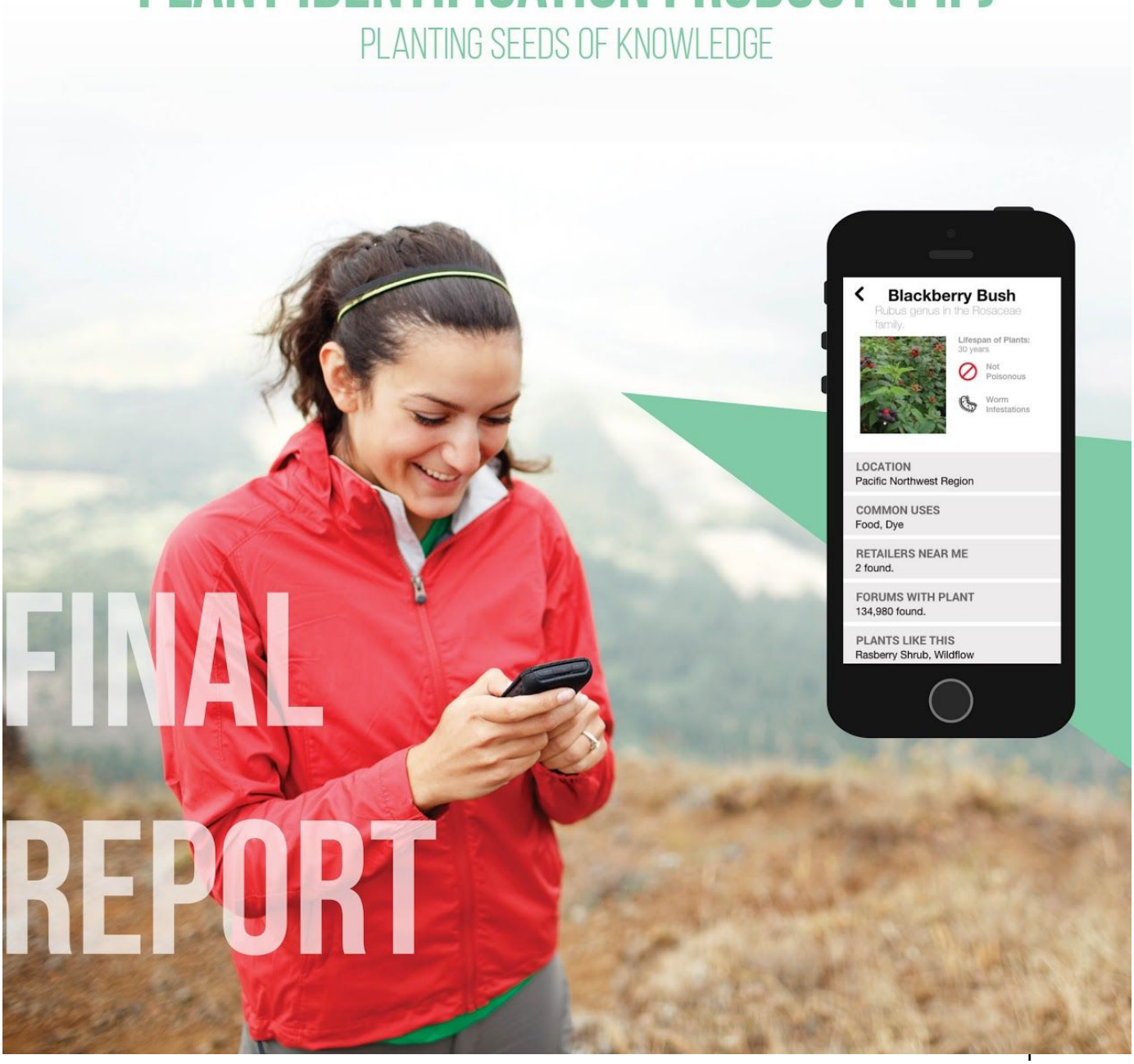
FLORAFINDERS

KIMBERLY HA NEHA NUGURU FINN THOMPSON

PLANT IDENTIFICATION PRODUCT (PIP)

PLANTING SEEDS OF KNOWLEDGE



FINAL REPORT

Contents

Introduction

Before plant identification apps existed, only a few trained taxonomists were able to identify plant species by manually going through a hierarchical taxonomy of questions regarding the characteristics of the leaves (thin, flat, etc.). This method is very tedious and can take hours. Current identification apps that exist also have their limitations with the process they use to identify plants.

Our team, FloraFinders, designed a system that can effectively identify a plant, classify its scientific traits and nomenclature, and display this information to the user in a simple and convenient format. Users will be able to classify what they find and access information about a plant without needless searching or complex testing.

The Problem

The need for a quick and easy plant identification emerges when people find themselves in a dire situation with plants. Plant identification can also be used as an informative tool for guidance in examining the ecosystem.

Encountering Plants in Dire Situations

People may encounter plants that they are unsure if they are poisonous or edible. For example, if a user is camping and accidentally comes in contact with a plant that suddenly gives them painful symptoms, they may not have the proper resources or knowledge to know what to do. Toddlers or pets may also ingest unknown berries which may put them in a life threatening situation. Often times, there is no service out in the wildness, so people don't have access to the Internet and can't immediately search online to find out what the plant is.

Developing a Successful Guide

In 2006, Anna Lawrence and William Hawthorne published a comprehensive guide on developing successful field guides. Their guide provides several valuable insights on how correct plant identification can improve many industries. For example, identifying trees in a region can help timber companies proceed effectively and sustainably, residents of an area can share more information about the local flora to tourists, or scientists could easily determine whether an unknown plant is invasive or otherwise threatening to an ecosystem or population (Lawrence and Hawthorne, 2006, p. 2).

Literature Review

In order to get a better understanding of design and technology challenges present in designing a plant identification system, we conducted a literature review on existing sources relating to our project. These sources provide an insight into content, user needs, existing software, and hardware devices that are present in designing a complex plant identification system like ours. A literature review not only gives us a thorough evaluation of our user base and needs, but it also allows us to assess the benefits and shortcomings of existing technologies that already have been developed.

Identification by Leaf Characteristics

Identifying a species by the leaf shape is one of the most helpful methods. Botanists often look at the shape of the leaves to identify plants. It is also one of the more obvious characteristics that stand out to the general population. It is important to note that some species of leaves can have similar shape but different colors. Leaves in nature are also not perfect; they could be damaged or deformed by insects or the weather so using solely the shape of the leaf for identification may be insufficient (Cope, 2012). Using flowers to identify a species can be ineffective because flowers are be too variable; the same species of plants can produce different types of flowers and they may only show during certain times of the year (Kumar, 2012).

The shape of a leaf can be easily extracted using simple threshold algorithms (Cope, 2012). Lots of other techniques have been developed to analyze the shape of an object such as a Fourier analysis (Cope, 2012). Leafsnap implements two Gaussian equations to extract the image of the leaf and determines the curvature of the leaf through histograms (Kumar, 2012).

An alternative way of identifying leaves on plants using Gabor wavelets. Gabor wavelets are a set of complex mathematical functions, and when applied to leaf topography, they can increase the accuracy of correctly identifying a type of plant. This acts as a highly functioning texture analysis that can be implemented into software, and based on an experiment conducted with 20 different species of Brazilian plants, it has a higher than average classification rate of 84% success (Casanova, 2009).

Competitive Analysis

Although image recognition is now a more accessible method to identify plants, there are many other issues that must be considered. For example, when you take a picture of a 3D object, you only see two dimensions so you can lose the "structural information" (Cope, 2012). Thus, we wanted to look at other systems and identification methods that currently exists through a competitive analysis.

Leafsnap is one of the first mobile apps to identify trees through images of leaves. The technology Leafsnap uses can recognize non-leaf images, extract the leaf image from a plain background, and identify the species from a dataset (Kumar, 2012). One issue that Leafsnap has encountered is the varying quality of the photos taken on different cell phones.

The CLOVER system was prototyped in 2005 that allowed users to sketch or photograph a leaf with a digital device to identify a plant (Cope, 2012). The system would interact with a server that had over a thousand images of Korean plants and match what the user inputted to a plant. The prototype had been successful with identifying plants through with its system.

The 2013 LifeClef challenge compiled images of plants taken by users during different times of the year. They called it a “multi-organ plant data set” that can be used to identify 1000 species of plants based on a certain “organ” of a plant such as the stem, flowers, branches, or fruits (Lee, 2016).

In 2008, Peter Belhumeur and others built a handheld plant identifying “visual” system. It incorporates three different plant databases and pictures of isolated leaf vectors in its software for maximum accuracy of identification (200,000+ images through crowdsourcing efforts from other botany institutes). It is currently being used by botanists at the Smithsonian Institution National Museum of Natural History. An augmented reality version of the system was also developed. A user can put on VR “goggles” and as they walk around a botanical area, markers appear next to plants. When these markers are selected through a “pointing” gesture, information about the plant type appears. This information comes in the form of type specimen, entire tree, bark, and a magnified view of the plant (Belhumeur et. al, 2008).

Current competitors, such as existing plant identification apps, are free for any users to install on their phone. While our specific platform is still tentative, we believe that in order to be competitive, our identification system should also be free.

User Research

In addition to extensive literature review, we also surveyed six participants who we believed to be potential users of our product. Through the survey assessments, we determined the context in which a user would use a plant identification system and what kind of features they would expect such a system to have. While the literature review allowed us to examine the technology and initial user need at a macrolevel, the survey allowed us to analyze the spectrum of user needs and motivations that exist in our user base at a more complex level.

Survey of Prospective Users

The goal of conducting a survey with prospective users was to understand their expectations of a plant identifier and explore the different contexts they could see themselves using it in. We recruited participants who had knowledge or interests in the outdoors, asked them questions to get more insight into our potential user base, and then analyzed the results.

Participants

We interviewed six participants with different interests pertaining to the outdoors. P1 is a high school student who spent a lot of times on trails because of cross country. P2 is a UW student who goes on hikes once in awhile. P3, P4, and P5 are all studying Environmental Science and Resource Management (ESRM). P3 also is double majoring in biology and P5 works for the Washington Trails Association to develop and maintain trails in the PNW. P6 is an officer for the UW Northwest Women Hiking group and an outdoor / hiking enthusiast.

Survey

We conducted six interviews, five of which were done verbally in-person and one was through Google Surveys. We asked participants the following questions:

1. How often do you hike or explore the outdoors in places with foliage?
2. Are you ever curious about the plants you see when you're outdoors?
    a. Have you ever seen a plant and been concerned about if it was poisonous?
    b. Have you ever seen a fruit-like plant and wondered if you could eat it?
3. Have you had a negative experience with plants?
4. Do you maintain or work in a garden?
5. Do you carry a smartphone or any other technology when you hike?
6. Have you ever identified plants before, learned either through a class, handbook, or other?
    a. If so, what traits do you use to determine a plant's identity?

7. When would you see yourself using a plant identifier?
8. What do you expect it to do?
    a. What type of content would you expect a plant identifier to display?
9. Do you know any other apps that are similar to this (an identifier app)?
10. How much are you willing pay for something like this?

