of research through design for interaction design in HCI (Zimmerman, Forlizzi, & Evenson, 2006) that maps most closely to Frayling's research for design (a conclusion also reached by Bardzell, Bardzell, & Hansen, 2015). Specifically, HCI research through design entails:

> “An active process of ideating, iterating, and critiquing potential solutions [where] design researchers continually reframe the problem as they attempt to make the right thing. The final output of this activity is a concrete problem framing and articulation of the preferred state, and a series of artifacts—models, prototypes, products, and documentation of the design process.” (Zimmerman, Forlizzi, & Evenson, 2007, p. 315).

Frayling’s three forms of design research, and research through design in HCI, all involve the dual creation of an artifact and an annotation. However, RtD in HCI focuses on iteration to a greater degree than the processes Frayling describes; and, in line with traditional user-centered design, often involves users in the design cycle (Zimmerman, Forlizzi, & Evenson, 2007). In addition, Frayling’s conceptualization draws on designs and annotated portfolios to jointly communicate artistic success that is judged primarily for its creative merit. Meanwhile, RtD is advanced as a method for addressing wicked problems, or “messy solutions with unclear or even conflicting agendas” that is by nature “research of the future, instead of on the present or the past.” (Zimmerman, Stolterman, & Forlizzi, 2010, p. 310).

Research through design as conceived by Zimmerman, Forlizzi, and Evenson is utilized by a number of HCI researchers and designers (2007). Researchers studying eldercare used RtD to build an assistive robotic table (Threatt, et al., 2014). Others have used RtD to support environmental awareness (Gaver et al., 2013), or to create tools for distributed intergenerational co-design (Walsh et al., 2012), to highlight just a few projects.

Following the presentation of RtD as an HCI methodology (Zimmerman, Forlizzi, and Evenson, 2007), researchers began to debate what a design artifact and what design annotation entail. Design artifacts are the artifacts produced through RtD. These may take the form of operational prototypes, whether physical devices or software; as material and conceptual design studies, that suggest new ways of designing or thinking about design; and, as design proposals, which encompass "potential, unrealized, and incomplete" design artifacts (Pierce, 2014, p. 739). These forms are not mutually exclusive. For example, while sharing a research through design artifact researchers might share initial low-fidelity prototypes that functioned as an early design proposal, to illustrate consistency with or contrast to a fully operational prototype (e.g., Gaver et al, 2010; Threat et al., 2014).

In some ways, design artifacts—particularly operational prototypes—speak for themselves (Frayling, 1993; Zimmerman, Forlizzi, & Evenson, 2007). Users, may intuitively grasp their intended use; designers, may understand the tacit knowledge embedded in a design (e.g., Gaver et al., 2010; Pierce, 2014). Yet artifacts do not always explain themselves fully, or communicate clearly to all intended audiences (Bardzell, Bardzell & Hansen, 2015). In addition, artifacts do not illustrate the historical process of their creation. Design annotations, often called annotated portfolios, bridge these gaps (Bowers, 2012; Lowgren, 2013; Zimmerman, Forlizzi, & Evenson, 2007).

The notion of annotated portfolios "entails selecting a collection of designs, re-presenting them in an appropriate medium, and combining the design re-presentations with brief textual annotations." (Lowgren, 2013, p.30). Annotated portfolios are indexical as they point to certain features of a design, with the aim of explaining where each feature comes from, or framing a larger discussion of meaning (Bowers, 2012). In the indexical sense, they are descriptive; annotated portfolios are also intended as generative, inspiring future designs.

Annotated portfolios take many forms, depending on their audience. Often, they are academic papers that illustrate a design and underlying theory to a research community. These papers typically contain recommendations for design, whether categorized as general “implications for design” or concise “framing constructs” that illustrate how to design for a problem context (Zimmerman, 2008). Annotated portfolios may also take more artistic formats, such as a collection of photographs with an introductory essay, or a museum exhibition (Bowers, 2012). Of course, the same design artifact may have multiple annotated portfolios for different settings—for example, a parenthetical artist’s statement for an object installed in art exhibit, which is elaborated in a peer-reviewed publication describing new knowledge.

Those who practice research through design also debate the type of knowledge this method produces. Many suggest that RtD produces intermediate knowledge, or knowledge that informs practice (Bowsers, 2012; Löwgren, 2013; Zimmerman, 2007). One important form of intermediate knowledge is knowledge of design methods and tools, or knowledge of the practice of design (Löwgren, 2013). In this sense, advances to the methodology of RtD itself can be considered a form of intermediate knowledge that offers insight on how to approach designing in general. But this type of intermediate knowledge also includes design guidelines or heuristics, which offer specific insight into how to design with certain goals, such as designing for the self, a process of helping "people become the people they most desire to be" (Zimmerman, 2007, p. 395). In this way, research "through" design can inform research about design.

A few argue that research through design can produce "relevant and rigorous theory" in line with other contributions (Zimmerman, Stolterman, & Forlizzi, 2010; Gaver, 2012). Gaver frames this problem space by using two theories from the philosophy of science to evaluate RtD contributions (Gaver, 2012). First, Gaver cites Kuhn's notion of falsifiability, which states that a single incompatible result can disprove an existing theory. Gaver argues that research through design can never produce knowledge that is falsifiable, as a single designer's representation of an ideal state can never be proven incorrect.

Gaver also discusses Lakatos' understanding of scientific research programs, which entail a core theory, accompanying hypotheses, and supporting evidence (Gaver, 2012). Scientific research programs are dynamic conversations around a topic fueled by the work of multiple researchers. Gaver argues that research through design is more likely to generate knowledge in line with Lakatos' understanding of knowledge advancement (Gaver, 2012).

To offer an illustrative example of scientific research programs in HCI, one group of designers explored how attachment theory could be applied to the creation of interactive prototypes designed to help parents feel like better parents (Ozenc, Brommer, Jeong, Shih, Au & Zimmerman, 2007). Their design of a reverse alarm clock adds to the collection of HCI knowledge by providing evidence for the relevance of attachment theory, while also advancing the notion of designing for the self. Other researchers may build on either stream of knowledge. For example, one group applied the concept of designing for the self by creating a chocolate machine as “a transformational product to improve self-control strength” (Kehr, Hassenzahl, Lasche, & Diefenbach, 2012).

Along with the need to establish the types of knowledge that RtD produces, there is a need to form criteria for evaluating RtD contributions. Zimmerman, Forlizzi & Evenson suggest four (2007). The first criterion, process, states that designers should rigorously apply their selected methods, and document their methods in a way that makes research reproducible. There is some pushback on this criterion; for example, Gaver argues that the application of RtD depends on the creativity of a specific designer operating in a specific context, and is thus never reproducible (Gaver, 2012). However, others agree that the process of documentation is important for understanding how knowledge is generated through the process of research through design (Pierce, 2014).

The second criterion, invention, suggests that RtD contributions should be novel and creative integrations of existing theory and practice that advance a research community (Zimmerman, Forlizzi & Evenson, 2007). This is accomplished in part by situating a contribution in existing literature. The third criterion, relevance, speaks to the need to establish why a designed-for, idealized state is preferential to the actual state. The final criterion, extensibility, suggests that the community at large should benefit from and build upon the knowledge produced (Zimmerman, Forlizzi, & Evenson, 2007).

These criteria may be addressed through annotated portfolios, composed by a designer to explain and situate their contribution. Other scholars propose an additional criterion for evaluating a research through design contribution: the critical reception of objects by others in the design community (Bardzell, Bardzell, & Hansen, 2015). Like extensibility, this criterion focuses on knowledge gains outside of the creator; however, while Zimmerman, Forlizzi and Evenson focus on the role of annotated portfolios in extensibility, Bardzell, Bardzell and Hansen believe that knowledge can be found in encounters with the artifact alone (Bardzell, Bardzell, & Hansen, 2015; Zimmerman, Forlizzi & Evenson, 2007).

Research through design follows an iterative process similar to user-centered design (Zimmerman & Forlizzi, 2008). Six distinct phases of the design process are:

- Research teams *define* a problem by selecting the focus, or the motivation, for a particular design exercise.
- Researchers *discover* by developing data collection plans, and collecting data.
- Researchers *synthesize* data, creating models that identify the relevant components in a problem space, and defining key opportunities.
- Researchers *generate* solutions by sketching various problem framings, iteratively prototyping, and critiquing evolving designs.
- Designers and developers *refine* evolving designs based on feedback.
- Researchers *reflect* on the problem framing, the achievement of a preferred state, the design process at large, and the resulting prototypes.

This iterative process unfolds in a number of ways. A designer may run through all six processes sequentially, numerous times. Designers may also iterate on a few phases before moving onward through the cycle (Zimmerman & Forlizzi, 2008).

A few alternatives to this conceptualization are proposed. Banbille & Halskov discuss four stages of research through design: *Coupling design and research interests* before an initial point of departure; *interweaving design and research interests* through initial development; *focusing on design interests* during production or development; and, *focusing on research interests* during evaluation of the finished product (Banbille & Halskov, 2012). While this is helpful for understanding the relationship between research and design activities, Zimmerman and Forlizzi's emphasis on holistic process is a better fit for understanding collaborative research through design with Floracaching (Zimmerman & Forlizzi, 2008).

With this background in mind, the present study applies CRtD, a type of research through design, to explore how a university community may be motivated to make citizen science contributions through Floracaching. This research followed the process outlined by Zimmerman and Forlizzi (2008). This research produced artifacts in the form of design proposals, which Pierce characterizes as potential but incomplete illustrations of a design idea (Pierce, 2014). Annotated portfolios take the form of this dissertation in its entirety; as a series of more specific framing constructs included in Chapter 7; and, as peer-reviewed publications (Zimmerman, 2008).

This contribution is expected to produce intermediate knowledge in the form of a new methodology, collaborative research through design, and in the form of recommendations for co-designing with a university community. This research also contributes knowledge in line with Gaver's framing of scientific research programs (Gaver, 2012). For example, this work will advance research on motivation in citizen science by exploring how gamification could be designed to motivate a new group of citizen science volunteers. This research will be evaluated with established criteria for evaluating research through design (Zimmerman, Forlizzi, & Evenson, 2007).

Cooperative design

The following sections introduce three related forms of cooperative design—participatory design, contextual design, and collaborative inquiry. In traditional user-centered designs, users often act as consultants; these three perspectives extend this role by inviting users to contribute to interactive systems as designers. This introduction is not a comprehensive review, but is offered to give a sense of the traditions and dialogues associated with different perspectives, and to inform the working definition of collaborative research through design presented at the conclusion of this chapter.

Note that some research through design is conducted using participatory methodologies, while other RtD is not. The Maypole project, which helped imagine the future of SMS messaging and demonstrated the importance of prototyping social experience, was conducted as participatory research through design (as described in Zimmerman, Stolterman, & Forlizzi, 2010). However, RtD conducted to create a reverse alarm clock was conducted with user-centered, but not explicitly cooperative, techniques (Ozenc et al., 2007).

Participatory design, contextual design, and cooperative inquiry are all forms of cooperative design or co-design, defined as "collective creativity as it is applied across the whole spectrum of the design process." (Sanders & Strappers, 2008, p. 6). Many forms of cooperative design draw on similar techniques, such as contextual or ethnographic interviews (Holtzblatt, Wendell, & Wood, 2005; Mueller & Druin, 2010). However, the different forms of cooperative design are unique in regard to their origins and theoretical or ethical perspectives. For example, participatory design is traced to Scandinavian researchers hoping to democratize work relationships (Spinuzzi, 2005), while contextual design was developed based on the need to understand organizational settings in the United States (Holtzblatt, Wendell, & Wood, 2005). The theoretical and ethical perspective of CRtD is explored later on.

Participatory design (PD) is "a set of theories, practices, and studies related to end-users as full participants in activities leading to software and hardware computer products and computer-based activities". (Muller & Druin, 2010, p.3). While the practice of participatory design is diverse, researchers and practitioners hold a common goal of deeply involving users in the design process. This goal is often framed as ethical or political, as in the participatory design that arose from Scandinavian movements for workplace democracy in the 1970s (described in Muller & Kuhn, 1993; Schuler & Namioka, 1993). In these cases, workers are empowered through valuation of their unique knowledge. Workers and designers alike benefit from mutual learning. Some recent implementations of participatory design honor this legacy by emphasizing community or social justice concerns (such as the capacity building undertaken by Merkel et al., 2004).

In addition to democratic empowerment, a second goal of participatory design is to make users' tacit knowledge explicit (Spinuzzi, 2005). This tacit knowledge is blended with the expertise of professional researchers and designers to create new tools and technologies that fit the needs of users in a specific context. Because of the ability to tease out tacit knowledge, participatory design is touted as a method for conducting user research in complex situations, such as those with high levels of context dependence, conflicting stakeholders, or unfamiliar user groups (Muller & Druin, 2010).

There are numerous criticisms of participatory design. Some believe this method has moved too far from its roots, by prioritizing the needs of managers or other authorities, and de-emphasizing goals of equality and democracy (Muller & Druin, 2010). In addition, the successes and failures of the method may be difficult to evaluate, especially given that few comparative studies of participatory and non-participatory methods are conducted.

To the second criticism, Spinuzzi recommends three criteria for evaluating participatory design contributions, which focus as much on outcomes of the process as the value of the design produced (Spinuzzi, 2005). First, participatory design should improve quality of life for users. Improvements may be found in democratic empowerment, such as the acknowledgement of a legitimate voice, or functional empowerment, such as the provision of a new tool. Second, participatory design should involve collaborative development. Ideally, participation will extend beyond a single phase of the research cycle such as data gathering, to also include stages such as data analysis or generative prototyping. This leads to the third criterion, iteration; as a process, participatory design should allow users to build on the work of others, including designers and other users (Spinuzzi, 2005).

Contextual design (CD) is a “customer centered design process” that unfolds in business settings (Holtzblatt, Wendell, & Wood, 2005, p. 20). Contextual design advances four main principles: context, partnership, interpretation, and focus (Preece, Sharp, & Rogers, 2015). Context designates the importance of understanding the affordances and limitations of the setting where a task is performed, traditionally a business environment. Partnership suggests that researchers and participants alike are responsible for collecting and interpreting data. Interpretation describes how design research can produce actionable (e.g., implementable) insights. And, focus suggests that data collection should align with a researcher’s goals (Preece, Sharp, & Rogers, 2015). While partnership does suggest an ethical dimension of involvement, this is less important than in participatory design. Instead, emphasis is placed on designing usable products, and success measured by utility and adoption.

The application of contextual design is flexible, drawing on different techniques based on changing research goals and settings. For example, the full contextual design framework involves numerous steps including: contextual inquiry interviews; interpretation sessions and work modeling; model consolidation and affinity diagram building; personas; visioning; storyboarding; user environment design; paper prototypes; and, mock up interviews (Holtzblatt, Wendell, & Wood, 2005). These steps may be modified, abbreviated, or omitted in respect to real-world constraints such as the time and budget allocated to user research.

A core component of CD—and one that is rarely left out—is the contextual inquiry interview. This is described as “a combination of observation, discussion, and reconstruction of past events” (Preece, Sharp, & Rogers, 2015, p. 368). Contextual inquiry interviews follow the master-apprentice model, where the researcher acts as an apprentice who learns from the master user about tasks situated within a specific context of use. By reversing traditional power dynamics, these interviews support the partnership principle of contextual design (Holtzblatt, Wendell, & Wood, 2005).

Contextual design has a number of limitations. For example, researchers in some companies may have difficulty securing resources to support contextual design, such as money for travel to research sites (Holtzblatt, Wendell, & Wood, 2005). In addition, contextual design may need to be modified for use outside of traditional business settings. One modification to contextual design is cooperative inquiry.

Cooperative inquiry (CI) is a method for developing new technologies for children (Druin, 1999; Druin, 2002; Guha, Druin, & Fails, 2012). Generally, researchers who practice cooperative inquiry believe that children should be involved in design as full partners, as descried below (Druin, 2002). Cooperative inquiry is rooted in the belief that children are historically under-represented in the design process, to the detriment of technologies that target young users. This method also emphasizes learning through design activities, adding a dimension of value that echoes empowerment in participatory design (Druin, 1999). However, as with contextual design the emphasis is placed on creating useful technologies in complicated problem spaces over democratic empowerment (Druin, 1999; Druin, 2012; Guha, Druin, & Fails, 2012).

Cooperative inquiry offers various techniques for involving children in design, which have been developed over time (Guha, Druin, & Fails, 2012). Early iterations of cooperative inquiry borrowed heavily from participatory design and contextual design (Druin, 1999; Druin, 2002). For example, the prototyping sessions common in participatory design were customized for cooperative inquiry by including art supplies such as markers, string, clay, and glue to support low-fidelity prototyping (collections described as “bags of stuff”: Yip, Clegg, Bonsignore, Gelderblom, Rhodes, & Druin, 2013). Similarly, the contextual inquiry interviews of contextual design (Holtzblatt, Wendell, & Wood, 2005) were modified for CI by emphasizing visual note taking for children acting as observers (Druin, 2002).

Recent work with CI has refined existing methods (Guha, Druin, & Fails, 2012), and examined the differences in target user groups such as design experts and domain experts (Yip et al., 2013). As a method, collaborative inquiry is suited for children in diverse age cohorts. However, specific techniques may be better for younger or older children (Guha, Druin, & Fails, 2012).

Collaborative research through design with Floracaching is a cooperative methodology that seeks to actively engage users in designing a new technology. Like cooperative inquiry, it seeks to modify existing techniques for a specific user group; like contextual design, it emphasizes a unique context. Criteria used to evaluate participatory design may be applied to collaborative research through design to position this new form of cooperative design in relation to other applications of cooperative design, as will be described later on.

Role definition in cooperative design

There are numerous entry points to categorizing participant involvement in cooperative design. Some practitioners believe that users should drive the entire process of design and implementation. For example, researchers with the Civic Network project consider their value as capacity building: they want "participants to take control of the process in terms of both directing what should be done and maintaining the resulting technology... the goal is to gradually fade away." (Merkel et al., 2004, p.8). Researchers adopted this perspective to embrace an ethic of community agency, and also to support sustainability by placing maintenance in the hands of the community.

Other researchers and practitioners believe that professional designers are responsible for leading the design process. This may be a matter of practicality, as researchers and practitioners typically have a research question (e.g., how co-design can engage primary school learners; Dodero, Gennari, Melonio, & Torello, 2014) or a design problem (e.g., how to build a new library; Somerville & Collins, 2008) in mind when beginning a project. Professional researchers and designers also have expertise, gained through their professional training and experience, that communities may lack (Merkel et al., 2004).

Within professional-led cooperative design, there is a spectrum of roles that designers, researchers, and participants play. The traditional design process places researchers in the role of translators who explain user needs to designers and developers.

In contrast, in co-design researchers become facilitators who support user creativity and guide the articulation of design ideas. For example, Druin identifies four roles that children can play in the process of design (Druin, 2002):

- *User*: the child uses a technology, while adult partners seek to understand how and why that technology is used.
- *Tester*: the child tests a technology prototyped by adult design partners.
- *Informant*: the child participates in the adult-led design process at various stages (e.g., ideation; prototype refinement).
- *Design partner*: the child is considered an equal partner in the design process, and is involved by adults at all (or almost all) stages of design.

Others discuss roles in terms of participation in the design process (or not). Researchers sharing the dialogue labs methodology suggest that co-design begins with problem definition, and early research and analysis that leads to specifications; evolves through ideating, generating concepts, and prototypes; and, finishes with evaluation and implementation (Luccero, Vaajakallio, & Dalsgaard, 2012). Outside of this cycle, dialogue labs relies on traditional user-centered design methodologies.

The questions of *how* and *when* to involve users design are linked to the question of *who* to involve. Given a population of interest, cooperative researchers may draw on the same participants for multiple iterations, or seek new co-designers at each subsequent stage of design. Some practitioners believe that “the ideal situation is a continual relationship that is marked by iterative meetings.” (Sanders, Brandt, & Binder, 2010, p.

198). Designing with the same users offers practical experience that may lead to better designs. Returning to the same group also supports buy-in for the final artifact produced.

Others engage different groups of participants in separate co-design sessions (Demirbilek & Demirkan, 2004; Wadley, Bumpus, & Green, 2014). These practitioners argue that relying on the same group of co-designers may constrain creativity by failing to bring in conflicting viewpoints. Conducting multiple focus groups with different participants also supports a form of triangulation, by allowing researchers to evaluate whether different co-designers generate similar ideas.

Researchers disagree on the best size for co-design groups, and some published studies fail to report on the number of participants (e.g., Somerville & Collins, 2008; Pommeranz, Ulgen, & Junker, 2012; Wadley, Bumpus, & Green, 2014). Many note that the number of users should match the techniques employed. The number of available researchers also determines group size. For example, researchers who conduct cooperative design with children may seek a 1:1 ratio of children to facilitators, so that a design team of 12 individuals will consist of 6 adults and 6 children (Druin, 1999). Previous research with Floracaching was conducted with groups of small to moderate size (7-14 participants) and large size (20 participants), with 1-2 facilitators (Bowser et al., 2013a; Bowser et al., 2013b). Generally, our research team found both sizes to be adequate, though smaller groups were better for design-focused activities, and larger groups preferable for evaluation-focused activities. We also found that co-design workshops were most effective when multiple researchers or facilitators were present, regardless of size.

CRtD with Floracaching was led by a team of researchers. However, this methodology seeks to involve co-designers in almost all phases of the design process in line with Druin's design partners (Druin, 2002). Because we are interested in designing for the broad population of a university community, different phases of design include different participants. A group size of 6-10 was targeted for each of the co-design workshops, which previous research with Floracaching suggests is an appropriate number (Bowser et al., 2013b).

Common techniques in cooperative design

A number of techniques (e.g., distinct processes designed to further a research goal as part of a larger method) are used in cooperative design. These include conceptual modeling, focus groups, future workshops, interviews, language analysis, literature study, observation, or video recording (Kensing & Muck Madsen, 1993); dramas, design games, cards, improvisations, high- and low- fidelity prototypes, or stories (Mueller & Druin, 2010); collages, diaries, improvisation, or storyboarding (Sanders, Brandt, & Binder, 2010); and, contextual interviews, design artifacts, environmental mapping, or personas (Holtzblatt, Wendell, & Wood, 2005), to name a few.

Various typologies classify these techniques. Kensing and Muck-Madsen identify six types of knowledge required for successful participatory design, and map each to supporting techniques (Kensing & Muck-Madsen, 1993). Muller and Druin focus instead on describing the methods, techniques, and practices of participatory design in terms of *spaces and places* including contexts, *narrative structures* for sharing information, and *constructions* such as *design games* (Muller & Druin, 2010). Finally, Sanders and

Stappers chart the landscape of human-centered design with two axes: 1) the role of the user, and 2) whether the process is dictated by design or research interests (Sanders & Stappers, 2008).

In agreement with others (e.g., Druin, 2002), Sanders and Stappers distinguish between the traditional role of users as subjects, and the participatory role of users as partners in the design process (Sanders & Stappers, 2008). On the participatory axis, partners are involved in informing, ideating, and conceptualizing activities during the early design phases. On the user-centered axis, design activities are driven by user research methods that uncover problems to solve, or by design methods that take aesthetics as a priority.

Sanders and Stappers map participatory design as a perspective that fully embraces the user as a partner, and may vary from being led by the researcher to being led by the designer (Sanders & Stappers, 2008). Within this broad bubble, they characterize Scandinavian participatory design as research led, and generative design research (e.g., design thinking or ideating) as design led. Some specific techniques, such as contextual inquiry, are charted in their schema; others, such as focus groups, are not. It could be assumed that the degree any individual technique can be characterized as user-centered or participatory depends on its implementation- though Sanders and Stappers do not explicitly make this point (Sanders & Stappers, 2008).

Three participatory techniques for conducting research with Floracaching are presented below: observation, including observation through a contextual inquiry interview; prototyping; and, focus groups. These techniques are presented as examples of participatory design techniques that are a good fit for collaborative research through design. Other researchers may apply other techniques. However, it may be that additional techniques are applied in the same spirit as those described below— towards the participatory, rather than the user-centered, end of the spectrum (Sandres & Stappers, 2008).

People often have difficulty explaining what they do (Holtzblatt, Wendell, & Wood, 2005; Preece, Sharp, & Rogers, 2015). Direct observation offers insight into participant actions, balancing the biases inherent in self-reported methodologies such as focus groups. Observational techniques that incorporate rich forms of documentation, such as photographs, also create prompts that remind researchers of important moments during data analysis (Portigal, 2013). Taking photographs supports visual documentation but is less demanding than video, which may be unnecessarily intrusive (Druin, 1999; Holtzblatt, Wendell, & Wood, 2005). Observation can be difficult, especially when there are many interesting things to pay attention to (Preece, Sharp, & Rogers, 2015). Thus, observation is often triangulated with other methods to ensure that data collection is broad and comprehensive.

One method for conducting observation is the contextual inquiry interview (Holtzblatt, Wendell, & Wood, 2005). Contextual inquiry interviews are one-on-one conversations between a researcher and a participant situated in the context where work takes place. The goal of a contextual inquiry interview is to understand the actual practices of users, instead of simply relying on the idealized practices documented in written policies.

Sanders and Stappers categorize contextual inquiry as a user-centered but not participatory technique that is equally driven by research and design interests (Sanders & Stappers, 2008). When this technique is utilized in participatory design, it is typically applied during early stages of the design process, and conducted to offer a researcher an entry point into their users' worlds before full engagement in a co-design session (Kensing & Muck-Madsen, 1993; Lucero, Vaajakallio, & Dalsgaard, 2012; Sanders & Stappers, 2008). However, a few researchers have expanded this application by involving users in contextual inquiry as opposed to participants. For example, Druin notes that children often have a hard time explaining what they do with technology (Druin, 2002). She suggested that having adults and children alike observe users through a modified version of contextual inquiry can help design partners understand children's actual practices.

In collaborative research through design with Floracaching, contextual inquiry is applied as a participatory technique where co-designers participate as researchers conducting contextual inquiry interviews. The application of this technique is designed to give co-designers a mechanism for conducting structured observations that take into account the person using the technology and the context of use. Like traditional applications of contextual inquiry (e.g., Kensing & Muck-Madsen, 1993; Lucero, Vaajakallio, & Dalsgaard, 2012; Sanders & Stappers, 2008), one goal of the interview is to show co-designers how practices unfold in an actual real-life context. A second goal is to encourage co-designers to focus not only on their own needs, but also to consider the needs of target users, or other members of a university community.

Design artifacts are creative products of the design experience, such as prototypes. Collecting design artifacts preserves important knowledge shared by participants, and documents experiences that words do not easily capture (Holtzblatt, Wendell, & Wood, 2005). These artifacts can also aid the researcher during data analysis, elucidating rich memories in the same way as photographs (Portigal, 2013). Artifacts support data quality by providing physical evidence of what actually happened to balance more subjective forms of data collection including observation. Thus, they are valuable as stable and persistent indicators of preferences and ideas.

Some co-design participants enjoy designing prototypes. Druin notes, “we have found that there is rarely a need to teach people how to prototype, since using basic art supplies comes naturally to the youngest and oldest design partners.” (Druin, 1999, p.25). Others disagree. Sanders and Strappers identify four levels of creativity: creating, or composing innovative designs; making, or building designs with one’s own hands; adapting, or modifying existing designs; and, doing, or simply “getting something done” (Sanders & Strappers, 2008, p. 203). Researchers note that participants on the doing level may dislike independent creative expression like prototyping, or find these expressions difficult. Thus, there should be a range of options for how to involve users in design.

Interviews and focus groups are qualitative techniques for understanding research participants (Preece, Sharp, & Rogers, 2015). While these techniques are similar, interviews typically involve one researcher and one participant, while focus groups involve at least one researcher or facilitator and many participants. For this reason, focus groups support not only interactions between a single participant and a researcher or a facilitator, but also conversations between participants.

Both techniques can be thought of as "conversations with a purpose," where the researcher and participant explore an important topic in depth (Kahn & Cannell, 1957, cited by Preece, Sharp, & Rogers, 2015, p. 228). Interviews and focus groups may be unstructured, or open and exploratory conversations with no pre-determined questions; structured, where pre-determined questions are asked in a specific order; or, semi-structured, where an interviewer comes prepared with a basic script but leaves room for deviation (Preece, Sharp, & Rogers, 2015).

Both interviews and focus groups are used in cooperative design. Interviews often occur early in the design process, as researchers seek to understand a new problem space (Holtzblatt, Wendell, & Wood, 2005; Muller, Wildman, & White, 1993). In contrast, focus groups may be held later in the design process, for example at the end of a prototyping workshop (Guha, Druin, & Fails, 2012; Wadley, Bumpas, & Green, 2014). The use of focus groups in later stages of co-design encourages reflection on the designs produced, and also reflection on the process of co-design, helping researchers structure future workshops and creating a sense of co-ownership for the co-design process (Bowser et al., 2013; Mueller & Druin, 2010; Pommeranz, Ulgen, & Junker, 2012).

Both interviews and focus groups have limitations. For example, while focus groups allow individuals to voice divisive or sensitive issues in a safe environment, they may lead to group think (Preece, Sharp, & Rogers, 2015). Focus groups may also fall off topic, and thus require careful facilitation.

Observation, prototyping design artifacts, and focus group discussions are common techniques used in cooperative design. The application of each of these techniques may vary on a spectrum of user-centered to participatory. In the present study, all techniques were applied as participatory; for example, contextual inquiry interviews involved co-designers as observers as well as participants in the interview process. These techniques were also applied in ways that prioritized group consensus over individual opinions. For example, while both interviews and focus groups are common techniques in cooperative design, focus groups were selected for this study because they allow participants to converse with one another instead of exclusively with a researcher. The implementation of observation, prototyping and focus groups is described in Chapter 4.

Towards collaborative research through design

This chapter introduced the key methodological framework of research through design (RtD), where practitioners create an artifact to study the progression from a current state to a preferred state (Zimmerman, Forlizzi, and Evenson, 2007). Research through design produces an artifact and also design annotations, called annotated portfolios (Bowers, 2012). RtD may produce intermediate knowledge, which informs practice, and theoretical knowledge (Gaver, 2012; Lowgren, 2013; Zimmerman, Forlizzi, & Evenson, 2007). Research through design may be evaluated in terms of process, invention, relevance, and extensibility (Zimmerman, Forlizzi, & Evenson, 2007). This chapter also introduced three cooperative methodologies—participatory design, contextual design, and cooperative inquiry—and a number of cooperative design techniques, including observation, prototyping, and focus groups.

Given this background, the exact methodology for this study is called *collaborative research through design (CRtD).* As a type of research through design, CRtD is defined as a collaborative process that illustrates how a problem can move from its current state to a preferred state. This process is made collaborative by drawing on the creativity of researchers and also users to prototype a new technology through cooperative techniques. Through this process, a shared vision of an idealized state is articulated in design. In short, collaborative research through design (CRtD) is a way to define and solve problems through the iterative process of cooperative design.

In the present study of Floracaching, collaborative research through design will produce a collection of prototypes that illustrate how citizen science for biodiversity data collection can move from the current state of limited participation, to a preferred state where new audiences such as a university community may be motivated to contribute data to citizen science. Design annotations will be published as a set of framing constructs (Zimmerman, 2008) and longer scholarly works. Collaborative research through design is a new methodology, and demonstrating how it may be conducted is one contribution of this research.

Chapter 3: Problem space: Citizen science, Motivation, and Floracaching

Introduction

This chapter offers the background required to understand the research question, *How might a gamified mobile app for citizen science biodiversity data collection be designed to engage a place-based citizen science community*? It opens with a discussion of motivation in citizen science, and then explores how design may support motivation though gamification. This chapter also presents early research with the Floracaching app.

Motivation in citizen science

In the context of citizen science, motivation designates the reasons volunteers contribute their time and/or data to citizen science activities. The motivation of citizen science volunteers is a topic of practical importance, as projects must recruit and retain sufficient participants to meet their goals. It is also an important research topic, as understanding motivation in citizen science may contribute to a larger understanding of motivation in open participation systems, including crowdsourcing, hacking, making, and DIY communities.

