HiveGuide: An Education and Crowdsourcing App for Bee Conservation

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ABSTRACT

Bees and other pollinator species are declining at an alarming rate. In 2006–2007, beekeepers in the United States reported colony losses of up to 90% (Barrionuevo, 2007). In a world reliant on pollination for plant growth, the population decline of bees and other pollinators is a reality that lacks attention through the means of modern technology. While some mobile applications exist to identify species and record user beekeeping data, few seek to provide educational resources and conservation methods for the public. Of these few, none are well-designed, engaging, or intuitive for users of modern smartphone technology. The following thesis project explores published literature in multiple areas: pollinator impact and bee conservation; the use of mobile applications in environmental awareness and sustainability efforts; the demand for intuitive and engaging user interfaces in mobile applications; and crowdsourcing in mobile technology and citizen science. These topics inform the HiveGuide app design which is presented in the form of annotated wireframes. This thesis project aims to merge bee conservation, mobile technology, and collaborative communication to protect the future of pollinators. HiveGuide is a mobile application that provides resources, tools, and crowdsourced data to promote bee and stinging pollinator conservation through a welcoming interface.

Keywords: bee, pollinator, conservation, mobile application, environmental awareness, user interface, crowdsourcing, citizen science

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INTRODUCTION

Problem Statement

On July 29, 2020, a team of Rutgers-led researchers published a grim statement: global crop yields are being significantly reduced due to a decrease in pollinators (Rutgers, 2020). The study notes the food security risks that are inevitable with a decline in honeybee and wild bee populations, suggesting that more robust conservation efforts are necessary for protecting pollinator numbers. According to the National Wildlife Foundation, some of these once-popular pollinator species are even endangered (NWF). Despite a general understanding of the necessity of pollination to produce crops, scientists in Germany found that misunderstandings and fear of stinging insects may be discouraging some humans from engaging in education and conservation efforts (Schönfelder & Bogner, 2017). Meanwhile, an increasing loss of habitat and food sources along with attacks from parasites and pathogens threatens bees and other pollinators (Goulson et al., 2015.

Many humans tend to fear insects that sting (Schönfelder & Bogner, 2017). Although both considered stinging insects, bees and wasps are fundamentally different from each other. Bees are herbivores, surviving on pollen, nectar, and honey, while wasps are carnivorous, attacking and eating other insects (Encyclopaedia Britannica, n.d.). However, bees and wasps have similar physical characteristics. Humans, as they fear getting stung, may not recognize definitive differences between bees and wasps at first glance.

Not all bees have stingers, though. In fact, the stinger is a female reproductive organ, so males cannot sting at all (Wilson, 2007). Additionally, honeybee stingers are barbed. When one stings an animal, a honeybee's body rips apart, leading to certain death. Therefore, honeybees will often avoid stinging except in the case of an extreme threat to their hives and colonies.

On the other hand, wasps do not have a barbed stinger and can sting many times during an attack (Wilson, 2007). This means that wasps are potentially more threatening to humans than honeybees or other bees with barbed stingers. When humans fear being stung by bees, the aversion is often rooted in the behavior of wasps attacking multiple times with their stingers without sacrifice.

The human habit of referring to all black-and-yellow, flying, bullet-shaped, stinging insects as *bees* does not lend any favors to the mostly harmless pollinator populations. Although more factors are contributing to the loss in bee populations, many people's negative attitude towards bees shadows the alarming truth of their steep decline (Schönfelder & Bogner, 2017). And yet, the global ecosystem relies on honeybees and other native bee species to pollinate the plants that, in turn, sustain humanity (Vanbergen & Insect Pollinators Initiative [IPI], 2013). With such a critical component of life at risk, humans need to destigmatize the presence of stinging insects in nature and learn to understand, protect, and coexist with pollinators of all types. With this problem in mind, the following thesis project has developed a product to address attitudes and behaviors towards stinging pollinators through educational resources via an easy to download mobile application.

A 2018 report from the Pew Research Center estimated that over 2.5 billion people own smartphones (Silver, 2020). This number is projected to rise in the coming years. Mobile app development is increasing to accommodate the growing interest in the melding of daily activities

and hobbies with the convenience of a personal device. With this interest in mobile app development comes an opportunity to merge sustainability and environmental consciousness with technology. However, there is a notable lack of approachable resources focused on pollinator information—a disconcerting truth considering the current plight of pollinator species.

As technology continues to advance and researchers develop analytic tools that gauge user engagement and appeal, more evidence points to the user experience and interface design as a leading factor in attracting or repelling new users (Holdener & Angerer, 2020). To retain current users and interest wider audiences, mobile apps need to be simple, intuitive, and efficient. Additionally, mobile apps and tools that rely on user-contributed information and communication are becoming increasingly popular in a tech-fueled world (Howe, 2006). Waze, for example, relies on crowdsourced data to provide commuters with ideal routes and traffic information (n.d.). Airbnb is a space to offer and accept accommodation arrangements (n.d.). Neither platform functions without collaboration amongst users. Indeed, the convenience and reliance on mobile technology have prompted new means of communication, allowing people to socialize and network regardless of location. Crowdsourcing, however, has existed for centuries. Scientific research, especially, has benefited from extensive volunteer contribution.

Throughout history, scientists and researchers enlisted public participation to accomplish testing goals and collect relevant data. *Citizen science* is the phrase used to describe the actions of volunteers around the world to collect and analyze data for use in scientific efforts (U.S. General Services Administration, n.d.). From the Oxford dictionary (Albrecht, 2017) to Audubon's annual Christmas Bird Count (National Audubon Society, 2018), countless projects have relied on laypeople to meet research deadlines and broaden study scopes. Today, citizen science efforts exist around the world and across fields of study. Research foundations,

museums, and environmental agencies continue to appeal to the public to assist in data collection, species identification, and wildlife population counts. As these initiatives continue, science and mobile apps are merging to create a user experience unique from any other industry.

At the same time, technology surfaced as a vital tool for maintaining public participation and appealing to a broader number of volunteers (Ullrich, 2012). However, in the field of pollinator and bee research, few citizen science projects are active and ongoing. Of these scarce initiatives, even fewer utilize efficient, easy-to-use mobile interfaces or applications that are approachable and intuitive to the general public. Researchers must make an effort to optimize projects for mobile technology to appeal to citizen science participants and maximize public volunteer potential. With this in mind, this thesis project offers a mobile application designed with a straightforward and engaging interface that focuses on community collaboration and participant incentive.

Considering the rising threat of decreased pollinator populations and a growing reliance and expectation for technology and mobile optimization, the lack of resources focused on bee habitat and activity awareness is alarming. Perhaps even more concerning is the scarcity of citizen science projects devoted to monitoring pollinator behaviors. This thesis project offers a solution to the lack of public communication and awareness around pollinator species, particularly bees, in the form of a mobile app that aims to engage users. As a collaborative and intuitive mobile application, the HiveGuide app will integrate an appealing user interface for citizen science participation and pollinator conservation.

This thesis project's design and development was guided by three inquiry questions which are stated in the next subsection.

Inquiry Questions (IQs)

The following inquiry questions guided the product development of this thesis project:

1. Can a mobile application effectively educate and inform users on stinging pollinator conservation efforts?
2. Can crowdsourcing features motivate users of a stinging pollinator conservation mobile application to contribute behavior and habitat information?
3. Can a stinging pollinator conservation mobile application collaborate with local ecology and conservation groups to drive user reach and support?

The next subsection explains the contents and purposes of this thesis project's sections and subsections.

Purpose and Expectations

This product-driven thesis project outlines the design and development of the HiveGuide app, a crowdsourcing and education mobile application for bee conservation. In the Introduction, I presented a Problem Statement that explains the reality and consequences of bee and pollinator declines. If these species continue to diminish, global food and economic security will be at risk due to less plant pollination and a consequential decrease in crop yields. The Problem Statement also describes the burgeoning demand for mobile applications that focus on environmental awareness and the importance of well-designed user interfaces in mobile technology. Finally, the Problem Statement analyzes crowdsourcing methods in mobile technology and the scientific

community. I also shared Inquiry Questions that guided the product development of the HiveGuide app. Finally, this Introduction section ends with a Purpose and Expectations section that is meant to summarize the main sections and subsections of this thesis project.

The goal of this product-driven thesis project was to create wireframes for an easy-to-use, engaging, and incentivized mobile app. With a simple and intuitive interface design, the mobile app aims to provide educational resources about bee conservation and create an active user community. The wireframes included in the Appendices of this thesis project show the development of the user experience and interface that allow for an educational, engaging, and collaborative experience for all users. Each Appendix provides an annotated wireframe for a different page of the HiveGuide app to detail the functions of the user experience and the purpose of each content area. Following the Introduction of this project, the final written report includes a robust review of literature.

In the Literature Review section, I provide a review of published research that informs the purpose and design of the HiveGuide app. In support of a conceptual framing that brings together three unique areas of research, I have included a discussion of the Ecological Impact of Pollinators; Environmental Awareness and User Engagement in Mobile Applications; and Crowdsourcing and Citizen Science in Mobile Technology. The subsection titled the Ecological Impact of Pollinators explains the importance of pollinator species on the global food and plant product industry. The subsection also discusses reasons for the ongoing pollinator decline and conservation methods for protecting population numbers. Next, the Environmental Awareness and User Engagement in Mobile Applications subsection discusses current efforts in mobile applications to support environmental conservation and education. The subsection also explains the importance of engaging user interfaces in mobile technology and how design affects user

motivation and participation. The final subsection, titled Crowdsourcing and Citizen Science in Mobile Technology, explains the use of crowdsourcing techniques in mobile applications. Additionally, the subsection explains the practice of crowdsourcing in scientific research through citizen science initiatives.

After the Literature Review, the Methodology section explores my motivation to develop the HiveGuide app and outlines a market gap for this type of product in a Needs Analysis subsection. Following this, I offer a Design Intentions subsection, in which I describe my process in creating the product's user interface and application flow. The Product Description will provide an outline of the general purpose and function of the HiveGuide app that appeals to potential users and market investors. In the final subheading of my Methodology section, I offer Limitations to explain the factors preventing me from further development, design, testing, and prototyping.

Next, the Product Analysis of this thesis project revisits the inquiry questions introduced above. Using the developed wireframes, I seek to answer these questions while reviewing the strengths and opportunities of the HiveGuide app. A critical review of the wireframe design at this time will allow me to assess the next steps in the development process, which I attempt to do in the final section of this thesis project.