Results

Most of our participants either hiked or explored the outdoors very often. Five out of six participants spent a fair amount of time outdoors every week with four participants who said they do this at least once a week. These participants who were outdoors often said that they have found themselves curious about the plants they see. Five out of six participants mentioned that they have encountered a fruit-like plant and wondered if they could eat it. One participant mentioned a blackberry bush and another mentioned mushrooms seen particularly often. Two participants mentioned that they were always too scared and simply stayed away from eating any fruits on plants.

We asked participants if they had ever had any negative experience with plants to see if our product could help prevent them from happening. Participants mentioned getting poison oak, sleeping on a patch of spiky plants, getting burrs stuck in socks, getting cut on thorns, and encountering stinging nettles while working on the trails.

Four out of the six participants have had experience identifying plants before. Three had taken classes and two had other means of learning such as a handbook or simply being out in the field and being taught by others. They identified plants through unique features in leaves, needle, bark, and more, and most of them knew how to identify common poisonous plants such as poison ivy or poison oak.

The cost that each participant would pay out of pocket for the identifier varied from $0 to $5. Three participants said they simply wouldn't pay for something like this. Two participants said they would pay $5 only if this app was "perfect." Participants also mentioned similar identification apps for identifying songs or birds. From these conversations, we can see that we may be able to charge a few dollars for this product.

When we asked participants what they expect the product to be able to do, we obtained the following list of functionalities:

- Takes a picture and matches it to a built-in database to identify
- Matches the picture to a built-in database
- Contains pictures, range map
- Works without internet connection
- Recognizes shapes, colors, and patterns
- Ability to download local regions for offline
- Shows the following information:
    - Plant name
    - Scientific name
    - Region where it's found / environment
    - Lifespan
    - Edibility
    - Root depth
    - Poisonous
    - Symbiotic relationship with other organisms
    - Characteristics
    - Plants of the same family

Design Issues

Through our research of different identification systems, we discovered different challenges we would have to face while designing our solution.

We had to consider the very large number of plant species users may encounter. Existing plant identification solutions are limited to common plants or to specific regions of the world. If users are out in the wildness, they won't have service so can't access an online expansive database.

How to go about identifying plants is a challenge in itself. Current solutions that exist have their issues depending how they approach identification. For example, image recognition has its processing power limitations and identifying plants by selecting a series of attributes requires high user effort and guess.

We also have a variety of potential users including outdoor enthusiasts, gardeners, scientists, and educators so we needed to present different levels of information that is useful to a variety users.

Features

From our research, survey, and competitive analysis, we identified the following features that would help users meet their needs in identifying plants.

Capture plant features for identification
Users will be able to simply take a picture of a plant's leaf, flower, etc. and the system will be able to identify the plant by matching attributes.

Search encyclopedia of plants conveniently without internet connection
Users will be able to download specific regional databases ahead of time so they can identify plants regardless of having internet access.

Information tailored to what the specific user wants
Basic information will be shown for general users such as the age of the tree or plant and common uses it has. More scientific information is available plant enthusiasts which includes the plant's position of genus, phylum in the plant kingdom along with its proper name and nomenclature.

Useful plant characteristics and cultivation information
Characteristics of plants will be displayed such as its toxicity, habitat, flower, fruit, seed, and common uses. Information for cultivation will also be displayed such as necessary light, soil, pH, and moisture for growth.

Performance Requirements

We refined our list of design and performance requirements in addition to the basic identification functionality based on our learnings from the literature review and surveys.

Our design must have the following performance requirements:

- Quick and accurate classification of plants
- Dynamically update database based on new plant discoveries and database
- Aware of plant presence based on location (GPS tracking of user)
- Intuitive camera capture
- Work without internet connection

Users

Our potential users of this product span various industries who encounter plants / vegetation in their daily lives. Our targeted population are outdoor enthusiasts who want to determine which plants are edible, recognize potentially dangerous or poisonous plants, and want to satisfy their curiosity about the world around them. This user population includes hikers, campers, gardeners, and scientists. Other users may include ecologists, urban planners, chefs, and educators who each have their own uses for a plant identifier. We anticipate that users will primarily need to identify plants outdoors in areas such as gardens, hiking trails, and public parks. It may also find its use in educational settings like museums or classrooms.

We expect the market size to be very large considering the variety of users and uses that a plant identifier has. The leading product for identifying plants and garden advice, My Garden Answers, claims to have over 750,000 users on its website. This existing market will provide a foundation to launch our product, while also leaving room for growth

among outdoor enthusiasts, niche users, and the general population as a whole. Given a global target audience, our market size can several million users.

Persona

We created a persona to develop our product for. The characteristics and attributes of the persona is based on our user research and who our target users are. Below is our persona Athena, an outdoor enthusiasts who values education and exploration.

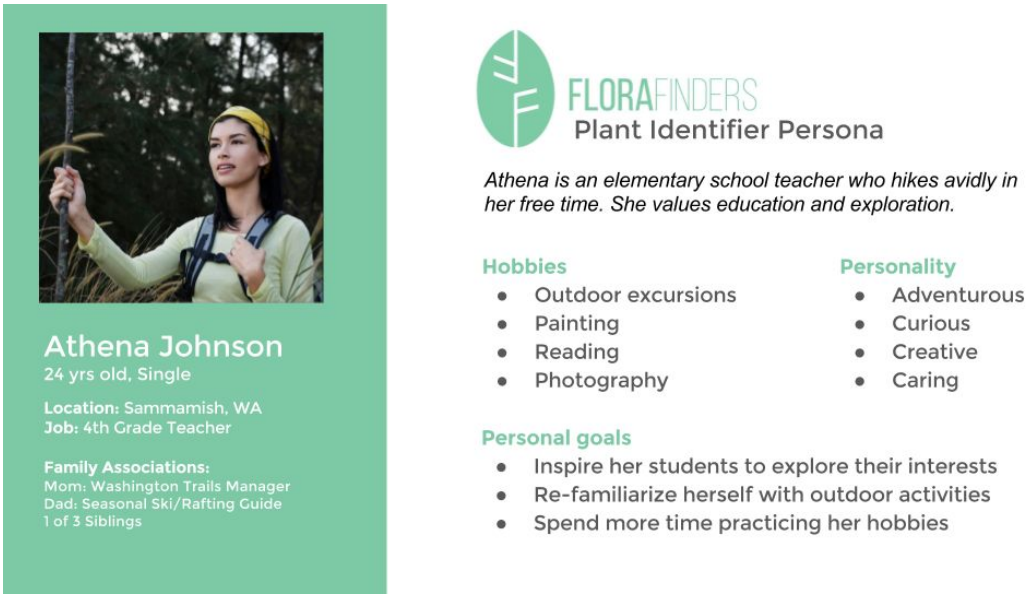


Figure 1. Profile of our persona, Athena Johnson

Background

Raised in the Pacific Northwest, Athena has always appreciated the outdoors and enjoyed exploring nature. She spends her summers hiking and swimming, and occasionally goes on week-long backpacking trips in the Olympics or Cascades when the weather is nice. From her time in nature, she has learned to value the little things in life through observing the minute details of the wilderness. Introspecting on her positive experiences outdoors, she decided to pursue a degree in education so that she could share the wonders of the wild with younger generations. Last year, Athena founded a hiking and exploration club, PNW Wilderness Alliance, to take groups of adults on hikes

in her spare time. She lives in Sammamish, WA, with her brown labrador Max and brings him along to hikes whenever possible.

Athena's personal goals are to become an effective teacher and inspire her students to pursue their personal interests. She also wants to take more time engaging in her hobbies: hiking, painting, and reading. She used to go camping frequently as a child with her parents and siblings, and her goal is to re-familiarize herself with outdoor excursions by exploring all that the PNW has to offer.

Scenario

It is a beautiful Saturday morning as Athena hikes Snow Lake Trails with her dog, Max. Athena walks along the trail when she suddenly feels a tug as the leash slips out of her hand. Caught off guard, Athena frantically turns her head towards the shrubs where Max has wandered off to. She finds Max chewing on a plant that looks unfamiliar to her. Athena panics and rushes besides Max, anxious that he might have eaten a poisonous plant.

Before PIP

Athena automatically reaches for her phone but realizes that she has no data or service. She can't Google the plant and she has no other way of knowing if the plant Max ingested is poisonous. She looks around to see if anyone else was on the trail but they were alone. Not willing to risk hiking the rest of the trail, Athena takes Max back down the trail and to the car. When she gets back home, she tries to Google the plant with adjectives of the plant she could think of but she had no luck finding it. Athena simply decides to keep a close eye on Max for any symptoms in next few days.

After PIP

Athena reaches for her phone and opens PIP in hopes of identifying if the plant Max ate is poisonous or not. PIP's offline database contained information about common, general plants in the Pacific Northwest via GPS location, but luckily Athena also downloaded the offline database for plants and vegetation in Snow Lake Trails before she came here.

Athena taps a camera icon, takes a picture of the plant, and waits. Seconds later, PIP identifies the plant as a Maximilian Sunflower, or Helianthus maximiliani. Right under the name, there is a label that says 'Not Poisonous.'

As Athena sighs with relief, she notices that right next to Max is a bright blue, dazzling flower. Driven by curiosity, she takes a picture of the flower using PIP, but seconds later, she gets a notification that the plant cannot be identified. PIP suggests that Athena submit the picture to the identification database and forum to be analyzed by a panel of botanists and other users. She selects 'agree' to accept the request and continues on her hike.

Two hours later, Athena is back at her home and reading a book on her patio when her phone vibrates on her table. She sees a notification that her submitted photo has been identified and added to the PIP base. She opens her phone to find that the plant is called a Blue Columbine. Its popular, bright-hued appearance makes it a favorite among gardeners. Many people in the forum commented that they had the plant in their own gardens.

Athena decides she is interested in growing Blue Columbines in her own garden. She selects "Retailers Near You" under the plant's profile to skim nearby locations where she can purchase the plant. Athena makes a note of the closest store, GreenGarden Depot, which is 1.2 miles from her house. She sees that it is open everyday from 9am - 2pm and plans to go there tomorrow.

Tasks

We defined a set of tasks that users must be able to complete in our app.

Identify a plant by taking a picture of it
Users must be able to seamlessly identify a plant by taking a picture of it.

Submit plant image to experts

In some cases, PIP will be unable to identify a plant identification, either due to poor image quality or unique flora. Users must be able to submit the failed identification image to experts and enthusiasts through online forums to expand the PIP identification database.

Learn extensive information about a plant

Users must be able to learn everything they want to about a plant they've identified. As users may have a wide range of prior plant experience, this information must be easily accessible for plant amateurs while also offering extensive details desired by botanists, outdoor enthusiasts, and other experts. Users must be able to quickly tell if a plant is poisonous or edible in order to determine if emergency is necessary in case a plant was touched or consumed.

Look up a plant by name or look up previously identified plants

To accommodate users who want to learn about plants in the comfort of their own home, PIP must offer the ability to search plants by name or open the encyclopedia entry of previously identified plants.

Set up identification databases for offline compatibility

Users will often find themselves without internet connection while out on hike or otherwise exploring the wilderness. As such, users must be able to identify plants without an internet connection. Towards this goal, users can download specific regional databases to their phone for offline identification.