Volunteers are motivated by different factors during initial and early participation (e.g., recruitment) and during extended participation (e.g., retention; Rotman et al., 2012; Rotman, 2013; Rotman et al., 2014). Key factors influencing initial participation include personal interest and self-promotion, while key factors driving sustained participation stem from interpersonal relationships (including trust, mentorship, or the reception of acknowledgement or attribution; Rotman et al., 2014).

Motivation also varies in respect to project type. Researchers studying motivation to contribute to Galaxy Zoo, a digital citizen science project, identified topical motivations related to astronomy (e.g., wonder at the *vastness* of space) and related to the Galaxy Zoo platform (e.g., *zoo*; Raddick et al., 2013). Further, motivation varies in respect to culture, as demonstrated by a comparative study of the US, India, and Costa Rica (Rotman, 2013).

Despite these variations, researchers find a number of motivations that are consistent across cultures, and/or stages of participation, and/or projects of different types. These may be mapped to seven broad categories: fun and enjoyment; learning or education; self promotion; recognition and acknowledgment; interpersonal relationships; supporting scientific research; and, supporting community goals. Of course, many of these categories could be aggregated up, further distilled, or presented in alternative schemas (e.g., intrinsic vs. extrinsic; Rotman et al., 2012).

Volunteers derive pleasure from citizen science activities. These motivations are so strong that many projects provide no explicit rewards (Wiggins & Crowston, 2015). Personal interest in a topic is one motivation expressed by citizen science volunteers (Nov, Arazy, & Anderson, 2011; Raddick et al., 2009; Rotman et al., 2012). As one Galaxy Zoo volunteer explained, *"I enjoy astronomy quite a bit…so obviously, seeing a project focused on galaxy classification garnered my interest.*" (Raddick et al., 2009, p. 11).

In some cases, citizen science adds value to an existing hobby. For example, eBird offers participants access to individualized “life lists” and visualization tools to incentivize data sharing (Sullivan et al., 2014). Sometimes, technologies or interfaces are motivating in themselves (Preece et al., 2014; Reed, Raddick, Lardner, & Carney, 2012). However, technology can be de-motivating if accessibility or usability issues cause disenchantment (Rotman et al., 2014; Wiggins, 2013).

Volunteers are motivated to learn (Raddick et al., 2009). They may approach a website such as the Encyclopedia of Life with a specific question in mind (Rotman et al., 2012). Volunteers also enjoy the gradual knowledge gains that accompany long-term participation (Haywood, 2014a). Typically, learning unfolds in informal settings, though citizen science also takes place in formal education (Oberhauser & LeBuhn, 2012) or in blended settings (Clegg & Kolodner, 2014). Note that in citizen science, learning is considered both a motivation, or a reason to participate, and an outcome, or an individual and social benefit to participation (Shirk et al., 2012).

Some volunteers consider citizen science a means of self-promotion, or a method for advancing one’s self interest. Those considering a career in science may view citizen science as a point of entry, or a “*career building step*” (Rotman et al., 2012). Here, participation allows volunteers to demonstrate their skills while expanding their networks.

Recognition and acknowledgement are strategies that encourage volunteers to keep contributing to a project over time (e.g., strategies to support retention). In a survey of 77 citizen science projects, Wiggins & Crowston found that public acknowledgement and volunteer appreciation events were the most common mechanisms projects used to reward their volunteers (Wiggins & Crowston, 2015). For some volunteers, a simple public expression of gratitude is sufficient: "*Just a name and this X and that Y was contributed by this or that person*" (Rotman et al., 2014, p. 116). Acknowledgement is also granted through more formal mechanisms, such as co-authorship (Khatib et al., 2011).

Citizen science volunteers value their relationships with practitioners, and their relationships with other volunteers (Rotman et al., 2012). Perceptions of relational closeness between practitioners and volunteers can be achieved through recognition, and through communication in general. Note that perceptions of relational closeness can also be met through distributed socialization supported by information and communications technology (ICT) including conference calls, email lists, or social media (Wiggins & Crowston, 2015)

An interest in science is often accompanied by the desire to contribute to scientific research (Raddick et al., 2011). However, while this motivation is intuitively one of the most important, it may be over-stated (e.g. Han et al., 2011). In early years, eBird unsuccessfully tried to motivate participation by emphasizing contribution to scientific research. Only by bringing in personally motivating tools did the project realize its current scope (Chu, Leonard, & Stevenson, 2012). However, while supporting scientific research is unlikely to function as an initial motivation for participating, it may become important over time (Rotman et al., 2012).

Some researchers disambiguate community goals from scientific goals. Volunteers in the European Union (EU) are often motivated to support a local community, a regional community, or a national community, by advocating for changes to public policy (Haklay, 2015). In the United States, grassroots projects motivated by local concerns may collaborate with formal authorities to enact meaningful change (e.g., The Clean Air Coalition of Western New York[10]).

Some researchers conflate the desire to support common or community goals with other motivations, such as supporting scientific research. Nov, Arazy, & Anderson highlight "collective motives" as a key driver, and discuss these both in terms of the importance attributed to scientific goals, and adherence to a shared ideology (Nov, Arazy, & Anderson, 2011). Similarly, Reed et al.'s "helping" designates both explicit support of scientific research and more general obligations (*"I want to make the world a better place"*; Reed et al., 2013). Other researchers avoid distinguishing between different types of collectivist motivations, for example by collapsing them all into a single category (Rotman, 2013).

The motivations described above are direct in the sense that they are considered basic reasons for participating in citizen science. In addition to these, researchers have identified a number of indirect motivations for participation. These mechanisms, which include feedback and gamification, function by activating a direct motivation.

For example, feedback overlaps with a number of the primary motivations listed above. It may lead to personal enjoyment by helping volunteers get better at something

[10] http://www.cacwny.org/. Accessed March 2015.

they care about. Feedback may support perceptions of closeness in interpersonal relationships if feedback comes from scientists. And, feedback may increase volunteers' perceptions that they are contributing to scientific research (Rotman et al., 2012).

Like feedback, gamification, or the use of elements of game design in non-game contexts, is effective when linked to a primary motivation.

The use of gamification in citizen science

There are a number of games, gamified apps, or prototypes designed to support motivation in citizen science. These include Foldit (Khatib et al., 2011); Eyewire (Iacovides et al., 2014); Tiger Nation (Mason, Michalakidis, & Krause, 2012); and, Happy Moths and Forgotten Island (Crowston & Prestopnik, 2012; Prestopnik & Crowston, 2013; Prestopnik, Crowston, & Wang, 2014), among others. This section briefly reviews Foldit and Eyewire[11], two citizen science games. Three gamified citizen science projects—Tiger Nation, Citizen Sort, and Old Weather—are explored in greater depth. This background is offered to illustrate how others design to take advantage of the motivational pull of game elements in a citizen science context.

Foldit is a virtual game that trains volunteers in the art and science of protein folding. Foldit was designed to contribute to scientific research in genetics, microbiology, and medicine by identifying new protein algorithms. Players have indeed made significant contributions to these fields, for example by identifying a protein responsible for the reproduction of PIV (HIV in primates; Khatib et al., 2011). Researchers also

[11] https://eyewire.org/signup. Accessed March 2015.

designed Foldit to "generate the evidence needed to prove that human protein folders can be more effective than computers at certain aspects of protein structure prediction."[12]

Motivations of 48 Foldit players were assessed through an informal survey (Cooper et al., 2010). Researchers identified four main motivations: purpose, achievement, social, and immersion. For Foldit, the largest number of players were motivated by scientific purpose, namely "*to crack the protein folding code for science*." Immersion *("It's fun and relaxing")* and achievement (*"to get a higher score than the next player")* were also important. Social motivations were less important overall.

Eyewire is a citizen science game where volunteers map the 3D structure of neurons.[13] Researchers from the University College London conducted interviews with four volunteers from Foldit, and four volunteers from Eyewire (Iacovides, Jennet, Cornish-Trestrail, & Cox, 2014). They found that players were initially motivated by an interest in science, while game elements such as points or leaderboards supported continued engagement. Specifically, these elements were "viewed as features that extend a particular session, e.g. *'the points don't motivate me but they do drive me further'*" (Iacovides et al., 2014, p. 1104). Players were also motivated to continue participating if they received feedback from scientists, or if they socialized with others through team work, forums, or chat rooms.

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[12] See: http://fold.it/portal/info/faq. Accessed April 2014.

[13] https://eyewire.org/signup. Accessed March 2015.

Tiger Nation[14] was created to promote the preservation of wild tigers through awareness and engagement with a gamified website. Some Tiger Nation users upload photographs of wild tigers, like those taken by tourists visiting wildlife refuges in India (Mason, Michalakidis, & Krause, 2012). As these photographs are uploaded, embedded metadata reveals information about a tiger's location that is added to a virtual map. An algorithm compares new photographs with those already in the database, using computer vision to propose "matches" that may represent different photographs of the same tiger.

Other Tiger Nation users visit the website and play a match game, where they confirm whether matched photos depict the same animal. Note that a similar approach is employed in Odd Leaf Out, a citizen science game where human expertise is combined with computer vision to support leaf matching and identification (Hansen, et al., 2011), and by Happy Moths, a part of the Citizen Sort Suite (Prestopnik & Crowston, 2012). Tiger Nation was described as "open beta" in 2012. Researchers suggest that game elements function as a motivating force, but do not investigate this claim in depth (Mason, Michalakidis, & Krause, 2012).

Citizen Sort[15] is a research project where volunteers classify images of different species, such as moths or sharks (Crowston & Prestopnik, 2013; Prestopnik & Crowston, 2012). Three distinct applications are part of the Citizen Sort Suite. Hunt and Gather is a "true" classification tool, lacking gamified elements. Happy Moths, a gamified classification tool, incorporates points and a game like interface. Forgotten Island is a

[14] See: https://www.tigernation.org. Accessed February 2014.
[15] See: http://www.citizensort.org. Accessed April 2014.

fully immersive game, where players classify images as part of a larger narrative. These applications were designed around two research questions: whether and to what extent game elements motivate classification tasks, and whether game elements have a detrimental effect on data quality (Crowston & Prestopnik, 2013; Prestopnik, Crowston & Wang, 2014).

Citizen Sort was evaluated through a study with 323 participants run on Amazon Mechanical Turk (Crowston & Prestopnik, 2012). Researchers found that a large number of participants (49 of 97) would play the game even if they weren't paid to do so (33 of 97 would not); this validated the premise that gamification can motivate contributions to citizen science. Researchers identified specific motivational factors including "how much fun," "interested in nature activities," "learn about months," and "compete with friends" during earlier studies (Crowston & Prestopnik, 2012).

Old Weather, a part of the Zooniverse suite, is a citizen science project where volunteers transcribe handwritten 19th century ship logs to digitize weather data for climate change modeling. Old Weather is gamified primarily through a ranking system with three levels for each volunteer: Cadet, Lieutenant, and Captain. Volunteers are placed into "ships" of 100 people; only the top contributor in each ship earns the role of Captain. To examine player motivation, researchers implemented a qualitative survey with 545 respondents and conducted 18 follow-up interviews (Eveleigh et al., 2013).

On the positive side, volunteers believed that the ranking system validated their efforts and helped them track personal projects. Respondents specifically found competition appealing: the title of the paper, "I want to be a captain! I want be a captain!"

is derived from the expression of one appreciative volunteer. Narrative immersion was

Table 2

Motivations for engaging in in citizen science or playing gamified citizen science apps.

	Engaging in non-gamified citizen science projects	Playing citizen science games or gamified apps
Fun and enjoyment	eBird facilitates enjoyment of birding (Sullivan et al., 2014)	"How much fun" (Crowston & Prestopnik, 2012)
Learning or education	About a topic of interest (Rotman et al., 2012)	Learn about moths (Crowston & Prestopnik, 2012)
Self-promotion	A career building step (Rotman et al., 2012)	Not found (though implicit in some game mechanics)
Recognition and acknowledgement	The most common reward (Wiggins & Crowston, 2015)	Not found (though implicit in some game mechanics)
Interpersonal relationships	Key for long-term volunteers (Eveleigh et al., 2014)	Social motivations (Cooper et al., 2009)
Supporting scientific research	"Crack the protein folding code" (Khatib et al., 2011)	Interest in science (Iacovides et al., 2014)
Supporting community goals	Through policy change (Haklay, 2015)	Not found
Feedback	Increases number of contributions (He et al., 2014)	Through game elements such as points (Iacovides et al., 2014)
Game elements/ experience	Generally not applicable (though competition is noted by eBird researchers; Sullivan et al., 2012)	"I want to be a captain!" (Eveleigh et al., 2013) [16]

also compelling—particularly because the "story" contained in arctic ship logs is real.

[16] Note that competition may also be de-motivating (Eveleigh et al., 2014)

Other users found the ranking system de-motivating, especially if becoming a Captain felt like a “distant competition they had no hope of reaching” (Eveleigh et al., 2014). Similarly, volunteers who achieved Captain status often felt pressured to retain their rank. And some players disliked that the system seemed designed to support quantity over quality, like by encouraging volunteers to submit more but less detailed contributions, or argued that the ranking system trivialized research objectives.

This review highlights motivations for participating in citizen science, and explores work on game design and gamification in citizen science. Primary motivations to contribute to citizen science in general, and to play citizen science games or gamified apps, are summarized in Table 2. Note that there is significant overlap, especially in regard to fun and enjoyment, learning or education, interpersonal relationships, and feedback. Based on these findings, it may be expected that Floracaching players will share motivations with players of other gamified apps. Early findings on the motivations of Floracaching volunteers are discussed later in this chapter.

Geocaching games

Geocaching[17] is a location-based game that unfolds through the pursuit of geocaches, which are small waterproof containers that may be hidden anywhere in the world (see Figure 2, left). The game is designed so that locations of geocaches vary—caches are hidden in natural settings, such as under a tree on a hiking trail, and in urban environments, such as under a park bench. Most geocaches are located on a virtual map, accessible through the Geocaching website and also through mobile apps (some

[17] https://www.geocaching.com/play. Accessed March 2015.

geocaches, such as mystery caches, may be hidden[18]). Once a player locates a geocache, they “check in” to document their successful find. Checking in involves signing a logbook, typically a small notebook stored inside the geocache. Players track the caches

Figure 2. A geocache and a floracache. Photo of the geocache by i_am_jim. CC BY-SA 3.0, via Wikimedia Commons. Photo of the Floracache is the author’s own.

they visit through the Geocaching website. Players may also create new geocaches for others to find.

Geocaching players are motivated by a number of factors. Some players characterize Geocaching as “social walking,” noting that the process of finding caches motivates them to spend time outdoors, and exercise with others (O’Hara, 2008). Other salient motivations include discovering and exploring new places, collecting different caches through checking in, and competing with peers to visit the most geocaches.

A few location-based apps follow the Geocaching model in citizen science. One group of researchers at iNaturalist and the California Academy of Sciences implemented

[18] https://www.geocaching.com/about/cache_types. Accessed March 2015.

a location-based Biocaching app to support data validation (Johnson & Yager, 2015). Volunteers use Biocaching to view observations of different species submitted by previous volunteers in nearby locations, and are encouraged to return to these locations to submit duplicate observations. A second group at the University of Calgary created ScienceCaching to explore how geocaching principles can support citizen science (Dunlap, Tang, & Greenberg, 2015). These researchers focused primarily on investigating data collection, validation, training, and volunteer coordination. Neither Biocaching nor ScienceCaching include gamification in any significant way. Floracaching does use gamification, as described below.

Early research with Floracaching

As in geocaching, Floracaching players use a map to find and visit different caches. However, in Floracaching caches are not physical containers, but living plants (see Figure 2, right). There are two core activities in Floracaching: creating caches, and checking into caches. These tasks are core in the sense that they are necessary for the app to achieve its goal of collecting plant phenology data. Other features and functions, including those implemented through gamification, build off the core activities of creating and checking in.

Early research with Floracaching built a strong foundation for the present study (figure 3). The author and her research team began designing Floracaching in 2011. The app was created as part of a larger project, "to develop and test evolving theories for designing socially intelligent systems in which enthusiasts and scientists partner with technology to collect and process the data needed for large scale observation-driven science." (Preece, Hansen, Jacobs, & Parr, 2010, p.1). Specific research questions asked, *How can a socially intelligent system leverage human effort to data collection and*

Figure 3. Early research with Floracaching. This includes the PLACE trials (Bowser et al., 2013b; Bowser et al., 2014) and early classroom evaluations (Bowser et al., 2013a; Bowser et al, 2014).

classification? and, *What will motivate enthusiasts and experts to contribute data?* (Preece, Hansen, Jacobs, & Parr, 2010, p.3). Within this project, the role of Floracaching was to help to understand and develop "theory-based 'design levers' that motivate enthusiasts and scientists to participate in productive ways" (Preece, Hansen, Jacobs, & Parr, 2010, p.11). In other words, Floracaching was initiated to investigate how the process of design research could shed light on the motivations of citizen science volunteers.

Our research team began prototyping Floracaching in 2011 and 2012. These efforts, which we refer to as the PLACE trials, are documented in Bowser et al. (2013b).

Initial prototyping was done during six co-design sessions held at the University of Maryland (UMD) and Brigham Young University (BYU) (Bowser et al., 2013b). Like Prestopnik & Crowston (2012), our team initially identified "gamers," or game and technology enthusiasts, as a potential new group of citizen science volunteers (Bowser, et al., 2014). We recruited participants from two user groups. First, plant experts and enthusiasts were recruited as proxy for citizen science volunteers. Second, game and technology enthusiasts composed our hypothetical group of new citizen science volunteers. Overall, 58 co-designers helped prototyping the Floracaching app, including 22 plant experts and 36 game or technology enthusiasts (Bowser et al., 2013b).

Participants in these sessions used evolving low-fidelity prototypes of Floracaching (Figure 3: Screens 1-2). The goals of these sessions were to investigate a methodology for prototyping low-fidelity location-based apps and games (named PLACE: Bowser et al., 2013b) and to understand the potential motivations of Floracaching users.

Each session began with a short orientation where facilitators introduced Floracaching and described the participants' role as co-designers. The bulk of the sessions were composed of free play, where participants completed activities from a pre-determined list based on personal interest. Following each co-design session, participants were invited to take an optional survey and participate in a focus group.[19]

[19] Note that one important difference between the PLACE sessions and later research, is that participants were later asked to conduct their own user research and also to prototype new designs. The differences between the PLACE sessions and later research are discussed in Chapter 7.

First, the PLACE sessions helped the research team understand how a collaborative approach to prototyping Floracaching could be effective. We identified six principles for prototyping location-based apps and games (Bowser et al., 2013b):

- *Start small and scale up the fidelity*. By iterating through six co-design sessions, we were able to incorporate feedback from early sessions into the prototype used by later co-design participants.
- *Treat participants as co-designers*. This led participants to extrapolate on the experiences of others, and offer creative suggestions for improving the app that moved beyond simple likes and dislikes.
- *Test in a representative space*. Understanding how participants would use the app in their daily lives helped us to make better designs, for example by creating notifications to highlight nearby caches.
- *Focus on activities more than interfaces*. Asking participants to focus on activities helped us understand the underlying motivations for using Floracaching.
- *Represent authentic social experience*. In real life, recruitment to social media is a continuous process instead of a one-time effort. Allowing participants to join in the middle of longer testing cycles helped show a realistic pattern of adoption.
- *Represent time authentically*. We learned that participants are unlikely to use Floracaching every day. But, they may spontaneously use the app during weekdays, or go on planned excursions during evenings and weekends.

Research also revealed six potential motivations of Floracaching users: discovery, nature, education, social, recognition, and science. *Discovery*, characterized as the desire to find plants, go on treasure hunts, or explore one's environment, was a key motivation for both plant experts and game and technology enthusiasts. Participants enjoyed the *"treasure hunt feel"* and opportunities to find *"something unique or visit a unique area."* Both groups were similarly inspired by *nature*, a motivation defined as the desire to be in nature and experience the outdoors. Users mentioned *"viewing beautiful parts of nature"* and *"being in the forest on a nice, sunny day."*

Education, or the desire to learn about plants, was a third motivation. Players from both user groups wanted to *"find out information about plants"* or to "*increase my ability to identify plants."* Game and technology enthusiasts alike also appreciated the social nature of Floracaching, and wanted to participate with friends, family, and others. Some even considered social interaction a condition of participation: *"Today was fun, because we were all looking, but I don't think I would want to do this alone."*

Recognition via badges, rewards, and competition was not expressed as frequently as other motivations. We attribute this to the relative low-fidelity of the interface in the first four sessions: badges crudely drawn on post-it notes are not a compelling reward. Still, some participants did say that they would be motivated to use Floracaching *"If there was a way to 'win' rather than just participating."* *Scientific* motivations, including a desire to help scientists or formal educators, were voiced less frequently than other factors. But a few co-designers saw value in Floracaching *"if it meant contributing to the scientific community in a meaningful way."*

In addition to identifying general motivations, we found three tensions between plant experts and game and technology enthusiasts (Bowser et al., 2014). First, game and technology enthusiasts needed guidance while using the app. One believed it would be *"more comfortable if everyone had prompts saying 'oh you found a conifer' or 'now go ahead and do this or that.'"* In contrast, plant experts wanted an autonomous user experience. Second, game and technology enthusiasts needed the app to integrate with their daily activities, or have personal value: *"I'm not going to drive an hour just to see if some plant bloomed."* Plant experts believed the app facilitated their existing hobbies, such as "*viewing beautiful plants.*"

Third, Game and technology enthusiasts enjoyed gamification, and wanted the app to be *"more like a game with badges, achievements, etc."* Broadly, they enjoyed "*competition, with my friends or with a larger community, perhaps for a prize.*" In contrast, plant enthusiast wanted to either opt out of competition, or compete on meaningful metrics such as "*accurately keyed specimens.*" Finally, we found that out of six sessions not a single plant enthusiast indicated that gamification would prevent them from using the app. Instead, these users suggested improvements to gamification, or ignored it entirely.

There were two types of lessons learned from the PLACE trials. First, our research team articulated PLACE as a scalable approach to prototyping location-based games and apps (Bowser et al., 2013b). This helped seed the methodology of collaborative research through design by showing the effectiveness of iteration, the value of a collaborative design approach, and the potential for design activities to answer research questions. We also began to understand the importance of context, including the geographic context, social context, and temporal context of use.

Second, our team began to understand what might motivate different user groups:

- In general, Floracaching users are motivated by discovery, nature, education, socialization, recognition, and a desire to contribute to science.
- Our two user groups, plant experts and enthusiast (proxy for current citizen scientist volunteers) and game and technology enthusiasts (proxy for new citizen science volunteers) experienced the app differently. Specifically, plant experts wanted an autonomous experience that supported their hobbies, and disliked meaningless competition; game and technology enthusiasts desired a guided, game-like experience that fit neatly within their lives.
- Despite these differences, gamification does not prevent plant experts and enthusiasts from participating. Because of this finding, we decided to focus our subsequent efforts on designing for new citizen science volunteers.

The PLACE Sessions allowed us to implement a high-fidelity prototype of Floracaching (Figure 3, screen 3). Using this prototype, we conducted research with millennial college students at the University of Maryland in early 2013 (Bowser et al., 2013a). These students evaluated Floracaching in a classroom setting; these sessions, are referred to as “early classroom evaluations.” During this research, we wanted to refine our first high-fidelity prototype of Floracaching by learning more about player motivations. Hoping that this would be the final version of Floracaching, we were less focused on improving our prototyping methodology.

We evaluated this version of Floracaching with a new target group of millennial college students. The first evaluation, with 71 students, was conducted as the culminating activity of a four-week unit on citizen science taken as part of a course on Economics, Technology, and the Environment. The second evaluation, with 90 students, was a stand-alone activity. Students were asked to evaluate an early prototype of Florachacing, and suggest how to improve the app in terms of both interface and content. As with the later PLACE sessions, this evaluation consisted of a brief introduction to Floracaching and a guided introductory activity followed by a period free engagement (Bowser et al., 2013a). Participants contributed to a brief group discussion, and completed a short survey.

Understanding the potential motivations of target users is important for building technologies that will be adopted and used. Evaluating Floracaching with millennials shed additional light on the motivations of a new group of citizen science volunteers.

First, our team learned that participants were motivated by three distinct forms of fun: creativity, exploration of a local environment, and relaxation. For example, noting a common theme across all his favorite activities, one participant wrote, *"They all involve being able to… create a physical result. It allows for the ability to create something as well as merely observing native flora."*

Participants also expressed a desire for discovery, which was almost always associated with locality (*"Why not appreciate native flora from your area?"),* or related concepts such as seasonality *("I think Cherry Blossom Blitz is a great idea in April—it ensures the opportunity to go out and view a good Cherry tree blossoming during the appropriate season").* Locality was particularly salient for Maryland natives: *"taking the* *time to look and appreciate native Maryland trees is appealing. This is especially due to the fact that I'm a Marylander and lived in a rural area where trees were abundant and gave a sense of peace and home."*

On a similar note, some participants were motivated to use Floracaching to support their local community, in this case a college campus. One wrote, *"[The maple marker activity] interests me because it can help with the maintenance of the campus."* Another would be motivated *"If a project can have a big impact on campus life."*

While some users were motivated "*to learn about plants and their environments,*" this was expressed as secondary. As one participant explained, *"If there was a larger community that I could learn from, I would be more likely to use it. I have some interest, but not enough motivation to go out with a field guide and start teaching myself."* Note that for volunteers who were curious about native plants like magnolias, this motivation is linked to locality.

Some participants appreciated that the app "*contributes valuable scientific data*." As one wrote, *"I would be motivated to participate in a similar activity because it can help scientists very much.*" But following the work of (Rotman et al. 2012), participants expressed motives such as fun as primary in their early experiences Floracaching: *"The only time I would use this particular app is if it were part of a competition. I am not particularly interested in plants, so while I understand that the app is very useful, and will certainly be helpful to scientists in the field, I would probably not use it."*

Community membership designates inclusion within a larger social group, while socialization suggests interpersonal interaction. Participants motivated by community involvement would use the app to fit in with existing social circles *("If the app became popular among my peers, I'd definitely use it to fit in with the crowd")* or to join new social circles. Regarding socialization, students would use Floracaching to enhance existing relationships: *"I could make it as a peer activity- use it to spend time with a romantic partner."*

Finally, students—especially those who indicated that they were likely to use Floracaching in the future—were motivated by gamification. This included competition: *"Introducing competition to citizen science applications can have a lasting impact on the overall effectiveness of the application."* Others noted that the badges *"were a nice touch, and I think they should be expanded for future users."* Notably, this group also wanted the app to become more gamified: *"I guess if this app was made into a game more than anything I would use it more."* For these users, it is clear that gamification makes it *"much it more fun and less tedious to participate in citizen science."*

We gained additional knowledge from respondents who explained their least favorite activities. First, participants disliked activities that required knowledge they lacked, such as the ability to identify different types of plants: *"Maple Marker was unappealing because I do not believe I am knowledgeable enough with Maple trees."* Some participants were nervous about completing tasks they did not have domain knowledge for: *"I would be scared to create a new Floracache that would wind up being incorrect."* Instead, many preferred familiar actions—"*I would be hesitant in making a floracache because I wouldn't be able to properly identify the tree. I would much rather visit caches."*

We also learned that participants disliked activities that *"are time consuming."* This involves a sense of spending too much time with the app: *"being the person with the most Floracaches would most likely require a lot of time to go visit many different Floracaches, which does not really appeal to me."* This echoes our finding from the PLACE trials that Floracaching should integrate into participants' existing activities. Additionally, while participants liked viewing seasonal plants, they disliked visiting plants not at their peak: *"I would not like to have to seek out a flower that hasn't even budded yet."*

While refining our methodology was not the main focus of this study, the classroom sessions gave us the opportunity to evaluate our research techniques. The spring 2013 trial, with 71 participants, was the first time that Floracaching was used by more than 20 users at once. Unfortunately, the large number of users attempting to create accounts, login, create caches, and check in led to slow page load times that frustrated participants. Additionally, the app had difficulty recognizing location on many devices.

A few users gave up on the prototyping session. But, the majority of those experiencing technical difficulties found friends to Floracache with. While we had observed the social aspect of Floracaching during the PLACE trials, seeing multiple groups of participants together emphasized the importance of social interaction as a core aspect of gameplay. We concluded that collaborative evaluations can make Floracaching more engaging, while reducing the burdens placed on the app and the server. We also learned that large classroom discussions are not as effective as smaller focus groups for generating high-quality insights. In retrospect this is unsurprising, as most focus groups contain between three and ten participants (Preece, Sharp, & Rogers, 2015).

Regarding the motivations of a new group, millennial college students, we learned:

- Millennial college students are motivated by fun, discovery (often associated with locality or seasonality), and social motivations (including socialization and the desire to support a local community). During initial engagement with the app, these users are less motivated to support science or learn about plants.
- These users desire even more gamification than was implemented.
- These users find activities that require expertise they lack, or activities that require too much work, de-motivating.

Evaluating the Floracaching prototype with millennials also helped us improve our methods. For example, we learned to keep focus groups small, and to encourage participants to work collaboratively, both to enhance their experience and to circumvent technical difficulties.

Based on the findings from the classroom sessions, our team made a number of improvements to Floracaching. We implemented the ability to comment on the profiles of other users to support social motivations. We identified key local specimens for the two target geographies of UMD and BYU. For example, at UMD we included *Quercus Rubu* (The Scarlet Oak, DC’s official tree); *Quercus Alba* (The White Oak, Maryland’s official tree); and, *Prunus* × *cistena* (a local strain of Cherry tree), to highlight during later gamification.

In addition, through our understanding of users and review of the gamification literature we identified missions as a promising game mechanic. Implementing missions supports the need for guidance observed during the PLACE sessions, and provides scaffolding by instructing users exactly what tasks to complete, when, and how. Missions further gamify Floracaching thorough narrative and badges (Deterding, et al., 2011). Finally, missions may be valuable to citizen science practitioners. For example, a scientist researching Scarlet Oak trees could create a mission instructing volunteers to check in to these trees, and submit data through the commenting feature.

Yet, despite the promise of missions we were unsure how exactly to implement this mechanic. In addition, findings from the early classroom sessions—including the clear desire for even more gamification—suggested that another iteration could lead to an even better app. For these reasons, we decided to hold a series of workshops to invite co-designers to prototype missions and also make general improvements to Floracaching. These workshops form the basis of the present study, described in the following chapter.

As with all earlier work, one goal of these workshops was understanding player motivations in order to create better designs. With this goal in mind, the author and her research team began articulating the iterative process of designing Floracaching as a form of research through design, where the process of design may uncover knowledge about the potential motivations of people who might use a gamified app for place-based citizen science data collection. Through this articulation we once again returned our focus to the prototyping methodology itself. Drawing on the earlier success of cooperative design, we decided to investigate how a cooperative approach could be applied to RtD.

Thus, by building off earlier research, the present study asks the questions, *How can cooperative techniques be effectively integrated into the research through design methodology*? And, *How might a gamified mobile application for citizen science biodiversity data collection be designed to engage a place-based citizen science community?* The first question is addressed through exploring the collaborative research through design methodology. The second question is addressed through the product of collaborative research through design: an updated prototype of Floracaching, accompanied by a series of framing constructs.

Summary

This chapter explored key literature on the motivations of traditional citizen science volunteers, and the motivations of volunteers who engage with citizen science games or gamified apps. Following this review, early research with Floracaching was described. This research produced PLACE, a scalable approach for prototyping location-based apps and games (Bowser et al., 2013b). It also suggested a number of motivations to design and gamify Floracaching around, including: fun, discovery, education, socialization, and community. The current study builds on the PLACE methodology by describing collaborative research through design, which explores the entire iterative process of design, rather than focusing on low- and mid- fidelity prototyping (the goal of PLACE). The current study also builds on earlier investigations into the motivations of Floracaching users.

Chapter 4: Research Methods

This chapter begins by presenting the current implementation of Floracaching, which participants used, evaluated, and designed improvements for (see Figure 4, screen 4). Following this presentation, relevant roles in the research process, including designer, facilitator, and co-design participant, are defined. This is followed by a description of four co-design workshops held at the University of Maryland (UMD) and Brigham Young University (BYU) in spring 2015. Data were collected through observations, design artifacts, and focus groups, and analyzed through an inductive approach similar to grounded theory (Glaser & Strauss, 1967) and thematic analysis (Braun & Clarke, 2006). This chapter concludes with a discussion of rigor, validity, and reliability.