The Conclusion section of this thesis project assesses new ideas or concepts I found and reviews the points made in my Problem Statement. Additionally, I suggest future work for environmental education and conservation efforts in mobile applications and user experience design in citizen science efforts. I also share my plans for next steps for the HiveGuide app should I secure funding to support a larger development team with a broader skill scope.

As noted above, the Appendices to this thesis project include the product's wireframes, showcasing various views of the HiveGuide app interface. These wireframes include annotations to describe defining features and actions available on different pages.

The following Literature Review section of this thesis project explores research topics that guide the development and design of the HiveGuide app.

LITERATURE REVIEW

Introduction

This Literature Review explores research in three primary areas that form the framework behind the HiveGuide app product: pollinator conservation, environmental awareness and user experience in mobile applications (apps), and crowdsourcing in science and mobile technology. This thesis project relies on advancements and studies in these topics to propose a mobile application that demonstrates knowledge in bee and pollinator awareness efforts, effective user engagement, and collaborative experiences in technology and science.

The research and work examined in this Literature Review reveals the strengths and opportunities in pollinator conservation efforts and the merging of environmental awareness with technology. Additionally, it discusses the impact of citizen science as a crowdsourcing effort to obtain data from research volunteers and its growing reliance on mobile applications. By analyzing such efforts, this Literature Review exposes a need for an intuitive, collaborative, and user-friendly mobile application to promote bee and pollinator awareness. Through the convenience and accessibility of smartphone technology, the HiveGuide app will promote pollinator conservation, focus on technology design and experience trends, and remain devoted to collaborative user engagement.

Ecological Impact of Pollinators

This section discusses the impact of pollinators on the global ecosystem, the background of their alarming population decline, and recognized methods of conservation. The first subsection will describe why pollinators have such a major effect on the world's economy and

ecology, maintaining that much of the world relies on pollinator activity for food and plant products. The next subsection explains why and how pollinators are experiencing an ongoing decline and the harmful effect it has on the environment and global economy. Finally, the last subsection discusses effective conservation techniques that can assist in strengthening pollinator numbers.

Pollinators affect the ecosystem

Plants relied on insects and animals for reproduction from as early as the Cretaceous period, 100 million years ago (Pollinator Partnership [PP], n.d.-a). Pollination involves the physical movement of pollen from male plants to their female counterparts, and a significant part of the ecosystem as we know it relies on pollinators to facilitate this movement. Many animals and insects are considered pollinators, including birds, bats, moths, butterflies, and beetles. Perhaps the most commonly recognized pollinator in the global ecosystem is the bee.

According to a 2008 European study, nearly 75% of the world's food economy relies on insect pollinators, either from plants directly pollinated by them or animals that eat plants the insects pollinate (Gallai et al., 2009). Globally, around 1,000 different types of plants used for food, medicines, fibers, and other human purposes depend on pollination of some sort (PP, n.d.-a). Though research efforts to place an exact monetary value on pollinators in our global economy has proven difficult, the same study concluded that pollinators contribute to around 9.5% of the total production value of food crops (Gallai et al., 2009). As global human populations continue to rise and demand for pollinator-dependent plants surges, this value will almost certainly increase.

Though most people are familiar with only honeybees and bumblebees, there are more than 20,000 species each of bees and wasps on the planet. Bees and wasps all belonging to the order Hymenoptera and suborder Apocrita, which comprises insect species that are largely beneficial to humans either as pollinators or parasites to insect pests. (Encyclopaedia Britannica, n.d.-a). Insect pollinators are widely recognized as vital to the world's economy and ecology. However, their population numbers are threatened by a variety of ongoing factors.

The decline of pollinators

In 2007, a *New York Times* article reported on the disappearance of more than a quarter of America's bee population, amounting to tens of billions of individual bees (Barrionuevo, 2007). Years later, another article noted how beekeepers found that their bees, after leaving the hive for the day in search of pollen and nectar, would never return (Haberman, 2014). An abundance of theories surfaced to explain the phenomena, called Colony Collapse Disorder (CCD). Unfortunately, researchers were unable to prove an explanation.

In the fall and winter of 2006–2007, beekeepers across the United States reported colony losses of up to 90% (Barrionuevo, 2007). Bee colonies have been declining since the 1940s, with causes pointing to toxic pesticides, immune system-attacking fungi, parasitic mites, or viruses. However, this new and dramatic calamity to the already struggling population was unlike anything beekeepers and scientists alike had ever seen. Some researchers suggest that the regular transport of large colonies to different farms affect bee diet and habitat, leading to high stress and poor physical health. Many entomologists believe that a pathogen is to blame for CCD, causing genetic breakdowns in colonies. Though many questions about the cause and eventual consequences of the disorder remain unanswered, Washington State University entomology

professor, Dr. W. Steve Sheppard, stated a consensus among the scientific community: “There could be a number of factors that are weakening the bees or speeding up things that shorten their lives…the answer may already be with us” (Barrionuevo, 2007, para. 23).

Perhaps the most apparent cause of bee declines in the long term is the loss of their natural habitats due to a demand for farmland. Over the 19th and 20th centuries, massive human movement and domestication has led to a loss of nearly 97% of ideal grasslands for bees and other pollinators (Goulson et al., 2015). Industry and urbanization continue to grow in populated areas, destroying necessary floral food sources and many undisturbed sites for potential nests and hives. With the loss of food-rich habitats comes the loss of a diverse diet for bees and other insects. A monotonous diet may lead to a lack of nutrition and an overall decline in physical health (Vanbergen & IPI, 2013). These health risks result in more susceptibility to pathogens and disease due to compromised immune systems. A significant danger for honeybees in particular is viruses caused by the *Varroa destructor* mite. These mites lead to wide-spread colony destruction due to regular human transport of the bees to different farms and hive sites (Goulson et al., 2015).

Toxic pesticides are other enemies of pollinators, particularly those known as neonicotinoids (Goulson et al., 2015). The chemicals in neonicotinoids can circulate through plants and reach the flowers and leaves—the feeding grounds for bees and other insects. These pesticides attack the bee’s nervous system, resulting in confusion, paralysis, and death. Additionally, herbicides play an impactful role in depleting food sources for pollinators, destroying many floral weed varieties that diversify insect diets and supply them with critical nutrients (Kearns et al., 1998). In response to the dangerous effect of such chemicals, France

issued a ban of neonicotinoids in 1999. In 2013, the European Union did the same. Despite these efforts, the bee population continued to decline (Goulson et al., 2015).

A variety of damaging factors contribute to the ongoing loss of bees and other pollinators. Fortunately, there are known conservation methods that, with widespread implementation, may protect these species from further decline.

Promising conservation methods

An effective step to increasing wild bee populations is to diversify crops and grow flower fields. Though honeybees tend to thrive on farms devoted to one crop, solitary wild bees have more success with multiple crop types in smaller areas (Wilson, 2007). Some countries provide monetary incentives for farmers who take initiative in the diversification of crops and other flora. However, these programs are not extensive, and more outreach on the benefits of biodiversity in pollinator populations may contribute to increased participation.

Additionally, urban and rural communities alike may contribute to biodiversity by planting bee-friendly flowers in gardens. Doing so not only provides more food sources for pollinators but expands the variety of available plants and creates a healthier diet for bees and insects. Also, urban planners and landscapers create healthier habitats for pollinators by promoting wild green spaces and building areas that allow for gardening and beekeeping (Vanbergen & IPI, 2013).

As mentioned earlier, France and the EU enforced government efforts to ban or reduce the use of pesticides that endanger vital pollinators (Goulson et al., 2015). Indeed, using such pesticides to foster more crop growth seems counterintuitive when the chemicals cause so much destruction to the pollinators the crops need to thrive. More comprehensive pest management,

using methods such as crop rotation, lessens agricultural reliance on pesticides and eases the environmental build-up of toxic chemicals. Further attention to regional and national legislation may contribute to greater conservation efforts, with projects such as the International Pollinators Initiative promoting research and coordinated global action (PP, n.d.-b).

A 2017 study by researchers in Germany concluded that a generally negative attitude towards stinging pollinators might be reduced through educational programming and by confronting misinformation about bee behaviors (Schönfelder & Bogner, 2017). The study shows that while most humans agree that bees are important and crucial to the global ecosystem, fear and aversion to the insects lead to a disinterest in conservation efforts. This thesis project will present a solution to the human misunderstanding of bees by reframing perceptions of pollinator behavior and activity. Through accessible educational resources and community participation, users will learn to respect and value bees and their importance in the global ecosystem.

This subsection used published, professional research to present the significant impact of pollinators on the world's economy and ecology. Additionally, this subsection explained causes and consequences of the rapid loss of pollinator numbers over the years. Finally, the last part of the subsection analyzed several methods of conservation and how their widespread utilization may protect pollinators from greater population losses.

The next subsection of this Literature Review discusses the use of mobile applications in environmental awareness and sustainability initiatives. Additionally, the subsection analyzes the impact of user engagement and interfaces in mobile applications.

Environmental Awareness and User Engagement in Mobile Applications

The following subsection analyzes the use of environmental awareness in mobile applications along with the significant impact that user experiences and interfaces have on overall user engagement. The first part of this subsection provides examples of mobile apps that promote environmental awareness and sustainability and their growing demand with the rise of technology. The next part of the subsection details the importance of well-designed user interfaces in mobile applications and the elements required to ensure ideal user experiences that motivate audience participation.

Mobile applications impact environmental awareness

In recent years, software developers made significant strides in creating mobile applications that monitor and facilitate everyday tasks, behaviors, and hobbies. Mobile apps exist for writing to-do lists, tracking workouts, streaming movies, mapping destinations, and shopping. It makes sense, then, that environmental initiatives are going mobile, too (Guarana, 2019). A number of conservation and awareness apps are currently available on mobile app stores, ranging in focus from ways to reduce carbon footprints to tracking daily water usage. A 2020 article on CNET compiled a list of sustainability-focused applications that include ethical thrifting service ThredUp and PaperKarma, a way to stop receiving paper-wasting junk mail (Brown).

From an educational awareness perspective, apps like #Climate allow the user to share and discover ways to take action against climate change, while iRecycle provides resources for conveniently recycling a variety of materials (Ecobnb, 2020). Every day, increasing rates of people rely on their mobile devices to solve problems and handle a growing number of everyday tasks. With such a seemingly inevitable rising demand for mobile convenience and usability

across industries, mobile app developers are taking on the challenge of answering questions regarding conservation efforts and environmental consciousness.

Many mobile app developers have responded to increasing demand for environmental awareness initiatives by merging technology and conservation efforts. The challenge, however, is creating a platform that remains relevant, innovative, and rewarding to use. The next part of this subsection discusses how the design and user experience of such mobile apps affects user motivation and participation.