Participate in online forums

Users must be able to participate in online forums, allowing them to help identify other users' failed identifications as well as share general information about finding or growing plants. The forums will fuel a strong community from which failed identifications can be crowdsourced for quicker, more accurate identification in the case that PIP cannot do so itself.

Design Criteria

Our design criteria for our plant identification consisted of many factors that would allow it to be competitive in the current market of plant identification tools and allow for maximum usability. We chose to design PIP as a mobile app, so it would not be an external accessory that people would need to carry in order to identify plants. This exemplifies ease of use, since users may be hiking or in a wilderness area, and would not be able to carry an additional tool along with their other possible equipment.

We focused on making our design as efficient, effective, and accurate as possible. In order for our product to be efficient, we included multiple ways for a user to identify plants. We also made sure that information about plants would be organized in a way that users could easily navigate the components that they were the most interested in. Creating intuitive system map flows with prominent green buttons for navigation and a muted palette allowed for easier accessibility to content.

Through our literature review, it was clear that plant databases were extensive, and matching could often severely lag due to matching plants without specific defining features. Our goal was to maximize effectiveness of database matching by having database partitioned into specific plant features, such as leaves or flowers, and then have it match through smaller sets of databases. Also, in order to be as effective as possible, it was important to incorporate an offline mode for the app as well. Since users could be in a remote area or a trail without cellular connection, our app had to make sure to accommodate plant identification regardless of cellular connection.

A plant identification tool can also appeal to a variety of potential users who have varied knowledge about plant taxonomy. Our user base includes students, wilderness enthusiasts, hikers, botanists, urban planners, and educators. To display the most accurate information for our user base, it was also a priority to make sure that information about plants was presented in a way that touched on both scientific and

general concepts. This was key in designing a user-friendly display of the plant profiles on PIP.

Our design criteria centering around having an efficient, effective, and accurate identification of plants ultimately allowed us to create a seamless user experience for our users, and remain a standout app from existing identification apps that lack these qualities.

Design

Functionality Overview

Ultimately, users can quickly identify plants that they encounter, and expand their plant-based knowledge through viewing plant profiles and interacting on PIP forums to communicate with others around the world with a passion for plants and flora-related facts.

Core Functionality: Identifying a Plant

There are three ways users can identify a plant. These methods include using the camera feed on mobile, searching a plant by name, and getting input from forums.

- **Identify Through Camera**
  User can take a picture of the plant they encounter, and PIP will match the picture to the existing plant database and bring them to the plant profile. If cellular network is not available, PIP will match to regional databases that were downloaded beforehand by user.

- **Identify through Search**
  If the user already knows the name of the plant, they can manually search the plant up using the 'Plants' search function. The 'Plants' page also allows users to

locate their previously identified plants, if they would like to revisit a previously visited profile.

- **Forums**
  Forums can be helpful in identifying a plant by getting community feedback. Simply post picture and description as a new thread, and get input from the PIP community. Forums can primarily be used for locating specific forum threads posted by members that relate to user interests. Users have an option to leave a comment of their own to any forum if they would like.

- **Offline Mode**
  The offline mode, as stated above, allows users to download databases populated with plants of a specific region ahead of time. This is useful if a user is unsure about the availability of cellular connection in the area they will be going to, and still want the ability to potentially identify plants in that region. Once databases are downloaded, that database can be used even in times when a user has no cellular connection.

- **Plant Profiles**
  Once a plant has been properly identified, users are directed to a plant's profile page. This page displays information such as its scientific name and classification, location where plant is found, common uses of the plant, retailers near user that sell the plant (if it is a common gardening plant), forums in which the plant has been tagged, and related plants.

Auxiliary Functionality

There are four main auxiliary functions that PIP provides.

- **Trending Topics Near Me**
  Within Forums, users can explore trending flora-related threads that are popular in their area. This helps users stay connected about regional issues or updates involving plants.

- **Directions to Retailers**

  If a user chooses to go to a retailer to purchase a plant within the Plant Profile, PIP can display directions and use location integration for GPS . Guidance to navigate a retailer's website to purchase plant online is also offered as well.

- **Profile Setup**

  A user can create a profile, and has the option of creating their own username that will be displayed when a user posts on a thread.

- **PIP Panel Verification**

  In case of an error in database identification, a user will be prompted to fill out a form to be submitted to a panel of real life plant experts working for PIP. This form includes the picture of the plant taken by the user. Once the panel has successfully identified the plant, the user will get a notification about the identification as well. This is especially vital to expanding PIP's database. In the event that a user has identified a new plant that does not currently exist in the database, PIP can be active in maintaining an updated catalogue of plants.

Visual Design: What Does it Look Like?

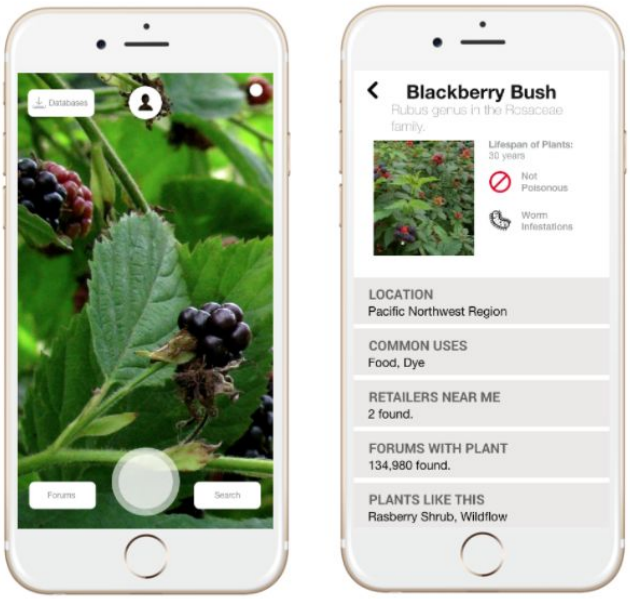


Figure 2. PIP's home screen (left) and a plant profile of a Blackberry Bush (right)

The prototype of PIP was created and streamed using Adobe XD. Users could stream the prototype on their own mobile phone when given a specific URL. While the all wireframe designs can be located in the Appendix, Figure 1 shows the home screen of PIP and a plant profile of a 'Blackberry Bush'. Note that the home screen of PIP includes a live camera feed, much like Snapchat's UI design, in order to facilitate quicker identification through photo verification.

Please See Appendices for supporting documents:
Task Analysis (Appendix F - p.52)
System Map (Appendix F - p.52)
Paper Prototype Design (Appendix G - p.55)
High Fidelity Screen Design (Appendix H - p.56)

Testing

To evaluate our design, we conducted user testing for each our low fidelity and high fidelity prototypes. We focused on testing the identification screens—both success and failure—as well as encyclopedia search, as these components comprise the core plant identification functionality.

Test Structure

We developed a standard test format to use across all of our interface evaluations to create a consistent experience among users and acquire consistent and relevant results. We collected users from two sources: acquaintances and random approaches in campus libraries. To introduce users to PIP, we briefly explained that we were testing a plant identification app prototype for an interface design class. We asked that they think out loud while during the evaluation to reveal what they were thinking as they used various components in our app. We informed them that we would be timing them as while also recording any interaction errors they make as well as any general use notes we observed as they navigated through our app. Users completed three tasks:

Task 1: ***Identify a plant***
You are hiking in the woods when you see an interesting bush that you are unfamiliar with. You pull out your phone and open the app which leads you to the main camera screen. Find out what that bush is!

Task 2: ***Submit a failed identification to PIP forums***
While heading back down the trail, another plant catches your attention. You had never seen anything like this plant before and you really want to know what this plant is! You pull out your phone again and open the app to try and find out what it is.

Task 3: ***Lookup a plant and find retailers***

You are back home from your hike later at night. You suddenly want to remember if blackberry bushes were poisonous or not and if you can grow your own.

After users completed all three tasks, we asked them to rate how much the liked the app and how easy it was to use, each on scales of 1-10 where 10 means more likeable and easier to use. In the tests, we originally defined ease of use as more difficult at higher ratings, but we inverted the scale for consistency while maintaining the relative values of the data. To conclude the evaluation, we asked participants to share any final comments, questions, suggestions pertaining to their overall experience with PIP.

Low Fidelity Prototype

For our first interface evaluation, we developed a low fidelity prototype using Figma, a collaborative design tool. In an in-class testing session, we printed our system out in black and white—to focus on function rather than form—and informally led classmates through our evaluation process in order to iron out any kinks in our design and test format. We then converted our design to an interactive prototype using InVision, allowing users to feel as if they are using an actual phone app during interface evaluations.

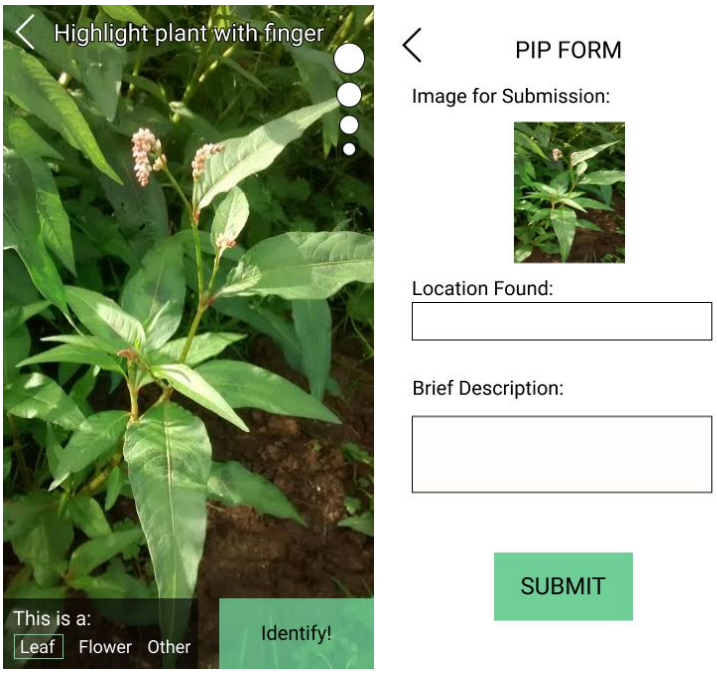


Figure 3. Low fidelity prototype. Secondary identification screen (left), PIP submission form (right).

Findings

Our low fidelity prototype evaluations allowed us to view an outside perspective and observe how non-design students would understand interaction through PIP. Participants generally enjoyed the simplicity of our app and the extent of plant information they could acquire, but they also disliked or were confused by several components of our design. In this revision of our design, after taking a picture, users would draw over the plant they wanted to highlight and then select what plant features—leaf, flower, or other—they had captured in their image. We included this component to theoretically speed up identification, but users were generally confused by it: most either asked us what to do or skipped both highlighting the plant and selecting the plant feature seen. On the failed identification submission, we expected users would note relevant details to help experts identify the plant, but in practice, most participants had no idea what information would supplement the image already being submitted. Upon submitted the image to PIP's forums for identification, they were offered the option to be notified of results by either phone or email, but participants disliked this feature, as they didn't want to share their contact information. Participants were also confused by our homepage layout, as "Databases" linked to offline mode setup, while "Encyclopedia" opened the functionality to search for plants by name; several users opened "Databases" when they were tasked to search the encyclopedia.