Figure 4. Floracaching for the current study. This chapter describes four co-design workshops conducted to improve screen 4.

The current implementation of Floracaching

As discussed in the previous chapter, there are two core activities in Floracaching: creating caches, and checking into caches. In order to check in to a Floracache, players must be located within 200 meters of that Floracache (this varies in regard to an exact phone's capabilities and wifi connectivity). While players will ideally be closer, this radius safeguards against some issues with location recognition that proved problematic during early user testing. Players may find nearby floracaches by looking on a map, or by searching through a list, and submit data through checking in. The core tasks of creating and checking in to floracaches support additional activities. One activity is commenting. Users may comment on caches through the process of creating and checking in, or may comment directly on another player's profile page.

Gamification is implemented through four primary mechanisms: the Floracaching interface, points, leaderboards, and missions.

A playfully designed interface begets a sense of play (Kappen & Nacke, 2013). Floracaching is designed with a game-like interface featuring bright colors, cartoon-like icons, and stylized images. A screen shot of the landing page of Floracaching is presented alongside a screen shot of Budburst Mobile, a non-gamified application, to show interface gamification through comparison (see Figure 5). When possible, Floracaching uses icons or images to communicate rather than textual labels, to evoke playfulness (Zicherman & Cunningham, 2012). For example, while the top menu bar for Project Budburst includes buttons labeled "home" and "menu," Floracaching uses visual icons to communicate these concepts.

Figure 5. The landing pages of Floracaching and Budburst Mobile.

Floracaching utilizes a system of "experience points," where players earn points for each action they perform (Zicherman & Cunningham, 2012). Points are implemented by assigning each activity a particular value, and then displaying accumulated points on a player's profile page. Points are designed to add value to

Floracaching primarily as a feedback mechanism informing players on their progress.

Through social comparison, leaderboards illustrate how good a player is at navigating a system (Zicherman & Cunningham, 2011). In this way, they motivate users by provoking a sense of competition. Floracaching currently includes two leaderboards. One ranks players on the number of caches created. The other ranks players on the number of caches checked in to. Having two leaderboards that chart different activities may also help users identify like-minded others, contributing to social motivations (Costa, Wehbe, Robb, & Nacke, 2013). This design decision is consistent with the findings of Eveleigh and colleagues that volunteers distinguish between the quantity and quality of contributions (Eveleigh et al., 2014).

Missions are guided collections of activities that direct players towards a real world goal. For example, in a gamified first-year computer science curriculum, each member of the freshmen class earned the “undying” achievement when 90% of the cohort passed a particularly hard course (Decker & Lawley, 2013). Missions may support citizen science activities if they are constructed as specific, structured data calls.

Floracaching missions are implemented as voluntary activities. An administrator with back-end access to the Floracaching app must build a mission by designating activities and associated constraints. For example, the mission “Cheery Blossom Blitz” reads, “The National Cherry Blossom festival is an annual celebration that recognizes the importance of cherry trees in local culture. Join in the fun by checking in to five local cherry trees over the next two weeks to collect phenological data about this important plant.” In this case, the mission activity is checking in. Constraints include the species (e.g., a cherry tree) and the time frame (e.g., two weeks). Each mission is associated with a badge, earned upon completion.

After creating missions, administrators designate users to receive invitations to their missions. At this point, a user receives a notification saying, “You have been invited on a new mission!” that offers information about the mission and a picture of the badge to be earned. Users may accept or decline a mission, by clicking on a button that reads, “Yes, I accept!” or “No thank you.” Due to technical constraints, users can only accept a single mission at any given time. Floracaching users receive a notification when missions are completed. At this point, a new badge also appears on their profile page.

Following this presentation of the artifact of Floracaching, the methodology for co-designing improvements to Floracaching is now explained in detail.

Roles in the co-design process

As described in Chapter 2, professional researchers or designers and participants play a variety of roles in cooperative design. The co-design research team is composed of the author and multiple facilitators. The author was responsible for leading the co-design process by designing, piloting, and implementing all four workshops. Facilitators advised the author, help recruit participants, and helped run the co-design sessions. In addition, facilitators supported data analysis through recording field notes, and one offered coding support.

Both the author and the facilitators acted as participant observers (Preece, Sharp, & Rogers, 2015). In this role, they focused first on facilitating user creativity, by interacting with co-design participants or by helping participants use Floracaching. They also documented the co-design workshops. The participant observer role (also recommended by researchers including Druin, 1999) was selected to minimize the power distance between the research team and co-design participants, and also to provide unique insights into the research results.

The author is the leader of this study. Note that the term “author” is selected over “designer” in part to highlight differences between this individual’s qualifications—

which primarily involve conducting qualitative research—and the qualifications of many research through design practitioners, which often involve training in the artistic aspects of design. This important difference is returned to later on. One facilitator is a member of the author's core research team, and a recent graduate of a UMD Masters program. The second facilitator, also a member of the author's core research team, is an associate professor at BYU. Thus, the author and both facilitators are representatives of the target user group, members of a university campus. On one hand, community membership supports deep insights into the contextual practices of other co-designers, and may enhance trustworthiness (Portigal, 2013). On the other, personal bias must be minimized.

A third role is co-design participant. Participants attended one of the four workshops, where they evaluated Floracaching, created new prototypes, and participated in focus group discussions. In this way, participants played a role that falls between informant and design partner, as each contributed to multiple but not all phases of the design process (Druin, 2002).

The target population for the proposed research is members of a university community. This population includes undergraduate and graduate students, but also faculty, other researchers, and administrators. The sample of participants recruited to the four co-design sessions can be characterized as purposive, given that participants represent the target population, and access to them is convenient (Preece, Rogers, Sharpe, 2014).

Participants were recruited to four focus groups: a small focus group initially intended as a pilot at the University of Maryland (M1), a larger focus group at UMD

(M2), and two focus groups at Brigham Young University (B1, B2). The first focus group, M1, was composed of the author's colleagues and friends recruited via word of mouth. The second focus group was recruited through the UMD College Park Scholars Program, an invitational program created to recruit and nurture academic excellence. The opportunity to co-design Floracaching was presented to these students as a "field trip." While all students in the program are required to take field trips, each may select from a number of options.

The third and fourth focus groups were recruited through various mechanisms. Some learned about the co-design sessions through printed advertisements; others, by email invitations sent by the facilitator. Still others simply accompanied their friends. Thus, participation in all focus groups was voluntary. While all participants were offered a snack as part of the co-design process, none received any incentive including extra credit for participation.

Forty participants were recruited to the four co-design sessions. While groups of 6-10 were considered ideal, group M1 (initially intended as a pilot) had four participants. In addition, while students enrolled in the College Park Scholars program were recruited for two separate field trips, inclement weather caused one field trip to be cancelled. For this reason, 20 co-designers attended the M2 session. Demographics for each session, and for the total sample, are summarized in Table 3.

Participants were asked to report their gender, age, race/ ethnicity, previous experience with citizen science, and habitual use of games. They were also asked, "Please tell us the city, state, and country that you consider home." A majority of participants (70%) were male.

Table 3

Select demographics of co-design participants

	M1	M2	B1	B2	All
# Participants	4	20	8	8	40
Gender					
Male	-	18	5	5	28 (70%)
Female	4	2	3	3	12 (30%)
Other	-	-	-	-	-
Age					
18-24	-	20	3	4	27 (68%)
25-44	2	-	4	4	10 (14%)
45-64	2	-	1		3 (8%)
65+	-	-	-	-	-
Race/ ethnicity					
African American	-	1	-	-	1 (3%)
Asian/ Pacific Islander	1	2	4		7 (18%)
Caucasian	1	15	4	8	28 (70%)
Latino or Hispanic	-	2	-	-	2 (5%)
Native American or Aleut	-	-	-	-	-
Other	2	-	-	-	2 (5%)
How often do you participate in citizen science?					
Never	1	15	6	7	29 (73%)
Rarely	-	5	2	1	8 (20%)
Sometimes	3	-	-	-	3 (8%)
Often	-	-	-	-	-
Frequently	-	-	-	-	-
How often do you play digital games?					
Never	1	-	-	-	1 (3%)
Rarely	2	2	1	3	7 (18%)
Sometimes	1	6	5	2	14 (35%)
Often	-	10	-	-	10 (25%)
Frequently	-	2	2	3	6 (15%)
Please tell us the city, state, and country that you consider your home.					
University town	-	-	4	5	9 (23%)
Within 50 miles	3	13	1	1	18 (45%)
Within 100 miles	-	1		1	2 (5%)
> 100 miles	1	6	3	1	11 (28%)

The largest number of participants (n= 27, 68%) fell into the 18-24 age bracket. In addition, ten participants were between the ages of 25 and 44 (14%) and three were between the ages of 45 and 64 (8%). On one hand, these age ranges do suggest a predominance of traditional undergraduate and graduate students in this sample. But other members of a university campus and non-traditional or continuing education students are also represented.

A majority of participants (n= 28, 70%) were Caucasian. A sizable minority (n= 7, 18%) identified as Asian or Pacific Islander. A few participants identified as Latino or Hispanic, African American, or Other. Achieving a more diverse audience would improve the atmosphere of each co-design session as well as the generalizability of the results, and is a goal for future work with Floracaching.

Most co-designers (n= 29, 73%) never participate in citizen science. In addition, eight (20%) rarely participate. The three participants who sometimes participate in citizen science are discussed below. Therefore, overall, these demographics suggest that our sample of college students, educators, and administrators (drawn from a larger population of a university community) does in fact represent a new target group for participation in citizen science.

Only a small number of participants never (n= 1, 3%) or rarely (n= 7, 18%) play digital games. Fourteen (35%) sometimes play digital games, while ten (25%) often play digital games and six (15%) sometimes play digital games. This may reflect recruitment materials, which used language including “games” and “gamification.” These responses may also reflect the larger trend that younger generations of Americans are more likely to play video games than older cohorts (Pew Research, 2010). Thus, while the sample may display more favorable attitudes towards games than the population at large, it is relatively consistent with expectations for the dominant age bracket of co-designers.

Thirty-one participants (78%) offered a location other than the current university town as the place they considered home (notably, 100% of co-designers in the M2 session, comprised entirely of first year college students, considered a location other than the university town as their home). Of the remaining participants, 18 (45%) selected a home within 50 miles of the university town, two (5%) selected a location between 50 and 100 miles away from the university town, and 11 (28%) selected a home more than 100 miles away from the university town. These demographics are discussed in Chapter 7, which explores theories of place awareness and place attachment.

The author and facilitators possess additional information on participant experience and expertise, acquired through previous interactions or during the co-design sessions. As noted above, three of the four participants in the first co-design session (M1) sometimes participate in citizen science. All four are also engaged in research on citizen science; thus, research activities and participation may be linked. Two of the participants in this session have contributed to previous co-design workshops that were hosted to design earlier research with Floracaching. One participant previously worked as a designer, and one had worked as a usability consultant.

Participants in the second co-design session (M2) were previously introduced to design thinking as part of the College Park Scholars curriculum. Many are considering a career in technology design or development. Two participants in the third co-design session (B1) are botany experts, working in an on-campus museum. Other participants in B1 possess knowledge of design gained through classroom experience or participation in a UX design club. Participants in the fourth co-design session (B2) also possess interest and experience with design; additionally, a few had designed or developed games.

Diverse voices enhance the co-design process. However, different levels of expertise and pre-existing relationships may bias results, for example if plant experts emphasize certain features, or if relationships with the author prevent co-designers from voicing criticism. Holding four focus groups helped mitigate this bias through data source triangulation, described later in this chapter.

Workshop procedure

Workshops were designed to unfold over a four-hour period. An overview of the aspirational structure of co-design workshops is summarized in Table 4, though it should be noted that—as described later on—workshops did not always unfold according to plan.

Prior to the workshop, 10-15 floracaches were created on each campus. This number was selected to offer participants a variety of floracaches to check in to without becoming overwhelming, and is selected based on previous research (Bowser et al., 2012a; Bowser et al., 2012b). On each campus, floracaches were created within walking distance of one another, and within an area that participants were expected to be familiar with.

Table 4

Floracaching procedure

Time	**Activity**
Workshop Introduction	
0:00 – 0:20	Session overview: introduce researcher and facilitator(s); introduces Project Budburst, plant phenology, and Floracaching; describe goals and session structure; collect consent forms
Field Experience	
0:20 – 0:35	Walk to field site
0:35 – 0:55	Introduction to 3 key plants; guided exploration with Floracaching
0:50- 1:10	Playing and observing I
1:10 – 1:30	Playing and observing II
1:30 – 1:45	Walk to classroom
1:45 – 2:00	Break
Generative Discussion	
2:00 – 2:10	Reflections on personal experience
2:10 – 2:20	Reflections on the experience of others
Prototyping	
2:20- 2:25	Distribute materials
2:25 – 2:40	Design general improvements to the app
2:40 – 3:00	Design missions
Report out and Focus group	
3:00 – 3:10	Break
3:10 – 3:30	Individual report out from each group
3:30 – 3:50	General focus group
3:50 – 4:00	Thanks and debriefing

In addition to setting up Floracaching, the author registered each participant with the Floracaching app. Pre-registration allowed missions to be assigned to different participants, a task not otherwise possible. Each user was invited to one of three missions, created by earlier research participants (note that the technical infrastructure of Floracaching prevents one player from accepting multiple missions at any given time). A random number generator determined which mission a particular user received. Including three missions instead of having each participant perform the same task was designed to demonstrate the diversity of mission design.

Some researchers suggest that introductory sessions should be kept to 15 minutes (Holtzblatt, Wendell, & Wood, 2005). However, due to the complexity of Floracaching and plant phenology, 20 minutes were allocated to support ample time for questions. The author began by introducing herself and the facilitator, and then described project Budburst, plant phenology, and Floracaching. She introduced the goal of designing Floracaching as “a mobile, location-based app for citizen science” that “collects plant phenology data for an existing citizen science project, Project Budburst.”

As plant phenology is a difficult concept that has caused confusion in the past, participants were shown a brief video where the Director of Project Budburst introduces this key concept.[20] The Floracaching app was introduced through a series of screen grabs, which covered core functionality and illustrated gamification through points, leaderboards, badges, and missions. Finally, participants were given an overview of the activities included in the co-design session, and introduced to the contextual inquiry interview technique (Holtzblatt, Wendell, & Wood, 2005). Informed consent forms and demographic questionnaires (Appendix A) were collected during this time.

After the introduction participants walked to the field site, an attractive area on campus with existing floracaches. Co-design participants were introduced to three trees

[20] Project Budburst. *The Stories Plants Tell.* Accessed September 1, 2015 from https://youtu.be/OHY-c_RDMkM

that represented local biodiversity. For example, BYU students learned about *Ulmus Americana*, the American Elm; *Populus tremuloides*, the Quaking Aspen; and, *Metasequoia glyptostroboides*, the Dawn Redwood. The Dawn Redwood is a native west-coast tree. The American Elm, also native, is a tree with strong historical value to the BYU campus. The Quaking Aspen is the state tree of Utah. As previous research demonstrated that many college students are unfamiliar with plants and their identification, this activity was intended to teach participants about key trees and thus make Floracaching more enjoyable.

At the third tree, each student received an index card with the Floracaching URL, their user name, and their password. All co-designers then checked in to the third tree visited. Earlier field studies demonstrated that Floracaching has difficulty recognizing location on certain devices. This variability was also evident in each of the four focus groups. Checking in together allowed the group to determine which devices were most effective.

Based on findings from previous research, participants were asked to break into pairs sharing a single cell phone. Each pair was given a clipboard with materials including a pen, a description of three local plants with pictures, a campus map, and multiple worksheets for taking notes during the contextual inquiry interviews. During the contextual inquiry interview, co-designers were asked to act in the following roles:

1. *Players* were invited to use Floracaching however they would like to. Players could decide to Floracache alone, or join other pairs. Their stated goal was to

understand what is possible with the app as implemented, and begin to think about how the app might be enhanced.

2. *Observers* watched players and recorded their activities, taking notes on worksheets provided by the researcher (Appendix B). Observers were instructed to ask players clarifying questions about what they were doing, and why. Their stated goal was to understand how others might use the app.

For the first half of the field experience, one co-designer acted as a player, and the other acted as an observer; for the second half of the experience, these roles were reversed.

Participants were given a break and offered a snack such as pizza before the first focus group. Questions were designed to be generative (Sanderes, 2002), e.g. to help co-designers identify the needs they, their partners, and others may have while Floracaching. Questions included:

1. What did you like most about your experience Floracaching? What did you like about how the app was designed, in terms of how it looked and what it let you do? What were your favorite activities? What did you have the most fun doing, and why?
2. What didn't you like about Floracaching? Were there any features of the application that you found frustrating? Were there any activities you found boring, or unnecessary?
3. What did you notice from observing your partner? Was there anything they particularly enjoyed? Was there anything they found particularly frustrating?

4. What do you think would motivate someone like you or your partner to use Floracaching? What activities could we change or add?

Not all questions were asked in order; instead, the author respected conversational flow while attempting to cover all topics listed above.

Following the generative discussion, students were asked to prototype improvements or new features for Floracaching. Co-designers were invited to break into pairs, or form small groups. Three sessions elected to work in pairs (M1, B1, B2), while one elected to work in groups of four to six (M2). For all four sessions, students who were paired during the contextual inquiry interview worked together.

To begin each session, each design pair was given a brown paper bag containing:

- Paper, including blank paper, a map of the university campus, and printouts of 6 key screen shots from Floracaching (Appendix C). Blank paper and print outs were offered in line with research on participatory design materials, which suggests that some participants enjoy manipulating representations of different interfaces, while others prefer to create new interfaces (Pommeranz, Ulgen, & Jonker, 2012). Paper maps were offered to encourage participants to think deeply about how Floracaching integrates with the university campus (Wart, Tsai, & Parikh, 2010).
- Tools for annotating and manipulating the paper supplies, including pens, markers, sticky notes, scissors, stickers, and glue (Figure 6). These “Bags of Stuff” were designed to support playful creativity (Yip et al., 2013). Some materials, such as markers and post-its, were “basic” in the sense that they could

support any co-design session (Lucero, Vaajakallio, & Dalsgaard, 2012). Others, such as emoji stickers, were "field specific," or directly applicable to Floracaching.

Students were asked to spend 15 minutes creating low-fidelity prototypes of general improvements to the Floracaching app. Co-designers were reassured that facilitators were not judging them on their designs, but rather providing them with tools to help them think critically about how to improve the Floracaching experience, and communicate their ideas to other students. Participants were also offered examples of how others had used the same materials to mock up existing designs, or create new designs.

For two groups (M1 and M2), participants shared their mockups after the first 15-minute prototyping session. Reporting out is a common technique in co-design (Dodero, Gennari, Melonio, & Torello, 2014; Guha, Druin, & Fails, 2013; Monfort-Nelson, 2014). This process helps participants articulate and justify design decisions, ensures that all voices within a session are heard, and allows participants to witness each other's

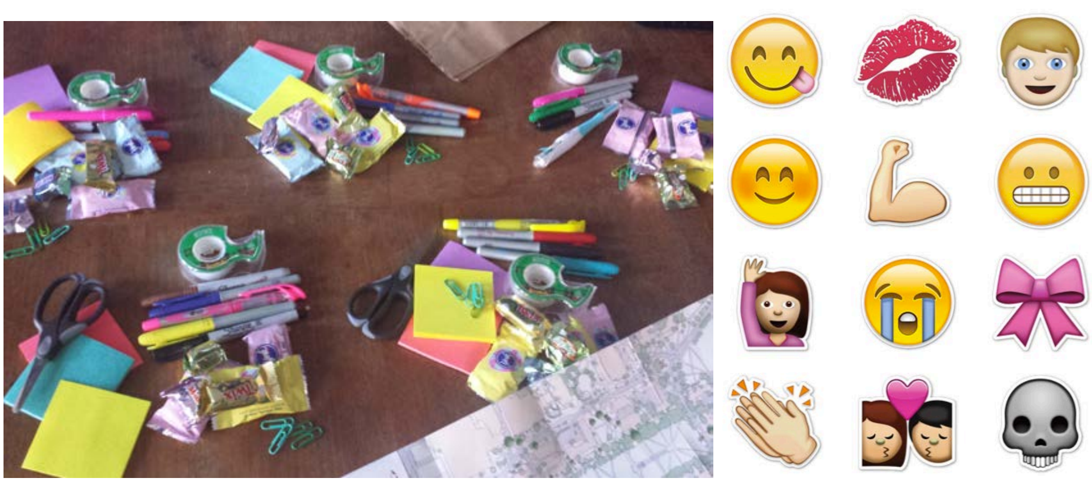


Figure 6. Co-design materials.

Each pair was asked to share their design and to explain the underlying rationale. Following each presentation, the entire design team including the researcher, facilitator, and co-design participants, was invited to ask questions.

Groups M1 and M2 then returned to prototyping for a second session designing Floracaching missions. To facilitate this exercise, co-designers were encouraged to consider missions in terms of: *goals*, or what players will achieve by completing this mission; *activities*, or what players will do; and, *rewards*, or what a player might gain from completing the mission. Facilitators also provided an example of a mission from earlier work co-designing Floracaching, and encouraged co-designers to references assigned missions through their cell phones.

The sessions at BYU unfolded a bit differently. While co-designers in the B1 session were asked to report out after the first round of prototyping, a few design pairs asked for more time to work on the interface (others were ready to move on). As a compromise, the author and facilitator encouraged some pairs to begin creating missions, while allocating more time for others to finish their interface designs. For this reason, interface designs and missions were presented together, at the session's conclusion. The second co-design session held at BYU followed a similar pattern.

A final focus group asked participants to identify the most promising "big ideas" (Guha, Druin, & Fails, 2013), or most important directions for future design. Co-designers were also asked to consider the structure of the workshop itself. Questions included:

1. Based on what we've heard from all the groups, what are the most promising ideas for improving Floracaching? What improvements should be made to the design of the app, including the interface and key actions like creating caches or checking in? What improvements should be made to the activities included in Floracaching? What improvements should be made to Floracaching missions?
2. Are there any opportunities for improvement that we talked about earlier, but didn't create designs for?
3. Overall, which features of Floracaching—either features included in the current app, or new features proposed—are most likely to motivate people like you to use the app?
4. What did you think about the general structure for today's session? Was there enough time allocated to different activities? Did you have enough materials for prototyping? Did everyone participate in the co-design process?

Co-design participants were also invited to raise questions of their own.

The workshop ended with a genuine expression of thanks from the author and facilitator. In addition, participants were reminded that Floracaching co-design is an iterative process, and invited to give feedback at a later point in time.

Data Collection

Data were collected from three main sources: observations, design artifacts, and focus group discussions.

All members of the co-design team collected observations during the field experience. Contextual inquiry participants acting in the role of observer also took notes on the worksheet. The author and facilitators documented the generative and prototyping phrases of the co-design workshop through written observations and photographs. In addition, following each co-design workshop, both the researcher and the facilitator recorded summaries of the session describing additional observations, and contemplating emerging themes. This is a practice borrowed from ethnographic methodologies (Portigal, 2013) that has proven effective in earlier work with Floracaching (Bowser et al., 2013b). Finally, the author and one facilitator shared observations during a debriefing session following the co-design workshops B1 and B2.

Design artifacts are considered prototypes created by the co-design teams. All artifacts were collected and preserved by the author. Note that the researcher and the facilitator contributed to some design artifacts through the course of participant observation.

Focus group discussions were held between all members of the co-design team. As described above, two to three focus groups were held during each session, depending on when different prototypes were shared. All focus group discussions were audio recorded with participants' consent. After recording, digital files were transcribed verbatim.

Each co-design participant filled out a paper demographic questionnaire. This questionnaire was used to characterize the sample, though certain questions (such as the question, "Please tell us the city, state, and country that you consider home") were also used in analysis.

Collected data may be sensitive to different degrees. To protect participant privacy, physical artifacts including design artifacts, photographs, and written field notes are stored in a locked filing cabinet. Digital files are password protected. In all cases where participant identity is given (e.g., through an email address, or by addressing a participant by name), identifying details are anonymized or removed.

Data Analysis

Two types of data were available for analysis: visual data in the form of photographs and prototypes, and written data in the form of observations, field notes, and focus group transcriptions. Visual data were annotated and incorporated into the general corpus of textual data. This corpus was analyzed through an iterative, inductive approach.

Visual data include photographs taken during the field experience or prototyping sessions, and prototypes created by co-design participants. The contextual design methodology suggests that annotations are helpful for analyzing visual data (Holtzblatt, Wendell, & Wood, 2005). While a number of annotations are recommended for different types of data, the following are particularly valuable for annotating the artifacts produced through Floracaching co-design:

- Uses: The specific activities a user is doing while Floracaching, or creating designs;
- Intents: The stated or implicit goals of an activity or design;
- Breakdowns: Activities or design features that caused confusion, or a similar negative response;

- Contexts: Environmental features of the Floracaching environment or the co-design environment, including other co-design participants.

In addition, many participants annotated the designs they created. To illustrate the annotation process, a prototype is presented in Figure 7:

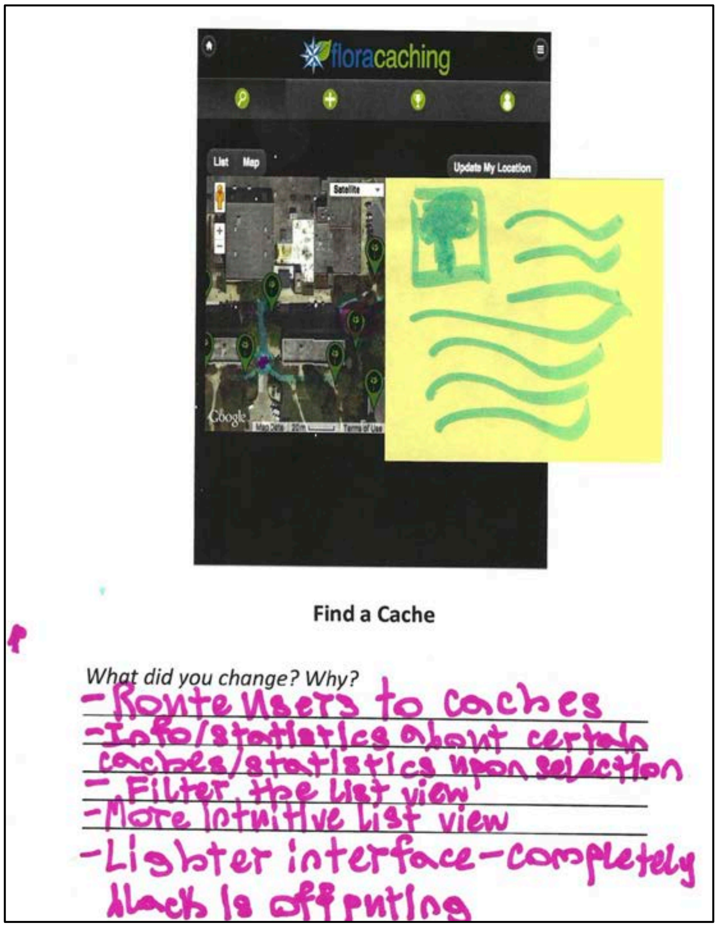


Figure 7. A sample annotated prototype.

The annotation for this prototype begins with notes made by the co-design participant: "route users to caches; info/ statistics about caches; caches/ statistics upon selection; filter the list view; more intuitive list view; lighter interface- completely black is offputting."

Annotations from the contextual design framework elaborated on the above user-generated content. These included, “uses: creating mock-ups with sticky notes and markers; uses: annotating mock-ups; intent: take participants directly to a specific floracache; intent: find certain types of floracaches through statistics; intent: filter out unwanted content; intent: allow participants to see nearby floracaches in a pop-up window; breakdown: list view is confusing; breakdown: black interface is undesirable.”

In this way the annotations for different artifacts preserved co-designers’ own explanations, while also supporting interpretation from the author. Annotations generated by co-designers and the author alike were collected and added to the collection of transcriptions. The database of annotations and transcriptions was analyzed as a single corpus, as described below.

The corpus of data was analyzed through an inductive approach influenced by grounded theory (Glaser & Strauss, 1967), thematic analysis (Braun & Clarke, 2006), and other qualitative research strategies (Miles & Huberman, 1994). Grounded theory is a method of developing theory through systematic analysis of a data set. Researchers who apply this method strive to be as objective as possible; grounded theory may be less appropriate than other processes when researchers have pre-conceived notions about which themes will be important (Lazar, Hochheiser, & Fenn, 2009). The goal of thematic analysis is to “focus on identifying and describing both implicit and explicit ideas within the data, that is, themes” (Guest, MacQueen, & Namey, 2012, p.11). Thus, thematic analysis is a phenomenological approach, where different aspects of an experience—e.g., people, artifacts, goals, and actions—are first deconstructed, and then re-constructed according to common themes (Braun & Clarke, 2006).

Thematic analysis may be applied as a deductive process, where existing themes are applied to a data set; or, it may be applied as an inductive process, where themes are allowed to naturally emerge from the data. Grounded theory is inherently inductive in its first iteration—though researchers often employ a later deductive phase as well. Early research with Floracaching did, in fact, produce a theoretical framework of motivations for using Floracaching. However, because this framework was developed using a much earlier version of the app and outside of a research through design approach, it was not appropriate to begin by using this framework for axial coding (e.g., a deductive approach to thematic analysis; Kolb, 2012).

Both grounded theory and thematic analysis suggest an iterative coding process. Grounded theory also emphasizes the importance of constant comparison, where each new case in a data set is compared to the previous instance of that case. Data analysis with Floracaching draws strongly on the phenomenological approach suggested by thematic analysis, while also benefitting from the emphasis on constant comparison and specific coding techniques advanced by grounding theory. Analysis was applied in the following stages:

1. **Immersion**. The author transcribed eleven audio recordings of the focus groups and debriefing sessions. In addition, each design artifact was annotated following transcription. The entire corpus of data was then re-read to gain a holistic understanding of its contents.
2. **Open Coding.** The corpus was first approached through open coding, where the author went through the data set line by line to identify key properties,

ideas, or dimensions. During the first round of open coding, paper printouts were manually annotated with highlighters and pens. A second round of open coding was conducted with the qualitative analysis software Dedoose.[21] Memos were recorded during both rounds of coding. Coding twice supported further immersion in the data and productive memoing through constant comparison (Glaser & Strauss, 1967).

3. **Axial coding.** To prepare for axial coding, each phrase selected during open coding was printed onto physical paper. These phrases were grouped into axial codes through affinity diagram analysis (Figure 8), which supported the iterative organization of codes around high-level constructs. Copious memos were recorded during this time. Based on this organization, a high-level codebook of axial codes was created.
4. **Selective coding.** Axial codes were applied to each manuscript through deductive coding in Dedoose. The first attempt at this process revealed a fatal flaw in the codebook, which caused the author to return to affinity diagraming. The second codebook proved more robust, and required only slight modifications for the remainder of coding (Appendix D).

This process yielded seven key themes with supporting evidence for each, and a set of memos describing each construct in depth, which also suggested how the constructs

[21] http://www.dedoose.com/. Accessed May 2015.