User experience design motivates user activity

Along with conservation and environmental awareness, mobile app developers have joined forces with medical professionals to create programs that promote health and wellness. In an early 2020 study, Swiss researchers sought to understand the effect of user engagement on the success of the European health app Ada (Holdener & Angerer). Though the overall concept is complex, Holdener and Angerer found that the most significant factors that contributed to user engagement were perceived usability, aesthetic appeal, reward, and focused attention (2020). Simply put, users are more likely to be engaged with a straightforward, appealing, and motivating interface.

A user's unique interaction and activity with an application, product, or service is called the user experience (UX). The specific aesthetic and graphics-driven experience is called the user interface (UI). As UX is all-encompassing of a user's relationship with an application, it's almost impossible to have a successful UX without an engaging and appealing UI. In today's mobile age, a crucial component of measuring a successful user experience comes from how developers optimize content for different devices. According to Imaginovation co-founder and CMO

Michael Georgiou (2018), 79% of potential users will abandon an un-optimized site or application, while 88% are unlikely to return after a poor experience. Georgiou also cites a research study that infers that well-designed UX and UI can go so far as to boost user conversion rates between 200 and 400% (Hogan et al., 2016). Clearly, developing a clean, easy-to-use, and aesthetically pleasing design along with an optimized and reliable interface is vital to ensure consistent user commitment and positive engagement.

The 2019 Mobile User Experience Awards, judged by a panel of design professionals from a variety of companies, chose the Balance: Meditation app as the winner of the Best Interface Design category. With calming pastel colors, consistent animation, and a customized experience for every type of user, the Balance: Meditation app adheres to the standards of well-done user experience design. In a top comment on Apple's App Store, one user described why they decided to keep coming back to the meditation app every day: "…it started off with short sessions and easy skills and builds from there…Thank you for making meditation so accessible and easy to develop into an everyday practice" (Jared Leal 75, 2019, para. 3). The comment suggests that successful design does not always need to be the most animated, exciting, or flashy to keep users motivated and engaged. In fact, less often does more when it comes to usability and satisfaction.

Another positive comment sums up the highly-rated user experience of Balance: "Engaging, modern, interactive app that looks clean, easy to navigate, intuitive…a meditation app that's been brought up to today's standards of ease of use, personalization…and being fun to use" (UlfhedinnErmana, 2020, para. 2). Like the previous comment, this statement encourages app design that is accessible, user-friendly, and intuitive.

The UX standards found in every well-designed mobile app play a crucial role in encouraging consistent user activity. For a mobile app that depends on the contributions of participants from various backgrounds and education levels, an easy-to-use, intuitive, and rewarding interface is necessary to drive success and results. However, the HiveGuide app is certainly not the first mobile application to rely on the public's efforts to fuel scientific initiatives and solve problems regarding conservation, sustainability, and the environment.

The above subsection analyzed current mobile applications that promote environmental awareness and a sustainable lifestyle. Additionally, the subsection used market research to address the impact of user interface and experience design on mobile application success. The next subsection of this Literature Review discusses crowdsourcing methods in mobile applications and science.

Crowdsourcing and Citizen Science in Mobile Technology

This subsection of the Literature Review explains the concept of crowdsourcing and how it manifests in mobile applications and scientific research. First, this subsection analyzes the history of crowdsourcing initiatives and its growing demand with the rise of mobile technology. The next part of this subsection explores the concept of crowdsourcing in citizen science as a way for researchers to collect extensive data and information for large-scale studies and projects. Additionally, the second part of the subsection will discuss the current and future demand for mobile technology in citizen science. Finally, this subsection will analyze recent citizen science projects and the lack of initiatives focused on bee and pollinator conservation and awareness.

Crowdsourcing is not a new concept

The term *crowdsourcing* was likely first used in a WIRED article by Jeff Howe (2006). Howe describes the boom of community-sharing applications and services in the rise of technology and mobile convenience. Focusing on the stock photo site iStockphoto along with research collaboration site InnoCentive and others, Howe makes an early case for the rising demand for crowdsourced services and solutions across nearly every industry.

The concept of problem-solving through public contribution is not new, however. Examples date as far back as 1714 with the British Longitude Act that sought to award prizes to anyone able to produce a practical method to measure a ship's exact longitude at sea (Nesta Challenges, n.d.). Another historical example lies in James A.H. Murray's late-nineteenth-century appeal to volunteers to assist in contributing words to include in the fledgling edition of the *Oxford Dictionary of the English Language* (Albrecht, 2017). Even with the support of thousands of contributors, the project still took about 70 years to complete.

Modern crowdsourcing methods are seen in apps like Waze, where users contribute data regarding navigation and traffic information (n.d.). Similarly, Airbnb provides a platform for hosts to share accommodations for users who leave reviews following their stays (n.d.). Though the incentives are not as explicit as a monetary reward or writing a piece of English language history, the community effort on both platforms stems from a shared desire for convenient travel and safe housing. Both apps rely on public contribution and user communication to fuel their purpose and are a small sample of the many mobile apps that depend on crowdsourcing techniques.

Crowdsourcing has long been a part of history, and it is increasingly in demand with the rise of mobile applications and ease of global networking. The next part of this subsection

explains how crowdsourcing initiatives support mass research and data collection in science. Additionally, this part discusses the rising impact of mobile technology in such initiatives.

Mobile technology supports citizen science efforts

Crowdsourcing is the foundation for citizen science. The concepts are similar in that they both rely on collaborative efforts from public volunteers to contribute information to large-scale projects. However, citizen science utilizes data collection methods specifically to aid in extensive scientific research and studies. The global history of citizen science dates back centuries. One of the first widespread examples in the United States was the Christmas Bird Count, founded by the Audubon Society in 1900 (National Audubon Society, 2018). Conservation efforts to protect bird populations were gaining popularity, so ornithologist Frank F. Chapman proposed a public bird census rather than a hunt to be held on Christmas Day of that year. The tradition continues to this day, and the initiative is recognized as the longest-running citizen science project in the country.

Citizen science projects have grown in numbers so significantly in recent years that an official government website database exists to organize them (U.S. General Services Administration, n.d.). The site currently accommodates 256 active projects organized by many different agencies and covering various scientific fields. Every project has its own website or mobile app for volunteers to submit data. Indeed, National Geographic cites GPS receivers and other sensors on smartphones that contribute vital information around location, weather, and air-quality in data capturing as a huge benefit to citizen science project efforts (Ullrich, 2012).

Though many citizen science projects rely mainly on public interest in a particular field or research topic, obstacles exist that prevent participant engagement and consistent activity. A 2015 study published by the Ecological Society of Japan lists such barriers as requiring methods

that are too complex for standard users and asking for data updates too frequently. (Kobori et al.). The study suggests that successful ways to overcome such challenges are to simplify data sampling methods, reward consistent users, and build community through discussion and networking. However, the researchers make a point in noting that few, if any, studies currently exist that explore how user incentive techniques can lead to greater participation in citizen science projects. This lack in research can be reconciled with attention to the previous section devoted to UX/UI design and how positive user experience with a product can drive app use.

A greater human reliance on mobile technology allows for increased reach and participation in citizen science efforts. The future of citizen science relies on well-designed mobile interfaces that support a user-friendly experience and motivate participant activity. The final part of this subsection explores the lack of citizen science projects that focus on bee and pollinator awareness and why such an absence matters to the future of stinging pollinators.

Citizen science lacks pollinator conservation initiatives

Despite the growing numbers of projects available in online databases and promoted by National Geographic and other environment-focused foundations, there is an alarming absence of citizen science projects concerning bee and pollinator conservation. On CitizenScience.gov, only one project is currently active and accessible on a functioning website. HiveScience, though admirable in its attention to bee colony health, is designed explicitly for beekeepers to monitor their hives. It is not an approachable project for laypeople with little to no prior knowledge of bee activity and habitats. This thesis project will further analyze the HiveScience project in the Needs Analysis subsection of the following Methodology section.

Elsewhere on the web, there are minor signs of crowdsourcing initiatives to raise pollinator awareness. Both Bumble Bee Watch and The World Bee Count ask users to take pictures of encountered bee species to add to its digital database. The World Bee Count, however, was limited in scope and ended in May of 2020 (Appalachian State University, n.d.). Bumble Bee Watch lacks the convenience of an optimized app, requiring users to upload data to a visually outdated website or navigate the equally uninviting mobile site. The absence of bee conservation in citizen science's booming world is troubling when considering how influential pollinators are on the global ecosystem. This thesis project will analyze the World Bee Count and Bumble Bee Watch projects in greater detail in the Needs Analysis subsection of the Methodology section.

This subsection analyzed a variety of professional research and publications to present the history and current state of crowdsourcing initiatives. Furthermore, the above subsection discussed the concept of citizen science and how crowdsourced data and information contributes to research efforts. A review of reports pointing to the growing demand for mobile technology and optimized user interfaces inform an analysis of the future of mobile applications in citizen science. Finally, the subsection addressed the lack of bee and pollinator citizen science projects.

The final section of this Literature Review summaries the research and findings of the previous sections. This section addresses each prior topic and describes how professional, comprehensive review and critique informs the HiveGuide app developed for this thesis project.

Closing

The HiveGuide app is developed and designed with research informed from three major topics: the ecological impact of bees and other pollinators, environmental conservation efforts

and user engagement in mobile applications, and the use of mobile technology in crowdsourcing and science. By studying these areas, the HiveGuide app project has a foundation in previous research and design strategies that allow it to be relevant and impactful to contemporary users.

As mobile app developers continue to design and build programs to enrich and accompany everyday life, there will be an increasing demand for services that assist in conservation efforts and scientific research. With the continuing decline of pollinators in the planet's ecosystems comes a loss in food supply and plant product revenue that plays a significant role in the global economy. The effort to protect pollinator populations, particularly in bee species, is one that developers can integrate with mobile applications through crowdsourcing and modern citizen science approaches. The HiveGuide app will bridge a gap between mobile apps built solely for crowdsourced scientific research and those developed for educational use and design satisfaction. Additionally, it fills the void in bee awareness efforts by creating a mobile resource that seeks to educate the public on identification and conservation efforts.

The following Methodology section of this thesis project describes the product design intentions focused on user experience and crowdsourcing techniques. The section will outline various features of the HiveGuide app that focus on three primary areas: education, collaboration, and communication. Additionally, the section will explain possible limitations in planning that come with designing a mobile app to fill previously discussed gaps in user experience and citizen science research.