Table 1. Low fidelity prototype evaluation results.

	P1	P2	P3	P4	P5	Average	Std. Dev
Task #1 time	22s	25s	68s	16s	18s	29.8s	21.6s
Task #2 time	69s	50s	53s	78s	103s	70.6s	21.5s
Task #3 time	40s	50s	36s	56s	21s	40.6s	13.5s
Errors	1	0	4	5	0	2	2.3
Ease of use (10=easy)	8	9	8	9	9	8.6	0.55
Likeability (10=like)	5	8	7	7	7	6.8	1.1

Design Improvements

From this initial design evaluation, we compiled a list of changes to make before moving on to a higher fidelity prototype:

- Remove the secondary selection screen from identification in which users highlight the plant and select the features they see in the image
- Add an explanation on what happens when the failed identification image is submitted to the PIP forums for experts to identify the plant
- Change the wording on the failed identification image description to suggest that information there is extra and supplemental—not required
- Remove the contact information page from the failed identification task, as we can notify users through the app itself
- Reorganize the home screen by moving offline mode ("Databases") into the encyclopedia functionality and rename the combined button to "Search"
- Tidy up plant profile page to be more readable and scrollable

High Fidelity Prototype

Using feedback generated from our low fidelity prototype evaluation, we redesigned and improved several components of PIP towards creating a more enjoyable and clear experience. For this high fidelity revision, we used Adobe XD to design and prototype our app, again using a phone form to simulate actual usage. As with the low fidelity version, we first tested this prototype on classmates before finding participants to complete full usability evaluations.

Findings

Like before, users really enjoyed the simplicity of the identification process in PIP—more so in this revision with the confusing secondary identification screen removed. Usability was affected slightly, however, by Adobe XD, as the screens did not fully fit within browser windows, requiring users to occasionally scroll in order to see the full extent of the screens. From participants' completion of the test tasks, we discovered places in which we could continue to improve our design towards a better user experience. For

the most part, users completed tasks quickly, but one user was extremely lost when she began using the app—she failed to notice the camera button and instead explored the remainder of the app when trying to identify a plant for task 1. We additionally found that our homepage still was unclear: "Search" failed to appropriately capture the encyclopedia functionality behind it. We also learned that the "Databases" link, now within the encyclopedia functionality, confused users as it lacked any explanation of what it was. Across the evaluation, participants completed tasks quicker on average than participants did in the low fidelity prototype, excluding the one participant who got lost, but variations in their task completion times showed us that we could do more to standardize users' experiences by reducing errors.

Table 2. High fidelity prototype evaluation results.

	P1	P2	P3	P4	P5	Average	Std. Dev
Task #1 time	59s	11s	18s	11s	12s	22.2s	20.7s
Task #2 time	79s	44s	38s	42s	25s	45.6s	20.1s
Task #3 time	104s	34s	30s	62s	32s	52.4s	31.7s
Errors	5	0	0	2	1	1.6	2.1
Ease of use (10=easy)	7.5	7.5	10	9	6	8	1.5
Likeability (10=like)	7	7.5	10	6	7	7.5	1.5

Table 3. Change in data from low fidelity to high fidelity evaluation.

	Average	Standard Deviation
Task #1 Time	-7.6s	-0.9s
Task #2 Time	-25.0s	-1.4s
Task #3 Time	+11.8s	+18.2s
Errors	-0.4	-0.2
Eases of use (10=easy)	-0.6	+0.9
Likeability (10=like)	+0.7	+0.4

Design Improvements

From our high fidelity design evaluation, we compiled an additional list of further design changes to improve our app:

- Relabel “Search” to “Plants” on the homepage to better reflect the encyclopedia and offline database functionality behind that button
- Add an explanation of the offline database functionality into the encyclopedia page itself, so users can avoid opening it if they have no need to
- Include a hint on the home screen to prompt first-time users to take a picture

These design improvements are included in the final product in this report and conclude the work that we completed over the course of the quarter.

Future Development

While we have finished design PIP in the context of this course, we see several ways in which it could continue to grow and develop moving forward. We could later include social features, such as sharing identifications to Facebook, Twitter, or other social media services with the goal of expanding the PIP identification community beyond just our forums. We also envision augmented reality identification where plant names are overlaid onto the live camera feed, allowing the user to easily select any plant they point their phone at. We could additionally add a virtual reality education module in which users can explore a virtual plant’s structures and organs from within. Overall, we see definite future development, some concepts more feasible than others, available in this design space that we have begun to flesh out with PIP.

References

Belhumeur, Peter N., et al. "Searching the world’s herbaria: A system for visual identification of plant species." *European Conference on Computer Vision*. Springer Berlin Heidelberg, 2008.

Casanova, Dalcimar, Jarbas Joaci de Mesquita Sa Junior, and Odemir Martinez Bruno. "Plant leaf identification using Gabor wavelets." *International Journal of Imaging Systems and Technology*, Volume 19, Issue 3, 5 Aug. 2009, Pages 236-243.

Cope, J.S., Corney, D., Clark, J.Y., Remagnino, P., Wilkin, P., "Plant species identification using digital morphometrics: A review", *Expert Systems with Applications*, Volume 39, Issue 8, 15 June 2012, Pages 7562-7573.

Kumar N., Belhumeur, P. N., Biswas, A., Jacobs, D. W., Kress, W. J., Lopez, I., and Soares J. V. B. Leafsnap: A computer vision system for automatic plant species identification. In Proc. ECCV, 2012.

Lawrence, A., Hawthorne, W.: *Plant Identification: Creating User-Friendly Field Guides for Biodiversity Management*. London: Earthscan, 2006.

Lee, S.H., Chang, Y.L., Chan, C.S., Remagnino, P.: "Plant identification system based on a convolutional neural network for the LifeCLEF 2016 plant classification task." In: Working notes of CLEF 2016 conference (2016)

Reflections

Kimberly Ha

Coming into HCDE 455, I had a strong understanding of the foundations of HCDE and was very excited, believing that I would be doing more design-focused work and learning about design principles. I knew that UX was focusing on the people side of technology and not just designing the visual aspect of interfaces and products like most people assume. I am glad that this class continued to reinforce this concept.

Creating an application means carrying a big responsibility because you are designing for potentially generations that will come after you. Even if technology and design is rapidly changing, future products or designs may be influenced by what you created and therefore you have played a role in the direction of that product or design.
Working in the field of HCDE, our job is to figure out what the users really need and making sure that is heard in the development process. Our role is to advocate for the user and make the interaction between humans and technology simple and intuitive. This is why I will always refer back to the 10 commandments for interface design.

I appreciate the idea of being assigned a group and project because it simulates the real world where you don't get to pick your teammates or the project you work. Working with my group of all HCDE students was rewarding in that we all were familiar with the UX design process and how to conduct user testing. We each had our own skills that we brought to this project. Having assigned a project gave me a real challenge with design constraints and with knowledge about an expertise that I was not familiar with. Because of this, I put a lot of effort into doing our literature review and learning as much about plant identification systems and methods that I could.

Because our project was simple and similar apps already existed, we iterated on the current systems. If I were to do this again, I would definitely think more creatively and not let technical feasibility get in the way. For our future endeavors, we definitely talked

about some cool ideas we could pursue using VR and AR in our plant identification app. Thinking Hats was a very interesting concept to learn and I wish we could have overtly applied it in our creative brainstorming process. From class lectures, we were also exposed to amazing, futuristic interfaces that people are working on and it is very helpful to see that those exist so we don't have to limit ourselves to common interfaces that we are familiar with.

Another thing we did not get to do is actually go out and observe real users who currently do or have the need to identify plants. I think that the context in which the user uses your product is very important and that user research always starts with observation. For this project, we only had the chance to "observe" and talk to our persona, but if I were to do this project again and we were serious about developing this product, I would go out there and observe and talk to a variety of users.

Looking back and compiling this final report has shown me what a team is capable of doing in just 10 weeks. We completed so much research, user testing, and design work. For our final presentation pitch of our project, it was very difficult fitting everything that we've done and into a hard five minutes. I had a lot of fun filming, directing, and editing our 30-second promotional video which I found to be very useful in showing the context scenarios that our app can be used in.

Through HCDE 455, I've learned the steps and the tools I need to tackle projects in a short timeframe. With all these skills and practice I've gained, I hope to step into the professional world ready to make a difference in the next year.

Neha Nuguru

HCDE 455 made me aware of how expansive the field of interface and interaction design really is. Before this class, I was limited to interface design in the context of mobile of desktop interfaces. Through doing the various assignments in this class, I realized that an interface is not limited to these screens, but really anything that facilitates interaction in order to complete a task could be seen as a viable interface. Through this class, I learned to think critically about how users could engage with the world around them through technology, and also what defines intuitive and engaging interface design.

I enjoyed the arcade game assignment, because as someone who has never really played arcade or video games, it was fun to approach it from an interface design critique and find components of the game that made it responsive to a user. I had to make sure I was allowing myself to focus on the various visual and auditory cues, and what potential aspects my game was lacking in.

I would say the most difficult part of the course was being assigned a topic I had no prior knowledge of. It was definitely challenging, and required a lot more literature review in order to understand all of the various facets of creating a plant identification interface. Working in a group did make this task easier, since I could share ideas to my group and we all could collaborate and facilitate discussions of possible features and components for our project. Because we were all from the same major (HCDE), we shared a similar foundation in User Experience design. This way, the process including research, testing, and iterative design was familiar to all of us and there was not a lot of confusion. We also did have different sets of skills that helped us gather and present our assignments very efficiently and meet our deadlines.

I think as someone who wants to pursue UX design, the process of researching and creating personas and storyboards to inform your design is something that I will definitely be using in the future. I believe that the design process we learned in this class can be applied to any career in engineering and design as well. What I would probably do

differently next time, is research more applications in the VR and AR realm for our product. Although there were many existing mobile apps, it would have been interesting to look more intensively at the other types of interfaces out there. Of course, we couldn't do as much as we wanted to due to time constraints, but overall I believe that our final product was well thought out and succeeded in being an effective plant identifier.

I think what worked in our group's process was scheduling meetings outside of class, and assigning specific components to different people based on skill. That ultimately allowed our individual skills to shine, and also provide a cohesive product that the whole group could agree upon. It was fun to design the final high fidelity product, and create a prototype that I was proud of using my design skills. Scheduling free time to meet was a challenge with everyone's schedule, but we managed to schedule a good amount of meetings throughout the quarter to develop our project.

I am proud of the fact that our group was able to consolidate all of our findings and designs into our 5 minute presentation, and everyone on the team worked very hard to make sure that our presentation clearly conveyed our product's use and value. We came a long way from our initial planning stages, and I think all of us are proud of our project and how it caters to our app's user base.

I think HCDE 455 was a wonderful class that taught me a lot about how to think about interface design in a critical and methodical way. It was amazing to share the experience of presenting the product with my group in front of industry professionals, and also to view everyone else's projects. I am glad I took this course, and I believe I have sharpened my own design thinking skills as well.