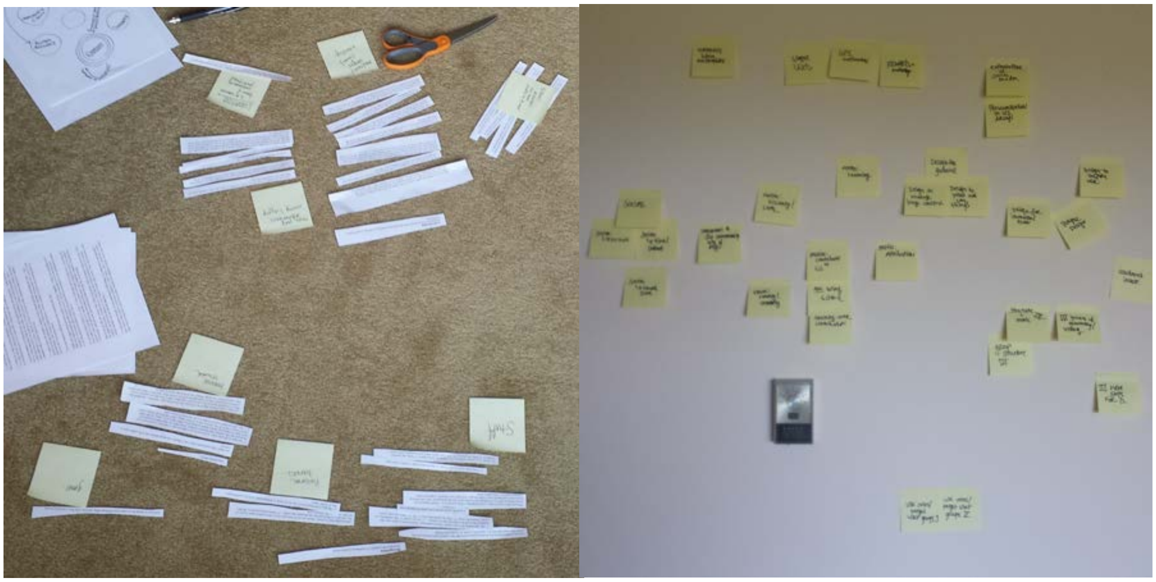


Figure 8. Different stages of qualitative data analysis (including axial coding and affinity diagram analysis, above).

were related to one another. Memos were then sorted into more formalized propositions, with duplicate memos removed (Miles & Humberman, 1994).

From these seven themes, the author began designing the next version of Floracaching. In line with Research through Design, which recommends combining user research with theory (e.g., from the behavioral or social sciences), and the creative process of design during the research process (Zimmerman, Forlizzi, & Evenson, 2007), the author referenced two important sources during this time. First, external theory helped reconcile conflicting suggestions and point to underlying meaning. Second, recognizing the difference between “design articulation of knowledge” and “verbal articulation of knowledge,” the author often referenced the prototypes created by co-designers (Pierce, 2014). This was an important step in the design process, and served as a check to remedy any loss of meaning that may have occurred through the process of annotating visual designs for textual analysis. Following this process of synthesis and design, the process of data analysis and interpretation was considered complete.

Writing Conventions

A brief explanation of writing conventions may offer clarity.

Quotations. Direct quotations support methodological rigor, and give life to a manuscript (Fereday & Muir-Cochrane, 2006). All direct quotes are included in quotation marks and italicized. These are verbatim, with the exception that non-sequiturs and non-word utterances (e.g., ‘like,’ ‘umm’) were not always transcribed.

Attribution. Some qualitative researchers attach pseudonyms to quotations, in order to evoke the diversity of participants and their voices. Unfortunately, when transcribing focus groups it is often difficult to attribute different voices to different participants with a high degree of confidence. Still, understanding how themes cross participants and co-design sessions is important for evaluating validity. For each quotation provided, the relevant co-design session is indicated in parentheses. In addition, language such as “one participant” and “a second participant” is used to highlight instances where multiple participants within a co-design session express the same idea.

Anonymity. In some cases, co-design participants refer to another participant by name. All names have been changed to support anonymity. Due to the large size of each university (over 20,000 students in each), university names have not been changed.

Methodological limitations

All methods have limitations. This section discusses three challenges to qualitative research methods: challenges to rigor, or the integrity and competence of a research practice (Fereday & Muir-Cochrane, 2006); challenges to validity (Kolb, 2012); and, challenges to reliability (Lazar, Hochheiser, & Fenn, 2009).

Rigor is an important consideration in qualitative research, as the exact implementation of techniques such as observation varies from study to study (Fereday & Muir-Cochrane, 2006). Yet, establishing rigor is key for gaining recognition from a larger research community. Drawing on Schutz's framework of social phenomenology, Fereday & Muir-Cochrane propose three mechanisms for supporting rigor in qualitative research: logical consistency, subjective interpretation, and adequacy (Fereday & Muir-Cochrane, 2006).

Logical consistency is met through in depth planning, careful attention to data collection and analysis, and clear articulation of results. This study seeks to achieve logical consistency through careful consideration of research methods, including revisiting earlier research with Floracaching, and analyzing the success of different techniques. Subjective interpretation emphasizes the importance of fidelity to the unique context in which a phenomenon unfolds (Fereday & Muir-Cochrane, 2006). This criterion is met by presenting findings in the voice of research participants. The expressions of co-designers are recognized through direct quotations, and by sharing design artifacts such as prototypes and photographs.

Adequacy describes how the credibility of analysis is verified. Credibility may be verified by research participants, by colleagues, or by objective outsiders such as conference attendees (Fereday & Muir-Cochrane, 2006). This research seeks to establish credibility with co-design participants by inviting participants to comment on the data analysis and prototypes constructed by the author, an activity that is in progress at the time of this reporting. Credibility is also established by submitting this research for critique through peer review.

A second important consideration in qualitative research and analysis is validity. Internal validity can be defined as the degree that a research project yields accurate and believable result (Kolb, 2012). Internal validity may be addressed through mechanisms including documentation and triangulation.

Constructing a database to provide documentation is a first step towards establishing validity (Yin, 2003; in Lazar, Hochheiser, & Fenn, 2009). By compiling all data in a single location, a database allows a researcher to search across a corpus to verify multiple occurrences of key findings or emerging themes. A database also provides a location for researchers to document their ongoing analysis, noting emerging reflections and recording unanswered questions. The qualitative analysis software Dedoose, used during this study, provides an excellent database that allows a researcher to search for important concepts, retrieve data based on codes, and record reflections or questions in the form of memos.

Triangulation also supports validity. Data source triangulation suggests that each interpretation should be supported by multiple data sources, for example by multiple interviewees (Lazar, Hochheiser, & Fenn, 2009). Collecting data from four co-design workshops supports data source triangulation by illustrating how participants in different workshops express the same themes. In addition, triangulation was supported when multiple participants within a session expressed the same theme.

A second type of triangulation is methodological triangulation, or use of different data gathering techniques (Preece, Sharp, & Rogers, 2015). This research achieves methodological triangulation by analyzing data collected through observation, focus groups, and design artifacts.

External validity is understood as the degree that research is applicable outside of a given context (Kolb, 2012). Some argue that external validity is not a goal in qualitative research, which instead focuses on rigor (Fereday & Muir-Cochrane, 2006). It should also be noted that extensibility is explicitly *not* a goal of research through design (Gaver, 2012). However, readers still need to understand how results and analysis are transferable to contexts outside of the immediate research settings. Clear documentation of research methods, including a description of participants and the research setting, allows readers to determine how applicable the current findings are to similar research questions posed in different contexts.

Reliability is important because qualitative research is by nature subjective; the same phrase or photograph may be not be interpreted by multiple researchers in the same way. In grounded theory and thematic analysis, reliability may be measured by inviting a second researcher to code a selection of the data corpus, and then calculating inter-rater reliability. This procedure was performed for the current research. However, after discussion the author and second researcher decided that, in this case, inter-rater reliability spoke more to the ability to write and follow a codebook, than to the quality of analysis itself. Therefore, inter-rater reliability is not offered as a metric for evaluating this contribution.

Summary

Four co-design workshops were held to address the two research questions proposed in this study. These sessions recruited co-designers from two university communities, the University of Maryland and Brigham Young University. Data were collected in the form of observations, design artifacts including photos and prototypes, and focus group discussions. Visual data were annotated, and added to the corpus of textual data, which was analyzed through an iterative, inductive approach. Rigor, validity, and reliability are key considerations in qualitative research. Each of these considerations is discussed.

Chapter 5: Findings on Key Themes for Floracaching

This chapter presents key themes associated with participation in Floracaching, and concludes with a summary of how participants considered the app valuable for reaching one ideal state (Zimmerman, Forlizzi & Evenson, 2007), namely participation in citizen science by a university community.

Key constructs for understanding perceptions of Floracaching

Following inductive data analysis, seven key themes emerged from the data: Personal relevance; design; gamification and reward; awareness and exploration; knowledge and learning; socialization; and, community and contribution (Table 5). These themes describe the values and motivations of co-design participants, or of imagined future Floracaching players. Many themes, such as knowledge, also describe deficiencies in the present state. This chapter describes each of the seven themes, and relates these themes to previous research. The process of integrating different themes to create a new version of Floracaching is reserved for the following chapter.

Personal relevance

The theme of personal relevance explores why people would use the app. Co-designers suggest that people will be drawn to Floracaching because it connects to a pre-existing interest, whether in plants or in games, or is otherwise relevant to their lives. Participants explored reasons why they personally would or would not use Floracaching, and extrapolated on the preferences' of other users. Players may be motivated by a specific interest in plants, or a general interest in nature. These types of users may include *"people who garden,"* (M2) or *"botany clubs"* (B1). Others, such as *"the younger*

Key themes in Floracaching

Table 5

Construct	**Definition**	**Components**
Personal relevance	Floracaching because of personal interest or life relevance	Personal interest in plants; personal interest in games; fit with life activities
Design	Appearance and function of the user interface or user experience	Streamlining and simplifying; adding scaffolding; supporting GPS
Gamification and reward	Clear, direct, and measurable benefits from Floracaching, often through enjoyment of gamification	Gamification; tangible rewards; intangible rewards
Awareness and exploration	Becoming aware of nature through Floracaching	Looking closely; persistent awareness; important plants; immersive technology
Knowledge and learning	Biological knowledge required to Floracache and acquired through Floracaching	Biological knowledge; local knowledge; learning
Socialization	In person or virtual engagement through the Floracaching app	Social interaction; social awareness; collaborative inquiry
Community and contribution	Awareness of different communities, relevance of contribution to communities	Content creation; content curation; social networks; recognition

crowd," may be drawn to Floracaching as a *"nerdy app"* (B2) or a serious game. Appreciating both gamification and nerd appeal, one participant explained, *"Because it's a nerdy app… I feel like this is already gamified enough as it is. Given if the interface had a makeover, I could see myself playing it. And I play games a lot."* (B2).

Co-designers recognized that different users will be drawn to different game mechanics. These include exploration (*"this app appeals to, on a certain level, people who are exploring the universe around them"* (B2)); "*competition"* (M2), and documentation (*"Wow, look at all those things I have checked off- people would love that."* (B2)).

Others may participate in Floracaching because it fits with their lives. For example, many described how Floracaching could be embedded in formal education, either as an optional *"study app"* (B1) or as *"part of the curriculum"* (M2). Floracaching may also be appropriate in informal science education settings, such as *"youth groups"* (B1) or *"4H clubs"* (M2). In addition, one co-designer suggested reaching out to *"older people, because they're retired"* (M2), and implicitly have a plethora of free time.

From these early adopters, social diffusion may draw in other participants. As one co-designer explained, "*initially you would be getting all the science majors here, and then home schoolers… but I think that hypothetically everybody could use it, even if they're not super into science.*" (B2). Diffusion would spread through social media. Secondary adopters would be motivated by seeing cool photographs of plants or gamified elements, and also by "*FOMO,"* or "*Fear of missing out… if people do it, and your friends do it, it becomes a thing."* (B1). FOMO contains an element of social pressure as well as a desire to be social: *"If you're not doing it, you don't even care about your environment that much."* (B1).

Personal interest is considered a condition for participating in citizen science (Nov et al., 2011; Rotman et al., 2012; Wiggins & Crowston, 2015). Indeed, successful recruitment depends on “focusing on the interests of the target audience at the start.” (Dickinson et al., 2012, p. 294). Researchers also find that social media may be valuable for reaching a large audience of potential volunteers (Robson, Hearst, Kau, & Pierce, 2013). By allowing a second space for interaction to unfold, tying Floracaching to external social media would also support the social motivations of volunteers. However, researchers caution that while social media helps raise awareness of a citizen science project, recruitment strategies that focus on topical interest lead to a larger number of actual participants (Robson, Hearst, Kau & Pierce, 2013). For Floracaching, this suggests that the initial group of first adopters may be larger than a secondary group of friends and family members reached through social recruitment.

Design

The design theme covers comments and recommendations for improving the user interface or user experience of Floracaching. Important components include standardizing and simplifying the user interface, adding scaffolding, and supporting better location recognition. While participants acknowledged that understanding motivation was a valuable activity, they also prioritized perfecting the Floracaching design. As one cautioned:

> *If you want to get more than just like super nerdy for science, the design has to be top notch…all the things that go into making a good app, in general, need to happen. Because if it’s a little bit iffy, people are going to be like whatever, I’m going to click on Ingress.* (B2).

Thus, Floracaching was understood as an application in competition with other games and social media platforms that should be *"top notch"* in all aspects of interface and experience design. While participants appreciated some elements of the user interface (*"I like the images, the icons"* (B2)), it was clear that the overall attractiveness can be improved; there was consensus that *"I wouldn't love to go on the app just to look at it."* (B1). Additionally, some icons including the missions icon suggested different functions than they were designed to represent: *"It has that trophy as its icon? That made me think it was the leaderboard tab? Like 7 times in a row?"* (M2).

All but one participant disliked the black background. Some recommended, *"a green app template that screams more, 'oh lets do this fun plant thing.'"* (B1). Others suggested a white background, *"because all the big social media sites, like Facebook and Twitter and YouTube, they all have white backgrounds."* (M1). Comments like these illustrated the need for consistency with existing standards, a reoccurring theme for the design construct.

Some characterized the font and logos as *"childish"* (M2, B1). At the same time, many asked for a simplified interface with more pictures and less text: *"Generally, just look at everything that you think it could live without, and take it out."* (M2).

This desire for standardization and simplification extended to the user experience. Co-designers considered finding and learning about plants the main point of Floracaching, and designed screens to reflect this priority; for example, by enlarging the map and moving it to a prominent place on the landing page, or by designing pop-ups of nearby trees. Again, references to other forms of social media were plentiful:

> *The picture of the tree could be a full screen… you could make a double tap, a swipe right kind of thing? When you find it or something like that...because that's how we're working now. Tinder, that's how it is, you swipe right, and Instagram you double tap. They want to double tap and get it over, go to the next thing.* (M2).

Despite the drive for overall simplification, co-designers acknowledged a need to add scaffolding in the form of extra tools or information required to complete different tasks. Many suggested an introductory tutorial *"to lay out exactly what one can do with the app at first"* (M2) with additional content on a help page. Others designed support for classifying plants, such as a dichotomous key or a machine vision function (discussed more below).

In addition to these general suggestions for improving the UI, co-designers focused on one significant issue, described succinctly as *"our GPS didn't work."* (B1).

Workarounds for GPS recognition issues

Table 6

Solution	**Explanation**
Pictorial navigation through familiar landmarks	*"We know campus, so the Elm? The Elm was like 'ok I know where the Maeser building is, and I can see it's by the Maeser building."* (B2).
Pictorial navigation through multiple pictures	*"Have a sequence of pictures of the tree that people had taken from different angles."* (B2).
Pictorial navigation through scale	*"Have a little human being, and just scale the tree to the human being"* (M2).
Navigation facilitated through chat or messaging	*"If we didn't work together…he can message me and I will know where the tree is."* (B1).
Navigation by description of tree location	Use the commenting feature to describe where the tree is; a series of directions that lead to the tree
Navigating by distance counter	Include information on a tree's current distance from the user

During the report out, the author and facilitators explained that moving Floracaching to a native platform (e.g., a downloadable app available through the Apple or Android stores) could mitigate location recognition issues. Still, citing examples including Uber, co-designers argued that even the best native apps sometimes have trouble pinpointing a user's precise location. They designed solutions for helping users find plants in Floracaching through photographs, chat, or textual descriptions (Table 6). For example, co-designers suggested building in pictorial navigation, which would allow users to navigate by seeing familiar landmarks in relation to a floracache. Sometimes these suggestions ideas were offered with clear caveats. For pictorial navigation to work, *"granted, you probably have to know the area pretty well."* (B1). Alternative navigation schemes were considered valuable not only for improving navigation, but also for benefiting the general experience: *"It was kind of fun looking at the picture and trying to figure out where on campus it was."* (B1).

The power of good design is not a new idea in HCI, nor in citizen science. In addition, some researchers argue that bad design or poor usability are actively demotivating (Rotman, 2013; Wiggins, 2012). Crucially, any "good" design will not fit all contexts; rather, technology design and development should be customized to "project goals, known characteristics of the participant audience that influence recruitment and retention, and data quality requirements." (Wiggins, 2013, p. 148). Such research speaks to the importance of iterative design for citizen science technologies, to the potential for research through design to uncover "known characteristics of the participant audience," and to the value of a cooperative design approach.

Gamification and reward

Co-designers suggested that users are motivated by clear, direct, and measurable personal benefits. The most common benefits expressed related to the experience of gamification, including the fun of using an app with points, missions, and playful design. Other topics related to reward and achievement covered tangible and intangible rewards.

Points are an important gamified feature. Points may be inherently motivating (*"as humans, we just naturally want to progress"* (B1)) or are motivating through association with game play (*"it's just part of the design for games"* (B1)). Points facilitate continuous engagement: *"If there's a running counter of how many days in a row you were using it, and checked in, it could give you points"* (M2), especially if *"there would be a screen that popped up and said 'congratulations, you just earned 50 more points!'"* (M2). Earning points is considered a significant achievement that deserves special recognition. Referencing Foursquare, one co-designer exemplified how *"When you check in… it would be this splash page with a fancy badge, and you oh you got points whoo! Look at me!"* (B2).

Points are particularly valuable in a social context, e.g. *"if I had friends who were doing it too."* In this case, the underlying motivation is competition. As one facilitator *"heard a lot of jokes on the way out and in about competition, beating each other, hacking each others' accounts to win, etc."* (MD), competition may be particularly salient for this group of users.

Like points, missions evoked a sense of accomplishment and enjoyment through competition. As one co-designer explained, *"I think [missions] is what would make it more enjoyable. Because if you're just finding trees there's not really any gratification. But if you complete a mission you kind of have that sense of accomplishment."* (M2). However, co-designers imagined a different implementation of missions than included in the current Floracaching app. First, there was consensus across co-design sessions that some missions should be constructed as competitions. For these, a *"win-loss record"* (B1) would be a significant motivator. Second, many co-designers were surprised to learn that badges were associated with missions in Floracaching design. Instead, co-designers considered badges indicators of *"achievements,"* (M2, B2) that signified accumulated experience and expertise. To contrast, missions were conceptualized as immersive experiences associated with points. Indeed, during the contextual inquiry experience one pair went on a self-assigned *"mission to get the most points."*

In addition to the direct application of game elements, co-designers generally advocated for playful design. One suggested modifying the user interface so that the "x" used to mark a user's location was replaced by a more playful indicator: *"P1: I put a little emoji with the hand pointing, so a little man or something would be cool. P2: So not just X marks the spot? P1: Yeah, it feels like you're on the other side of a gun."* (M2).

Co-designers were also playful with mission design. Referencing marijuana consumption, one created a mission to *"get some buds"* that required a player to recruit others for a social Floracaching expedition, implicitly conducted under the influence (M2; others in the session, appreciated this punning as "*comic relief.*"). A second group designed a mission, "*slow the decay*," that compelled participants to check in to neglected caches that were now decaying (B2). Finally, participants in two sessions suggested that Floracaching could be expanded into a full or embedded augmented reality game.

A second class of clear, direct, and measurable benefits includes tangible rewards. Some suggested rewards linked to the nature of participation: *"It would be cool if you got a free plant for logging plants."* (M2). Co-designers in multiple sessions also requested more general rewards or prizes, such as sandwiches, pizza, ice cream, gift cards, listening to music on the Internet radio station Pandora, or *"a billion dollar prize."* (M2).

These direct and intangible rewards were related to personal gain. For example, after the moderator of one focus group compared Floracaching to volunteering, co-designers enthusiastically suggested *"you could maybe link it with community service* *hours*” (M2) assigned for on-campus violations. In the same vein, others interpreted volunteerism through Floracaching as *“something to put on your resume.”* (M2).

There are many similarities between the current study and the findings of other researchers. Players of Happy Moths considered gameplay inherently “fun” (Crowston & Prestopnik, 2012). This study challenges other scholarship. Researchers who studied Old Weather suggested that game mechanics do not offer initial incentive, but only motivate sustained contribution: *“’the points don’t motivate me but they do drive me further’”* (Iacovides et al., 2014, p. 1104).

This discrepancy may reflect different demographics, and issues related to self-selection. Overall, the sample for this study is younger than the general population, and plays games more frequently than older generational cohorts do (Pew Research, 2010). Unfortunately no information on Old Weather participants is offered to carry this argument to conclusion. Regardless, the finding that players are motivated to use Floracaching as a fun, game-like application supports the general hypothesis that game elements may engage new types of citizen science volunteers (Bowser et al., 2013; Newman et al., 2012).

Awareness and exploration

Co-designers believe that awareness and exploration of a natural environment is a key benefit to Floracaching. This benefit is explained through the components of looking closely, becoming persistently aware of a natural environment, and focusing on important plants. For some, awareness may be achieved through immersive technology.

Participants characterize their typical campus experience as *"cruising to a destination"* (M2) or "*tromping through the library to get to class."* (BD). It is particularly easy to default to cruising in *"a place you've always been a lot"* (M2). When cruising is a habit, deciding to experience nature is a deliberate geographic departure: *"a lot of times we go into the mountains to explore nature."* (B1).

Floracaching breaks this model by bringing the experience of nature into mundane daily life. One co-designer loved *"just looking closely at the trees, and just seeing it, looking more closely than I normally would. And the conifer that we looked at had little pinecones that were barely forming? I don't know, it was cool to see them. I never would have seen them without having this experience."* (B1). As others demonstrate, this ability to *"look closely"* can transcend the immediate co-design experience:

P1: It was really nice, when we found the little flowers.

P2: Haha, yeah.

P1: When we found the little flowers and you were describing them. And I had never noticed those little flowers before but now I'm always going to.

P2: Little blue blossoms.

P1: I'm always going to see them when I'm passing by. (M1).

The ideal of persistent awareness is also evident in missions connected to seasonality. One mission, inspired by the beauty of cherry blossoms that are synonymous with Maryland spring, suggests: "*you take pictures of the progression of how the cherries are when certain trees are blossoming, and what rate they're blossoming at.*" (M1). Co-designers also created missions instructing users to *"take a picture of the same tree in all four seasons,"* (B1) or even *"take a picture of the same tree every day so you could see a series of photos and see the subtle changes- and narrate the different changes."* (B1). Thus, through seasonality Floracaching users are encouraged to look closely not just once, but numerous times.

But looking closely, especially through Floracaching, has its limits. The number of caches in a single area may become overwhelming: *"There just becomes a point when the screen's not loading, and you're waiting for it, and you're like 'aaaaah' and then suddenly there's sixteen caches on your screen."* (BD). And, users do not feel the need to look closely at everything. Instead, they want to take beautiful pictures of floracaches that depict *"not just any oak tree"* (M2) but are in some way *"important to look at."* (B1).

Important plants include seasonally beautiful plants; plants relevant to a local environment, such as native or invasive species; and, plants that are *"important to the scientific community."* (B1). Finally, relevant plants include those that may enhance or disrupt daily life. Both "*a tree that you could eat something from"* (M2) and *"poison ivy, so I don't step in it"* (M2) are of worthy of inclusion in Floracaching.

Participants created numerous designs to facilitate awareness and exploration. Scavenger hunt missions direct players to important trees, and may be rewarding in themselves, for example by taking users to caches *"in the shape of a star"* (M2) or *"an alien."* (M2). Push notifications can remind players *"oh there is a birch tree… maybe three meters, you didn't notice it,"* (M1), although there was consensus that notifications should not overwhelm. Rather, like the selection of plants for caches, notifications should be curated to maximize the user experience. For example, they might ask a player to go Floracaching on *"a really nice day"* (M2) or highlight new activity around a favorite tree.

During one co-design session, a facilitator questioned whether the use of technology would interfere with a player's ability to become truly aware of their environment. To the contrary, some co-designers argued that missions can *"feed into this concept"* (B2):

> *When we're on campus we're just in the go mode of school, so we have to have something that pulls us out of thinking of going in between class and the library. And so something like a mission, or the goal from points, just something to help explore and guide your break from studying.* (B2).

To this end, missions could be designed as immersive *("once you start a mission it should stay with that"* (B2)), potentially through *"augmented reality"*. Narrative is a second game element that can support immersion. This is demonstrated through the mission *"slow the decay,"* (B2), where players are asked to visit caches that have been neglected and are thus decaying, to prevent these caches from disappearing completely.

Despite these possibilities, analyzing the annotated prototypes revealed how some designs may support looking closely without actually requiring players to be in nature. As a database of existing Floracaches illustrates, *"you can just click this, and you can kind of go through all the database, of stuff that has already been discovered."* (B1). Thus, participants may be able to use the app to see all of the most interesting biodiversity on a university campus, from the comfort of their dorms. This highlights a second issue associated with using technology to bring people closer to their natural environments.

There is a rich tradition of scholarship discussing the value of everyday natural environments (e.g., Kaplan, Kaplan, & Ryan, 1998). This theme is also explored by other citizen science researchers. Wiggins, describes how place-based citizen science can transform a front yard landscaping "from an everyday taken-for-granted, and therefore nearly unseen space, into a place where important scientific tasks can be accomplished." (Wiggins, 2012, p. 360-361). Haywood similarly explores how places also acquire meaning through personal investment, as volunteers return to the same site again and again (2014). Scholarship on location-based games also suggests that games create value by helping players see beauty in the mundane (O'Hara, 2008), or by enhancing the social meaning of a place (Procyk & Neustaedter, 2014).

Knowledge and learning

The theme of knowledge and learning refers to biological or scientific knowledge, knowledge of a local place, and how Floracaching can lead to scientific knowledge gains. While relating the experiences of their contextual inquiry partners, many co-design participants described breakdowns, or discrepancies between actual scientific knowledge and the knowledge required to floracache. On a basic level, participants struggled with checking in. Some wondered what to write in the comments box: "*all I wrote was big tree. That's not necessarily awesome.*" (M1). Others questioned their phenological observations, noting that Floracaching labels articulate precise, categorical phenological stages when phenology actually exists on a continuum. As one explained, *"there are* *leaves on there that are changing color, so it's not—it's like well is that really what they're asking? So I kind of have to intue it, like I think what they really mean is it's changing color for the season. So I guess I'll say that there are no leaves changing."* (B2).

Contending with multiple trees of the same species was similarly challenging: *"We cached one, and then we didn't know should we cache the other, or is one good enough?"* (B2). As with confusion over phenology, most participants understood "*from a standpoint of having valid data, if you cache this one or this one it won't really matter,"* (B2) but also noted "*as a user, if you're there and you're like 'ok I gotta find* ***this*** *tree****,*** *I gotta check in to* ***this*** *tree' it's like well, I don't know, a user might stress out about that.*" (B2). Some participants offered points as a simple solution for rewarding and re-enforcing behaviors, such as checking in, that may cause anxiety. Another suggested that adding the technical ability to create a *"strand"* (B2) of similar trees could prevent confusion over what is *"good enough."*

Anxiety over checking in may reflect a larger problem, namely the difficulty of creating a floracache (a process that, ideally, requires users to submit the genus and species of a plant) without strong biological knowledge. Some participants turned to outside tools, which often proved ineffective: "*If you look up a tree on Google images… there are ten different pictures and they're all of the same tree I guess? But they're in different states, and it's at different times of the year, so they're all completely different*." (B1). Others created caches without accurate labels, hoping that *"someone comes by later and can tell us exactly what it is."* (B2).

Despite existing biological knowledge gaps, co-designers loved the idea of Floracaching as a tool to learn about plants. One appreciated the description of a floracache as *"actually genuinely interesting to read. As opposed to busywork, or a textbook, or something like that."* (B2). Keeping descriptions short by offering *"just enough information"* (M2) and including fun facts or trivia contributed to this appeal. Noting that local knowledge does not transfer, co-designers with knowledge of plants appreciated Floracaching as a tool to explore a new location.

Even inexperienced users wanted to identify or validate a plant's identification. Some believed that this was possible *"because you have to dig into the description."* (B2). Others prototyped tools like *"Google image searchers…so you could take a picture of a leaf and it identifies it"* (M2). Still others said that the app could be improved *"with a dichotomous key, where you look at it and say, does it [have] one petal, is it lobed, or is it tiered, is the leaf shape serrated… oh, this is a Gingko!"* (B1). Keys that were based on pictures or avoided botany jargon were particularly desirable, though one participant with existing knowledge of plants disliked these features, and would *"just want to put in the name"* (B1).

Many missions were designed to facilitate learning. Some were simple, scavenger-hunt style quests to learn about different plants: *"being able to see, and learn about, what is an aspen tree, what is an elm tree."* (B2). In contrast, a participant with strong plant knowledge suggested a harder challenge:

> *How do trees spread their seeds? Find a tree that spreads its seeds by water. Find a tree or a plant that…the dispersal mechanism is by air, the dispersal mechanism*

> *is either by an animal eating it or getting stuck on their fur and get carried to another place. Or Rhizomes, like quakies grow just from roots that pop up like that?* (B1).

Despite the complexity of this mission, which would likely require research on dispersal mechanisms in addition to knowledge of plant identification, the reaction from other co-designers in the session was uniformly positive. One exclaimed in awe, "*I would learn so much from that.*" (B1).

The most complex mission of all required students to develop hypotheses about the relationships between different natural phenomena:

> *Observe trees to see, are there certain types of trees that seem to be more bird friendly? Do you see a certain kind of tree that has nests in it very often? And you'll find robins that nest in a certain type of tree, whereas a magpie nests in a completely different type of tree…* (B1).

In addition to missions, participants suggested that social features could support learning, as described below.

A second type of important knowledge is knowledge of the local environment. Arguing that *"you kind of limit yourself by only doing plants"* (M2), co-designers suggested that Floracaching could include other content, including *"restaurant reviews"* (M2). In one focus group, participants spent considerable time discussing an "*Introduction to Maryland*" mission (M2). This mission took new or prospective students to *"cool places on campus,"* including *"the mall"* and "*frat row."* However, while local knowledge enhances the app's value, some participants wondered whether this was an appropriate addition. For example, users in session B2 discussed whether it would be permissible to create a Floracache of the Tree of Wisdom, a sculpture of a tree on the BYU campus.

The importance of learning is consistent with research on other gamified citizen science apps (Crowston & Prestopnik, 2012; Iacovides et al., 2014). Enhanced knowledge of a topic or enhanced knowledge of science is also a valued outcome of participation in citizen science (Brossard, Lewenstein, & Bonney, 2005; Crall, Jordan, Holfelder, Newman, & Waller, 2012; Shirk et al., 2012). Researchers often draw on constructivist theories to understand learning in citizen science, as explored in the following chapter.

Socialization

The socialization theme designates in-person or virtual engagement with another person through Floracaching. Key components include social interaction, undertaken for a direct benefit; social awareness; and, collaborative learning.

Co-designers characterize Floracaching as inherently social. This is true even for co-designers who would not use the social features themselves but understand that others would:

> *As a designer I would say that adding those features, making it more social would be awesome. As a player, you know on social media and stuff I'm more of a lurker, I don't post terribly often? So I wouldn't use it. But as a designer I could see a lot of users being like oh my gosh this is the coolest thing. Or, that gets your other friends interested too and you can play together.* (B2).

Numerous co-designers enjoyed the experience of Floracaching together. One explained, *"I felt like I got to know Jonah a little better? And I could see myself like going on a date doing this? So it's a cool opportunity to share time with other people."* (B2). Another echoed, *"it was fun to work together."* (M1). One group of co-designers agreed that they would not Floracache alone, or would only Floracache alone *"if it was an assignment."* (M2). Others designed social missions, such as "*family tree*," where each member of a human family would check in to cache representing a different member of the same tree family (B1).

Some aspects of gamification, such as competition, are inherently social: *"I want to challenge somebody, 30 minutes, on your mark, get set, go. How many can you get?"* (B1). In addition to one-on-one competitions, players want to compete in small groups (*"The space team, we four would want to do the challenge at the same time"* (B1)) or in large groups, for example through competitions between students at different universities.

Socialization is enabled by awareness of the Floracaching community. Co-designers wanted to know who was using the app at any given time—*"there should definitely be a live feed of other people Floracaching"* (M2)— potentially by viewing other players on a map. They are interested in content generated by friends (*"oh your friend just cached this"* (M2)) and strangers (*"X amount of people have cached this plant today, you should go ahead and try it."* (M2)).