METHODOLOGY

The Methodology section of this thesis project first offers a Needs Analysis for the HiveGuide app based on existing bee conservation and data collection projects. It examines the strengths and weaknesses of such initiatives and describes how the HiveGuide app fills the gap for an engaging mobile application focused on bee conservation and education. Next, this section presents a Product Description of the HiveGuide app that attracts potential users and project investors. Finally, this Methodology section explains the Limitations of this thesis project and how such obstacles prevent further project development and design at this time.

Needs Analysis

The literature reviewed above revealed a lack of relevant, impactful, and engaging mobile applications that focus on bee conservation. Despite a rising focus on environmental-friendly companies and personal initiatives, there are no reliable and consistent platforms that educate the public on bee activity and behaviors. Furthermore, crowdsourcing practices through citizen science are becoming increasingly reliant on mobile technology and uncomplicated user interfaces (Ullrich, 2012). However, I found very few active citizen science projects that focus on bee activity and conservation with none that intend to last longer than a predetermined project end-date. For example, the HiveScience project requires a background in beekeeping and focuses on a single threat to bee colonies. The World Bee Count initiative ended in May of 2020 with no indication of resuming in 2021. Finally, Bumble Bee Watch is limited in scope and does not provide a comprehensive space for educational tools and resources. I explain these projects and programs in greater detail below.

As noted in the above Literature Review, CitizenScience.gov is the government website that serves as a database for citizen science projects in the United States. In conducting this Needs Analysis, I searched on CitizenScience.gov for the word *bees*, and only eight results appeared (see Figure 1). Of those eight results, only five are unique projects, and only two are specific to bee and pollinator data collection: Broodmapper and HiveScience. Of the two pollinator-focused projects, only HiveScience had a working and live website link (U.S. General Services Administration, n.d.).

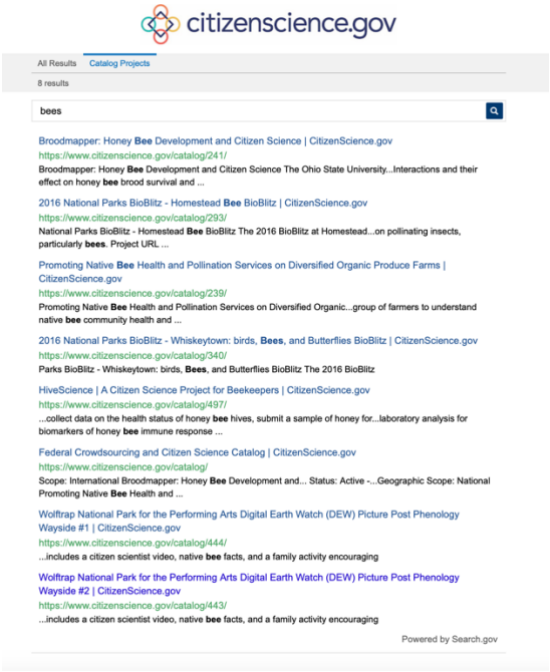


Figure 1: screenshot of search results for 'bees' (U.S. General Services Administration, n.d.).

The HiveScience project, sponsored by the Environmental Protection Agency (EPA), focuses on collecting hive data from beekeepers in an effort to monitor and control outbreaks of Varroa mites (n.d.). The website, though informative, is dense with text and information that is not easily interpretable to the general public. Figure 2 shows a screenshot of instructions for project participants.

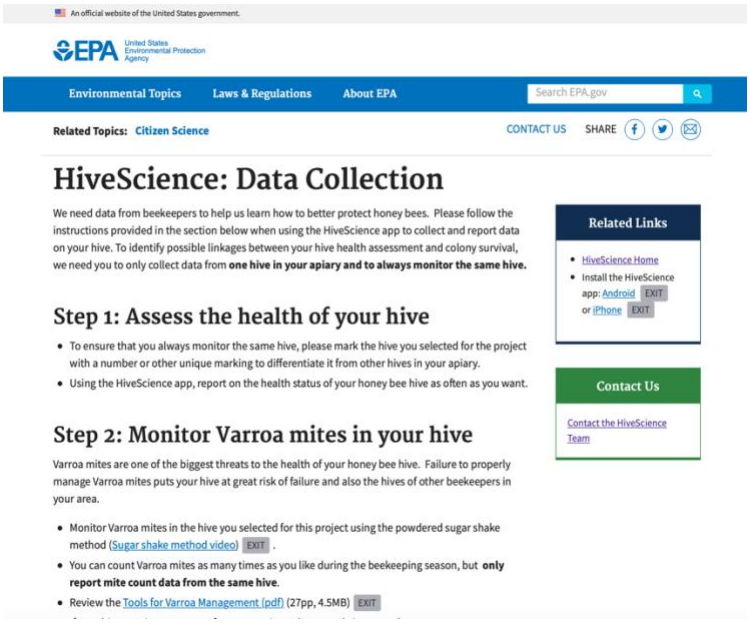


Figure 2: screenshot of HiveScience project instructions (EPA, n.d.).

In fact, the public is not able to use the project app at all as only beekeepers with active hives are able to register and contribute (see Figure 3). The interactive map mentioned on the website, meant to track and view reported mite activity, requires EPA login information to access. This is counterintuitive for a world reliant on collaborative mobile technology that is accessible to users from all backgrounds. Furthermore, widespread environmental conservation efforts rely on extensive reach and resource availability to ensure success. HiveScience, though devoted to bee conservation efforts and admirable in its actions in monitoring a major threat to hive populations, is not an accessible educational resource to anyone outside of the EPA or beekeeping world. The HiveGuide app, however, allows the general public to access all of its educational resources and data collection tools regardless of any prior beekeeping or

conservation experience. Doing so ensures a welcoming experience for users of all backgrounds and skills.

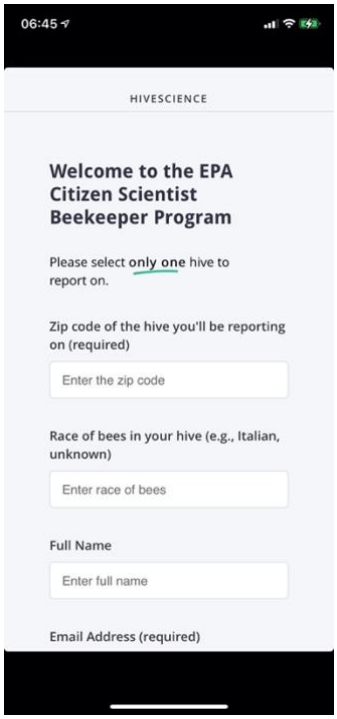


Figure 3: screenshot of HiveScience app launch screen (EPA, n.d.).

In addition to the citizen science projects listed on the government database, I identified some other project websites that appear to focus on bee awareness and conservation efforts. However, most are limited by a predetermined end-date, location specifications, or scope of species focus. The World Bee Count, for instance, ended in May of 2020 and no longer provides a detailed, interactive map to track user contributions. The home page of the project (see Figures 4 and 5) states "this page shows an overview of the map, a sampling of images…and regions/countries where images were submitted." ("Global Pollinator Map," 2020). Though the project seems to have been a popular collaborative effort, with over 20,000 submitted images from participants around the world, time restrictions prevent a lasting impact on the ongoing

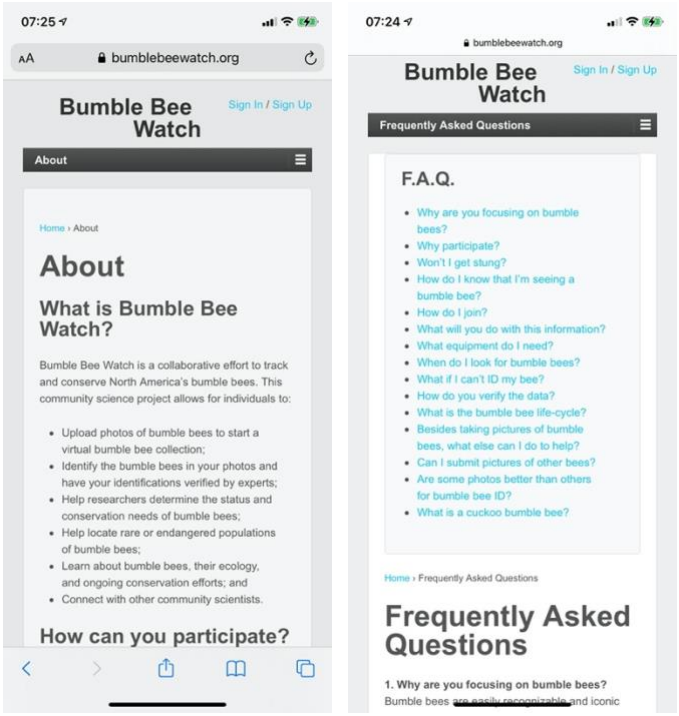
challenge of bee and pollinator awareness. The website shows no indication of a renewed counting effort in the future.

Figure 4: screenshot of World Bee Count data page ("Global Pollinator Map," 2020).

Figure 5: screenshot of World Bee Count data page ("Global Pollinator Map," 2020).

Out of all the bee and pollinator citizen science and conservation endeavors, Bumble Bee Watch appears to be the most comprehensive and engaging project. With a variety of tools and resources on its website, Bumble Bee Watch makes a commendable effort to educate the general public on bumblebee behaviors, habitat information, and identification techniques (n.d.).

However, as shown in Figures 6 and 7, the sheer amount of information and resource links available on the site result in an overwhelming, cluttered interface. Furthermore, the site is not ideally optimized for a mobile device. The text is compact and difficult to read, and the abundance of links can make for a cumbersome and frustrating touchscreen experience. Users must scroll or swipe multiple times on the screen to comprehend all of the content.



Figures 6 and 7: screenshots of the Bumble Bee Watch mobile site (Bumble Bee Watch, n.d.).

The tables of reported species and photo galleries are also difficult to view on a mobile device, appearing unbalanced and cramped (see Figure 8). Additionally, the color scheme of the site is cold and unwelcoming with gray and black themes occasionally punctuated by bright blue links.

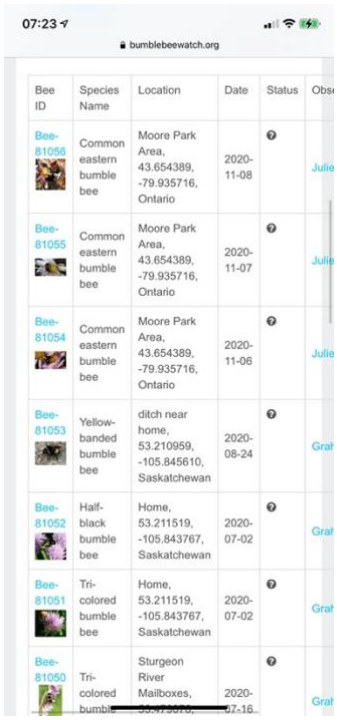


Figure 8: screenshot of the Bumble Bee Watch mobile site (Bumble Bee Watch, 2020).