Finn Thompson

Throughout the quarter and the process of designing PIP, I learned a lot about working to conceptualize and design projects from start to finish while keeping in mind important considerations such as interface design guidelines and iterative user feedback at every stage of the process.

In addition to HCDE/INDE 455, I also took HCDE 318 this quarter, in which we conducted a very similar design process to create an app as a group project. In that class, we focused a bit more on theory than on actual interface and interface design, but we completed many of the same steps throughout creating the app: user research, personas, scenarios, storyboards, system maps, paper prototypes, wireframes, and high fidelity prototypes summarized in a final presentation and final project. In HCDE 318, we defined our own app and spent time on wireframes rather than conduct two separate extensive user evaluations in which we recorded tangible data, as we did in 455. At times, using these similar techniques in both classes clashed and became repetitive, but overall, I found it helpful to understand two different perspectives on the design process while bouncing theoretical ideas between the two classes.

I particularly enjoyed working with users at several points in the design process, both in getting to know them through initial user research and later observing how they use our product in usability evaluations. I find others' perspectives to be interesting, especially when I use or observe them in the context of designing a product. In contrast, I didn't much enjoy the points where we developed and worked with our persona, such as in creating scenarios and storyboards. I found it far more helpful, while designing, to think of what I learned from actual people rather than what we combined into our persona. I do appreciate, however, how personas are especially beneficial in larger teams, where not every member of the team has necessarily interacted with or gotten to know users directly, thus relying on personas developed by the members who have had that real user connection.

Although I am an HCDE student, I have a background in computer programming, which I have done extensively since high school. In my free time, I created several plugins and standalone applications in which I created every aspect of the project, from the experience to the interaction to the code behind it all. It was at that point in my life that I began somewhat understanding user interfaces and how to design things around the user. I released several of these programs online, either through other product's forums (for plugins) or through websites of my own (for standalone applications), and I became very involved with the thousands of users of my products, incorporating their feedback wherever possible. With this background in mind, it's interesting to learn and take a formal, tested approach to human-centered design. I certainly see myself going through this design process again in the future, especially if working with a group. Working alone, I would likely prune a few aspects of the design process.

I found working with a group to be very beneficial throughout the quarter. In my aforementioned software development projects, I typically worked alone, and the few times I did work with teams, our group work generally did not turn out as well as I would have liked—possibly due to working remotely with people over the internet who I had never met in person. It's nice to work with a team in-person and to see how ideas bounce around between group members, changing for the better with each bounce. Furthermore, my group in 455 worked very well together all quarter, making this process even more enjoyable. I found that my 455 group was an interesting contrast to my HCDE 318 group, where we did not define team member roles at the beginning of the quarter and consequently floundered at times, struggling to work collectively towards goals.

Towards the end of the quarter, as I saw how creative other teams were with their projects, I wished we had taken a more unique, less feasible approach to designing our plant identifier. From the beginning, we sought to design something that could actually exist with today's technology for the sake of users understanding how to use it—such as a smartphone rather than a novel device. At one point in the quarter, Professor Furness mentioned using infrared and ultraviolet light to help identify plants, but we discarded this concept due to our self-imposed smartphone limitation. Chun suggested that we take a Pokemon-inspired approach where we gamify plant identification with a "gotta

catch them all" mentality, but we decided not to take this approach since a previous project, the bug identifier, did something similar and we didn't want to copy their style. In one of our last in-class feedback sessions, one classmate asked if we had considered an augmented reality approach, where users would simply point their phone at a plant or plants and identifications would pop up on screen for users to select from. This idea led us to similarly consider how virtual reality could be incorporated into our design, hence the idea where the user could enter a VR world to explore the structure of a plant from within. In hindsight, it may have been more interesting to go a step further and create a novel identification device like a glove in which users point at or pick up a plant to identify it, although this approach may have issues with long-term comfort, ease of carrying an entire new device, and disturbance of wildlife.

Overall, I feel that I gained a lot from this class in building my perspective on the design process. I was especially impressed by the unique, cool ideas I saw all quarter both in lectures and in other teams' projects towards the end of the quarter. Moving forward, I hope to further hone these skills and become a professional in design and development, and ideally I'll be working on a project as creative as those I've seen in this class.

Appendix - Final Phases

Appendix A - Team Identity

Mission Statement

Flora Finders' mission is to help users identify plants and vegetation by providing a quick and easy way to classify what they find, displaying accurate information about the flora without needless searching or complex testing. We strive to dramatically improve the ways in which users identify and interact with the flora around them.

Motto

Our team motto is **Planting seeds of knowledge**. We decided this phrase will represent our goal to educate users and provide them with a foundation from which they can expand their floral familiarity.

Values

Throughout the development of the project, we will incorporate a set of values that we believe will aid an enjoyable user experience while offering relevant information to both inexperienced users and floral enthusiasts.

- Efficient
- Accurate
- Informative
- Convenient
- Intuitive
- Effective
- Dynamic
- Scientific

Team Information

Team members / contact info

Name	Email	Voice
Neha Nuguru	nehanuguru@gmail.com	408-391-3062
Finn Thompson	nnifinn@gmail.com	530-414-4849
Kimberly Ha	kimberly.ha12@gmail.com	206-474-4828
Quinn Mau	mauq@uw.edu	360-742-9838

Team assignments

Name	Skills	Assignment
Kimberly Ha	User research, writing, project management	Project Coordinator
Quinn Mau	Design, programming	Archivist
Neha Nuguru	Design, prototyping	Course Schedule Keeper
Finn Thompson	Programming, writing	Team Communications

Appendix B - Prospectus

Product Functionality

What is it supposed to do?
Our product helps users identify plants and vegetation by providing a quick and easy way to classify what they find and displaying accurate information about the flora without needless searching or complex testing. More specifically, our product will do the following:

- Help users easily identify plants and vegetation
- Provide quick and accurate classification of flora
- Display plant characteristics and cultivation information
    - Necessary light, soil, pH, and moisture for growth
    - Form, habitat, flower, fruit, seed, foliage, and uses
    - Category and genus
- Show basic information for entry-level users
- Ability to show extensive information for plant enthusiasts
- Offer the expanse of an encyclopedia conveniently

What problem does it solve?
Current existing plant identification solutions lack universality. Identification is limited to common flora or specific regions of the world. Current solutions further face issues depending on how they approach identification: image recognition faces processing power limitations, attribute filling out requires high user effort, and crowdsourcing doesn't yield instantaneous results. Our product will aim to tackle these issues.

Features (Preliminary)

What features does it need to have?
Our product has certain features that must be accommodated in order to be an effective plant identifier. It must have the following features:

- Work outdoors regardless of weather conditions
- Display information tailored to what the specific user wants
- Capture leaves, bark, flowers, and other plant constituents

- Search encyclopedia to determine identity
- Determine age of plant/tree
- Place into position of genus, phylum in plant kingdom
- Provide proper names and nomenclature

How much can it cost?

Current competitors, such as existing plant identification apps, are free for any users to install on their phone. While our specific platform is still tentative, we believe that in order to be competitive, our identification system should also be free.

User Population

Who will use it?

- Botanists
- Gardeners
- Outdoor enthusiasts
- Science educators
- Survivalists
- Chefs
- General population that takes interest in plant identification

Why will they use it?

- Identifying common uses for a plant
- Analyzing commonalities between similar plants
- Determining which plants are edible
- Recognizing potentially dangerous or poisonous plants
- Instructing students or museum-goers
- Satiating user curiosity about the world around them

In what environment will they use it?

We anticipate that users will primarily need to identify plants outdoors, such as in gardens, on hiking trails, or in public parks and campsites. PIP may also find its use in educational settings like museums or classrooms.

What is the market size?

The leading product for identifying plants and garden advice, My Garden Answers, claims to have over 750,000 users[1]. Our team believes that this existing market will provide a foundation to launch Pip, while also leaving room for growth among outdoor enthusiasts, niche users, and the general population as a whole. We expect that the market size, given a global target audience, will be closer to several million.

Resources

The resources that we have to work with consists of all the skills each of us brings to the team. Our team's skills include design, user research, coding, and writing.

Name	Major	Skills	Role
Kimberly Ha	Human Centered Design & Engineering, Mathematics	User research, Writing, Project Management	Project Coordinator
Neha Nuguru	Human Centered Design & Engineering	Design, Prototyping	Designer, Course Schedule Keeper
Finn Thompson	Human Centered Design & Engineering	Programming, Writing	Archivist, Team Communications

Constraints

Our team must work within three major constraints: limited time, limited development resources, and limited knowledge and skills.

Limited Time

The lifespan of this project is ten weeks. We are following a dictated schedule with set deadlines to complete throughout the quarter. The time that we have limits the scope that the project can cover. We may need to include fewer features in our final product or we may not be able to collect a substantial amount of data to back every design decision we implement.

Limited Development Resources

When our team develops the final product, we will have access to a limited budget, tools, and a task force. As college students, our budget is bounded by what we have from our own pockets to put towards this project. We only have access to tools that are available on campus or we can easily gain access to for free. Our task force for this project is

[1] Garden Answers homepage: http://www.gardenanswers.com/

restricted the three of us, limiting the amount of work that can be distributed and completed within the allotted time.

Limited Knowledge and Skills

We are not experts in the domain of botany, limiting our knowledge to what we research and learn in the time frame of this project. This factor could impact the creativity of the ideas that we can come up with when presenting information relating to plants or vegetation. Furthermore, our team consists of only HCDE students, limiting the skillset that we can bring to the project.

Project Schedule

Week	Deliverables Due	Tasks
1	**Tuesday: Team Identity + Info**	● Bring 3 articles ○ Current technology ○ Potential user base
2	**Tuesday: Project Prospectus**	
3	**Tuesday: Characterization**	● Lit. review 5 articles ● Survey 4+ prospective users ● Refine list of features
4	**Tuesday: Personas**	● Powerpoint slide ● Write up
5	**Tuesday: Storyboards**	● Powerpoint slides ● Write up
6	**Tuesday: Task Analysis**	● Task tables ● Flow charts
7	*Schedule meeting this week for project progress*	
8	**Tuesday: Flipbooks**	● 4 slides in powerpoint
9	**Thursday: Mockups**	● Bring mockups to class ● 3 powerpoint slides
10	**Friday: Presentation**	Thursday: Finish Slides
11 Finals	**Monday: Final Report**	● Drop off at box in front of office!! ○ AERB 141A

Appendix C - Project Characterization

Introduction

Our team, Flora Finders, is aiming to design a system that can effectively identify a plant, classify its scientific traits and nomenclature, and display this information to the user in an convenient and simple format. Our system will use plant identification software to scan an extensive database of flora and match the plant to the correct species.

In order to get a better understanding of design and technology challenges present in designing a plant identification system, we will first conduct a literature review on existing sources relating to our project. These sources provide an insight into possible content, user needs, existing software, and hardware devices that are present in designing a complex plant identification system like ours. This gives us a thorough evaluation of not only our user base and needs, but it also allows us to assess the benefits and shortcomings of existing technologies that have already been developed.