Co-designers advocated for advanced profile pages to make the social aspect of Floracaching more prominent. They incorporated personal representations: *"P1: You could put your own face in there, or an avatar. P2: Or a plant. Whatever you want."*

(M1). Leaderboards could also display additional information about users *"to make it extra attractive and engaging"* (M1), such as *"a tally of different scores, their total score, their highest achievement and their number of check ins or something… you could have a lot of data."* (B1).

Some co-designers wanted *"a friend feature"* (B2) that would show them friends who were Floracaching, or allow them to quickly access the profiles of others for social comparison. However, others cautioned, *"you wouldn't want to make it another social network. I think you'd want to integrate with what's already out there."* (B2).

A chat feature and a discussion forum could also support interpersonal interactions. These features serve two purposes. They allow players to organize social events: *"you could say like oh, Floracaching members are having some kind of event, some place around the school come in and participate."* (M2). In addition, access to a community of Floracachers can help players *"find other people who enjoy doing this"* (M2), or identify opportunities for future social interaction (*"You see this random person you just met and oh look we've cached 15 of the same trees in our lives."* (B1)).

Finally, Floracaching can support collaborative learning. For example, players Floracaching together in person may pool their knowledge: *"He knows aspens. And I know birches because birches are the East Coast relation of the aspen. And he knew about leaves, and I knew about, I was taught to identify them based on bark.…"* (B2). In this way, working together can help overcome individual knowledge deficiencies.

Knowledge is also shared when multiple people experience plants together. One co-designer described looking at changing leaves with a biologist friend:

> *P1: This friend started to explain to me why the color begins… that actually the red, the red color is always the green? It's actually the green that fades away.*
>
> *P2: Interesting!*
>
> *P1: So I was thinking maybe, I was thinking that other plants behave like that. And maybe it's more interesting for people study that but also…[gestures around the table]* (M1).

Thus, knowledge is socially created and also socially shared. Finally, social confirmation builds confidence. *"If you're by yourself you think 'oh I don't know it might be this,' just having another person to talk it out with gives you more confidence."* (B1).

Findings around socialization are consistent with other research on citizen science games (e.g., Khatib et al., 2011) and with research on location-based games such as Geocaching (O'Hara, 2008). The value of interpersonal relationships is also recognized more generally in the citizen science literature, especially as participation continues over time (Eveleigh et al., 2014; Rotman et al., 2012; Wiggins & Crowston, 2015). However, in this context the emphasis is often placed on the relationships between volunteers and scientists, over the relationships between volunteers (with exceptions including Haywood, 2014). One possible reason for this discrepancy is explored later, by drawing on the theoretical lens a sense of place (e.g., Ramkisson, Wiler, & Smith, 2011).

Community and contribution

The construct of community, which refers to a general awareness of different communities and what it means to contribute to these communities, is strong and multi-faceted. On one hand, Floracaching constitutes a virtual yet at the same time place-based community that contains different roles associated with different types and levels of importance. On the other hand, participants referenced a number of external communities—including personal social networks, and scientific researchers—in their discussions.

The Floracaching community, like the game itself, was portrayed as fundamentally collaborative. For example, a *"collaboration mission"* asked players to *"create a certain number of caches, verify a certain number of plants, explore a certain number of people's profiles, and then invite a certain amount of your friends to the app."* (M2). As this mission outlined, valuable contributions to the Floracaching community include content creation, content curation, and social engagement.

The value of content creation became evident through discussion of creating caches and checking in to caches. There was a broad consensus that creating caches *"is more interesting than checking in, because it's something that you created to put out there."* (M2). One co-designer appreciated watching her partner perform this task: "*I liked that she thought to create her own cache. I would never have done that…And she was very descriptive in creating her own cache."* (M1). In contrast, notes from one contextual inquiry interview stated, "*He didn't want to check in. Boring and not valuable.*" (B2). Generally, creating caches was considered a valuable contribution.

Curation is a second form of contribution. The most valuable curation is performed by plant experts, whose knowledge enables others to *"just throw it up without trying to identify it"* (B1), or say *"here's our guess, can you help us out?"* (B2). For some, players *"rank up"* to becoming a seasoned *"arbitrator. Get different points if* *you're an arbitrator… how many correct identifications you make while arbitrating."* (M2). In line with this value, co-designers suggested that creating caches should be associated with more points than checking in, and thus participants with knowledge of plants would occupy a higher status on the leaderboard.

Community members lacking knowledge of plants can also contribute through curation. They may filter content through voting or giving a *"thumbs up"* (M2) to caches or photographs of trees (players may get *"a prize for being the number one picture"* (M2); this reinforces the idea that content in Floracaching should be special or unique). Finally, all users contribute to Floracaching as social community members. This often plays out through recruitment: *"you have a referral system, where you recruit five friends and once they create accounts than you complete the mission."* (B2).

Social recruitment requires knowledge of the norms and preferences of an external community. Reflecting on their community knowledge (e.g., *"here in Provo, we're known for family activities? Every Monday night we get together and go do things"* (B1)), co-designers suggested that recruitment could unfold through family connections or experiences such as dates. Thus, external communities comprising the social networks of different players are valuable because of the possibilities that these networks hold for recruiting new players.

On the flip side, participants describe how content generated through Floracaching could be shared with external networks: *"Facebook, Twitter, Instagram, you should definitely utilize those social media sites… when you take a picture for the cache, you could have an option to like Instagram it or something. And filter it"* (M2). In this way, the ability to share content on social media is valuable as a contribution to an external community itself, e.g., as a picture of a beautiful tree with an artfully applied filter that brings aesthetic enjoyment, as well as for recruitment potential that benefits the internal community of Floracaching players.

Compared to external social networks, the scientific research community was considered less relevant to Floracaching. Though co-designers clearly understood that they were doing scientific work, few considered Floracaching valuable as a contribution to science. As one facilitator noted during debriefing, *"they did not talk about the scientific contribution of the data at all.*" (BD). Indeed, reference to Floracaching to support scientific research came up only three times in the entire corpus. One participant suggested that a website, *"could have more information about Floracaching, or how the data you're collecting is helping scientists, or some sort of progress about how your data matters."* (M2). In addition, two designs—including one articulated during a report-out—took players to plants of scientific interest.

While contemplating Floracaching as volunteerism for science, one co-designer explained why this would not be motivating: *"I don't think that's a strong enough motivator… there's a lot of greater goods. Poor orphans and stuff."* (M2). In other words, citizen science through Floracaching is not sufficiently valuable as a form of volunteerism to outweigh other service opportunities.

Community is an important theme in citizen science, and is often discussed in terms of project governance. Shirk and colleagues describe five models of citizen science based on degree of participation, where co-created projects are full collaborations between scientists and local communities (Shirk et al., 2012). These projects are linked to individual outcomes including “strong sense of community, commitment” and “appreciation of complexity of ecosystems” (Shirk et al., 2012, p. 40). Projects with a deep degree of community participation are also linked to stewardship and policy change (Haklay, 2015).

While citizen science researchers consider attribution from scientists or project coordinators to be a strong motivating factor (Khatib et al., 2011; Rotman et al., 2012; Wiggins & Crowston, 2015), this was absent in discussions of Floracaching. In general, scientific researchers were perceived as external to the Floracaching community. This may be because researchers had no immediate personal connection to players. Connecting Floracaching players directly with Project Budburst researchers, in line with Shirk et al.’s collaborative model, might increase this group’s relevance to Floracaching players (Shirk et al., 2012). However, other findings suggest an alternative explanation: that participants simply cared more about in-game acknowledgements given in front of other Floracaching users and especially friends, than they do about recognition from scientists.

Towards a new articulation of Floracaching

While data analysis did not tally the frequency of each theme, a few themes appeared in transcriptions of focus groups and debriefing sessions again and again. In addition, co-designers often offered high-level assessments of the app’s primary appeal.

Students from one session suggested that the app might be more appealing if it were re-framed from an app that benefits scientists, to an app that benefits users. As one explained, *"It seems like the app wants people to help with something else? But maybe if you don't know what kind of plant a tree is you would want to look it up, you could use the app for that, and then the Floracaching would be on the side."* (M2). In this way, participants would begin Floracaching to learn more about plants and incidentally contribute scientific data.

A second group of co-designers similarly emphasized the personal benefit of the app, in terms of both education and awareness:

> *P1: All the trees they're here in the background, they're there for the peripheral, right? That's all they're there for me. So that's why it's cool for me, I'm going to stop and realize that this is straight up cool. And honestly learning that this is an American Elm? One thing I noticed is knowing about these trees just made me feel like a better person. I feel better about myself knowing what that tree was.*
>
> *P2: Yeah for sure.*
>
> *P1: I don't know why, that's just how I felt.* (B1).

Following this exchange, a third participant echoed, *"That's kind of where I am too. It's mostly about learning. Being able to learn more about trees, and experience."* (B1).

As the group continued to contemplate the value of Floracaching, one participant raised an additional value of the experience: *"I was going to say there could be some conservation implications if people feel, like that? I'm a better person for knowing about these trees, and thus I'm going to take care of them? Or the earth better?"* (B2). Together, these excerpts reveal the importance of the relationship between knowledge and awareness, and also the potential implication for stewardship of a local or even a global community.

When considered as an overarching rationale for Floracaching, these suggestions represent a significant departure from the initial goal of our research—e.g., to use gamification to encourage college students to collect plant phenology data for use by Project Budburst scientists. To this point, debriefing sessions revealed facilitators questioning, *"what's the primary goal?"* (Debriefing). Noting the historic coupling of science and education in citizen science, they eventually reasoned, *"I think it would be a bad thing to say lets not put in the stuff that would make it educational and fun…we might break the app if we tried to only get useful data."* Thus, following fieldwork participants and facilitators alike characterized Floracaching as an application that would need to establish personal value to volunteers, likely by evoking contextual awareness and exploration, or facilitating learning, in order to be adopted.

Summary

This chapter presented seven main themes that emerged following qualitative data analysis. These include: Personal relevance; design; gamification and reward; awareness and exploration; knowledge and learning; socialization; and, community and contribution. In addition to sharing information on these important themes, co-designers began to formulate a vision for Floracaching that prioritized the needs of volunteers over the needs of professional scientists. This new vision is now explored.

Chapter 6: A New Iteration of Floracaching

This chapter synthesizes the seven key themes described in Chapter 5. This synthesis was driven by the creative process of designing a new version of Floracaching led by the author (Figure 9). Sketching a new prototype required understanding similarities between themes, sometimes prioritizing or reconciling small differences, and drawing on theories from the social and behavioral sciences. Key theories include experiential learning (Kolb, 2014); a sense of place, including place attachment (Ramkisson, Weiler, & Smith, 2012) and place identity (Gustafson, 2001); and, the reader-to-leader framework (Preece & Shneiderman, 2009). This design process led to a new prototype of Floracaching, and a set of framing constructs (Zimmerman, 2007) that illustrate how a gamified citizen science app can be designed for a university community.

Figure 9. A new version of Floracaching. By synthesizing the seven themes that emerged from collaborative prototyping (screen 4), a new version of Floracaching is presented (screen 5). The evolving methodology is presented in Chapter 7.

Integrating key themes through experiential learning

Co-designers prioritized awareness of an immediate natural environment, and knowledge, or learning about nature or a local environment, in their discussions and designs. Both themes are prominent in other research on citizen science (e.g., Brossard, Lewenstein, & Bonney, 2004; Crall et al., 2012; Haywood, 2014; Wiggins, 2012). Different constructivist learning theories, which are often used to explain knowledge, often touch on awareness as well.

Science inquiry involves learners in all steps of the scientific method (Crall et al., 2012), often by focusing on personally relevant topics (Clegg, Gardner, & Kolodner, 2010). *Discovery learning* explores how learners use science to explain relationships between natural phenomena (van Joolingen, de Jong, Lazonder, Savelsbergh, & Manlove, 2005). Drawing on *experiential learning* (Kolb, 1984), *experiential education* stresses the value of structured reflection (Brossard, Lewenstein, & Bonney, 2005).

What these theories have in common is a focus on the construction of scientific inquiry around real world problems of personal relevance. Because of the dual emphasis on knowledge and awareness, Kolb's theory of experiential learning is especially promising for understanding learning in Floracaching (Kolb, 2014). Experiential learning, defined as a form of learning from life experiences, draws on the work of scholars including Vygotsky, Lewin, Dewey, and Piaget. To a greater degree than other constructivist theories, experiential learning emphasizes direct, sensory experiences embedded in meaningful, real life contexts (Kolb, 2014). Experiential learning has been applied to scholarship on higher education, management, software use, and medicine

(Kolb, Boyatzis, & Mainemelis, 2000). It has also been applied to game design, for example through Kiili's experiential gaming model, which integrates experiential learning with Csikzentmihaly's theory of flow (Kiili, 2005).

Experiential learning is an iterative process, where real life experience evokes certain beliefs and ideas, which are examined and refined. This process is holistic, involving "the integrated functioning of the total person—thinking, feeling, perceiving, and behaving," and contextualized within a social learning environment (Kolb & Kolb, 2008, p. 43). Experiential learning begins with a *concrete experience*, which can be a new situation or a reinterpretation of an existing experience. This experience is processed through *reflective observation*, where inconsistencies between old and emerging knowledge are resolved. Reflection leads to *conceptualization*, where a learner has a new idea or modifies an existing concept. This idea is *applied* through testing in the world, where more new experiences start the cycle anew (Kolb, 2014). One example of an experiential learning cycle in Floracaching is:

> *Just looking closely at the trees, and just seeing it, looking more closely than I normally would. And the conifer that we looked at had little pinecones that were barely forming? I don't know, it was cool to see them. I never would have seen them without having this experience.* (B1).

Here, the concrete experience of Floracaching helped a co-designer become aware of nature not as background, but as a thing deserving attention and inquiry. This changing perception deepens through reflection, in this case inspired by participation in the co-design process. Following reflection, a learner re-conceptualizes plants as entities of interest that change over time—for example, by forming little pinecones each spring.

Thus, in Floracaching awareness and knowledge mutually enforce one another. Awareness leads to knowledge through an initial, concrete experience. The desire to test new conceptualizations with real world examples leads to greater awareness of the natural environment, where new exemplars are found.

It is easy to imagine how this learner may return to nature after the co-design session to test whether his understanding of conifers transfers to other plant families. The cyclical nature of experiential learning through Floracaching is enforced by the theme of persistent awareness: consider the co-designer who discovered little blue blossoms, and is now *"always going to see them when I'm passing by"* (M1), or the mission inviting users to take a picture of the same tree through out the seasons. According to Kolb, experiential learning is inherently social because it takes place in a social context (Kolb, 2014). Experiential learning may be, but is not always, technology mediated. A holistic view of experiential learning through Floracaching is presented in Figure 10.

Scaffolding, or providing the information needed to complete a scientific inquiry, is necessary for constructivist learning to succeed (Hmelo-Silver, Duncan, & Chinn, 2007). Scaffolding works by making disciplinary strategies explicit and associated tasks easier; by embedding expert guidance; and, by simplifying complex tasks to reduce cognitive load. In this way, scaffolding provides the resources required for learning to take place outside of formal and more structured settings.

While the majority of conversations around knowledge and learning focused

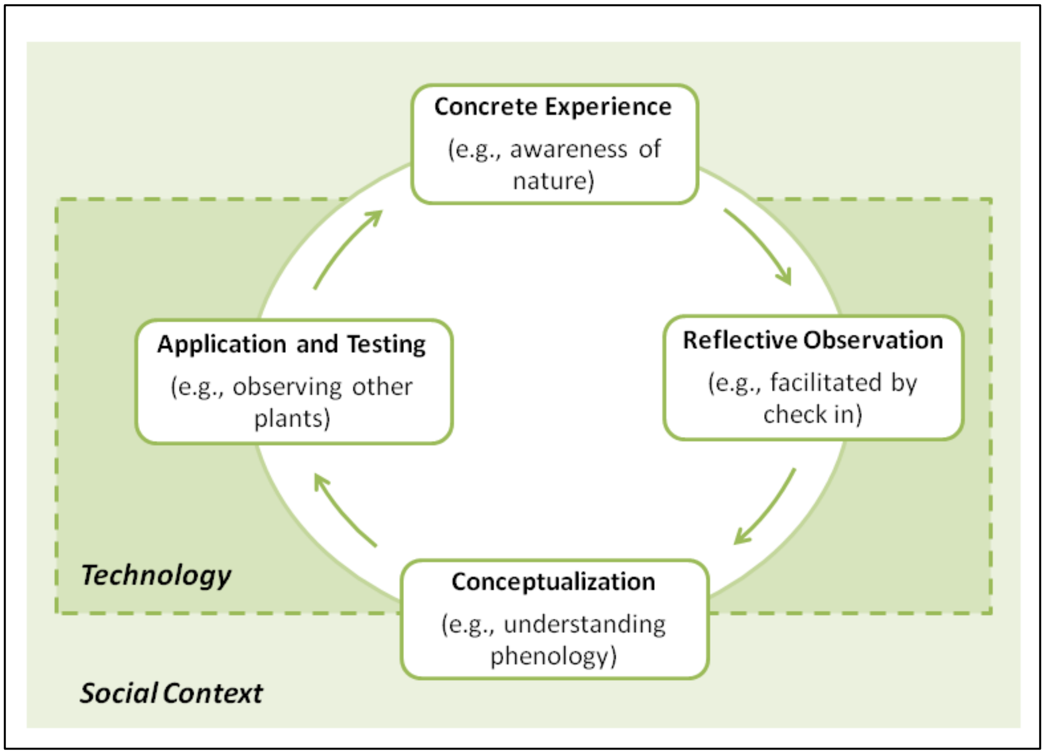


Figure 10. Experiential learning in Floracaching.

on plants, participants also discussed knowledge of the man-made features of a place. For example, some co-designers wanted to use Floracaching to take new students to places of cultural interest on campus, such as places to eat or frat row. Thus, there are two overlapping forms of knowledge in Floracaching: general knowledge of plants and their environment, which is occasionally but not always local knowledge, and knowledge of a geography that is inherently local, but not necessarily knowledge of plants. This second type of knowledge is also studied by researchers who suggest that Geocaching is valuable to “help find places perhaps more off the beaten track and dependent on the local knowledge of the person placing it there.” (O’Hara, 2008, p. 1180).

Designing to support experiential learning begins by supporting awareness, as described above. The experiential learning stage of reflection could be supported through a check in process, for example by asking players targeted questions such as “What makes this plant interesting?” instead of offering a generic comments field. Reflection may also be facilitated by some forms of curation, including narrating a set of photographs of the same tree.

Some scaffolding is implemented in Floracaching. For example, descriptions of plants may be considered a form of “just-in-time” content presented once there is an established need (Hmelo-Silver, Duncan, & Chin, 2007). Co-designers appreciated this information, especially when it included playful fun facts that contrasted the monotony of textbook-based education. Scaffolding through automated expert guidance could be implemented through machine vision algorithms designed to identify a plant from its leaves, as requested by some co-designers. Other guidance could be incorporated through videos recorded by formal educators or expert players. Classification aids such as a dichotomous key would provide important scaffolding by simplifying the complex task of creating a cache and making some forms of disciplinary knowledge, e.g., how is a conifer different from a deciduous tree, explicit.

Finally, scaffolding could be implemented through gamification. An introductory mission could walk players through the process of making a phenological observation. Scavenger hunt-style missions could support new topical knowledge of different species. More complex missions, such as those asking players to research plant dispersal mechanisms or create hypotheses about trees and nesting, could also offer players the opportunity to deeply engage with the scientific method, a goal of many citizen science projects (Crall et al., 2011; Jordan, Gray, Howe, Brooks, & Ehrenfeld, 2011). Finally, given that knowledge of plants and local knowledge are similarly valued, Floracaching might be expanded to include non-plant caches.

Integrating key themes through as sense of place

Awareness and knowledge were integrated through Kolb's theory of experiential learning (2014). Drawing on theories of place attachment (Ramkisson, Weiler, & Smith, 2012) and place meaning (Gustafson, 2001), experiential learning is integrated with additional themes including personal relevance, socialization, and community and contribution. The remaining themes of design, and gamification and reward, then become relevant as a new gamified interface is created to reflect the full analysis of research with Floracaching.

There is a strong tradition of considering place as a social and cultural phenomenon in Human-Computer Interaction (HCI). Citing scholars from humanistic geography, Harrison and Dourish contemplated the roles of place and space in collaborative systems design (Harrison & Dourish, 1996). From the premise that space represents opportunity while place is understood reality, they conclude, "It is a sense of *place*, rather than the structure of space, which frames our behavior," (Harrison & Dourish, 1996, p.74, emphasis original).

Scholars in citizen science have also considered the importance of a sense of place (Haywood, 2014; Wiggins, 2012). Also drawing on humanistic geography, Haywood examines the role of place meaning in volunteers' contributions to COASST, a west-coast citizen science project where volunteers study dead birds. He argues the value of this theoretical lens:

> The geographic concept of 'sense of place' is…an empirically underdeveloped, yet theoretically robust, entry point to explore how participatory science volunteers make connections between embodied experiences and behaviors and how such interactions may shape perceptions, values, and attitudes towards science and the environment. (Haywood, 2014, p. vi).

The application of a sense of place to citizen science and technology design suggests that these theories might also prove useful for the present work. In addition, analyzing Floracaching through this lens can support research on citizen science by evaluating the validity of Haywood's call (Haywood, 2014).

There are many entry points to theorizing a sense of place. Many acknowledge the foundational work of Yi-Fu Tuan (Tuan, 1977). More recently, Ramkisson, Weiler, and Smith proposed a conceptual framework for place attachment (Ramkisson, Weiler, & Smith, 2012). This framework illustrates how individuals develop strong emotional bonds with a place, and begins to explore how place attachment can lead to pro-environmental behavior (also suggested by Haywood, 2014; Manzo & Perkins, 2006; Tuan, 1974; Whitmarsh & O'Neill, 2010). The four dimensions of place attachment are:

- *Place dependence***,** or attachment to the geographic features of a place. Place dependence is associated with the idea of uniqueness, and influenced by the degree a person depends on a place for social, economic, or spiritual well-being.

- *Place identity* refers to a connection between geography and personal or collective identity. This construct is associated with lived experiences and memory.
- *Place affect* is the emotional bond an individual feels with a place. Place affect is often portrayed as a visceral need to experience nature. Place affect is associated with the complex sensory experiences of a place.
- *Place social bonding* describes how interpersonal relationships contribute to the value of a place, like thorough shared experience that lead to community bonding (Ramkisson, Weiler, & Smith, 2012).

Haywood draws heavily on place attachment in his discussion of the citizen science project COASST. In addition, researchers outside of citizen science have explored how place attachment leads some people to participate in community planning (Manzo & Perkins, 2011) or react to the renovation of a coffee shop (Milligan, 1998), to name just two applications.

A second contribution to place theory is Gustafson's conceptualization of place meaning (Gustafson, 2001). Gustafson considers three aspects of place meaning—self, others, and the environment—and also three relationship between these factors.

- *Self* refers to an individual's changing life path. Places acquire and lose meaning based on a person's progression through important life stages and involvement in key activities.

- *Others*, specifically other community members, also influence how places are understood. This construct designates interpersonal relationships and also the character of inhabitants of a shared place.
- *Environment* is variable in terms of distinctive features, including geographic features and natural conditions such as weather. Environments also become distinct through unique events.
- *Self- Others* shows how places become meaningful through interactions between inhabitants. This relationship also refers to perceptions of closeness or anonymity.
- *Environment-self* describes how meaning is shaped through knowledge of a place, and by the opportunities a place affords.
- *Others- Environment* is the atmosphere or climate jointly created by other inhabitants, and distinctive features of an environment (Gustafson, 2001).

Gustafson also considers the relationship between place meaning and scale. He notes that small places, such as neighborhoods or towns, “were often given meaning situated in the self pole of the model or in the self’s relations with others and/or the environment,” while larger places, such as countries, derive meaning associated the “others” or “environment poles” (Gustafson, 2001, p. 12).

The limited application of place theory to citizen science has focused on place attachment over place meaning (Haywood, 2014; Wiggins, 2012), potentially because researchers using this theory stress the outcomes of participation over time. Outside of citizen science, place meaning has been used to understand how people relate to everyday

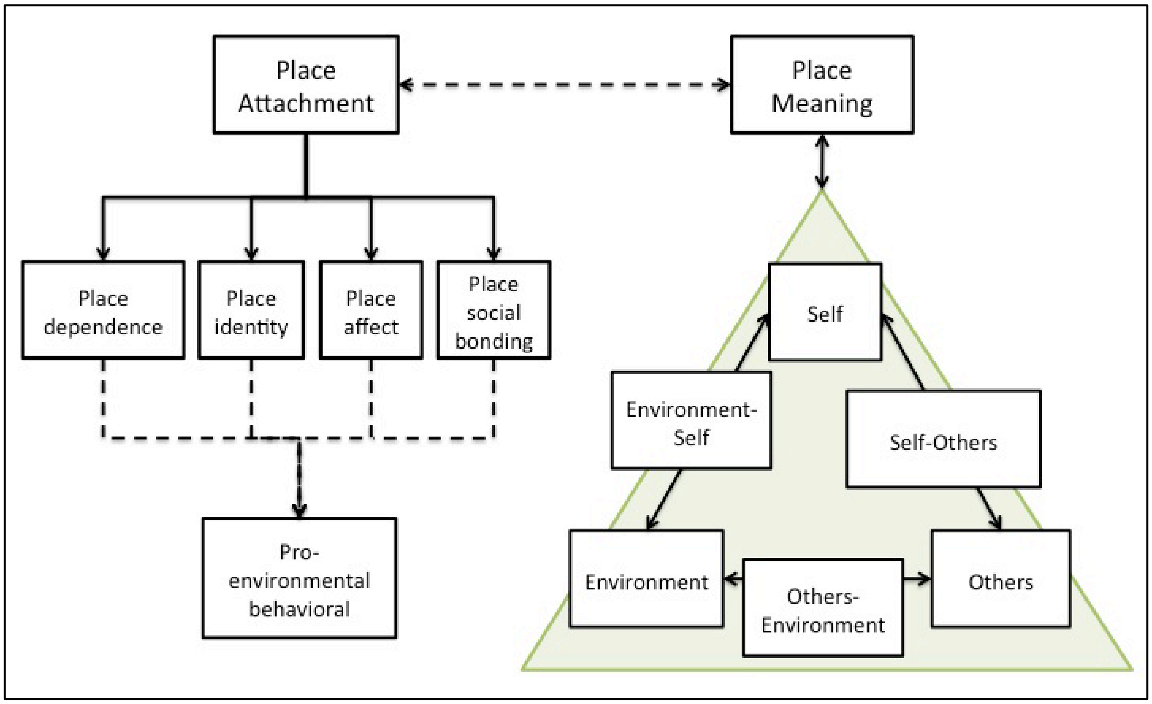


Figure 11. The relationship between place attachment and place meaning. This diagram shows the four constructs of place attachment (Ramkisson, Weiler, and Smith, 2012) and the six constructs of place meaning (Gustafson, 2011). While it is clear that place attachment and place meaning are related, more research is needed to understand exactly how these theories overlap (Manzo, 2003).

geographies such as city neighborhoods (Manzo, 2005) and also tourist destinations (Davenport, Baker, Leahy, & Anderson, 2010). The different dimensions of place attachment and place meaning are depicted in Figure 11.

While similar, the constructs of place meaning and place attachment are not identical; two people may find different types of meaning in a place, but share similar high or low levels of attachment (Manzo, 2003). However, changes in one construct are often linked to changes in the other. For example, becoming more aware of one's role within the environment (e.g., a facet of place meaning) may lead to enhanced appreciation, and eventually to attachment to that environment. Place attachment may similarly re-enforce place meaning when inhabitants take an active part in making a place their own, like by establishing social relationships or renovating a house (Gustafson, 2001).

Haywood takes one step towards understanding the relationship between place attachment and place meaning by introducing the idea of spatial dependency (Haywood, 2014). He suggests that when volunteers are highly dependent on a unique place, such as a specific beach, place meaning becomes a catalyst for place attachment. Conversely, when participation leads volunteers to recognize meaning in beaches in general, attachment is not evoked. To apply the idea of spatial dependency (Haywood, 2014) to Floracaching, it could be argued that members of a university community are likely to be very dependent on their college campus. For example, a UMD professor derives the social and economic values associated with employment from the UMD campus specifically; it's doubtful whether the same professor would find the same level of value in a different university setting. This suggests that in Floracaching, place meaning may become a catalyst for place attachment—though the full implementation of Floracaching is required to evaluate this hypothesis.

The relationship between specific constructs of place attachment and place meaning are also understudied. For example, both place social bonding from place attachment, and the self-others relationship from place meaning, emphasize the importance of social relationships. But, place social bonding necessarily involves interpersonal interaction, while the self-others relationship also encompasses perceptions of relational closeness or distance. Thus, despite the similarity between different dimensions of place attachment and place meaning, it is premature to collapse similar dimensions from each theory.

Important dimensions of place attachment (Ramkisson, Weiler, & Smith, 2012) and place meaning (Gustafson, 2001) for understanding the current study are highlighted in Figure 12. Within place attachment, the constructs of place dependence and place social bonding are particularly important (Ramkisson, Weiler, & Smith, 2012). Within place meaning, relevant constructs include the environment-self relationship, the self-others relationship, and the self.

It may be assumed that some co-designers, particularly the first year college students in group M2, depend on a university campus for fulfilling their basic and social needs. However, during Floracaching co-design place dependence became relevant primarily through the emphasis on the unique features of a place.

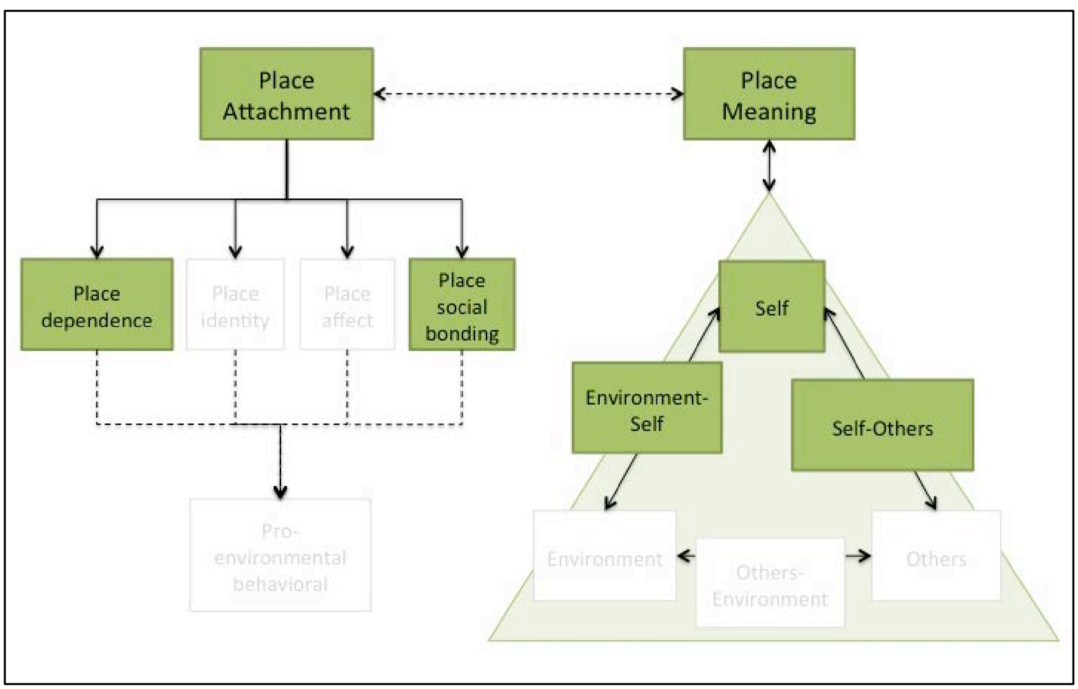


Figure 12. Place attachment and place meaning in Floracaching.

The desire to see unique or special things is in part aesthetic: as described in the previous section, co-designers want to see beautiful images of plants, regardless of whether pictures are accurate representations of a plant, or artificially enhanced through an Instagram filter (note that through enhancements like these, uniqueness becomes a value that may be created or applied). But co-designers also want to see caches that are unique in the sense that they are seasonally appropriate, or temporally relevant. For example, cherry trees should be viewed at the peak of their beauty, in the spring. Seasonal appreciation is aesthetic to a degree, but also gives meaning to an environment by illustrating the cyclical nature of change. In some cases, observing seasonal changes through phenology may signal forthcoming events of cultural or personal relevance, such as an autumn birthday, or Halloween.