Bumble Bee Watch does, notably, have a downloadable mobile app that has the potential to be a competitor to the HiveGuide app. However, it quickly becomes apparent that the Bumble Bee Watch mobile app has limited content and is currently only comprised of a bumblebee identification list (see Figure 9). In its current state, there is no other conservation or educational information on the Bumble Bee Watch mobile app. The HiveGuide app will include more than identification resources. As the main goal of the HiveGuide app is to promote pollinator awareness, it is necessary for the app to include information about conservation methods and environmental protection techniques from reputable researchers and scientists.

Finally, the Bumble Bee Watch project is limited by its focus on only bumblebees. Though the website included resource links to information on other pollinators, the overall site remains devoted to tracking and identifying bumblebee species (n.d.). Though the HiveGuide

app will focus on bees, the educational content will not focus on one species of bee specifically. Additionally, the HiveGuide app will provide conservation and awareness information on a wide variety of stinging pollinator species. Allowing for a greater scope in content will create a space for more thorough education in bee and pollinator behaviors and promote greater understanding for the vast diversity of bee and stinging pollinator species.

Figure 9: screenshot of the Bumble Bee Watch app (Bumble Bee Watch, 2020).

Despite its design weaknesses, Bumble Bee Watch has partnerships with a number of reputable foundations and groups such as Wildlife Preservation Canada, University of Ottawa, and National History Museum, London (n.d.). The project also enlists a team of volunteer scientists to verify reports of sightings, adding validity and credibility to the project. Though Bumble Bee Watch has a limited scope and uninviting interface, it was a noteworthy model for

the development of the HiveGuide app in its comprehensive educational approach and collaboration with reputable scientists and groups.

The current list of conservation projects specific to bees and stinging pollinators is alarmingly short given the growing threat of decreased population numbers. With initiatives limited in time, scope, and design choices, there is a significant opportunity and need for the HiveGuide app that integrates the convenience of technology with crucial conservation efforts, engaging user interfaces, and ongoing collaborative activity.

The next subsection analyzes the design and user experience of the HiveGuide app. It refers to annotated wireframes provided in the Appendices of this thesis project.

Design Intentions

As the HiveGuide app is a mobile application meant for interaction with users via smartphones, developing an engaging and intuitive interface was crucial to its design. I began designing the architecture of the HiveGuide app by dividing the content into four distinct areas: (1) Plan, (2) Learn, (3) Report, and (4) Contact. After a description of the Launch and Home screens, this section will continue with an explanation of each of the four areas listed above.

Before accessing the different content areas, the HiveGuide app user views the initial Launch and Home screens. I provided wireframes of the Launch and Home screens along with other sample page designs in the Appendices of this thesis project. Appendix A shows the Launch page, and Appendix B features the Home page. To convey a clear and welcoming user experience from the first interaction with the app, these pages need to be simple and straightforward. The Launch screen shows the HiveGuide app logo and log in/sign up buttons. The Home screen maintains a minimal design with the HiveGuide app logo and four buttons

representing the four content areas. By tapping these buttons, users navigate to the different areas. The rest of the HiveGuide app interface follows a simple, clear design to ensure enough white space to minimize user eye strain and prevent an overwhelming amount of text from deterring users.

In the Plan section, users may search for locations within the HiveGuide app service area to research known stinging pollinator activity. The Plan section includes three content areas that users may access via the Plan screen: Location Guide, Trip Tracker, and Packing List. Appendix C shows an example of the Drop-Down Menu users can access to choose a specific content area in the Plan section. The HiveGuide app Location Guide provides a review of stinging pollinator species native to the area along with any user-reported behavior. The Trip Tracker tool allows users to enter a start location and multiple destinations to provide a comprehensive report of findings without needing to search multiple areas individually. Finally, the Packing List provides users with vital tools and supplies necessary for specific outdoor activities in a selected location.

In the Learn section, HiveGuide app users can explore the characteristics of different species of stinging pollinators. The Learn content area contains three distinct parts (see Appendix E): Identify, Save the Bees, and Beekeeper Guide. The Identify area helps users understand the defining distinctions between bees, hornets, and wasps. The Save the Bees component provides information on the importance of stinging pollinators and the history of their declining population. The section will also present a breakdown of major conservation efforts and how individuals from all walks of life can aid in this work. The Beekeeper Guide provides users with an introduction to beekeeping and tips on how to maintain their hives.

The Report section of the HiveGuide app serves as an interactive map (see Appendix D). Users may swipe to view different locations and markers that indicate reports from members of

the HiveGuide app community. An icon will indicate the user's location on the map, and a menu will show options to create a new report and open the device camera to take a picture of a found species or habitat.

Finally, the Contact section (see Appendix F) serves as a portal for users to find local, state, and national resources on pollinator conservation, hive or nest relocation, and general environmental protection agencies and groups. These resources will be unique to the user's current location to ensure relevant information when further assistance is required.

On each screen of the HiveGuide app, users have the option to access their profile page and the FAQ area. On the User Profile page, shown in Appendix G, users may view and make edits to their name, password, picture, and location in the profile portal. On the FAQ page, featured in Appendix H, users will see a list of potential questions regarding app use, community guidelines, and conservation information. Users will tap each question to expand a collapsible text field that holds the answer.

I faced a significant challenge in planning incentives for user activity and reporting. Initially, I planned to provide different membership options at a cost that would allow additional access to tools and resources. However, I do not believe the HiveGuide app has enough variety in these areas to prompt users to pay for a membership. Instead, I determined that if I am able to obtain partnerships and sponsorships from environmentally conscious companies and groups, I may be able to offer discounts on products or experiences as user incentives. For example, partnerships with companies such as REI, Clif Bar, Patagonia, and Sierra Club may allow users to trade their bee sighting records in the HiveGuide app for rewards in the form of product discounts or access to exclusive experiences.

As users report more bee sightings, they gain access to more rewards as their membership level rises. With this model in mind, reporting zero to ten sightings is considered a ‘standard’ membership level, ten to fifty sightings indicate ‘premier’ membership, and greater than fifty sightings will place the user into the ‘champion’ membership group. Sightings and membership levels are tracked through the Membership Level page found on the User Profile page. Since I do not have partnerships or sponsors in the initial planning of the HiveGuide app project, there is a limitation in committing to monetary-based incentive strategies. I explain this obstacle in more detail in the Limitation section of this thesis project.

Along with planning the HiveGuide app navigation and content areas, I recognize a need to choose a color theme and font style that is unobtrusive yet appealing. The logo is also critical to the HiveGuide app design, as it will represent the product in mobile app stores and be the first image users see on the launch and home screens. These artistic steps pose a limitation for my project as I do not have much graphic design experience. However, my experience with information architecture and user interface design allows me to recognize this as a critical next step in my project development as I obtain funding to expand the HiveGuide app team. I detail these and other project obstacles in the upcoming Limitations section.

The following subsection presents a description of the HiveGuide app that appeals to potential users and project investors.

Product Description

HiveGuide is a mobile application that provides resources, tools, and crowdsourced data to promote bee and stinging pollinator conservation through a welcoming interface. The goal of the HiveGuide app is to empower its users to help solve the problem of rapidly declining bee

populations to protect the global economy and ecosystem. By embracing the age of mobile technology with a smartphone application, the HiveGuide app will encourage bee and pollinator conservation through incentivized participation and seek to protect the future of our pollinator populations.

The HiveGuide app has three key components: Education, Collaboration, and Communication. In terms of education, users learn about the differences in appearance, behavior, and habitat across different bee and pollinator species. Humans often confuse harmless bees with more aggressive wasps and hornets. With the HiveGuide app, users will understand key physical and behavioral differences between stinging pollinator species and gain understanding of the importance in protecting these vital creatures. Users collaborate to share information and location of bee sightings, including found beehives and swarms. The HiveGuide app has company partnerships to incentivize this crowdsourcing tool that include product and experience discounts through REI, Patagonia, Clif Bar, and Sierra Club. Finally, a focus on communication allows users to connect with area conservationists and ecology centers for safe removal or relocation of hives and to learn more about local conservation efforts.

The HiveGuide app caters to users of various backgrounds, from children as young as 12-years-old to senior citizens. Though most users of the HiveGuide app will likely be adults who are active in outdoor activities, its user experience and interface will be accessible to anyone seeking information on bee behavior and conservation efforts. Though several mobile applications exist that cater to environmental awareness and sustainability, there are not enough publicly available resources that focus on bee conservation. With attention to motivating user activity and public awareness, the HiveGuide app will bridge the gap between scientific research and engaging user participation through technology.

The next Limitations subsection states the various obstacles faced during the development and design of this thesis project.

Limitations

The most significant limitation to the initial development of the HiveGuide app is the lack of user product testing with wireframe prototypes. Though the structure and layout choices presented in wireframes may imply user interface and design intentions, the physical activity of navigating an app is impossible to replicate without building it. At this stage of product development, I do not have a tangible prototype for user testing. Therefore, I cannot adjust the HiveGuide app design based on findings in app speed, intuition, and location accuracy. However, understanding this limitation lays the groundwork for a definitive next step in the development of the HiveGuide app: obtaining funding to hire mobile app developers to build the first prototype based on the wireframes presented as part of this product-based thesis project.

Furthermore, another limitation to this project's scope is the lack of a full development team. As one person completing a thesis project, I alone reviewed literature, built wireframes, and analyzed design choices. I recognize that I am not an app developer, graphic designer, or software engineer, and I do not have the skill to build a beta app or convert my design ideas to a physical app. Those steps, though crucial to the future of the HiveGuide app, will require funding for a team of industry professionals.

Additional limitations come in the inability to source initial information needed to produce the educational aspects of the app at this early development stage. Without partnership with scientists, environmentalists, or conservation experts, it is challenging to construct a database of information on species identification or accurate conservation methods. As this information grows, users will have more comprehensive and rewarding experiences. This

limitation should not be overlooked, as the success and impact of the HiveGuide app rely on professional advice and research and should only come at the approval of such experts. Again, this limitation offers a direct plan of action should funding be acquired and the HiveGuide app development team can expand in number and scope.