In addition to extensive literature review, we have also surveyed 6 participants who we believed to be potential users of our product. Through the survey assessments, we aimed to determine the context in which a user would use a plant identification system, and what kind of features they would expect such a system to have. While the literature review allowed us to examine the technology and initial user need at a macrolevel, the surveys allowed us to analyze the spectrum of user needs and motivations that exist in our user base at a more complex level.

Literature Review

Before plant identification apps existed, only a few trained taxonomists were able to identify species. Currently, one can manually identify trees by going through a hierarchical taxonomy, answering questions about the characteristics of the leaves (thin, flat, etc.). This method is very tedious and can take hours; amateurs are often discouraged by this long process. Although image recognition is now a more accessible method to identify plants, there are issues that we must consider. For example, when you take a picture of a 3D object, you only see two dimensions so you can lose the “structural information” (Cope, 2012).

Identifying a species by the leaf shape is one of the most helpful methods. Botanists often look at the shape of the leaves to identify plants. It is also one of the more obvious characteristics that stand out to the general population. It is important to note that some

species of leaves can have similar shape but different colors. Leaves in nature are also not perfect; they could be damaged or deformed by insects or the weather so using solely the shape of the leaf for identification may be insufficient (Cope, 2012). Using flowers to identify a species can be ineffective because flowers are be too variable; the same species of plants can produce different types of flowers and they may only show during certain times of the year (Kumar, 2012).

Existing Identification Systems and Methods

Leafsnap is one of the first mobile apps to identify trees through images of leaves. The technology Leafsnap uses can recognize non-leaf images, extract the leaf image from a plain background, and identify the species from a dataset (Kumar, 2012). One issue that Leafsnap has encountered is the varying quality of the photos taken on different cell phones.

The CLOVER system was prototyped in 2005 that allowed users to sketch or photograph a leaf with a digital device to identify a plant (Cope, 2012). The system would interact with a server that had over a thousand images of Korean plants and match what the user inputted to a plant. The prototype had been successful with identifying plants through with its system.

The 2013 LifeClef challenge compiled images of plants taken by users during different times of the year. They called it a “multi-organ plant data set” that can be used to identify 1000 species of plants based on a certain “organ” of a plant such as the stem, flowers, branches, or fruits (Lee, 2016).

In 2008, Peter Belhumeur and others built a handheld plant identifying “visual” system. It incorporates three different plant databases and pictures of isolated leaf vectors in its software for maximum accuracy of identification (200,000+ images through crowdsourcing efforts from other botany institutes). It is currently being used by botanists at the Smithsonian Institution National Museum of Natural History. An augmented reality version of the system was also developed. A user can put on VR “goggles” and as they walk around a botanical area, markers appear next to plants. When these markers are selected through a “pointing” gesture, information about the plant type appears. This information comes in the form of type specimen, entire tree, bark, and a magnified view of the plant (Belhumeur et. al, 2008).

Identification by Leaf Characteristics

The shape of a leaf can be easily extracted using simple threshold algorithms (Cope, 2012). Lots of other techniques have been developed to analyze the shape of an object such as a Fourier analysis (Cope, 2012). Leafsnap implements two Gaussian equations

to extract the image of the leaf and determines the curvature of the leaf through histograms (Kumar, 2012).

An alternative way of identifying leaves on plants using Gabor wavelets. Gabor wavelets are a set of complex mathematical functions, and when applied to leaf topography, they can increase the accuracy of correctly identifying a type of plant. This acts as a highly functioning texture analysis that can be implemented into software, and based on an experiment conducted with 20 different species of Brazilian plants, it has a higher than average classification rate of 84% success (Casanova, 2009).

Developing a Successful Guide

In 2006, Anna Lawrence and William Hawthorne published a comprehensive guide on developing successful field guides. Their guide provides several valuable insights on how correct plant identification can improve many industries. For example, identifying trees in a region can help timber companies proceed effectively and sustainably, residents of an area can share more information about the local flora to tourists, or scientists could easily determine whether an unknown plant is invasive or otherwise threatening to an ecosystem or population (Lawrence and Hawthorne, 2006, p. 2).

Lawrence and Hawthorne also explain difficulties a guide designer may face with varying localized names and cultures. Flora varies greatly from place to place, and consequently, some people have different names for similar plants, or conversely, similar names for plants that share traits despite being different species (2006, p. 62). Furthermore, cultures around the world differ from our own and may have unique perspectives on plants that should be considered when designing a field guide to support the area (2006, p. 175). In the Pacific Northwest, for example, we may want to consider if any Native American groups have specific uses with certain plants.

Survey of Prospective Users

The goal of conducting a survey with prospective users was to understand their expectations of a plant identifier and explore the different contexts they could see themselves using it in. We recruited participants who had knowledge or interests in the outdoors, asked them questions to get more insight into our potential user base, and then analyzed the results.

Participants

We interviewed six participants with different interests pertaining to the outdoors. P1 is a high school student who spent a lot of times on trails because of cross country. P2 is a UW student who goes on hikes once in awhile. P3, P4, and P5 are all studying

Environmental Science and Resource Management (ESRM). P3 also is double majoring in biology and P5 works for the Washington Trails Association to develop and maintain trails in the PNW. P6 is an officer for the UW Northwest Women Hiking group and an outdoor / hiking enthusiast.

Survey

We conducted six interviews, five of which were done verbally in-person and one was through Google Surveys. We asked participants the following questions:

1. How often do you hike or explore the outdoors in places with foliage?
2. Are you ever curious about the plants you see when you're outdoors?
    a. Have you ever seen a plant and been concerned about if it was poisonous?
    b. Have you ever seen a fruit-like plant and wondered if you could eat it?
3. Have you had a negative experience with plants?
4. Do you maintain or work in a garden?
5. Do you carry a smartphone or any other technology when you hike?
6. Have you ever identified plants before, learned either through a class, handbook, or other?
    a. If so, what traits do you use to determine a plant's identity?
7. When would you see yourself using a plant identifier?
8. What do you expect it to do?
    a. What type of content would you expect a plant identifier to display?
9. Do you know any other apps that are similar to this (an identifier app)?
10. How much are you willing pay for something like this?

Results

Most of our participants either hiked or explored the outdoors very often. Five out of six participants spent a fair amount of time outdoors every week with four participants who said they do this at least once a week. These participants who were outdoors often said that they have found themselves curious about the plants they see. Five out of six participants mentioned that they have encountered a fruit-like plant and wondered if they could eat it. One participant mentioned a blackberry bush and another mentioned mushrooms seen particularly often. Two participants mentioned that they were always too scared and simply stayed away from eating any fruits on plants.

We asked participants if they had ever had any negative experience with plants to see if our product could help prevent them from happening. Participants mentioned getting poison oak, sleeping on a patch of spiky plants, getting burrs stuck in socks, getting cut on thorns, and encountering stinging nettles while working on the trails.

Four out of the six participants have had experience identifying plants before. Three had taken classes and two had other means of learning such as a handbook or simply being

out in the field and being taught by others. They identified plants through unique features in leaves, needle, bark, and more, and most of them knew how to identify common poisonous plants such as poison ivy or poison oak.

The cost that each participant would pay out of pocket for the identifier varied from $0 to $5. Three participants said they simply wouldn't pay for something like this. Two participants said they would pay $5 only if this app was "perfect." Participants also mentioned similar identification apps for identifying songs or birds. From these conversations, we can see that we may be able to charge a few dollars for this product.

When we asked participants what they expect the product to be able to do, we obtained the following list of functionalities:

- Takes a picture and matches it to a built-in database to identify
- Matches the picture to a built-in database
- Contains pictures, range map
- Works without internet connection
- Recognizes shapes, colors, and patterns
- Ability to download local regions for offline
- Shows the following information:
    - Plant name
    - Scientific name
    - Region where it's found / environment
    - Lifespan
    - Edibility
    - Root depth
    - Poisonous
    - Symbiotic relationship with other organisms
    - Characteristics
    - Plants of the same family

Refined Features and Performance Requirements

From these literature reviews and surveys, we have refined the list of features and performance requirements we intend to incorporate in addition to the basic identification functionality:

- Determine if plant species is poisonous, how user should interact/handle plant
- Dynamic - able to update database based on new plant discoveries (possibly store information on frequently encountered plants based on user)
- Aware of plant presence based on location (GPS tracking of user)

- Camera feature
- Work without internet connection

Conclusion

Throughout the characterization of our plant identification project, we gained significant insight from both existing literature and prospective users. Technology already exists to use computer vision to identify plants based off of their leaves and other organs, so we will likely use image recognition technology in our project. Furthermore, we learned about cultural considerations to keep in mind when developing localized identification solutions. From our user survey, we discovered a potential price tag as well as additional features, such as working offline and being weatherproof, that our product will need to fulfill that price tag. Overall, we can use these ideas moving forward to design a far more inclusive, successful plant identifier.

References

Belhumeur, Peter N., et al. "Searching the world's herbaria: A system for visual identification of plant species." *European Conference on Computer Vision.* Springer Berlin Heidelberg, 2008.

Casanova, Dalcimar, Jarbas Joaci de Mesquita Sa Junior, and Odemir Martinez Bruno. "Plant leaf identification using Gabor wavelets." *International Journal of Imaging Systems and Technology*, Volume 19, Issue 3, 5 Aug. 2009, Pages 236-243.

Cope, J.S., Corney, D., Clark, J.Y., Remagnino, P., Wilkin, P., "Plant species identification using digital morphometrics: A review", *Expert Systems with Applications*, Volume 39, Issue 8, 15 June 2012, Pages 7562-7573.

Kumar N., Belhumeur, P. N., Biswas, A., Jacobs, D. W., Kress, W. J., Lopez, I., and Soares J. V. B. Leafsnap: A computer vision system for automatic plant species identification. In Proc. ECCV, 2012.

Lawrence, A., Hawthorne, W.: *Plant Identification: Creating User-Friendly Field Guides for Biodiversity Management*. London: Earthscan, 2006.

Lee, S.H., Chang, Y.L., Chan, C.S., Remagnino, P.: "Plant identification system based on a convolutional neural network for the LifeCLEF 2016 plant classification task." In: Working notes of CLEF 2016 conference (2016)

Appendix D - Persona

Name

Athena Johnson

Age

24

Gender

Female

Background

Raised in the Pacific Northwest, Athena has always appreciated the outdoors and enjoyed exploring nature. She spends her summers hiking and swimming, and occasionally goes on week-long backpacking trips in the Olympics or Cascades when the weather is nice. From her time in nature, she has learned to value the little things in life through observing the minute details of the wilderness. Introspecting on her positive experiences outdoors, she decided to pursue a degree in education so that she could share the wonders of the wild with younger generations. Last year, Athena founded a hiking and exploration club, PNW Wilderness Alliance, to take groups of adults on hikes

in her spare time. She lives in Sammamish, WA, with her brown labrador Max and brings him along to hikes whenever possible.