Finally, co-designers want to understand what makes a place persistently unique and distinct from other places. While frat row may not be a universally appealing destination, it is undoubtedly part of what makes the university experience distinct from life in one's hometown, particularly for first year students at a large state school.

Participants described how looking closely helped them find beauty and significance in their local geography. Specifically, a heightened awareness led some players to abandon the conceptualization of campus as a space, or a blank canvas for meaning (Harrison & Dourish, 1999). Instead, campus as a natural environment emerged as a place with three types of actors: the self, others, and the environment (Gustafson, 2001; Harrison & Dourish, 1999). When awareness begets an experiential learning cycle, the meaning of a place deepens, and the importance of geography becomes cemented in the construction of everyday experience (e.g., the "*little blue blossoms*" will always be seen, and appreciated (M2)).

Both place dependence (Ramkisson, Weiler, & Smith, 2012) and the environment-self relationship (Gustafson, 2001) suggests that geography is valuable because of the opportunities it supports. Co-designers pointed to places of value, such as places for finding food, by strategically placing them next to floracaches or suggesting that these places could be caches themselves. Floracaching also highlights the potential for a new environment (e.g., a university campus as experienced by first-year students) to lead to new social relationships, thus blurring the self-environment relationship with the self-others relationship, and the construct of place social bonding.

Co-designers offered many suggestions for supporting interpersonal relationships through Floracaching. For example, competitions to see who could get the most floracaches in a limited time frame were viewed as social activities that offered the opportunity to explore campus with a friend, submitting phenological observations along the way. Co-designers also created group competitions, for example suggesting that players on one university campus could compete against players on another. This illustrates how the self-others relationship is not just explored through interpersonal dynamics, but community membership as well.

Features such as the ability to friend other players or pull in existing social networks, suggest the importance of one-on-one relationships. Requests including those for detailed profiles of all players, and badges to signify different experience and expertise, show a need for players to understand community and its constituents more broadly. Regardless of whether relevant others are individuals or groups, co-designers wanted to see how they themselves were positioned in regard to others. This desire may have influenced designs that depicted the player in relationship to other human actors on a map. The need to understand the self in relation to others who share a place is also evident in the request for a leaderboard page that allows players to easily compare themselves to community frontrunners.

As with place dependence and the environment-self relationship, there is significant overlap between the self-others relationship (Gustafson, 2001) and place social bonding (Ramkisson, Weiler, & Smith, 2012). Co-designers created social missions as activities that facilitate relationship building around an experience with a geographic place. Seeing the self in relation to others also supports the identification of like minded others who are potential friends (e.g., a player who has *"cached 15 of the same trees."* (B1)). Players derived pleasure from collaborative learning, for example by figuring out the identification of a plant together. Many also appreciated the contextual inquiry interview as a shared experience of a place, suggesting that learning about an interview partner was part of what made the field experience fun.

Regardless of whether an individual player was interacting with human or non-human actors, co-designers consistently emphasized the importance of the individual player in Floracaching. This is evident in discussions of how Floracaching must have personal value, and in the design of gamification to support reward and achievement, which keeps the focus on the player over the contribution. The high emphasis on the self in a constrained geographic community comprised of a university campus is consistent with Gustafson's framework, which predicts that smaller scale geographies will engage in meaning-making around the self (Gustafson, 2001).

In this way, the emphasis on the individual may be related to the geographic scope of participation. But it is also likely that the importance of the self is related to the study sample, which included many undergraduate and graduate students. The significance of late adolescence and college as pivotal stages in identity development suggests that students may place an even greater emphasis on the self over other actors during this time (Jones & Abes, 2013; Jones & McEwen, 2000; Luyckx, Goossens, & Soenens, 2006). This is especially true when students leave home to attend college, an act that serves as a catalyst for identity development by removing existing social and geographic dependencies (Chow & Healey, 2008). Because a majority of Floracaching co-designers—including all first year students—articulated a home that was not their university's town, this sample is likely engaged in significant identity development spurred by a geographic transition.

In identity development, the process of becoming aware of a community may be as important as the final state of awareness itself (Manzo, 2005). Exploration in breadth and exploration in depth are two concepts that characterize how adolescents form identities by exploring new hobbies and environments, and through conscious reflections on their experiences (Luyckz, Goossens, & Soenens, 2006). Citizen science through Floracaching supports both types of exploration. Players have the opportunity to try scientifically meaningful activities at a relatively low investment of time and monetary resources. If these activities are deemed enjoyable, participation in Floracaching may serve as an activation experience that helps students scientize, or forge a science identity (Clegg & Kolodner, 2014). For college students who have yet to declare a major, participation could be particularly valuable for discovering an affinity (or a dislike) towards science, and selecting a curriculum accordingly. Or, as will be explored in the following chapter, helping to design a citizen science application could lead co-designers to explore a career path involving technology or design.

Identity is socially constructed (Berger & Luckmann, 1991). College students define themselves in part through their experiences, and in terms of how their experiences and reflections compare to their peers (Luyckz, Goossens, & Soenens, 2006). The process of Floracaching supports socialization directly, and also illustrates the activities of a larger university community. Thus, Floracaching supports identity development by allowing players to interact with one another, and to make social comparisons through the app. For example, players might learn which types of expertise (e.g., the ability to take beautiful photographs; plant identification skills) are valued by their community, and reflect on the meaning of this valuation for their personal lives and activities.

The current prototype allows participants to contribute independent content to the Floracaching community. Subsequent iterations will allow participants to share these contributions with their external networks via social media. With features to support curation, such as the ability to rank or give a “thumbs up” to a cache or a photograph, participants will be able to understand how their content is received by internal and external community members, developing a greater understanding of their identity through the process of receiving social feedback.

In this way, place attachment and place meaning provide a cohesive narrative that links several key constructs into a single thematic thread, illustrating how Floracaching may become personally relevant to a university community. Awareness helps participants recognize why their immediate natural environment is special and unique. This understanding that encompasses the geographic as well as social features of a university campus, and map deepen through experiential learning. Awareness and knowledge frame the environment as a legitimate actor, giving meaning by revealing the different opportunities that campus as a place affords.

One such opportunity is social interaction. Social engagement through Floracaching leads to place-based social bonding. Floracaching also supports socialization through engagement with a community. Players may see how different roles and activities are valued, and find like-minded others who might become friends. The four themes of awareness, knowledge and learning, socialization, and community and contribution, are supported by design. For example, gamification encourages participants to continue engaging with the application by offering small rewards, provides important feedback, and may be linked to other motivations, such as learning about a campus community.

A sense of place is pertinent to many in situ citizen science projects, but may be particularly relevant for university communities, which by definition include a significant population of college students. As students are at a pivotal stage of identity development, any activity that facilitates identity construction—whether facilitated by social comparison; by exposure to science; or, by the unique experience of playing a citizen science game itself—acquires significant value. In this way Floracaching has the power to become personally relevant as a tool for exploring and understanding a local place, which leads to an enhanced understanding of the self, especially as participation continues over time.

Unfortunately, Gustafson's framework stops short of explaining how place meaning develops, and does not contemplate how orientations towards the self, others, and the environment change over time (Gustafson, 2001). Similarly, theories of place attachment only begin to hypothesize how attachment changes over time (Ramkisson, Weiler, & Smith, 2012). To begin to understand how these changes might occur, it is necessary to draw on scholarship from different areas.

Applying the reader-to-leader framework to Floracaching

Through the reader-to-leader framework, Preece and Shneiderman examine community participation by emphasizing how community members may contribute in different roles (2009). These roles include readers, who consume content; contributors, who add content; collaborators, who work with others; and, leaders, who help establish and enforce community norms. Different roles in Floracaching were explored in Table 7.

Players begin using the app because it has personal relevance. This may be derived from a topical interest in plants, or an interpersonal relationship. As readers explore the app, they learn what activities are technically possible. They begin to understand community norms by watching how others players act, and witnessing how different roles and contributions are valued (in the context of citizen science online communities, this process of learning by observing others is described as accessing practice proxies (Mugar, Østerlund, DeVries, Hassman, Crowston, & Jackson, 2014). Because the interaction design of Floracaching emphasizes contribution through creating and checking in to floracaches, the period of readership will likely be brief.

Once participants are familiar with a community and its norms, they may begin making small contributions, for example by giving a five star rating to a beautiful picture of a tree (Preece & Shneiderman, 2009). As players become more experienced, they will likely make more involved contributions such as creating or checking in to floracaches. During this time, awareness and awe of local biodiversity may activate an experiential learning cycle, deepening engagement through different facets of place attachment and place meaning.

As contributors, players are likely to begin appreciating gamification as they rack up points and earn badges. For some players, the process of earning game mechanics will be a fun and rewarding experience in itself. Others will be driven by social comparison, especially if the awareness of others' supports identity construction. Still others will appreciate gamification that enforces primary motivations, as when missions direct players to seasonally relevant plants.

Applying the reader-to-leader framework to Floracaching

Table 7

Role	**Activity**	**Relevant constructs**
Reader	Understand technical capabilities and community norms	Personal relevance; Community
Contributor	*Early* Content curation: rating existing content Content curation: verifying a Floracache (during checking in) *Evolving* Content creation: creating a floracache Content creation: making creative content Content creation: sharing local knowledge	Personal relevance; community; gamification; awareness; knowledge
Collaborator	Social recruitment Helping others	Personal relevance; community; gamification; awareness; knowledge; socialization
Leader	Recruit other players Mentor new players Participate in co-design	Personal relevance; community; gamification; awareness; knowledge; socialization

Collaborators work together to share or create knowledge (Preece & Shneiderman, 2009). Players may collaborate by helping others through the app, for example by helping a new user find or identify a floracache. They may also use the application as a platform to organize in-person social events, such as group excursions on sunny weekend afternoons. Finally, collaborators may work with others outside the Floracaching community, for example by sharing their new knowledge with classmates. Even though they are not mediated through the platform, these interactions give value to

Floracaching by reinforcing that knowledge gained through participation is broadly appreciated.

Leaders in online communities synthesize the contributions of others, and set and enforce the norms of participation (Preece & Shneiderman, 2009). Floracaching users acting as contributors will partake in low levels of curation, as described above. But the emphasis on locality suggests that a significant amount of content such as missions must be tailored to the cultural and geographic needs of a local community. If Floracaching is to scale, community leaders will be required to act as regional administrators (admins) and perform a curation role that extends beyond a simple rating system.

Some leadership activities, such as the ability to add or approve icons designating how a certain floracache is unique, may be unlocked as a user reaches a certain point threshold. Other activities, such as the ability to create, edit, or approve missions, may be reserved for users who are designated as an admin first by the research team, and later by other community administrators. And players who recruit others, or mentor new community members through extensive training, may assume leadership roles even before they develop significant experience. Note that this is consistent with the reader-to-leader framework, which suggests that the progression from reader to leader is often but not always linear (Preece & Shneiderman, 2009).

As invested community members, leaders will likely be motivated, to some extent, by all themes including personal relevance; community; gamification; awareness; knowledge; and, socialization. But they may experience the motivational pull of these constructs differently than players in other roles.

Applying the reader-to-leader framework to Floracaching illustrates how some themes or motivations, such as community, are experienced at different stages of participation. The same motivation may take on slightly different meanings at different stages in time.

Take, for example, community. For players contributing to Floracaching in the role of readers, community is important as something to understand and emulate. In their discussion of virtual citizen science, Mugar and colleagues observe how studying practice proxies, or the traces of other users' behaviors, alerts newcomers to socially desirable behaviors and to community norms (Mugar et al., 2014). Floracaching has a mixed level of social translucence; behaviors such as creating caches are visible through the caches that result, but the process of checking in is by and large invisible. In addition, because many participants may begin using the app through social recruitment or potentially even because of gamification, initial topical knowledge may not be as high as in other citizen science projects utilizing different recruitment strategies. At the same time, if Floracaching becomes a catalyst for place meaning or place attachment, the desire to understand a local community may be particularly strong.

In contrast, players acting as collaborators may wish to share creative contributions, such as a beautiful photograph of a tree, both with other Floracaching users and their external social networks. While there may be a performative aspect to sharing that is directed towards the self, there is also a genuine desire to share content representing information of a local area that others will appreciate for their own benefit.

This form of community as a motivation is therefore (to extents that will vary with individual players) directed towards others and also towards the self.

Finally, players with knowledge of plants—either acquired through the process of Floracaching, or as pre-existing knowledge—may contribute to the community of Floracaching players by helping others with poor plant identification skills, or by creating localized content. While the desire to help is self-enforcing to the degree that it lets an individual consider themself as a helpful person, this motivation is more strongly characterized as altruistic, and oriented towards others. In this way, when motivations to participate in Floracaching are analyzed through the lens of a sense of place, potential motivations—including personal relevance; awareness; learning and education; community; socialization—are not categorically directed towards the self or others, but may be considered on a spectrum from self-oriented to others-oriented.

Designing to support research and theory

Research through design produces a design artifact that illustrates how the world may move from its current state to a preferred state (Zimmerman, Forlizzi, & Evenson, 2007). By taking a collaborative research through design approach, this study asked co-designers from university communities to prototype an application designed to support the ideal state of participation in citizen science.

The research discussed above hypothesizes a temporal model for participation in Floracaching with six relevant constructs, described below. As discussed in Chapter 4, this model emerged through the process of data analysis, and also through the creative process of design. Specifically, the challenge of designing a new version of Floracaching led the author to search for theory to elaborate upon user research; at the same time, new theory challenged evolving designs and led to better prototypes. The results of this iterative process of design and synthesis led to a new prototype of Floracaching (Figures 13-16).

Design artifacts are accompanied by annotations, which elucidate key aspects of a design (Gaver, 2012). Pierce characterizes the artifact-annotation contribution as a concept-thing, suggesting that annotations are valuable for illustrating the tacit knowledge and understanding in a design (2014). When presented as concept- things, the new designs for Floracaching and framing constructs offer a succinct answer to the question, *How might a gamified mobile app for citizen science biodiversity data collection be designed to engage a place-based citizen science community?* The six constructs are: Nature is everywhere, contribution, socialization, topical knowledge, local knowledge, and the self in place. These constructs build on the themes presented in the previous chapter. But, they expand these themes by bringing in a deeper level of analysis conducted through drawing on external theory during the creative process of design.

In writing annotated portfolios, it is important to find a balance between providing sufficient information to highlight key features of an artifact, and providing so much information that the interpretive power of design is handicapped (Bardzell, Bardzell, & Hansen, 2015; Bowsers, 2012). New designs of Floracaching are presented as artifacts below, and expansions of the six framing construct listed above form the main annotated portfolio. More detail on how specific design elements relate to the six framing constructs may be found in Appendix E.

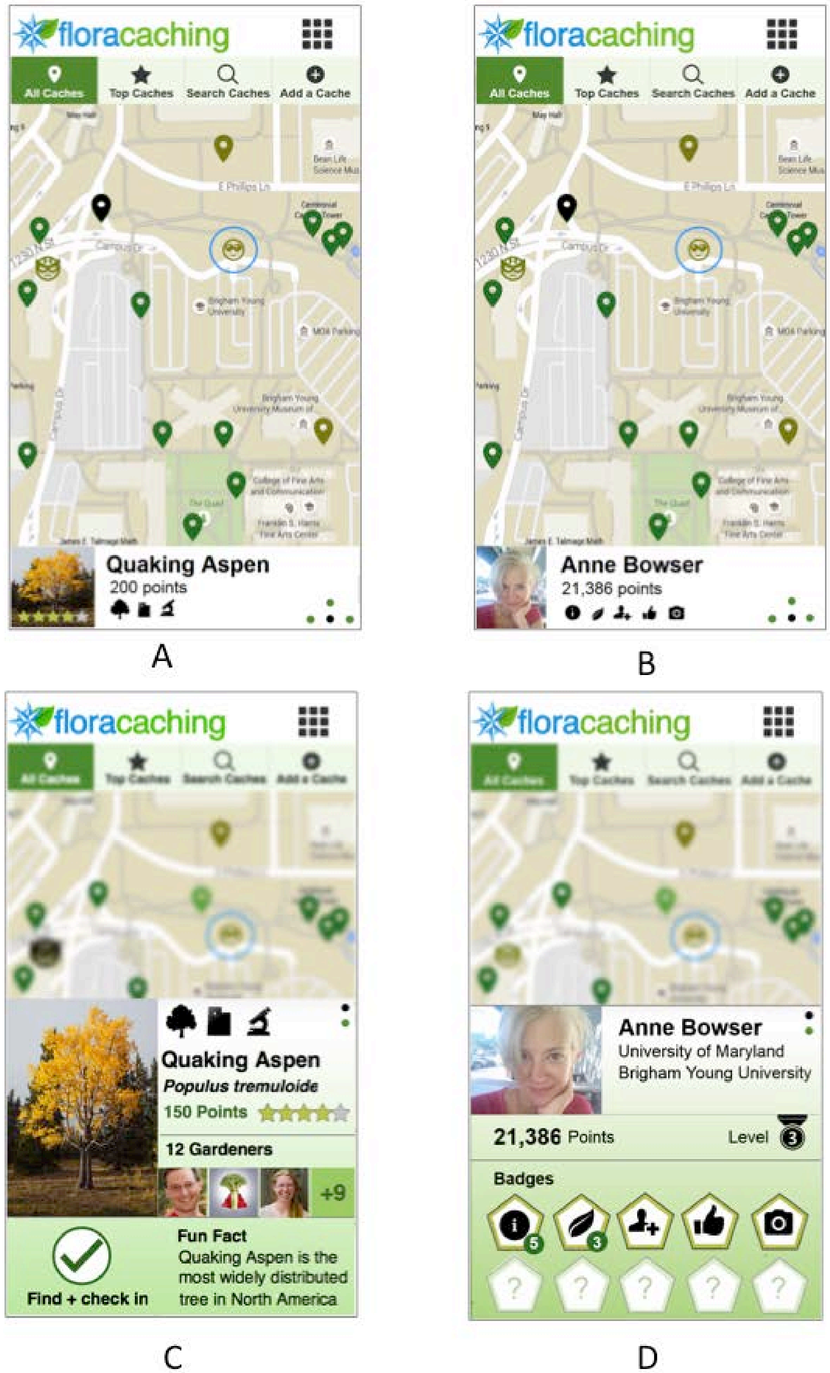

floracaching
All Caches
Top Caches
Search Caches
Add a Cache
Quaking Aspen
200 points
A
Anne Bowser
21,386 points
B
Quaking Aspen
Populus tremuloide
150 Points
12 Gardeners
+9
Find + check in
Fun Fact
Quaking Aspen is the most widely distributed tree in North America
C
Anne Bowser
University of Maryland
Brigham Young University
21,386 Points
Level
Badges
D

Figure 13. Screen shots of Floracaching: home screen with an expandable bottom container (A, B); plant profile page (C); Player profile page (D).

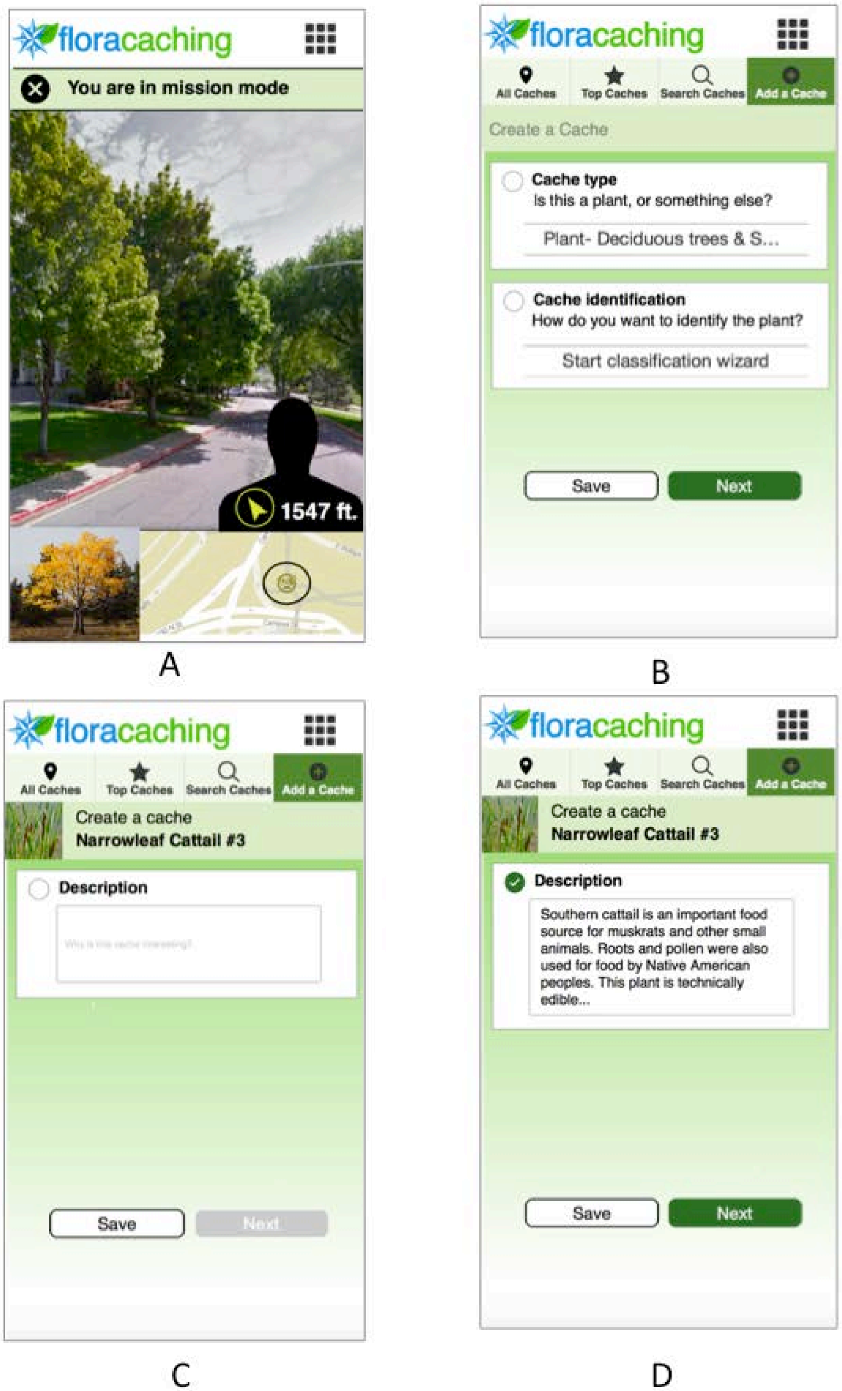


Figure 14. Screen shots of Floracaching: mission mode (A) and different steps in the create a cache process (B, C, D).

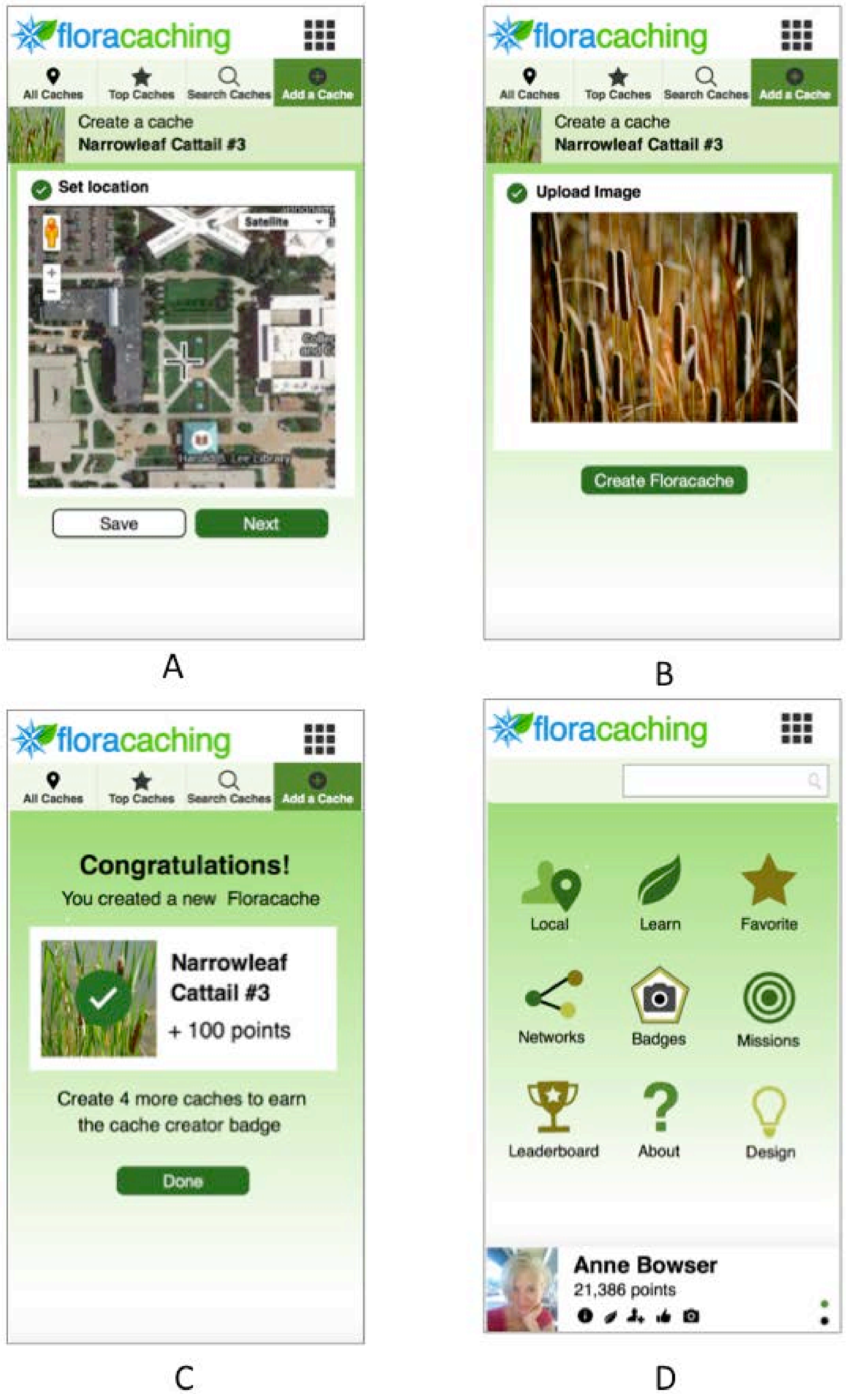


Figure 15. Screen shots of Floracaching: different steps in the create a cache process (A, B, C) and the content page (D).

Figure 16. Screen shots of Floracaching: the local page (A) and leaderboard (B).

Nature is everywhere. In contemporary society nature is often constructed as a destination, which requires a geographic and perceptual departure from everyday life. Floracaching reverses this model by showing how everyday natural environments, such as a university campus, hold beauty and significance. When a player selects a Floracache to check in to, the app enters “mission mode,” which shifts the default screen view perspective from third- to first- person with the goal of directing a user’ attention towards the natural context of use. The app is also designed to support persistent awareness, for example by awarding the role of “gardener” to players who habitually visit and check in to the same tree.

Contribution. Citizen science experiences should be designed to support participation from anyone, regardless of skill. Floracaching supports lightweight participation in the form of content curation. Players may rank different Floracaches for beauty and interest, or give players props through a "thumbs up" feature; those with significant knowledge of plants may also validate existing caches. Curation encourages initial, lightweight contributions (Preece & Shneiderman, 2009), and also acts as a feedback mechanism by establishing "practice proxies" that illustrate to newcomers which roles and contributions are considered most valuable (Mugar et al., 2014).

Socialization. Co-designers considered Floracaching an inherently social process. Players would go Floracaching with existing friends, use the app to make new connections, and draw on the knowledge of others through a digital chat feature. Integrating Floracaching with other social media, such as Instagram, facilitates social recruitment. A page displaying local content highlights in-person opportunities for socialization through a linked calendar. Using badges to designate player expertise makes it easy for a new player to find plant experts (or others with interesting skills) to chat with.

Topical knowledge. Learning is a primary motivation for contributing to citizen science, regardless of whether participation may be characterized as place-based, or virtual (Raddick et al., 2011; Rotman et al., 2012; Shirk et al., 2012; Wiggins & Crowston, 2011; Wiggins & Crowston, 2015). Floracaching helps players learn about plants and their environment first by exploring existing content, like by reading different fun facts about nearby trees. The app also offers scaffolding to support learning while creating and checking in to Floracaches. Players struggling to classify a plant may lean on a machine vision feature that identifies trees based on leaf shape (e.g., Leaf Snap; Kumar et al., 2013), or alternately reason their way through a pictorial dichotomous key.

Local knowledge. As the most widely distributed tree in North America, *Populus tremuloides* (the Quaking Aspen) is recognizable in a myriad of locations. But as the state tree of Utah, the Aspen takes on a special significance for players at BYU. Floracaching utilizes a system of icons to designate caches as locally, seasonally, culturally, and/or scientifically relevant. Recognizing that local knowledge is not restricted to biodiversity, Floracaching allows users to create a small percentage of caches that are not living plants.

The self in place. Places acquire meaning as people begin to understand their relationship to local human and non-human actors. The landing screen of Floracaching maps players in relation to nearby caches, and other players. Through the default interaction of browsing, an indiscriminate collection of nearby floracaches, other caches, and players appear on the bottom of a user's screen. Players may cycle through these to get an overview of the community, or pursue a promising profile by swiping up. Social comparison is also facilitated by the layout of screens such as the leaderboard, which allows a player to quickly assess how they stack up to community leaders.

Summary

This chapter discussed seven key themes related to Floracaching, synthesizing these under theories of place attachment (Ramkisson, Weiler, & Smith, 2011) and place meaning (Gustafson, 2001). Following this synthesis, the reader-to-leader framework was applied to understand how participation may change over time. The process of analyzing the collaborative research through design sessions by integrating relevant theory through the creative process of design produced prototypes to inspire the next version of Floracaching. These designs illustrate how limited participation in citizen science may move to an ideal state of expanded participation through using gamification to target the members of a university community.

Six framing constructs are advanced to answer the research question, *How might a gamified mobile app for citizen science biodiversity data collection be designed to engage a place-based citizen science community*? These include:

- **Nature is everywhere**. Floracaching encourages players to pay attention to their everyday natural environment.
- **Contribution**. Users can begin by exploring lightweight contributions, such as curation, before making more significant contributions over time.
- **Socialization**. Floracaching is an inherently social activity, and the app supports virtual and in-person social interaction.
- **Topical knowledge**. Players may use Floracaching to learn about plants, for example by making classifications with the aid of a dichotomous key.
- **Local knowledge**. Players may also use Floracaching to learn about their local place, for example by visiting caches of local landmarks.

- **The self in place**. Floracaching is designed to help players continually reflect on their role in a specific local environment, and their relationship to other humans and the environment.

Each of these framing constructs is derived from integrating user research with external theory during the iterative process of design. The relationship between these framing constructs, key themes from qualitative data analysis, and external theory, is explored in table 8.

Table 8

Framing constructs, themes, and theory

Framing Construct	**Key themes from qualitative data analysis**	**Relation to relevant theory**
Nature is everywhere	Personal relevance; design; gamification and reward; awareness and exploration; community and contribution	A new awareness of the natural world may lead to experiential learning (Kolb, 2014); understanding a local environment leads to place meaning (Gustafson, 2001)
Contribution	Community and contribution; gamification and reward	Floracaching supports expanded participation and new contributions over time (Preece & Shneiderman, 2009)
Socialization	Community and contribution; socialization	Place social bonding leads to place attachment (Ramkisson, Weiler, & Smith, 2012); the self-others relationship supports place meaning making (Gustafson, 2001)
Topical knowledge	Personal relevance; knowledge and learning	Experiential learning may lead to new knowledge of plants (Kolb, 2014)
Local knowledge	Personal relevance; knowledge and learning; community and contribution	Experiential learning may lead to new local knowledge (Kolb, 2014); place meaning develops as the relationship between the self and a local environment becomes clear (Gustafson, 2011)
The self in place	Personal relevance; gamification and reward;	Observing the behavior of others helps players acclimate to community norms

	awareness and exploration; socialization; community and contribution	(Preece & Shneiderman, 2009); the self-others relationship shows how an individual begins to understand their role in a place (Gustafson, 2001);

The discussion now turns to the process of designing Floracaching with collaborative research through design, in order to understand and situate the methodological contribution of this research.