Finally, there is a recognizable limitation in the time required to complete this initial development and design report. Over the course of only three months, I identified a problem, developed a solution, and designed a product to solve the problem. Though I accomplished much in these short months with analyzing significant literature, building a framework for product development, and creating wireframes, this project requires more time and attention to construct a tangible, testable prototype.

The next section of this thesis project is a Product Analysis of the HiveGuide app. The section describes how the project design effectively answers this thesis project's inquiry questions. The Product Analysis refers to wireframe prototypes provided in the Appendices of this thesis project.

PRODUCT ANALYSIS

This section of the thesis project examines the design of the HiveGuide app and answer the Inquiry Questions presented in the Introduction. The inquiry questions that guided my product design are:

1. Can a mobile application effectively educate and inform users on stinging pollinator conservation efforts?
2. Can crowdsourcing features motivate users of a stinging pollinator conservation mobile application to contribute behavior and habitat information?
3. Can a stinging pollinator conservation mobile application collaborate with local ecology and conservation groups to drive user reach and support?

By assessing the wireframes of the HiveGuide app in relation to the above inquiry questions, the following Product Analysis will identify the strengths, weaknesses, and opportunities that will continue to shape the evolution of this product's development.

Mobile applications can effectively educate and inform users on stinging pollinator conservation efforts

Informed by the review of literature and critique of existing products in this space, the HiveGuide app product aims to educate and inform users on the importance of stinging pollinators in the global ecosystem and economy. In Appendix E of this thesis project, an annotated wireframe presents the Learn page of the HiveGuide app where users will find a

comprehensive platform for bee and pollinator education. By tapping on the Identify link, users will learn how to identify and differentiate bees from wasps and other stinging pollinators. Tapping the Save the Bees link will take users to an area devoted to conservation methods to protect bee and pollinator habitats and populations. Finally, tapping the Beekeeper Guide link will navigate users to a comprehensive guide of best practices and procedures for new and existing beekeepers.

The Learn wireframe exhibits a clean, uncluttered layout to prevent an overwhelming user experience and the ability to navigate to other areas of the HiveGuide app. The three different areas that make up the Learn section of the HiveGuide app allow space for resources rooted in professional research from scientists and organizations. The HiveGuide app product could continue to be developed by securing such research and educational information from specific sources. Though the Learn wireframe annotations indicate navigation options for the user experience, the Identify, Save the Bees, and Beekeeper Guide pages have not yet been designed. As the HiveGuide app team grows in number and scope, the educational material can be collected, categorized, and published.

The development of the HiveGuide app product suggests that mobile applications can effectively educate and inform users on stinging pollinator conservation efforts by providing an accessible interface that accommodates a variety of professional, scientific resources.

Crowdsourcing features can motivate users of a stinging pollinator conservation mobile application to contribute behavior and habitat information

The design of the HiveGuide app is informed by research on the effect of experience and interface design in driving user activity in mobile applications. Additionally, a review of mobile

applications powered by crowdsourced information and communication provided insight into what tools and incentives the HiveGuide app will offer. Appendix D shows an annotated wireframe that displays how the HiveGuide app will display crowdsourced data from the community and allow users to report new pollinator activity. The Map/Report screen will use an interactive map that allows users to view locations of user sightings and contribute photos and information to new reports.

Appendix G shows a User Profile screen that displays the current user's name, password, membership level, and location. The membership level will be an incentive for HiveGuide app users to contribute sightings as it will upgrade based on the number of submitted reports. Tapping the Your Membership link at the bottom of the screen will take users to a description of the different membership levels. Additionally, the Your Membership screen will inform HiveGuide app participants on the various benefits and rewards offered at each level.

The HiveGuide app product will continue to develop in the implementation of crowdsourcing tools and user incentives. As mentioned in the above Limitations subsection, membership rewards and benefits will rely on partnership with businesses and organizations. Until these partnerships and project funding are secured, further development of membership incentives in the HiveGuide app is challenging to execute.

The design and collaboration elements included in the development of the HiveGuide app accompanied by an incentivized membership structure suggest that crowdsourcing features can motivate users of a stinging pollinator conservation mobile application to contribute behavior and habitat information. However, this inquiry question could be answered in greater detail with more time and team expansion.

A stinging pollinator conservation mobile application can collaborate with local ecology and conservation groups to drive user reach and support

The resources and information provided within the HiveGuide app are informed by pollinator behavior and conservation research conducted by professional scientists and organizations. With this focus in mind, the HiveGuide app wireframes present a means for users to communicate with local environmental groups and learn more about conservation and awareness initiatives at a local, state, and national level. Appendix F provides an annotated wireframe of the Contact screen of the HiveGuide app which displays contact information for these three levels. Contact information may include phone numbers, websites, email addresses, and location addresses. The information provided on the screen will be based on the user's home location, found in the User Profile page (see Appendix G).

Along with providing organization and group information, the HiveGuide app could develop further collaboration methods through advertising and promotional material. Appealing to conservation and ecology groups to encourage participation within their communities can increase the reach of the HiveGuide app and motivate activity. Additionally, businesses and companies that partner with the HiveGuide app—including those mentioned above—could encourage app use within their customer bases through social media posts and blogs.

The design intentions of the HiveGuide app, discussed in the above Methodology section, show a focus on collaboration with a variety of environmental groups and organizations. The Appendices of this thesis project exhibit straightforward access to contact information for such groups in a clean user interface. Therefore, this thesis project suggests that stinging pollinator conservation mobile application can collaborate with local ecology and conservation groups to drive user reach and support. As previously discussed, the next steps for the development of the

HiveGuide app depend on successful partnership and collaboration. However, collaboration cannot take place without agreement from all parties, and such conversations and arrangements have not been made at the completion of this thesis project. This inquiry question could be addressed in more depth as partnership agreements are made.

The following section is the Conclusion of this thesis project. Subsections of the Conclusion include Additional Findings discovered in the development of this thesis project, a return to concepts addressed in the Problem Statement of this thesis project, and Future Implications for the HiveGuide app and other work in the topics that informed this thesis project.

CONCLUSION

The Conclusion of this thesis project presents closing thoughts and analyses found in the development of the HiveGuide app product. The three subsections included in this section are: Additional Findings, Return to Problem Statement Concepts, and Future Implications. The first subsection describes new topics and questions procured in the development of the HiveGuide app project that could inform further content and design choices. Next, this section revisits the topics discussed in the Problem Statement of this thesis project and analyzes how the developed product addresses these concepts. The final subsection presents the next steps for the future of the HiveGuide app. The subsection also suggests further work in citizen science through mobile applications and crowdsourced projects focused on bee and stinging pollinator conservation.

Additional Findings

During the development of this thesis project, I made product design and content decisions informed by an analysis of research topics and a critique of current market offerings. As I conducted research and built wireframes for the HiveGuide app, I found additional concepts and questions that could influence the future development work of this project. These topics include hardware and software differences in smartphone models, privacy concerns in mobile technology, the use of cellular data and Wi-Fi in smartphone applications and verifying reliability and reputation of resources.

As I began designing the HiveGuide app wireframes (see Appendices), I first chose a master shape to serve as the foundation for my interface choices. Possible options for these smartphone outlines included various shapes of iPhone and Android models. For the purpose of

this thesis project, I chose to base the design of the HiveGuide app off of the newest iPhone model available at the start of my development process. However, it will be important to consider all possible smartphone hardware options in the next stages of development, as the user interface and experience will rely on optimization across all platforms. Additionally, the software included on iPhones and Androids are different and contain distinct design and navigation functions. The HiveGuide app developers will need to consider these software differences when building the app to ensure that it is compatible across various smartphone systems.

As I made choices regarding the tools and functions of the HiveGuide app and considered factors of the user interface and crowdsourcing methods, I reflected on the use of location tracking and possible privacy concerns. Users may feel discouraged over the thought of sharing their location, but pinpointing such locations to make reports and capture bee activity is a vital function for the HiveGuide app. The time restraints I faced during the development of this thesis project prevented me from exploring the topics of privacy and location further, but they will be important to consider in the future to gain user trust.

Another topic I need to research further as the HiveGuide app continues to develop is the user of cellular data and Wi-Fi in smartphone applications. At the conclusion of this thesis project, I have not analyzed the differences in reliability and availability between the two mobile data sources. The HiveGuide app relies on functionality in outdoor areas, oftentimes in places that are remote and may not have access to a strong cellular data signal. Furthermore, Wi-Fi networks are often less accessible in outdoor settings and are likely not a viable way to provide the data needed to run the HiveGuide app. This topic is beyond my scope, as I recognize that I am not an expert in mobile data technology. I will require additional support to explore cellular and Wi-Fi connectivity before making further development decisions.

Finally, as the HiveGuide app will provide educational material and resources for users, I found myself asking a significant question: What makes a resource reputable and reliable? The success of the HiveGuide app will depend on accurate, science-based information. However, how will the HiveGuide app team vet possible sources? Some of the current pollinator app offerings mentioned in the Needs Analysis of this thesis project cite professional partnerships with museums and organizations. For example, Bumble Bee Watch promotes its partnerships with Wildlife Preservation Canada and the National History Museum, London (n.d.). Its website also states that the project works with volunteer scientists to verify user reports. Developing a resource verification and vetting process will be another vital step in the future of the HiveGuide app and will require additional team members and time.

With this subsection, I reflected on the additional topics and ideas that could impact future development decisions for the HiveGuide app. These topics require additional time and team member support that the confines of this thesis project did not allow, as mentioned above in the Limitations subsection. Though I was not able to explore these concepts further, they are important to consider in informing the next steps in the development of the HiveGuide app.

In the following subsection, I assess how this thesis project addresses the Problem Statement concepts I presented in the Introduction.

Return to Problem Statement Concepts

In the Problem Statement of this thesis project, three topics were introduced that informed the development of the HiveGuide app product. First, bees and other pollinator numbers are declining at an alarming rate. However, negative human attitudes towards bees and other stinging pollinators are harmful to conservation and awareness efforts required to protect

these vulnerable populations. This thesis project answers this problem by offering a product that presents bees and stinging pollinators as vital parts of the global ecosystem and economy. Through educational resources and partnerships with environmentally and sustainably focused companies and organizations, the HiveGuide app will help users understand how to coexist with bees and other pollinators without fear.

Next, there is a constant demand for mobile applications that inform and assist users in everyday life. With this demand comes an increasing number of apps that guide users towards sustainable and environmentally conscious lifestyles. In order for a mobile application to remain relevant and popular amongst its users, the interface and overall user experience must be engaging, rewarding, and easy-to-use. This thesis project addresses this topic by presenting a mobile application with a clean, intuitive, and incentivized interface. The HiveGuide app's multiple content areas and user tools are designed with clarity and simplicity in mind to resist overwhelming new users and promote regular activity. Annotated wireframe examples that reveal the HiveGuide app design are provided in the Appendices of this thesis project.