Family associations

Athena has always been involved with the outdoors through her family. Her mother works for the Washington Trails Association organizing working parties to develop and maintain trails, and her father works as a ski guide in the winter and whitewater rafting guide in the summer. Athena has an older brother who, diverging from the rest of their family, became a marketing consultant for Google. She also has a teenage younger sister who is the top high school skier in Washington state and will soon try out for the 2018 Winter Olympics.

Personality

Athena is an adventurous and curious individual. As a teacher, she values the importance in being educated in subjects she is passionate about. She is always looking to develop an understanding of the world around her—every opportunity can be a learning experience. She is a caring individual and is always finds creative ways to educate her students in the classroom.

Hobbies

- Hiking, backpacking, and exploring the outdoors
- Reading
- Painting
- Photography / Instagram

Professional life

Athena has been a 4th grade school teacher for the past two years at Discovery Elementary School in Sammamish. She loves her job because she inspires kids to learn who they are and about the world around them.

Personal goals

Athena's personal goals are to become an effective teacher and inspire her students to pursue their personal interests. She also wants to take more time engaging in her hobbies: hiking, painting, and reading. She used to go camping frequently as a child with her parents and siblings, and her goal is to re-familiarize herself with outdoor excursions by exploring all that the PNW has to offer.

A day in her life

5:30am: Athena wakes up to prepare for a bonding hike with fellow teachers before the school day starts. She has RSVP'd her and four of her teacher friends to a hike with her club, PNW Wilderness Allegiance.

6:00am: She picks up teachers from their respective homes and they head to Rattlesnake Ledge.

7:00am: Athena's squad begins hiking, and she acts as their trail guide, pointing out local geographic and floral features. She snaps some pictures on her phone of some interesting trees.

8:00am: At the top of the hike, she and her club take some group photos and relax for a moment before proceeding back down at a brisk pace.

9:00am: Returning home, Athena uploads a few wilderness photos to Instagram and eats a quick breakfast before heading to the elementary school for work.

9:30am: Athena shows up to her class of 4th graders and starts her day of teaching.

12:30pm: On her lunch break, Athena browses local hikes to decide where to take her club next. She also responds to several comments on Instagram.

1:00pm: In science class, she teaches her 4th graders about ecosystems and how plants provide oxygen for animals to breathe.

4:00pm: Athena returns home and grades homework from her class.

4:30pm: Athena collects her belongings to prepare for a weekend backpacking trip through the Cascades with her dog. She decides to check out an area she's never been to before, and she packs food, water, and a camera to take wilderness shots.

5:00pm: After parking her car, she begins her weekend journey.

6:30pm: Four miles into her hike, Athena stops to take a quick break and sees a fruit-bearing plant that looks like a blackberry bush, and she picks a few berries to eat before continuing on her journey.

6:40pm: She begins feeling somewhat sick to the stomach, and she stops again to give herself a moment to feel better. Despite her attempts to hold everything down, Athena's

stomach empties its contents on the side of the trail. She decides she can't continue on the trip.

8:30pm: Athena gets back to her car and drives home, deciding to never eat a wild plant again unless she knows exactly what it is.

Appendix E - Storyboard

In this storyboard, our persona, Athena, is hiking with her dog when he eats what may be a poisonous plant. Before having access to our product, PIP, Athena cannot do anything but helplessly hope the plant is safe to eat. With PIP, however, Athena could be certain of her dog's safety while also using our product to contribute to people's knowledge of plant species or find where to buy a plant she sees out in the wilderness.

Scenario

It is a beautiful Saturday morning as Athena hikes Snow Lake Trails with her dog, Max. Athena walks along the trail when she suddenly feels a tug as the leash slips out of her hand. Caught off guard, Athena frantically turns her head towards the shrubs where Max has wandered off to. She finds Max chewing on a plant that looks unfamiliar to her. Athena panics and rushes besides Max, anxious that he might have eaten a poisonous plant.

Before PIP

Athena automatically reaches for her phone but realizes that she has no data or service. She can't Google the plant and she has no other way of knowing if the plant Max ingested is poisonous. She looks around to see if anyone else was on the trail but they were alone. Not willing to risk hiking the rest of the trail, Athena takes Max back down the trail and to the car. When she gets back home, she tries to Google the plant with adjectives of the plant she could think of but she had no luck finding it. Athena simply decides to keep a close eye on Max for any symptoms in next few days.

After PIP

Athena reaches for her phone and opens PIP in hopes of identifying if the plant Max ate is poisonous or not. PIP's offline database contained information about common, general plants in the Pacific Northwest via GPS location, but luckily Athena also downloaded the offline database for plants and vegetation in Snow Lake Trails before she came here.

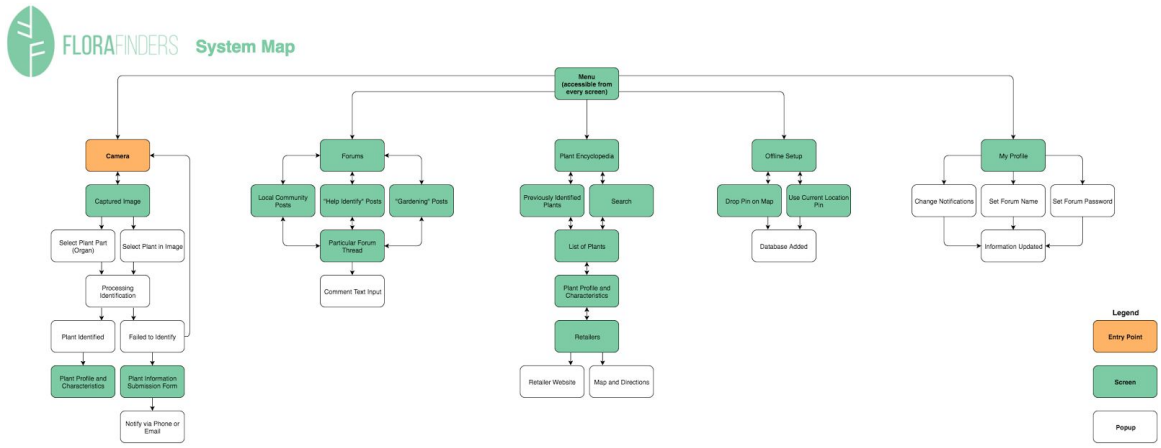
Athena taps a camera icon, takes a picture of the plant, and waits. Seconds later, PIP identifies the plant as a Maximilian Sunflower, or *Helianthus maximiliani.* Right under the name, there is a label that says 'Not Poisonous.'

As Athena sighs with relief, she notices that right next to Max is a bright blue, dazzling flower. Driven by curiosity, she takes a picture of the flower using PIP, but seconds later, she gets a notification that the plant cannot be identified. PIP suggests that Athena submit the picture to the identification database and forum to be analyzed by a panel of botanists and other users. She selects 'agree' to accept the request and continues on her hike.

Two hours later, Athena is back at her home and reading a book on her patio when her phone vibrates on her table. She sees a notification that her submitted photo has been identified and added to the PIP base. She opens her phone to find that the plant is called a Blue Columbine. Its popular, bright-hued appearance makes it a favorite among gardeners. Many people in the forum commented that they had the plant in their own gardens.

Athena decides she is interested in growing Blue Columbines in her own garden. She selects "Retailers Near You" under the plant's profile to skim nearby locations where she can purchase the plant. Athena makes a note of the closest store, GreenGarden Depot, which is 1.2 miles from her house. She sees that it is open everyday from 9am - 2pm and plans to go there tomorrow.

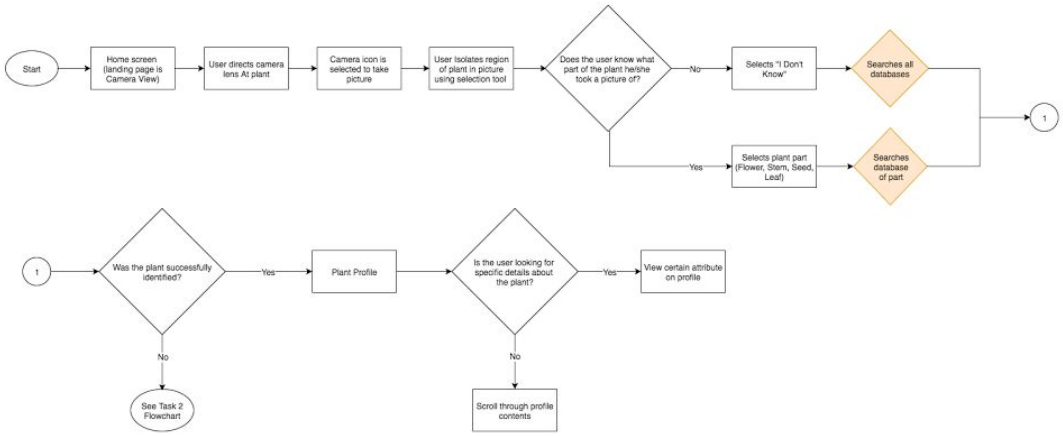
Appendix F - Task Analysis

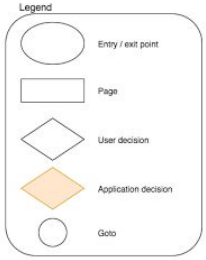


Task to be performed:
Identify an unknown plant to find what it's called and learn about its characteristics.

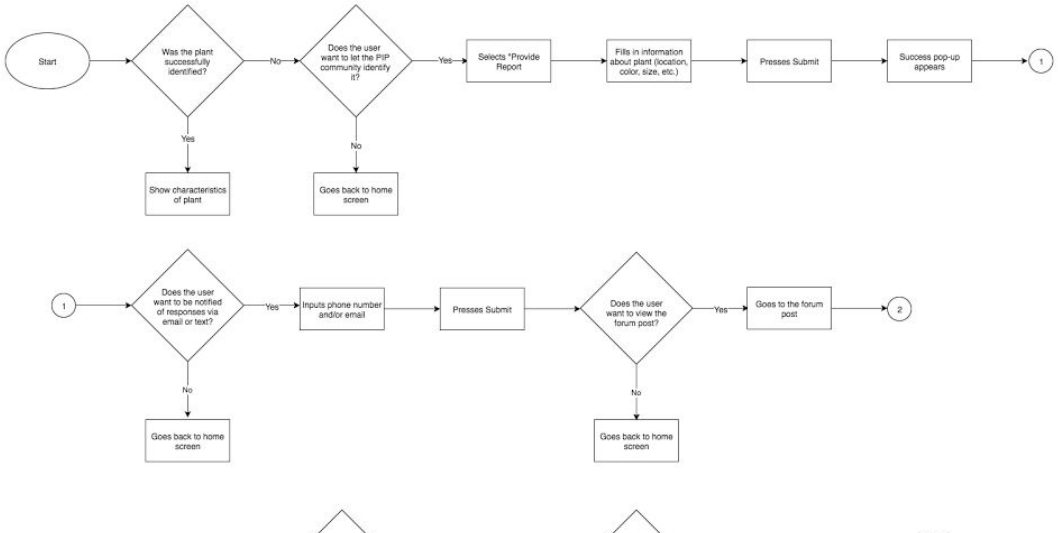
Step #	Step to be performed	What they need to know	How to know it	Way to be performed	Feedback
1	Take a picture of a plant	How to take a picture	Read screen instructions and see camera-like interface	Use PIP's take-photo button while pointing phone at plant	After picture is taken, picture is isolated and user is asked if this is the photo they want to use
2	Isolate plant in image	How to select a plant from the image	Read instructions explaining to outline the general region of the plant to be identified	Draw with finger a general outline	Remainder of image is darkened to indicate the area in the image to focus on
3	Confirm selected region in image	How to confirm the previously outlined area	See option to confirm selection or discard it and redraw a new area	Press confirmation button	Loads page to indicate specific plant structures within the image
4	Indicate specific plant features pictured	What structure of the plant the picture contains	Read instructions to identify visual cues (does it look like a leaf, flower, bark, etc.)	Select the button with the icon and label that matches the structure	Color change for button selected, After submit button, loading wheel shows up. Maybe visual cue like "Searching 'Flower' Database
5	View the plant identity profile	How to read and understand information present	See identifying details on screen	Cross-check plant features between PIP and actual specimen, pressing confirm or deny	General plant encyclopedia information is shown
6	View specific plant details	How to open specific details	See button labeled "more details"	Press the "more details" button	Expanded plant details page opens