Chapter 7: Findings on Collaborative Research through Design

This chapter evaluates collaborative research through design (CRtD), a new approach to research through design. RtD produces an artifact that represents how the world may move from a current to a preferred state. Collaborative research through design applies a cooperative design perspective, influenced by participatory design, cooperative inquiry, and contextual design, to research through design. Collaborative research through design is thus defined as an iterative process of cooperative design, where the collaborative vision of an ideal state is embedded in a design. While other researchers have used cooperative techniques in RtD in the past (Zimmerman, Forlizzi, & Evenson, 2009), this study is unique because it was initiated in part to understand which cooperative techniques were suited for research through design, and how these techniques should be applied.

Collaborative research through design was used in the design of Floracaching, a gamified application created to promote citizen science in a university community. The case study of Floracaching is used to evaluate the CRtD approach. This chapter begins by discussing the implementation of CRtD, in terms of the roles of co-design participants and the research team and the specific techniques of observation, prototyping, and focus groups. Following this discussion, the value of CRtD is evaluated with metrics borrowed from research through design and participatory design. This chapter concludes with suggestions for conducting CRtD, and for co-designing with our target user group, a university community.

The process of collaborative research through design

One important question in cooperative design is when to involve users in design. A second consideration is who to involve in the co-design process. A third, is how to involve participants in co-design, or what techniques to use. Answering these questions for the present study sheds light upon how to best implement cooperative techniques in research through design.

When should participants be involved in collaborative research through design? There are six distinct phases of research through design (Zimmerman & Forlizzi, 2008). Researchers first define a problem space, then discover data, synthesize data, and generate solutions. Solutions are refined based on feedback; finally, researchers reflect on the problem framing, the achievement of a preferred state, and the artifact itself. One value of collaborative research through design is to empower users to articulate their desired end state. *To maximize this value, participants should be involved in CRtD to the greatest extent mutually beneficial to researchers and co-designers*.

To this end, some researchers suggest that designers work closely with a community while defining problems (Bjogvinsson, Ehn, & Hillgren, 2012). Here, a community partner is identified before a problem statement is formed; thus, design activities prioritize user needs over researcher interests. CRtD with Floracaching takes a different approach. This study was initiated under the goal to "design Floracaching, a gamified citizen science app to collect plant phenology data for Project Budburst." Thus, both the problem space—e.g., designing a gamified citizen science app—and the appropriate framing—e.g., to support scientific research—were predetermined. However, during the course of CRtD it became clear that participants considered Floracaching valuable not as an app to support scientific research, but as one designed to connect users to human and nonhuman actors in a place-based community.

The research team found their problem framing evolving in tandem with these views. The new prototypes of Floracaching emphasize themes including awareness and education, making tradeoffs that favor user-stated goals over the goals of scientists (for example, by allowing players to create caches of things other than plants). This suggests that while in some cases it may be appropriate for researchers to select projects with communities, it may also be appropriate for researchers to suggest a problem to solve—provided they are willing to modify their framing, or potentially even abandon their problem if co-designers do not consider it a valid one.

CRtD with Floracaching helped co-designers discover data through contextual inquiry. Each co-design group synthesized data during focus group sessions. Solutions were generated through prototyping; these solutions were also critiqued through focus group sessions.

Zimmerman and Forlizzi suggest that the next stage in research through design is refining a design based on feedback (2008). This model assumes that users were not involved in discovering and synthesizing data. For Zimmerman and Forlizzi, the goal of refinement is then to bring users back into the process to offer feedback on a designer’s work (2008). CRtD reverses this model. During refinement, a single researcher (or a small team) synthesizes numerous prototypes created by many co-designers into a single design. Refinement and synthesis allow a researcher to draw on relevant theory, contributing their interpretations to an artifact and adding an additional dimension of understanding.

Following the next iteration of Floracaching, it will be necessary to conduct user testing to evaluate whether a jointly articulated ideal state is effectively codified in the app, and also to evaluate the app's usability. Co-designers should actively participate in user testing. Some may act as subjects evaluating a design. But, just as this study involved co-designers in formative user research through contextual inquiry, co-designers may lead evaluation through usability testing. Future work with Floracaching will invite participants into the role of usability testers to evaluate this claim.

The final stage in collaborative research through design, reflection, is a joint endeavor. Soliciting reflection to evaluate whether the artifact truly reflects a preferred state is necessary from an ethical point of view. In addition, through hearing participant critiques a researcher may better understand how to be a partner in the collaborative research through design process.

The author began the process of reflection by creating a blog, where the designs showcased in Figures 13-16 and the associated framing constructs were published. The URL was shared with co-design participants from all four sessions. While this evaluation is still ongoing, early responses suggest overall appreciation for the new designs. One co-designer offered the compliment *"those designs look awesome"* (B2). Others provided suggestions for improving the designs even further, or pointed to open issues (*"Do you envision any photo moderation…somebody will photograph a body part.").* These early evaluations suggest that while the new designs are on the right track, there is still future work to be done. It should also be noted that only a small portion of co-designers responded to the request for feedback. This is returned to in the subsequent chapter, which discusses limitations of the present study.

Submitting this research to the scrutiny of peer reviewers will begin a second stream of reflection, as members of the design community and the citizen science community alike are invited to critique the design, the underlying meaning, and the CRtD process.

What are different roles in collaborative research through design? A team of researchers including the author and facilitators led the CRtD process. This team embraced the role of participant observers, focusing first on facilitating user creativity and secondly on contributing to discussions and prototypes. Users were responsible for leading the creative effort of understanding and designing for their community. In this way, co-designers were considered design partners, who truly shared the responsibility for research and design with the research team (Druin, 2002).

In the role of design partners, participants were able to influence how the co-design workshops unfolded. During the first few sessions, facilitators were struck by how positively co-designers responded to basic expressions of respect. For example, during the introduction to session M2, the author informed co-designers that activities were not likely to take the full amount of time allocated. One participant interrupted the author's monologue—an infrequent occurrence in the sessions at large—with an emphatic "*thank you.*" (M2). Recognizing the importance of letting co-designers take ownership in not just the product of co-design, but in the process as well, the research team took flexibility as a goal during later sessions.

The roles of facilitators as participant observers, and participants as design partners, aligned with value of collaborative research through design for contributing well-designed artifacts, and for advancing the collaborative vision of an ideal state. One important part of this process is harnessing theory to make better designs (Zimmerman, Forlizzi, & Evenson, 2007). This is primarily the responsibility of the researcher, especially in situations where a problem is pre-determined by the research team. In this situation, the role of co-design participants is to help researchers identify relevant knowledge to explore.

For example, one co-designer suggested that increased awareness of a local place may have stewardship implications. This hypothesis was interpreted as an opportunity for the author to find and consider literature on stewardship and place (e.g., Ramkisson, Weiler, & Smith, 2012). A second co-designer referenced Bartle's work on player types directly (Bartle, 2004). These examples suggest that co-designers may share constructs with theoretical relevance, and also theory itself. Future applications of CRtD will directly ask co-designers for suggestions on important ideas to look into, to better guide the process of weaving together external and user research.

Collaborative research through design is valuable because it supports interpretation—from the researcher, from a group of users, and from other community members. All who become engaged in the co-design process, either through contributing to evolving designs or evaluating completed designs, provide interpretation through critique. But because collaborative research through design aims to produce a community vision, the intended users of a design are the ultimate stakeholders in critique. Giving voice to this community is the researcher's responsibility, though it is also helpful for participants to offer feedback on how well the researcher is doing in their role as a design partner. Thus, the role of a researcher in collaborative research through design is to:

- Provide participants with the opportunity to exercise their creativity and share their ideas;
- Contribute to generative prototyping and summative evaluations; and,
- Communicate expectations for how co-designers will be involved at different stages of collaborative research through design.

The role of a co-designer is to:

- Shape the direction of inquiry, through directing problem framing, and generating and evaluating design solutions;
- Contribute to generative prototyping and summative evaluations; and,
- Help researchers understand how to be effective partners in collaborative research through design.

Collaborative research through design with Floracaching was conducted with a university community. While a majority of this sample were college students, community members such as researchers and administrators were also represented. All participants may be considered domain experts, e.g., experts on university campus life and activities.

In addition to this domain expertise, some co-designers were familiar with research on citizen science; others, were botanists; still others, prolific game players. In addition, numerous participants had experience with art, design thinking, user-centered design, or game design. This diversity enhanced the co-design experience for participants, and led to high quality and creative designs. For example, drawing on the expertise of botanists in session B1 led one user to create prototypes that incorporated a new knowledge of plant science (the "*family tree*" mission, asks different members of a human family to visit different species in a tree family). Co-designers who were botanists benefited from hearing others share their preferences for different games.

Researchers who study creativity in co-design suggest that users may participate on the doing, adapting, making, or creating levels of creativity, asserting that "expertise, interest/passion, effort, and returns grow with each level" (Sanders & Stappers, 2008, p.8). Our research team found that participants with design experience performed on higher levels of creativity as defined by Sanders and Stappers (2008). As an added benefit, these co-designers helped others visualize their ideas, either as formal design partners or through casual advice. Thus, actively recruiting participants with design experience benefits the co-design process because these participants produce high quality designs, and enable others to do the same.

This is not to suggest that all participants in co-design must be experts; all co-designers offered *"thoughtful"* contributions (Debriefing). There is also a benefit to involving participants who have an interest in design, but not yet expertise. Co-designers in three of the four sessions indicated a tentative interest in design or technology development career paths. For these students, co-designing Floracaching was appreciated as an opportunity to experience user-centered design firsthand.

What specific techniques should be applied in collaborative research through design? The methodology of collaborative research through design with Floracaching involved three main techniques: observation, prototyping, and focus group discussions. These techniques, which were implemented in a flexible environment, were selected to build consensus between co-designers. Discussing these techniques illustrates how collaborative research through design may be implemented, and investigates the process of co-designing with a university community.

The methodology presented in Chapter 4 unfolded slightly differently in each session. For example, some groups prototyped both general improvements to the app and missions at the same time, while others completed these tasks sequentially. In addition, slight tweaks were made to accommodate the evolving interest and needs of different co-designers.

While participants in the M2 session were fairly engaged during the initial round of prototyping and reporting out, attention drifted during the exercise of prototyping missions. By the time the small groups were called to share their missions, energy in the room was waning. Reflecting that these co-designers were particularly competitive, the author decided to ask students if they wanted to vote on the best mission prepared. This suggestion seemed to wake up the room. A few participants sat up straighter in their seats; one group, began to hurriedly discuss a number of missions in order to select the best one to submit to the contest. Energy remained high through voting, and into the concluding focus group. While reflecting after the session, both the author and facilitator considered this adaptation a success (“*suggesting that students vote on ideas of other tables was great.”* (MD)). With this flexibility in mind, each individual technique is discussed.

There were two types of observation in this study: observation of co-design participants by the author and facilitators, and observation of and by co-design participants through the contextual inquiry interview. Observation by the author and facilitators led to a series of insights on the process of collaborative research through design. For example, watching different groups of co-designers work together while prototyping suggested the need to support different levels of confidence and creativity. However, compared to other techniques, observation by the author and the facilitator was less valuable for answering the research question on how to design a gamified citizen science app for a university community.

Conversely, observation through contextual inquiry was extremely successful. This technique was selected with numerous goals. First, the research team wanted participants to explore Floracaching and become familiar with key features, such as gamification that unfolded over continuous use. With this goal, a paired experience was designed to reduce frustration with known location recognition issues. Contextual inquiry was also selected to encourage co-designers to think as designers who were responsible for creating an interactive technology for a larger community, rather than as users, who typically focus on their personal preferences. Finally, the research team wanted co-designers to consider the larger context of use instead of focusing solely on the interface.

For understanding the app, participants vastly preferred the field experience over the classroom introduction. As one explained, *"it's better to fumble around with it. Because when [the facilitator] is doing the PowerPoint of all the different functionalities of the app, I don't think it stuck with a lot of people, without using it firsthand."* (M2). In addition, co-designers found value in *"working together to figure it out"* (B1).

But not all features of Floracaching were uncovered through contextual inquiry. During the initial report out, participants in numerous sessions recommended creating features that already existed. In addition, during prototyping one annotated a screen shot of the leaderboard with a sad face and the words, *"I never saw this screen."* (M2).

Allocating more time for the contextual inquiry interview could lead to a more comprehensive understanding of the app. However, the research team agreed that due to the interaction design of the prototypes, and more importantly the temporal nature of gameplay, simply lengthening the experience by a magnitude of minutes (as opposed to days or weeks) would be ineffective. This is consistent with previous research with Floracaching, where user studies held over a period of weeks were helpful for understanding the full context of use (Bowser et al., 2013b). This discrepancy also points to a tradeoff between a short, succinct field experience that offers ample time for design, and longer experiences that enable full immersion in Floracaching. For the present research, which focuses on generative design and evaluation, a short field session was preferable to allocate more time for prototyping. Later stages, which will involve collaborative evaluation, may require an extended timeframe.

The second goal of the contextual inquiry interview, to facilitate a contextual understanding of Floracaching, was met with mixed success. This is attributed to changing materials. In the first two co-design sessions, participants were offered worksheets with blank spaces to record different observations (See Figure 17, left). These spaces were labeled “Observation #1,” “Observation #2,” etc. Through these worksheets co-designers offered some thoughtful contributions, often reflecting on their partners experience: *“Clarisse noticed that the black background is a little bit hard to see in the light.”* (M1). In this way, some early contextual inquiry interviews were successful at raising awareness of a larger community of potential users. However, many co-designers using these worksheets focused on the app itself as opposed to the holistic context of use (e.g., *“suddenly five caches show the green check in label”* (M1)). Furthermore, when one group was asked, “What did you learn from observing your partner?” during the initial focus group, the question needed to be re-phrased before responses were offered.

Following the first session (M1), participants were given extra information on the interview process during classroom introduction. After the second session (M2), the worksheet itself was modified (See Figure 17, right). Instead of soliciting generic observations, space was allocated for “Observations about ‘the person’ using Floracaching,” “Observations about ‘the place’ Floracaching is used,” “Observations about the Floracaching app itself,” and other notes.

Almost all participants who completed these worksheets made direct references to the use context. For example, under “Observations about ‘the place’ Floracaching is used,” one co-designer noted, *“BYU is a good place—lots of variety.”* (B1). In addition, sharing this observation during report out led to a lengthy discussion of local biodiversity, which suggests that other co-designers were sensitized to contextual cues. Participants in

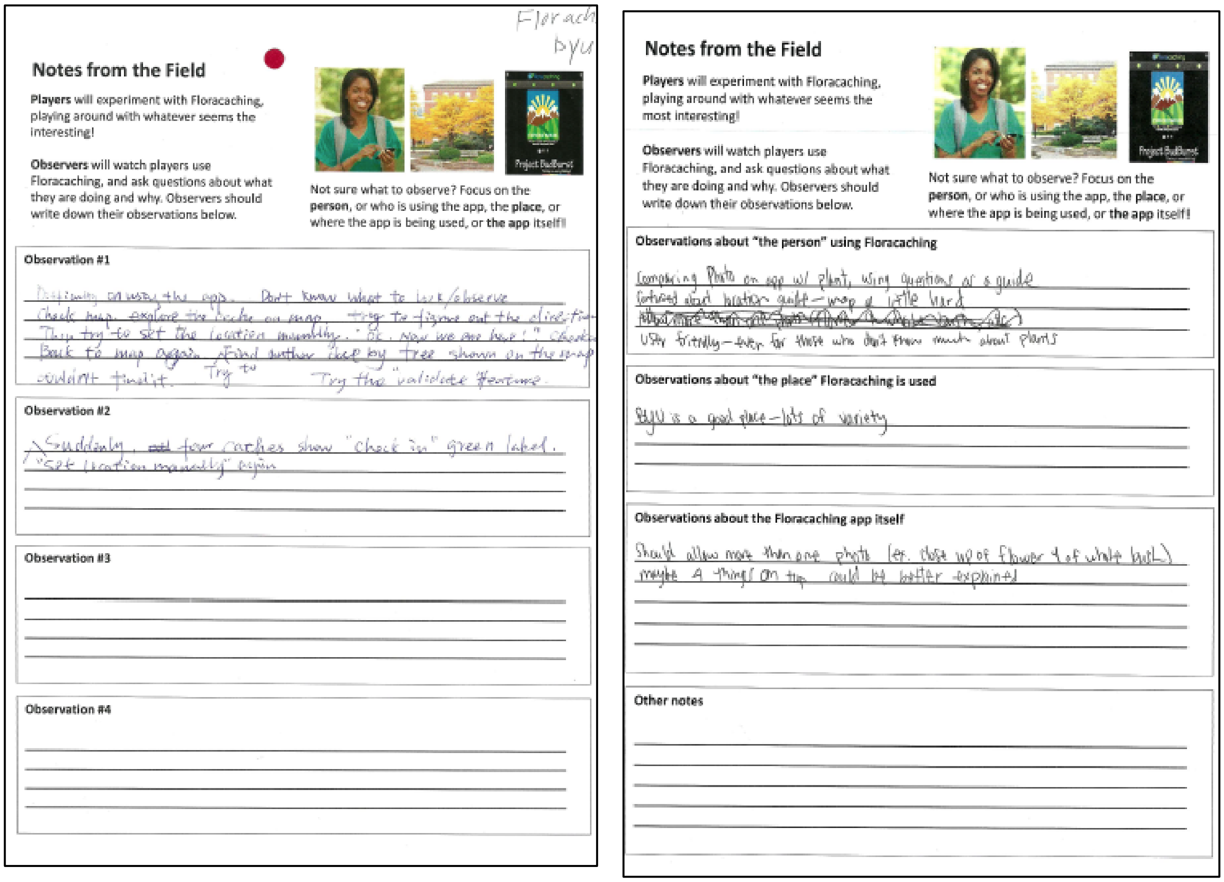


Figure 17. Two contextual inquiry worksheets.

B1 and B2 were also more articulate when answering, "What did you learn from observing your partner?"

Finally, when asked "What did you think about the general structure for today's session?" Participants in B1 and B2 complimented the contextual inquiry interview. One co-designer explained its value as:

P: I think the advantage was, for me just being able to watch Kathleen. I could *see what she was doing, what she was struggling with. She was talking out loud. And there's no way she would be saying 'oh I was wondering about this,' put down her phone, and write it down. So having a partner is invaluable.*

One alternate explanation for the varying success of contextual inquiry could be demographic differences between the four groups. However, given the expertise of group M1, these participants would theoretically be most proficient with the contextual inquiry technique. Because this group struggled along with group M2, the explanation of demographic differences is rejected. Instead, it is concluded that given ample guidance, co-designers drawn from the population of a university community can effectively participate in contextual inquiry in the role of researcher as well as in the role of user.

This conclusion extends the value of the contextual inquiry interview technique beyond the traditional implementation as sensitizing researchers to a participants' environment (Holtzblatt, Wendell, & Wood, 2007). In the past, participatory contextual inquiry was customized for a group of children by allowing children acting in the role of interviewers to record their observations as drawings instead of words (Druin, 2002). The current study builds on this work by suggesting how contextual inquiry can be customized for a sample of college students and other members of a university community. While contextual inquiry is generally effective, instruction should not be delivered from a facilitator, but provided as just-in-time content for co-designers to make sense of in the field.

Participants enjoyed the prototyping experience, and many asked for extra time to design. All co-designers actively contributed to prototyping, though the methods of collaboration, the designs produced, and an appreciation for materials varied between participants.

Prior to the first co-design session, facilitators planned to break contextual inquiry pairs apart for prototyping, in order to support cross-pollination of experiences and ideas. But when co-designers were asked to indicate their preferences, all wished to stay with their partner. As one explained, *"I think it's important to keep the group because that way you have the knowledge from before, and you don't have to start the wheel explaining all over again why you're making this suggestion."* (M1). Participants in subsequent sessions agreed: *"It was helpful to remember. When you're with another person, you don't have to explain it, you can just go on and make a new version."* (M2). Thus, co-designers were encouraged to stay in pairs for the duration of co-design sessions.

The design team hoped that co-designers would work in small groups to collaboratively critique existing design ideas and generate new ones. The second session was set up with this goal in mind; the room was designed to cluster four or five participants around a single table (recall that there were only four co-designers in the first session, so participants in this session were asked to work in pairs). However, even after co-designers were asked to work in small groups, the author and session facilitator noted that most participants seemed to be working in alone. Indeed, the room remained quiet even after one facilitator circled the room encouraging co-designers to collaborate.

Thus, it was surprising when during the initial report-out session each table only shared a few ideas. In some cases, a single person presented the table's work; in other cases, multiple co-designers spoke. It was also difficult for the author to extract extra ideas through prompting. For example, when one participant was asked what he thought of the leaderboard, he answered *"I didn't have that one."* (M2).

While the design team initially attributed this result to a lack of interest and minimal participation, the final focus group suggested otherwise. As one co-designer explained, each table collaborated by first distributing the screen shots; then, working independently; and finally, by asking for feedback on their designs. This process was explained as, *"P1: More single, and then shared sort of afterwards…P2: To see if everyone agreed with the suggestions."* (M2). Only ideas that were collaboratively considered valuable were shared with the larger group during focus group presentations. This model of collaboration is supported by analysis of the paper prototypes, as more design are found in the prototypes themselves, than were shared in the focus groups.

Based on this experience the research team kept the structure of the third and fourth focus groups flexible, suggesting that it may be helpful to work in pairs or small groups but explicitly allowing for other models. In both sessions, participants elected to work in groups of two. However, while some pairs prototyped in relative isolation, others interacted with their neighbors. Sometimes one pair would actively *"ask each other for feedback, or opinions."* (B1). These conversations frequently started with *"eavesdropping."* (B1).

Eavesdropping supported new ideas: *"It's validating if you have an idea and you hear the other person saying, 'yeah, we noticed that too.'"* (B1). Co-designers also observed that this form of collaboration helped incubate and advance ideas. As one explained, *“Hearing one of his ideas would trigger an idea, is kind of synergistic. Hearing what they were saying you think ‘oh yeah, and….’”* (B1). Through this process, good ideas from two co-design pairs would become fused into a single, highly creative idea.

One example of such fusion is the *“slow the decay”* mission, where the points assigned to each floracache increase with the amount of time elapsed since the last check in. This mission is creative in the sense that it is novel (e.g., no similar ideas were voiced in the other sessions, or during previous research), and in the sense that it combines the goals of plant phenology—namely, to consistently monitor a single plant over time—with gamified elements—including points, and time pressure. In contrast to co-design pairs that collaborated, pairs that kept to themselves *“didn’t have as many transformative ideas…they were more like thoughtful ideas about the existing interface.”* (BD).

Overall, participants enjoyed the group experience; multiple co-designers suggested that the sessions could be even more collaborative. One suggested “*a class group think…like put it up on the board, side by side, and say ‘do you guys think we should change this?’*” (M2). A second recommended sharing paper prototypes to build on the designs of others, a technique demonstrated to be successful in co-designing with children (Walsh et al., 2010).

Important materials for supporting prototyping included screen grabs, bags of stuff (Yip et al., 2013), and mobile phones. Participants found printed screen grabs helpful as a concrete starting point for improving Floracaching. As one facilitator observed, screen grabs also helped co-designers understand the full functionality of the app: *"The first thing they did was unpack and go through the screen shots. And they could see what they missed. A couple of times they were like 'oh, there's the leaderboard."* (BD). Other researchers have similarly found that screen shots help users' understand a design (Pommeranz, Ulgen, & Jonker, 2012). Co-designers also referenced the app to see how newly discovered screens were linked to screens they had accessed previously.

Most participants appreciated the "bags of stuff"; there were audible expressions of delight in each of the four focus groups. Prototyping materials were characterized as *"cool,"* (M2, B1) *"fun,"* (M1) and *"awesome- and there were treats in them."* (B2). One participant appreciated the implication of playful materials, as much as the materials themselves:

> *The fact that you dumped them on us? Even if we didn't use it it's like 'oh they want us to open our minds to play.' I used them too, but just bringing these here? It was an invitation about seeing things like a kid, opening your mind, don't constrict yourself to anything.* (B2).

However, at least two participants didn't appreciate the *"arts and crafts,"* (M2), characterizing supplies such as colorful markers and stickers as too *"second grade."* (B1). Additionally, while some participants did take advantage of different materials to create their own prototypes, others chose to simply annotate existing screens with pens or markers (Figure 18).

This finding, which aligns with previous research, suggests that materials should be flexible to support different types of contributions (Pommeranz, Ulgen, & Jonker, 2012) and users acting on different levels of creativity (Sanders & Stappers, 2008). Participants also used their smartphones to reference external websites. These included social media sites, digital games, and generic interfaces. For example, one participant

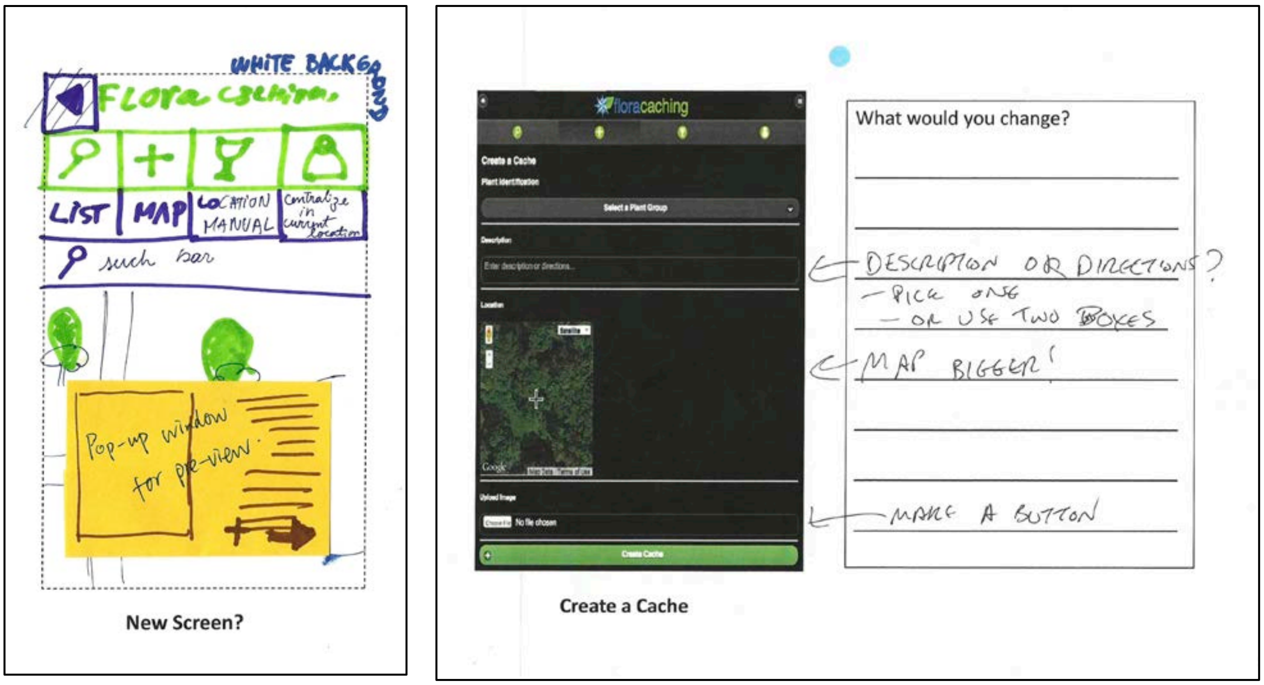


Figure 18. Different levels of creativity in Floracaching. Some participants created new designs (left), while others simply annotated the existing prototypes (right).

used his smartphone to research different green color schemes.

Focus groups were held at three key junctures including after the contextual inquiry interview, while sharing new designs, and at the conclusion of the co-design workshop. Co-designers enjoyed this process, and considered it helpful: *"I liked hearing everyone's ideas. I think that was interesting. Some of the things I've never thought of* *before, so that would help with brainstorming other ideas."* (M1). The author and facilitators also evaluated focus groups as effective, observing participants challenge and build upon one another's ideas.

However, one participant did suggest that a brainstorming session might help participants solidify ideas and build confidence before sharing with the group. Our team contemplated this recommendation, but ultimately decided that the session structure was effective as planned. While brainstorming would be beneficial early in the co-design process, for these sessions the goal of prototyping was reaching consensus, a process that by nature requires group engagement.

For many, participation in a co-design workshops was not a one-time engagement with Floracaching. Four participants had helped co-design earlier versions of the app. An additional four had critiqued Floracaching during their semester long-project. In addition, co-designers described how their engagement with Floracaching might continue through future iterations.

One suggested allowing co-designers to take a leadership role in the next iteration: *"it would be cool to let some of the participants just go loose? And build an app, based on this. Build a paper app…come up with the whole blueprint of it."* (B2). A second participant saw contribution as ongoing, recommending, *"a place where you could put any ideas that came up a little later."* (M2; note that the Wordpress blog is a first step towards addressing this suggestion). Co-designers also considered how and in what contexts the finished app would be used. One, who worked in a museum, volunteered to help Floracaching reach new audiences: *"I would love to have some sort* *of connection to Floracaching. Whether the database could be tied to our website and people could look at it, or they could get points for coming to our herbarium and finding that plant in our herbarium."* (B1). Others suggested that corporate partnerships or licensing agreements could provide funding and help reach an audience of passionate outdoor enthusiasts.

The research team also considered next steps during debriefing. One open question is whether to involve the same participants, or recruit new groups of co-designers, in future sessions. One facilitator mentioned a downside to recruiting new participants: *"bringing them up to speed wouldn't mean as much because they hadn't experienced the co-design firsthand, and they hadn't seen the back and forth process of vetting ideas."* But on the other hand, bringing in new participants (especially participants representing new university campuses) would enable the research team to evaluate the extent that the ideas proposed by students at BYU and UMD are extendable to other university communities. A compromise might be reached by training former participants to act as researchers during user testing. These participants would bring their knowledge of the rationale that went into different designs, while at the same time recruiting a new group of users to act as testers.

<u>*Evaluating collaborative research through design with Floracaching*</u>

Collaborative research through design with Floracaching may be evaluated with criteria from research through design and from participatory design to consider the value of CRtD. This evaluation helps show how collaborative research through design is similar to and distinct from these methodologies. It also shows how the current contribution may be considered by designers in research through design and participatory design communities.

Zimmerman, Forlizzi, & Evenson suggest four criteria for evaluation RtD contributions (Zimmerman, Forlizzi, & Evenson, 2007). Process, suggests that methods should be applied in a rigorous and reproducible way. Invention, suggests that RtD should integrate existing theory to make novel contributions. Relevance, suggests the need to establish the value of an idealized state. Finally, extensibility suggests that communities of research and/or practice should benefit from the knowledge produced.

As noted in Chapter 3, there is some debate regarding whether the first criterion of process is indeed appropriate for creative activities such as Research through Design (Gaver, 2012). As Gaver argues, no two designers will produces identical solutions to a problem, even if all situational factors are the same. At the same time, offering a detailed description of techniques such as the contextual inquiry interview and focus group discussions increases the probability that re-applying these techniques would yield similar (if not identical) results. The criterion of process is met through the documentation found in this thesis, and subsequent publications.

In regard to the criterion of invention, the Floracaching prototypes and associated framing constructs are novel as early efforts to design technologies to support place-based citizen science. Floracaching is also novel as an early citizen science geocaching game. In addition, many aspects of the design, such as the immersion designed in “mission mode,” are relatively novel in citizen science technology design at large.

When planning the collaborative research through design workshops, our research team held the goal of designing Floracaching as a mobile app to support biodiversity data collection for use by Project Budburst scientists. Working with co-designers helped us re-frame this goal to one of engaging a university community in citizen science to support constructs including awareness, knowledge, socialization, and place-based community membership. In this way, applying a collaborative approach to RtD, enabled us to ensure that the criteria of relevance was met (Zimmerman, Forlizzi, & Evenson, 2007).