Finally, the Problem Statement introduced the use of crowdsourcing in mobile applications and within the scientific community. Citizen science initiatives that rely on user-contributed data and information have been popular throughout history, but there is a severe lack of projects that focus on bee and pollinator conservation and awareness. The programs and projects that do exist are not accessible to the public, lack inviting and optimized mobile interfaces, or are limited by time and scope constraints. The HiveGuide app addresses this problem by providing a mobile application fueled by crowdsourced data that promotes bee conservation and stinging pollinator awareness. Through incentivized membership levels and collaboration with companies, organizations, and environmental groups, users will feel

motivated to contribute reports and pollinator sightings to the HiveGuide app community. As the number of users increases through partnership outreach and promotional messaging, the amount of user-contributed data will grow and lead to more significant understanding and awareness of bees and other stinging pollinators that are vital to plant and human life.

This subsection explained how the HiveGuide app addresses the topics introduced in the Problem Statement of this project. The next subsection of this Conclusion explains the necessary next steps in the development and design of the HiveGuide app. Additionally, it suggests future goals for mobile technology in citizen science and initiatives devoted to stinging pollinator awareness.

Future Implications

As the HiveGuide app seeks to create an environment of user-friendly and appealing engagement and interface design, additional testing will be required to conclude how design affects crowdsourcing activity in mobile environmental awareness initiatives. Furthermore, citizen science efforts must focus on user engagement across mobile application interfaces to remain relevant to new users. Finally, bee and pollinator conservation initiatives deserve a deeper focus in citizen science research, particularly across mobile technology platforms.

The initial design and development planning for the HiveGuide app lays a foundation for measurable next steps for the project. First, the HiveGuide app team must obtain funding from technology and startup investors to support growth and compensation. As an NYU alum, I will appeal to New York University's Innovation Venture Fund, Impact Investment Fund, and Prototyping Fund for initial investment capital. The HiveGuide app may acquire additional funding through environmental foundations such as Sierra Club, Patagonia, REI, and the Clif Bar

Family Foundation, as these programs offer grants and partnerships to projects focused on environmental protection and educational initiatives and offer awards regularly.

As the HiveGuide app receives funding and sponsorship, the development and design team will grow to allow for physical prototype building, multiple rounds of user testing, and collaboration with scientists. Hired graphic designers will address the design limitations discussed previously, and a team of researchers will be able to source educational material to include in the Learn and Plan areas of the app.

The development of the HiveGuide app presumes that the future of citizen science resides in technology, particularly in smartphones. As more scientific studies rely on data collected by research participants, technological advancements must keep up with the demand along with the growing reliance on fast, reliable mobile platforms. These conclusions mean that citizen science project experiences must compete with the wide variety of other mobile applications that rely on design to attract and retain new users. As technology advances, users require near-instant gratification to motivate activity and participation in crowdsourcing. The HiveGuide app recognizes this need in the citizen science community and will lead the development and design of more mobile applications that focus on conservation and the environment.

Assuming that citizen science projects continue to attract participants to a variety of initiatives, scientists and researchers must develop methods to include stinging pollinator conservation efforts through mobile platforms. Bees and other pollinators will continue to be at risk unless awareness methods are communicated through relevant, accessible means. Until contemporary, updated ways of sharing conservation and education resources are developed through mobile applications and community collaboration, there may be little change in the dire prospects for pollinator species. The HiveGuide app will guide this ambitious step in

encouraging bee and pollinator representation in mobile applications, but other projects must follow suit to ensure global awareness and understanding.

This final subsection of the Conclusion of this thesis project offered insight into the future of mobile applications in citizen science projects and collaborative efforts focused on bee and stinging pollinator conservation. Furthermore, this subsection addressed goals for the future development of the HiveGuide app and steps that can be taken to achieve them.

The Conclusion of this thesis project summarized the success and opportunities of the HiveGuide app product. By answering the guiding inquiry questions of this project and addressing relevant topics introduced in the Problem Statement, this Conclusion section establishes that the HiveGuide mobile application is designed to use education, communication, and collaboration to promote bee and pollinator conservation. Additionally, this section offers insight into future goals and ambitions for the HiveGuide app design and development. Finally, this Conclusion encourages additional work in mobile technology and user engagement in citizen science along with greater attention to the ongoing plight of bee and pollinator population declines.

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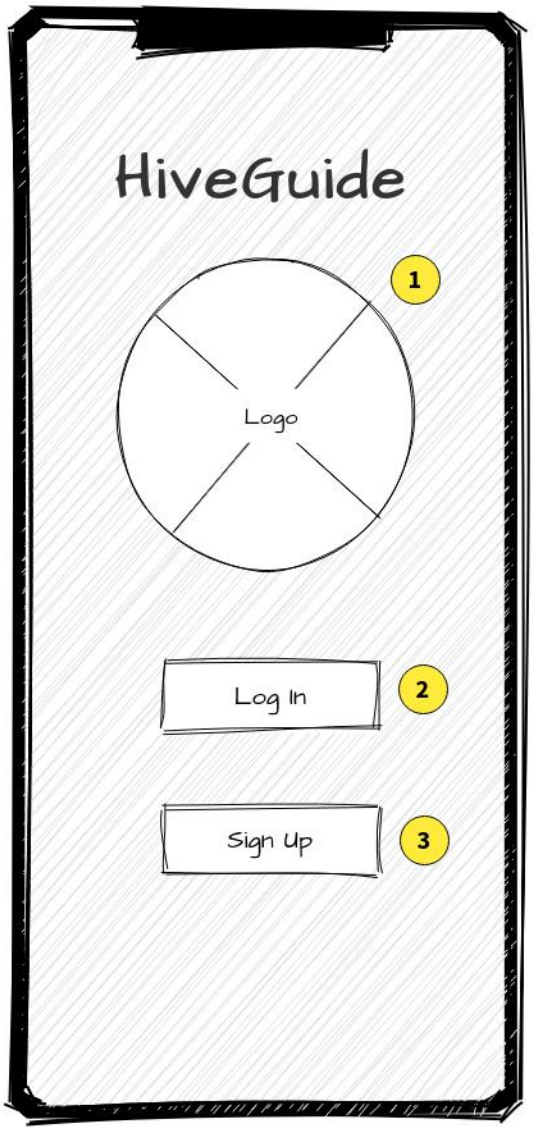
APPENDIX A: Launch Page

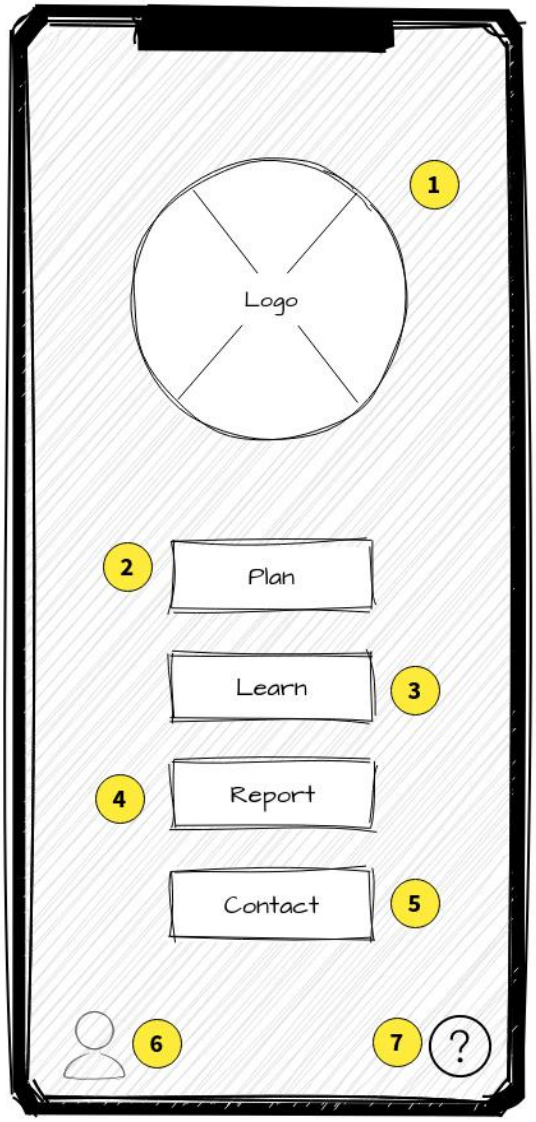
HiveGuide: Annotated Wireframes



Number	Label	Description
1	Logo	This image is the logo for the HiveGuide app.
2	Log In	Tapping this button takes users to a log in portal.
3	Sign Up	Tapping this button takes users to a sign-up portal.

APPENDIX B: Home Page

HiveGuide: Annotated Wireframes



Number	Label	Description
1	Logo	This image is the logo for the HiveGuide app.
2	Plan	Tapping this button opens a drop-down menu for Plan pages. Tapping twice takes users to the Plan landing page.
3	Learn	Tapping this button opens a drop-down menu for Learn pages. Tapping twice takes users to the Learn landing page.
4	Report	Tapping this button takes users to the interactive map.
5	Contact	Tapping this button takes users to the Contact landing page.
6	User	Tapping this icon takes users to their User Profile page.
7	Help	Tapping this icon takes users to the FAQ page.

APPENDIX C: Drop-Down Menu

HiveGuide: Annotated Wireframes

Number	Label	Description
1	Logo	This image is the logo for the HiveGuide app.
2	Plan	Tapping this button opens a drop-down menu for Plan pages. Tapping twice takes users to the Plan landing page.
3	Drop-Down Menu	This menu shows the Plan subpages. Tapping each link takes users to the corresponding page.
4	Learn	Tapping this button opens a drop-down menu for Learn pages. Tapping twice takes users to the Learn landing page.
5	Report	Tapping this button takes users to the interactive map.
6	Contact	Tapping this button takes users to the Contact landing page.
7	User	Tapping this icon takes users to their User Profile page.
8	Help	Tapping this icon takes users to the FAQ page.