Regarding the criterion of extensibility, which suggests that others should benefit from the knowledge that a designer practicing RtD produces, we hope to reach and inform numerous communities. The first community is comprised of design researchers and practitioners engaged in various forms of cooperative design and research through design. The second is a community of citizen science researchers and practitioners hoping to understand how to design citizen science technologies, especially those that incorporate the motivational affordances of games.

Evaluating collaborative research through design with criteria used to evaluate research through design paves the way for comparing how CRtD relates to other forms of RtD. This single evaluation does not suggest when CRtD may be preferable over other forms of RtD, such as non-collaborative RtD driven by the creativity of a single designer or design team (e.g., Zimmerman, 2009). Instead, this evaluation is offered to contribute to a large and ongoing debate on the value and significance of research through design in its various forms (e.g., Bardzell, Bardzell, & Hansen, 2015; Gaver, 2012; Pierce, 2014; Zimmerman, Solterman, & Forlizzi, 2010).

To understand how CRtD may be evaluated as a form of participatory design, it is helpful to refer to Spinuzzi's three criteria: quality of life, collaborative development process, and iteration (Spinuzzi, 2005).

Because Floracaching is not yet fully implemented, it is impossible to assess whether participants' daily lives are improved through use. Yet, the process of participating in co-design encouraged members of university communities to imagine how Floracaching might be implemented to lead to an ideal state. For example, through dialogue and design participants illustrated the value of heightened awareness to a local community, including but not limited to awareness of biodiversity. Numerous design decisions, such as the move to a map-based landing page and the creation of "mission mode," are designed to support this value, and thus provide an opportunity for improving university life at a later point in time.

In addition, participatory design empowers participants by giving them voice (Spinuzzi, 2005). By articulating the desired state of a community, participants in CRtD with Floracaching were encouraged to reflect on individual and shared values. This process helped co-designers develop a more complete understanding of themselves and of their communities, allowing them to become better advocates for their communities at large (Cook & Quigly, 2013).

The criterion of collaborative development suggests that co-designers should be involved at multiple phases in the design cycle. This is a key tenet of the collaborative research through design methodology. During each of the four sessions described in this study, participants contributed to user research through the contextual inquiry interview, contributed to ideation through generative prototyping, and evaluated different ideas in focus groups. In addition, as a follow-up exercise participants were asked to evaluate new prototypes hosted on the Wordpress blog. Note that this level of involvement extends the practices of many co-design practitioners, who often involve users only during ideation and prototyping (e.g., Lucero, Vaajakallio, & Dalsgaard, 2012).

In line with the criterion of iteration, participants were involved in multiple cycles of development. To date, Floracaching co-design has gone through two significant iterations during the PLACE trials (Bowser et al., 2012b), a third iteration during early classroom evaluations (Bowser et al., 2013b), a fourth iteration immediately following the early classroom evaluations, and a fifth iteration through the current research. Each of these iterations involved participants as co-designers; future iterations will do the same.

Following this argument, it is clear that collaborative research through design may be effectively evaluated as a participatory methodology and can meet all criteria of participatory design to some degree. This evaluation facilitates comparison between CRtD and other forms of cooperative design that are not driven by a research through design perspective. This discussion also advances the ongoing dialogue on research through design by illustrating the benefits that a cooperative approach may bring to the RtD process.

Suggestions for other researchers and practitioners

The above discussion is synthesized into a number of short suggestions for other researchers and practitioners. All suggestions are relevant for those wishing to explore collaborative research through design. A number of suggestions will also support practitioners working with university communities. Combined with the above, they address the research question, *How can cooperative design techniques be effectively integrated into the research through design methodology*?

Take flexibility as a goal. Participatory design holds worker empowerment as a core value. Following this tradition, CRtD with Floracaching suggests that participants should be invited to influence how co-design sessions unfold. This is a practical need, as ensuring that participants remain engaged and comfortable with the process is necessary for a productive session. There is also an ethical dimension to flexibility. Letting participants control how a session plays out signals the respect a facilitator has for their design partners. Flexibility is especially important for facilitators who begin the process with a research question in mind, as fidelity to the ethical ideals of cooperative research through design may require researchers to re-frame their problem statement in light of participant concerns. This suggestion is relevant to CRtD conducted with a range of audiences.

Enable independence and agency. In collaborative research through design, participants are encouraged to take on roles—such as leading a contextual inquiry interview—often reserved for "professional" designers. Our research team found simply telling users how to act in these roles was ineffective. However, co-designers succeeded when provided with just-in-time content in the form of (for example) a structured worksheet that encouraged them to learn contextual inquiry by doing it. The lesson here is simple and straightforward: when predictable information is needed, such as guidance on a specific research technique, that information should be easily accessible to participants when they need it the most.

Because collaborative research through design requires that participants are offered and accept a high degree of agency, this is a best practice for all CRtD. It may be particularly important to support independence for participants in a university community. Power differences between groups such as workers, and employees; adults, and children; and, professors and their students, may influence cooperative design (Druin, 2002; Spinuzzi, 2005). Working to neutralize pre-existing relational dynamics will lead to equal and productive collaborations. Note that researchers studying undergraduate education similarly suggest that neutralizing power differences is productive for improving in-classroom learning (Cook-Sather, 2002).

Choose techniques that create agreement or consensus. Co-design techniques such as brainstorming support individual creativity. But collaborative research through design is not conducted to generate multiple or fragmented visions of a preferred state; rather, it aims to demonstrate a shared vision of the future. Techniques that encourage synthesis and consensus are more effective at moving towards this goal than techniques designed to support individual creativity.

CRtD with Floracaching began with a contextual inquiry interview. This established a common understanding between the interview pair, which was often shared with other co-designers. In this way, the contextual inquiry interview became a boundary object (Star & Griesmer, 1989) that enabled all participants in a session to reference a shared understanding when creating or evaluating ideas. Beginning with collaborative techniques thus provided a strong foundation for continuing to generate and explore solutions as a group.

Our research team observed a range of collaboration strategies. These included assigning different Floracaching screens to different team members; working closely within isolated pairs; and, exchanging ideas to challenge and confirm evolving designs. Many of our participants, particularly those in session M2 (composed entirely of undergraduates), emphasized the importance of consensus. For example, co-designers in this session vetted their ideas in small groups before sharing successful ideas during report out. One participant in this session also suggested that the entire co-design session should be conducted as a group exercise.

This is consistent with research that suggests the importance of peer experiences and opinions during college (e.g., Luyckz, Goossens, & Soenens, 2006). There are numerous ways that facilitators can make sure college students feel comfortable sharing and iterating on ideas. One, which we also found effective in previous workshops, is to encourage students to bring their friends along to participate in activities. Working closely with a friend, where a trusting relationship already exists, may help some students feel more comfortable expressing themselves. A second possibility is to (as one co-designer suggested) allocate time for individual brainstorming to let participants fully develop their ideas before sharing. Each of these suggestions may be appropriate for different sessions, with distinct participants and goals. This conclusion reinforces the importance of flexibility, and suggests that a research team should begin a co-design session with a variety of ideas for implementing various techniques in mind.

Recruit from a range of relevant backgrounds. The premise of cooperative design is that involving people with domain expertise leads to better technologies with a higher rate of adoption. As members of a university community, all of our participants were domain experts—though museum professionals, researchers, undergraduate students, and graduate students all brought a different perspective on the university experience. In addition, some participants were skilled as user experience researchers; others, game designers; still others, botanists. This range of backgrounds helped participants focus on designing for a holistic university community. Having participants with different types of expertise also created a more democratic atmosphere, as co-designers could ask facilitators and also their fellow participants for advice.

A number of our participants decided to attend the sessions not because of a passion for plants or citizen science, but because they were interested in exploring user-centered design. Here, researchers benefit through access to co-designers who are truly engaged in getting as much out of the experience as possible. Participants benefit from the opportunity to explore user-centered design before fully committing to a career path, or even a semester-long class.

Summary

This chapter discusses the collaborative research through design methodology. It begins by addressing key questions in cooperative design, including which specific cooperative techniques to use. The information presented in this chapter answers the research question, *How can cooperative design techniques be effectively integrated into the research through design methodology*?

This research suggests that participants should be involved in the research through design process to the greatest extent mutually beneficial to researchers and co-designers. Drawing on the stages of research through design advanced by Zimmerman and Forlizzi, co-designers were involved in problem framing, discovering data, and generating solutions (Zimmerman & Forlizzi, 2008). The role of co-design participants in CRtD can be characterized as design partners (Druin, 2002). As design partners, co-design participants may shape the direction of inquiry, contribute to prototyping, and help researchers understand how to be good co-design partners.

Specific techniques for collaborative research through design may include user research techniques, such as observation through a contextual inquiry interview (Holtzblatt, Wendell, & Wood, 2005). Effective techniques also include prototyping and focus group discussions. Investigating whether CRtD can effectively engage co-design participants in evaluation, for example by leading usability testing, is left for future research.

This chapter also advances a number of suggestions for other researchers hoping to implement CRtD. These include, take flexibility as a goal; enable independence and agency; choose techniques that create agreement or consensus; and, recruit from a range of relevant backgrounds.

Chapter 8: Conclusions, Limitations, and Future work

This chapter begins by revisiting the research questions, summarizing important conclusions and considering possible limitations of this research. This helps scope the contribution of this study, and leads to a series of open questions for future work (Figure 19).

Figure 19. Future work with Floracaching. Future work is suggested by screen 6.

Research questions revisited

One purpose of this study was to learn how to design Floracaching, a gamified citizen science app created to mobilize a university community as citizen science volunteers. Floracaching was designed through collaborative research through design (CRtD), a new approach to the research through design methodology (Zimmerman, Forlizzi, & Evenson, 2007). Collaborative research through design is defined as an iterative process of cooperative design, where the collaborative vision of an ideal state becomes embedded in a design artifact. While CRtD builds upon and extends earlier research (especially the PLACE methodology; Bowser et al., 2013b), the present study is the first attempt at systematically exploring this new approach. Thus, the second research question asked, *How can cooperative design techniques be effectively integrated into the research through design methodology*? This question was explored through a single iteration in the Floracaching design process. This iteration was conducted with 40 participants during four co-design sessions held on two university campuses. Collaborative research through design involved customizing and combining a number of existing research techniques.

A modified version of a contextual inquiry interview (Holtzblatt, Wendell, & Wood, 2007) was used to involve co-designers as both researchers and users. This technique worked best when co-designers were able to work autonomously, while provided with just-in-time information in the form of structured worksheets. Contextual inquiry was valuable for encouraging participants to act as designers, considering important tradeoffs and the holistic context of use. The interview also became a boundary object (Star & Griesemer, 1999) that supported later discussions within and between contextual inquiry pairs.

A second important technique in CRtD is prototyping. Working on different levels of creativity (Sanders & Stappers, 2008), co-designers critiqued current designs and created new ones. Participants who contributed the most creative prototypes often began by incubating an idea in pairs before consulting other co-designers to evaluate and build on an evolving design.

A third important technique in CRtD is focus groups. By supporting conversations between multiple participants and the research team, focus groups enabled co-designers to build off one another's experiences and ideas. Focus groups supported consensus, one of the key goals for this stage of collaborative research through design.

On one hand, it is premature to mandate that all collaborative research through design should unfold like the present study. On the other, it may be helpful to offer guidelines to others who wish to experiment with this research approach. Suggestions for collaborative research through design include:

- Recruit from a range of relevant backgrounds. Inviting co-designers with a range of expertise (including plant identification and game design) showed that different forms or knowledge were respected, and helped co-designers see each other as resources.
- Take flexibility as a goal. Letting participants influence how each session unfolded, like through re-allocating time to different activities, helped participants take ownership of the design process and led to strong design ideas.
- Enable independence and agency. Providing co-designers the resources they needed to understand design methods, such as contextual inquiry, was more effective than telling them exactly how to do the contextual inquiry interview.
- Choose techniques that create agreement and consensus. Focus groups allowed co-design participants to collaboratively weigh the pros and cons of different design ideas, and helped create a shared understanding of what the goal for Floracaching should be.

This exploration of collaborative research through design constitutes one contribution of this study, which is offered as a form of intermediate knowledge (Lowgren, 2013) that advances two important HCI methodological approaches: cooperative research, and research through design.

Recognizing that citizen science is an inherently cooperative process (in line with a cooperative approach), and that citizen science technology design often addresses wicked problems (in line with a research through design approach), collaborative research through design may be particularly beneficial in the context of citizen science. At the same time, CRtD may be appropriate in other situations where a community could help design for an ideal state. For example, CRtD may be valuable for helping practitioners understand and design for problems that carry significant moral or ethical weight, like the design of "smart" homes or buildings that may threaten the privacy of their inhabitants.

A second form of intermediate knowledge, and a second contribution of this study, is the "concept thing" produced (Pierce, 2014): new prototypes of Floracaching, accompanied by a set of framing constructs. This contribution addresses the second research question, *How might a gamified mobile application for citizen science biodiversity data collection be designed to engage a place-based citizen science community?* Framing constructs include: Nature is everywhere; contribution; socialization; topical knowledge; local knowledge; and, the self in place. When framing constructs are offered as a form of design pattern (Zimmerman, 2007), this contribution is generative of design. These framing constructs may also advance the discussions of volunteer motivations and user groups among citizen science researchers and practitioners.

Limitations

This study has a number of limitations. The most prominent limitations are discussed below, to scope the present contribution and inspire future work.

First, there are limitations to the implementation and evaluation of collaborative research through design. As discussed throughout this thesis, there is a debate in cooperative design regarding whether to involve the same participants as co-designers over time, or to recruit new co-designers for each new iteration (see, for example, Demirbilek & Demirkan, 2004; Sanders, Brandt, & Binder, 2010; Wadley, Bumpus, & Green, 2014). In line with the ideal of building broad consensus around an ideal state, cooperative research with Floracaching took the later approach, where each session invited new participants into the design process.

While this model was effective for generating a range of design ideas early on, and understanding which ideas were embraced by a large and diverse number of potential users, it was less effective for encouraging co-designers to provide feedback on the new prototypes. Further exploring the tradeoffs between working with the same users over time, versus recruiting new users, is an important direction for future work. For example, during future iterations with Floracaching, the design team will likely recruit "consultants," or participants who are invited to contribute to a single session, and "advisors," who remain engaged with the project through numerous iterations over time.

To date, there have been multiple iterations of cooperative design and evaluation with Floracaching. However, a final version of the app is not yet implemented. A full evaluation of cooperative research through design will be possible only after implementation takes place. Furthermore, there has been no cost-benefit analysis comparing CRtD with other, less laborious, design methodologies. This is a second limitation to the present study.

There are also limitations to research on the motivations of Floracaching users. Most obviously, in line with other research through design (e.g., Zimmerman, 2007) this study created a new version of Floracaching for an aspirational future state, where a new group of volunteers, members of a university community, would be motivated to contribute to citizen science. Designing for an ideal is not equivalent to studying the actual practices of citizen science volunteers, which would require the implementation and adoption of Floracaching. This is a goal for future work.

An additional limitation is the specific group of users sampled and targeted. While culturally different, the University of Maryland and Brigham Young University are both large research universities in the United States. It is unclear whether findings from research conducted on these campuses will also apply to other less similar environments, such as small liberal arts colleges or universities outside of the United States.

Finally, to be of the greatest value, Floracaching should be adopted not only by a university community, but by a wider range of citizen science volunteers. Involving volunteers who are not members of a university community in future research would help ensure that the app is not scoped too narrowly. Regarding the question of value, there may be an additional limitation associated with the evolving framing of Floracaching—from a mobile application designed to collect plant phenology data for Project Budburst, to one designed to help connect students, faculty, and others to a place-based community. A number of design decisions, such as the inclusion of non-plant caches, support this new framing over the initial framing of supporting scientific research. Exploring how Floracaching can remain valuable for researchers may involve the implementation of new protocols or functionality (such as expert review as a form of data validation).

Other open questions for future work

By applying cooperative design approaches to research through design, collaborative research through design has the potential to draw on the benefits of each approach. However, CRtD with Floracaching is not yet complete; in addition, this is just one example of the collaborative research through design approach. A short list of open questions is offered to provoke future research on collaborative research through design.

What can collaborative research through design teach us about research through design? One open question in research through design is the type of knowledge that RtD, and by extension other types of design, may produce (Bardzell, Bardzell, & Hansen, 2015; Bowsers, 2012; Gaver, 2013). This study embraced research through design as a way of solving a difficult problem, namely how to design Floracaching to engage a new group of citizen science volunteers with unknown motivations. Through this process, the author built on her skills collecting data and drawing on external theory, to conduct additional creative analysis through the process of design. The differences between the seven themes that emerged from textual analysis, and the framing constructs later presented, illustrate the value of taking a CRtD approach to solving this particular problem. Specifically, the themes are summaries of deficiencies in a present state, and early thoughts on an ideal state; the framing constructs, are mature and theoretically grounded articulations of a preferred state, which are generative of design.

Research through design needs more examples, particularly those with detailed reporting of the exact methods used (Zimmerman, Stolterman, & Forlizzi, 2010). In line with the argument that progress will be made through “proliferation rather than agreement,” the current case study is offered as an additional example of research through design (Gaver 2013, p. 938). This case may be particularly helpful as a contrast to more recent work that highlights the *artistic* rather than the *research* elements of design (e.g., Bardzell, Bardzell, & Hansen, 2015; Pierce, 2014).

This study contributes two forms of intermediate knowledge—knowledge on how a collaborative approach may be applied to RtD, and knowledge in the form of indexical framing constructs (Bowers, 2012). While these framing constructs fall squarely within Fraylings’s research *for* art and design, work on the methodology itself may be considered research *through* art and design (Frayling, 1993). Similarly, Bardzell, Bardzell, and Hansen’s critique may be read as research *into* art in design (e.g., the critique itself) and research *through* art and design (e.g., the suggestion that critique is an important part of the RtD process; Bardzell, Bardzell, & Hansen, 2013). These examples highlight that a single RtD contribution may produce multiple types of knowledge. Exploring the full value of RtD contributions as producers of different types of knowledge may support and expand the dialogue around knowledge in RtD and other forms of design.

A final suggestion along these lines: while analyzing an aspirational design is not equivalent to conducting empirical research on volunteer motivation, the present study does suggest which motivational forces may be important in Floracaching. Thus, while research through design is typically considered generative of design, RtD may be generative of research as well.

What is the value of taking a cooperative approach to research through design? By taking a cooperative approach to research through design with Floracaching, the research team hoped to work with co-designers to articulate a shared vision of the ideal state of participation in citizen science. As CRtD was developed to help the author understand what would motivate a university community, this is a research goal inspired by research through design. At the same time, it is an ethical goal inspired by participatory design.

Our exploration of collaborative research through design began during the PLACE trials, which were conducted with the goal of understanding how to collaboratively prototype games and apps by considering location, activities, and collective experience over time (Bowser et al., 2013b). During these sessions, co-designers experimented with an early prototype of Floracaching before providing feedback and design ideas through focus groups and surveys. From the PLACE sessions, our research team began to understand how Floracaching should be designed to reflect user preferences and motivations (such as by emphasizing the social aspect of game play, and including more gamification).

During the four co-design sessions described in this thesis, our research team expanded the PLACE methodology in important ways. Instead of asking co-designers to simply play around with a prototype, we used techniques such as the contextual inquiry interview (Holtzblatt, Wendell, & Wood, 2005) to encourage co-designers to conduct their own user research to understand how the app might be used by members of a university community. In addition, we asked our participants to modify existing screen shots of Floracaching, and to actively create new designs.

Involving participants as co-designers responsible for conducting user research and generating new ideas, instead of simply asking for feedback on existing designs, produced a rich corpus of data. Focus group deliberations on key features of Floracaching and the overall value of the app also led the research team to re-frame our vision of an ideal state for Floracaching, from participation in citizen science *to support scientific research,* to participation in citizen science *to support a local community.* At the same time, we gleaned valuable insights on what would motivate Floracaching users to engage in citizen science. Through the iterative process of re-designing Floracaching that followed the four co-design sessions, our knowledge of participant motivation expanded beyond the simple list of motivations identified through previous research (e.g., Bowser et al., 2013a) into a complex and nuanced set of framing constructs that explore how different motivations interact. For example, the framing construct “the self in place” reflects the motivation to socialize, and also the motivation to explore a local environment.

Thus, when comparing the results of the PLACE trials with the present study, it can be demonstrated that:

- Compared to asking for feedback on designs, actively engaging participants in design research and prototyping—a benchmark of the CRtD methodology—generates higher quality data and ideas.
- CRtD that unfolds through design research, prototyping, and focus group reflections can allow participants significant control over the design process, even allowing them to re-frame the purpose of an application.
- When combined with qualitative data analysis, the iterative process of design that takes place during CRtD can uncover motivations for using an application, and also explore how these motivations relate to one another.

A second goal of collaborative research through design was to create an app that is likely to be adopted. Assessing whether CRtD will be able to support this goal is left for later iterations, and future work with Floracaching.

Who can conduct collaborative research through design, and what might their contributions be? The author of this study has stronger research expertise than design experience. This is a departure from traditional applications of research through design, which are often led by professional designers (Zimmerman, Forlizzi, & Evenson, 2007).

Pierce explores the presentation of design artifacts in research through design, distinguishing between verbal and design articulations (Pierce, 2014). Pierce suggests that RtD often produces artifacts with a strong design articulation, which are understood by other designers, and often appreciated by an external community (Pierce, 2014).

The present study is much stronger in its verbal articulation of Floracaching. As RtD grows in its various forms, it may be beneficial for practitioners who are strong verbal articulators, and practitioners who are strong design articulators, to work together. These collaborations could generate contributions strong in their verbal and their design articulation of an ideal state, that could reach diverse communities.

What are the implications for research on citizen science? In addition to the above questions, which are offered to inspire future work on RtD and CRtD, this study reveals opportunities for new scholarship in citizen science. For example, the conceptualization of motivation as self- or others- oriented suggests a prominent direction for expanding previous work. Rotman studied how motivation to participate in citizen science changes with time and culture (Rotman, 2013). Her participants expressed motivations that could be characterized as part of two "silos"—self directed, and collectivistic—with "self-directed" motivations important early in and through out participation, and "collectivistic" motivations becoming relevant later on (Rotman, 2013, p. 240). The present study supports the finding that the self is important early in participation, while others become relevant later on. But the present study also suggests that some motivations previously assumed to be inherently "collectivistic," such as contributing to a community, may actually be experienced as either self- or others-oriented. Fleshing out this idea will require additional research.

A second area for future scholarship is applying the theoretical lens of sense of place to understand research and practical questions in citizen science. Others have already started using this lens (Haywood, 2014; Wiggins, 2012), and find it effective for exploring topics such as the lived experiences of citizen science volunteers (Haywood, 2014). The present study builds on this research by illustrating how the specific theories of place attachment (Ramkisson, Weiler, and Smith, 2012) and place meaning (Gustafson, 2001) may be valuable. In addition, this study complements previous work by using a sense of place to understand motivations, or reasons for participation, rather than experiences, or perceptions of participation. Just as citizen science researchers and practitioners may benefit from drawing on a sense of place, phenomenological geographers may benefit from seeing this theory applied in citizen science, as applications may advance the theory as a whole (for example, through Haywood's use of spatial dependency to explore the relationship between place attachment and place meaning; Haywood, 2014).

In general, co-designers did not believe that scientists were an important stakeholder to consider while prototyping Floracaching. Yet, the importance of contribution suggests that co-designers do want to use the app to benefit others. Future research could explore what factors make a stakeholder community "relevant" to Floracaching design, potentially by inviting local scientists or university researchers to participate in co-design activities.

Finally, the importance of education and learning in the present study suggests a need to expand pervious research on learning in citizen science (e.g., Brossard, Lewenstein, & Bonney, 2005; Crall et al., 2012) to study learning and education in a university community. One possibility is to explore how and whether students scientize, or develop a science identity, through citizen science in university settings (Clegg, Gardner, & Kolodner, 2010). Future research might also expand the consideration of experiential learning (Kolb, 2014) to explore other learning theories, such as physical or virtual affinity spaces (Gee, 2004). This study also suggests that participation in citizen science technology design may help co-designers explore career paths in user-experience or other forms of technology design.

Of course, many of the empirical questions raised above could be approached through a collaborative research through design approach. In this way, knowledge construction through design may truly be seen as an iterative cycle that is valuable for advancing scholarship, and for supporting practical work.

Appendix A: Demographic Questionnaire

Please answer the following questions to help us understand who came to the co-design session today. All questions are optional. For questions 1-5, please circle the answer that best matches your personal identity or experience. For questions 6 and 7, please write your answer in the space provided.

1. Please tell us your gender.

   Male   Female   Other

2. Please tell us your age.

   13-17   18-24   25-44   45-64   65+

3. Please tell us your race/ ethnicity.

   African American (non-Hispanic)   Asian/ Pacific Islander

   Caucasian (non-Hispanic)   Latino or Hispanic

   Native American or Aleut   Other

4. How often do you participate in citizen science (for example, by contributing to projects like the Audubon Christmas Bird Count and Galaxy Zoo)?

   Never   Rarely   Sometimes   Often   Frequently

5. How often do you play digital games (such as computer or video games)?

   Never   Rarely   Sometimes   Often   Frequently

6. How often do you design or develop mobile applications?

   Never   Rarely   Sometimes   Often   Frequently

7. Please tell us the city, state, and country that you consider your home.

   ____

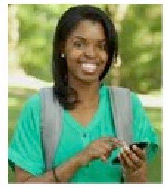
8. Please tell us how you learned about today's co-design workshop.

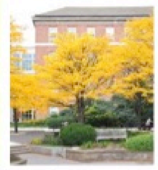
Appendix B: Contextual Inquiry Worksheet

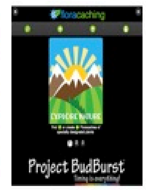
Notes from the Field

Players will experiment with Floracaching, playing around with whatever seems the interesting!

Observers will watch players use Floracaching, and ask questions about what they are doing and why. Observers should write down their observations below.







Not sure what to observe? Focus on the **person**, or who is using the app, the **place**, or where the app is being used, or **the app** itself!

Observation #1

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Observation #2

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Observation #3

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Observation #4

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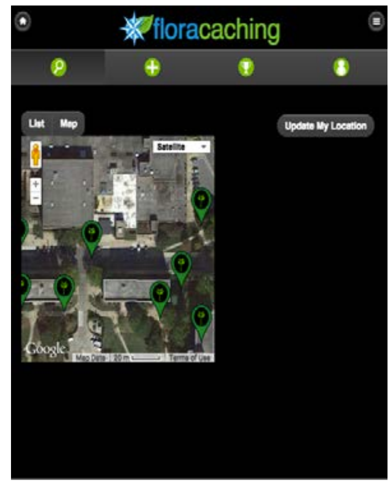
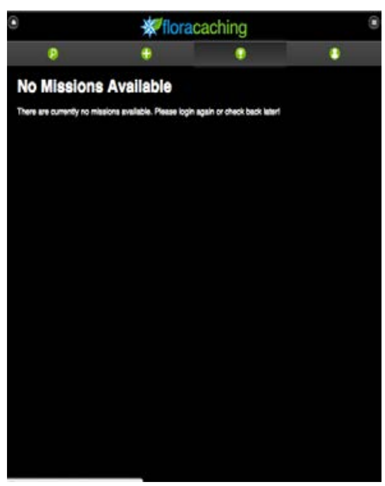
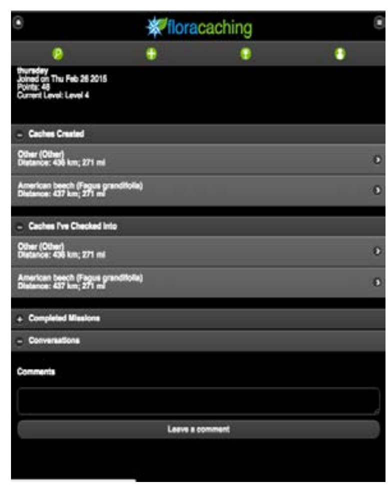
Appendix C – Screen Shots from Floracaching







Appendix D - Floracaching Codebook

Below are seven themes related to perceptions of Floracaching. Each of these may be experienced as positive or negative. For example, “knowledge” may refer to a lack of knowledge about plants, or knowledge gained by using Floracaching.

Table 9

Codebook

Definition	Examples	From the text
Personal Relevance Using the app because of personal interest or life relevance; use cases	Personal interest in plants; personal interest in games; fit with life activities; primary users; secondary users	*“Initially you would be getting all the science majors here, and then the home schoolers…”* *“if your friends do it, it becomes a thing”*
Design General comments related to the user interface or experience, NOT related to gamification	Interface design; interaction design (e.g., problems with location or solutions for addressing these); reference to other forms of social media	*“the design has to be top notch… all the things that go into making a good design need to happen.”* *“Have a little human being, and just scale the tree to the human being”*
Gamification and reward Direct, measurable personal benefits to participation AND design to support reward	Reference to game elements (e.g., missions) or mechanics (e.g., progress); personal rewards (e.g., something to put on a resume)	*“[points are good because] as humans, we just naturally want to progress”* *“you could maybe link it to community service hours”*
Awareness and exploration Becoming aware of a natural environment; persistent awareness of a natural environment AND design to support awareness	Attention (or lack of attention) to natural environment; perceptions of nature; attention to local community; desire to explore local community	*“just looking closely at the trees, and just seeing it, looking more closely than I normally would”* *“on campus I’m just cruising to a destination”*

<u>Knowledge and learning</u>		
Knowledge of plants and their environments; local knowledge AND design to support knowledge	Knowledge required to go Floracaching (e.g. , how to make an observation); knowledge gained by using the app; insider knowledge of a local area	Biological knowledge; local knowledge; learning
<u>Socialization</u>		
In person or virtual engagement with others through Floracaching AND design to facilitate socialization	Social interaction; awareness of others; collaborative learning	*"It's a cool opportunity to share time with other people."* *"a pop up saying 'oh your friend just cached this'"*
<u>Community and contribution</u>		
Awareness of different communities; relevance of contribution AND design to facilitate community	Community of Floracaching players; external social networks; different contributions to these communities (e.g., creating caches, checking in; recruiting others)	Creating caches *"is more interesting than checking in, because it's something that you created"* *"a referral system where you recruit five friends… and you complete the mission"*

Appendix E – Key features of Floracaching design

Table 10

Key features of Floracaching design

Framing Construct	Related screen	Explanation
Nature is everywhere	Figure 13, screens A-D; figure 14, screen A; figure 16, screen A	Figure 13 shows the map of a local area as the landing page, evoking awareness of a player's immediate natural environment. Figure 14, screen A shows how mission mode is designed to facilitate immersion in nature. The concept of a gardener, or a frequent caregiver of a Floracache, illustrates persistent awareness of nature in figure 16, screen A.
Contribution	Figure13, screens C-D; figure 16, screen B	Floracaching supports lightweight contribution through content curation, show in Figure 13, screen C by the ability to rate a floracache. Figure 13, screen D and figure 16, screen B illustrate how gamification, including badges and a leaderboard, is used to show what a community considers valuable contributions.
Socialization	Figure 13, screens A-D; figure 16, screens A-B	The map facilitates socialization by showing the location of Floracaches, and also other players (figure 13, screens A-D). The "local" page (figure 16, screen A) and leaderboard (figure 16, screen B) support social interaction and social comparison, respectively.
Topical knowledge	Figure 13, screen C; figure 14, screen B	Figure 13, screen C displays a short "fun fact" about a plant. Learning plant identification is also possible through a dichotomous key (Figure 14, screen B) supported by the create a cache process.

Local knowledge	Figure 13, screens C-D; figure 14, screen B; figure 16, screen A	Floracaching players can learn about local plants (figure 13, screen C; figure 14, screen B) and also local people (figure 13, screen D; figure 16, screen A). In addition, players can create caches of interesting things that are not plants (figure 14, screen B).
The self in place	Figure 13, screens A-D; figure 16, screens A-B	The map interface is designed to make players persistently aware of their position in a local ecosystem of human and non-human actors (figure 13, screens A-D). Awareness of the self in place is also encouraged through a local page, which displays information about local people and the local environment (figure 16, screen A), and through the leaderboard, which shows the self in relation to others (figure 16, screen B).

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