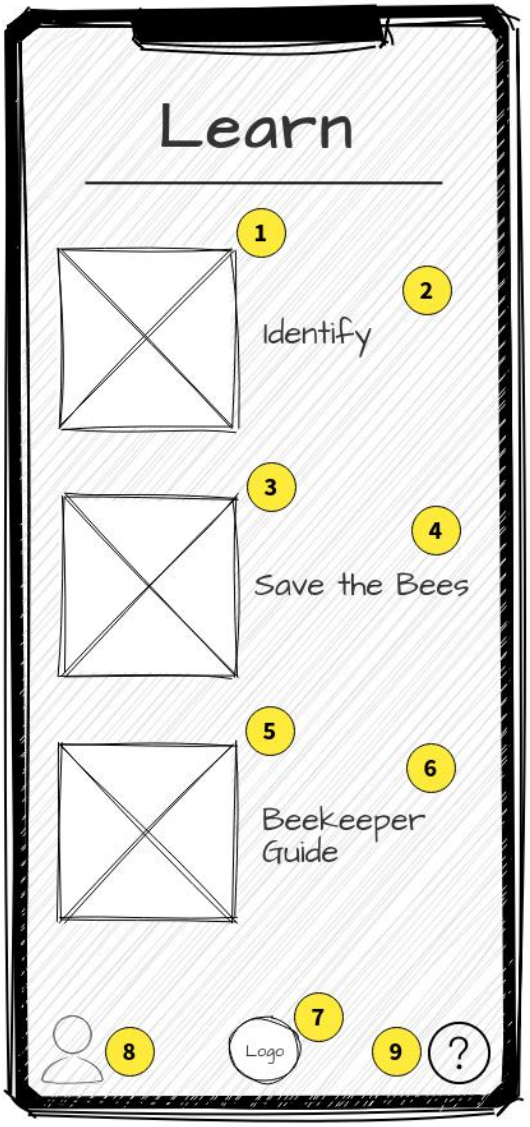
APPENDIX D: Map/Report Page

HiveGuide: Annotated Wireframes

Number	Label	Description
1	Interactive Map	Users tap and drag around the map to view and interact with community reports.
2	Activity Mark	This icon shows where HiveGuide community members have reported activity.
3	Action Menu	This menu shows action options for users.
4	Location Mark	This icon shows the current location of the HiveGuide user.
5	Logo	Tapping this image takes users to the app Home page.
6	User	Tapping this icon takes users to their User Profile page.
7	Help	Tapping this icon takes users to the FAQ page.

APPENDIX E: Learn Page

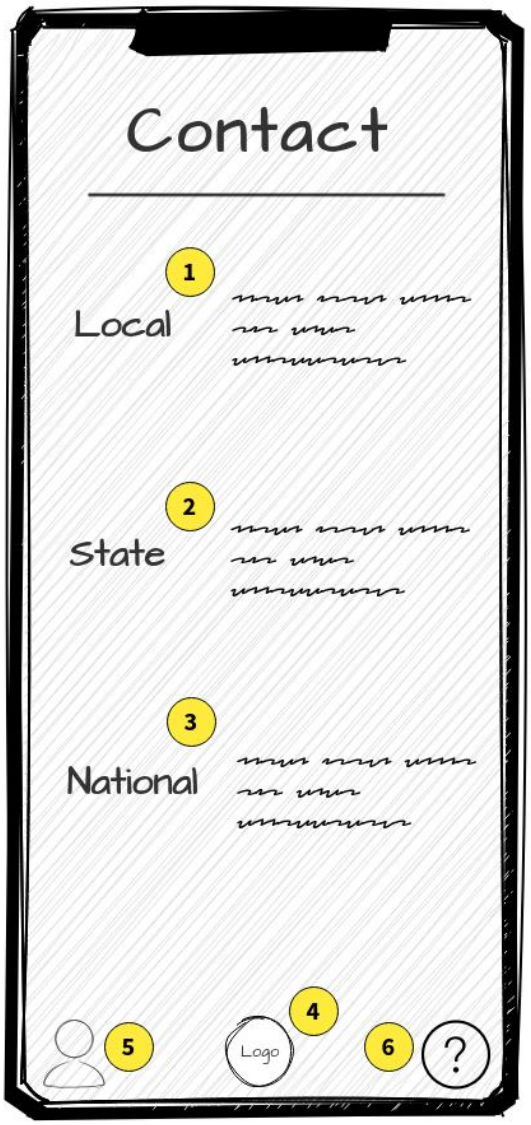
HiveGuide: Annotated Wireframes



Number	Label	Description
1	Image 1	This image represents the Identify section.
2	Identify	Tapping this link takes users to the Identify page.
3	Image 2	This image represents the Save the Bees section.
4	Save the Bees	Tapping this link takes users to the Save the Bees page.
5	Image 3	This image represents the Beekeeper Guide section.
6	Beekeeper Guide	Tapping this link takes users to the Beekeeper Guide page.
7	Logo	Tapping this image takes users to the app Home page.
8	User	Tapping this icon takes users to their User Profile page.
9	Help	Tapping this icon takes users to the FAQ page.

APPENDIX F: Contact Page

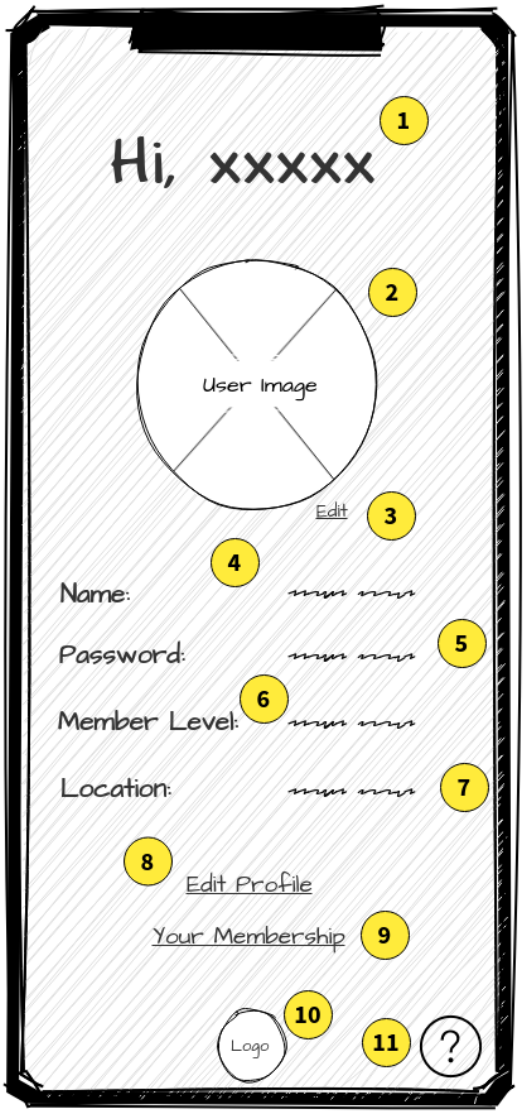
HiveGuide: Annotated Wireframes



Number	Label	Description
1	Local	This text displays information about Local environmental and conservation groups.
2	State	This text displays information about State environmental and conservation groups.
3	National	This text displays information about National environmental and conservation groups.
4	Logo	Tapping this image takes users to the app Home page.
5	User	Tapping this icon takes users to their User Profile page.
6	Help	Tapping this icon takes users to the FAQ page.

APPENDIX G: User Profile Page

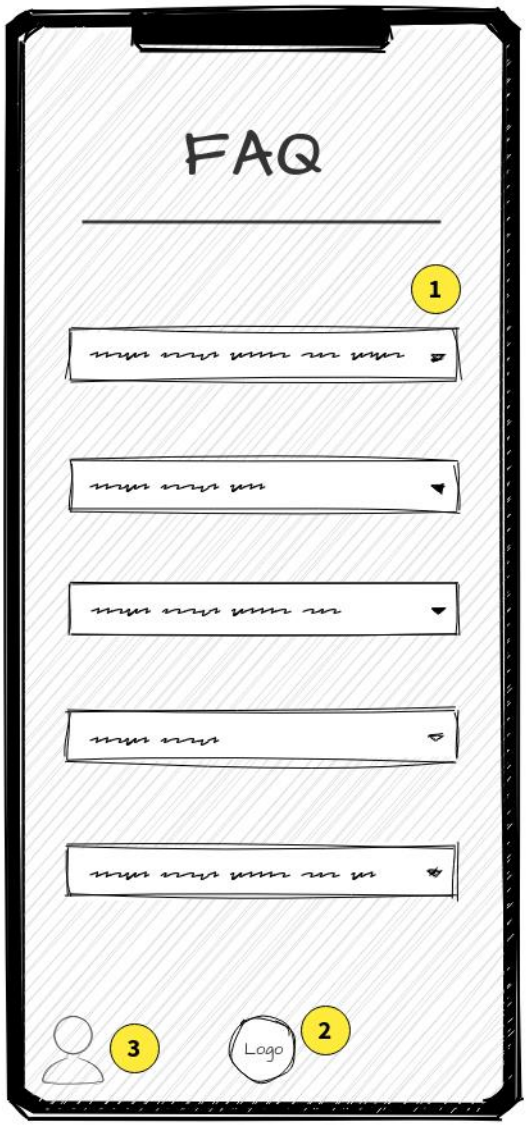
HiveGuide: Annotated Wireframes



Number	Label	Description
1	Welcome	This text displays a greeting and the user's name.
2	User Image	This image shows the user's uploaded profile image.
3	Edit	Tapping this link allows users to edit their profile image.
4	Name	This text shows the user's name.
5	Password	This text shows the user's password, representing characters in "●●●● ".
6	Member Level	This text displays the user's membership level.
7	Location	This text shows the user's registered location.
8	Edit Profile	Tapping this link takes users to a profile editing page.
9	Your Membership	Tapping this link takes users to a page explaining different membership levels.
10	Logo	Tapping this image takes users to the app Home page.
11	Help	Tapping this icon takes users to the FAQ page.

APPENDIX H: FAQ Page

HiveGuide: Annotated Wireframes



Number	Label	Description
1	Collapsible Menu	Tapping this button opens a collapsible text box that answers the question in the button. Tapping again closes the text box.
2	Logo	Tapping this image takes users to the app Home page.
3	User	Tapping this icon takes users to their User Profile page.

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This thesis project would not have been possible without my parents, who instilled in me a love and respect for insects at a very young age. I particularly appreciate my father, Ken McGwin, for spending his retirement tending two beehives. He shares his joy and passion with me in the form of jarred honey and visits to the colonies whenever I'm home on the farm.

I'd also like to acknowledge and thank the Urban Park Rangers of New York City Parks. On July 22nd, 2020, I visited Fort Greene Park to read, as I often do on summer days. I came across a swarm of Cicada Killer Wasps in my normal picnic area and immediately noticed signs posted along the fence alerting the public of the wasps' gentle nature. The signs, put in place by the Rangers, asked park visitors to respect the wasps and leave them alone. These signs sparked the idea for my thesis project, and I've never looked back.