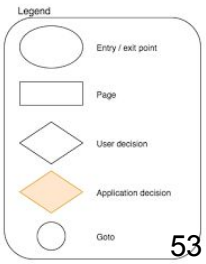
Task 1: Identify an unknown plant to find what it's called and learn about its characteristics



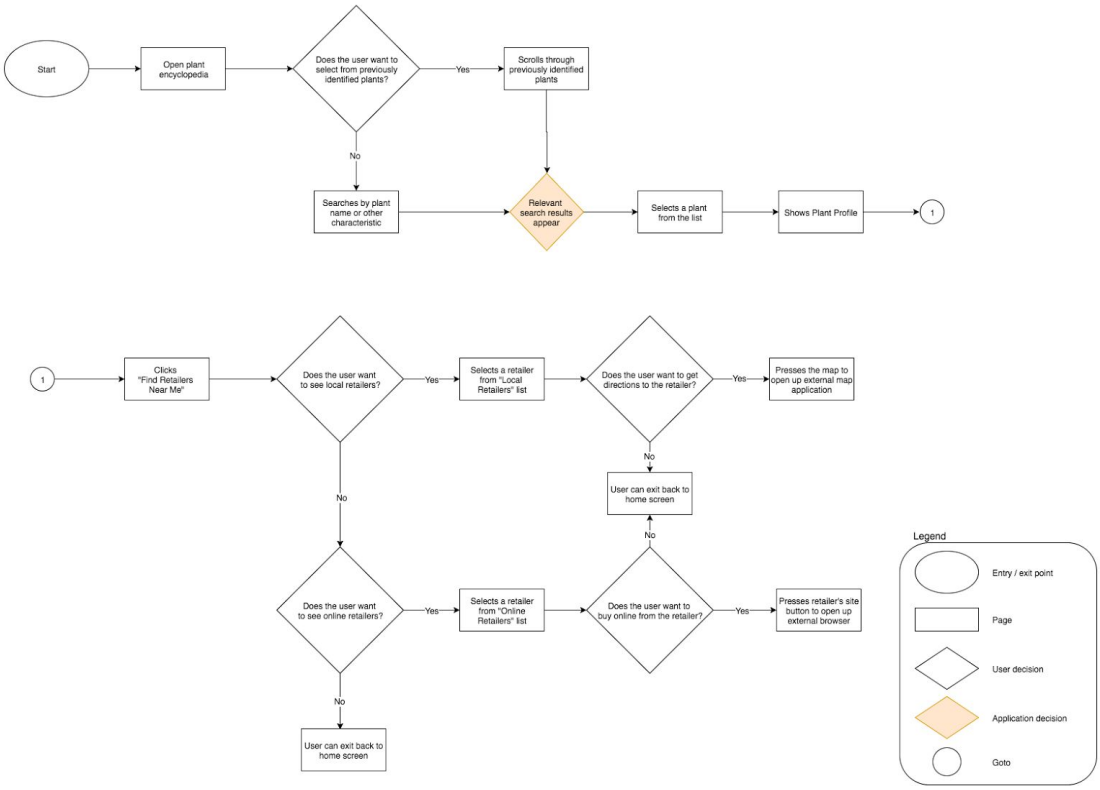


Task 2: PIP fails to identify a plant; share unidentified plant with experts via forums

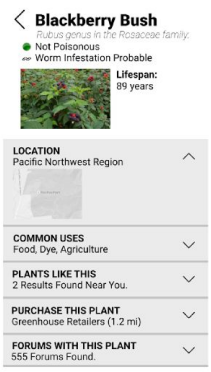


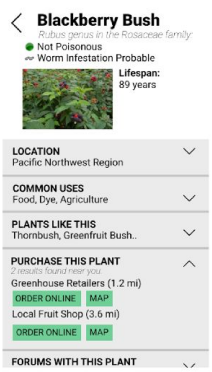


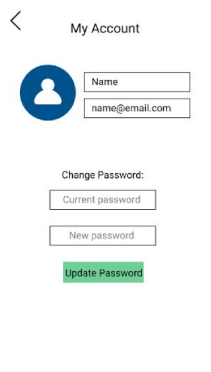
Task 3: Find local / online retailer to buy a plant

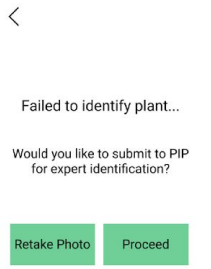


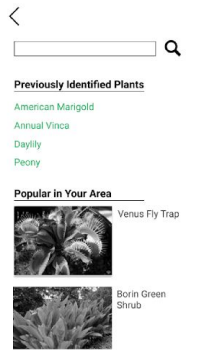
Appendix G - Flipbook

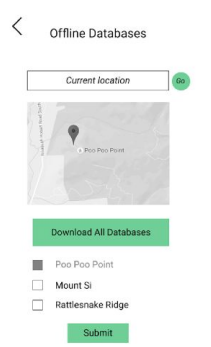






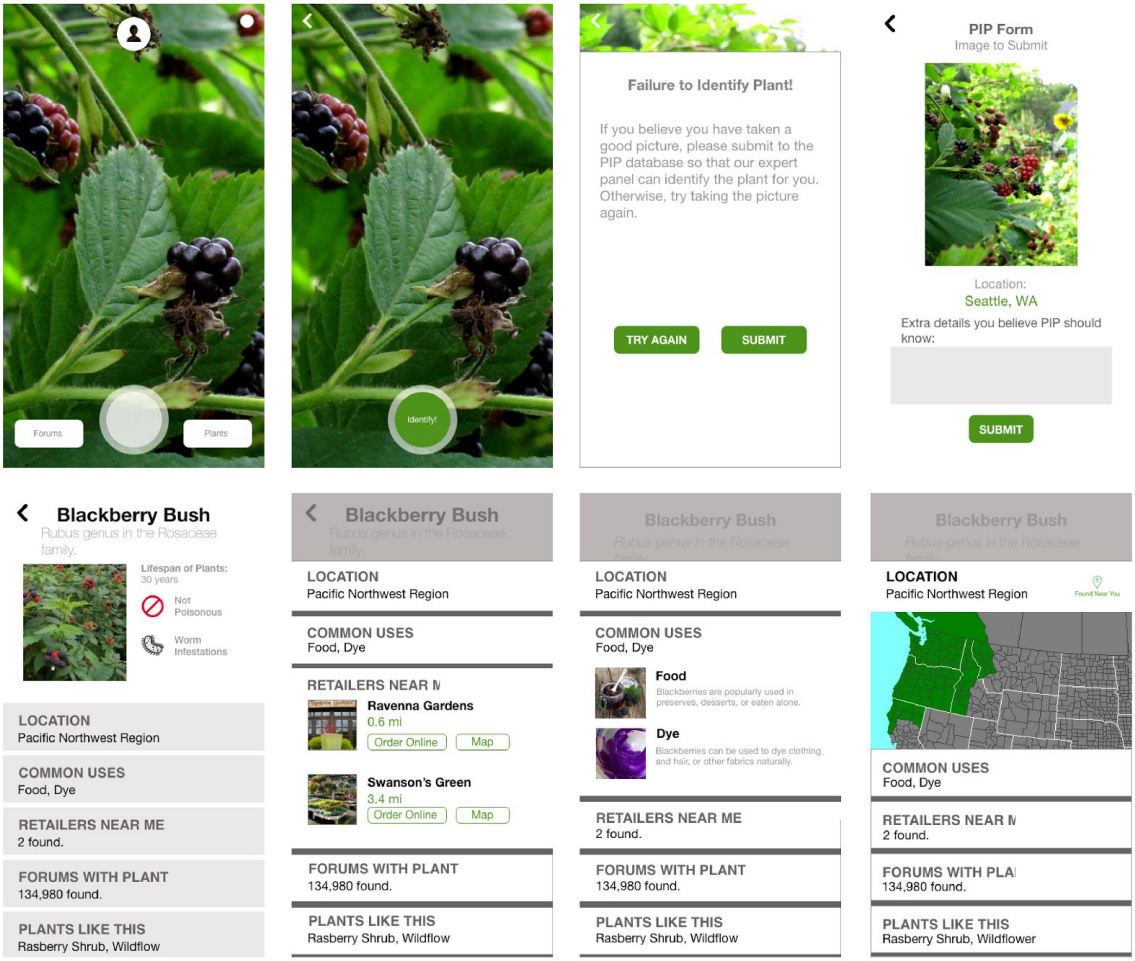


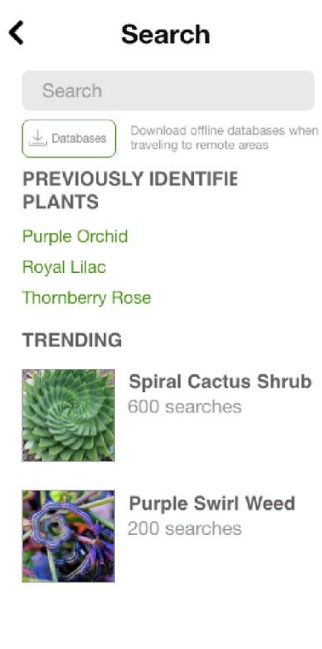


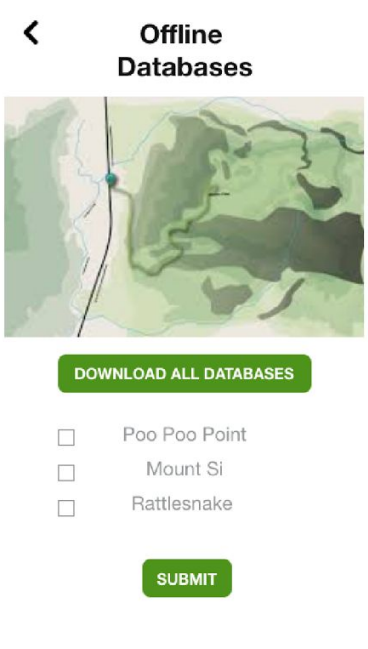


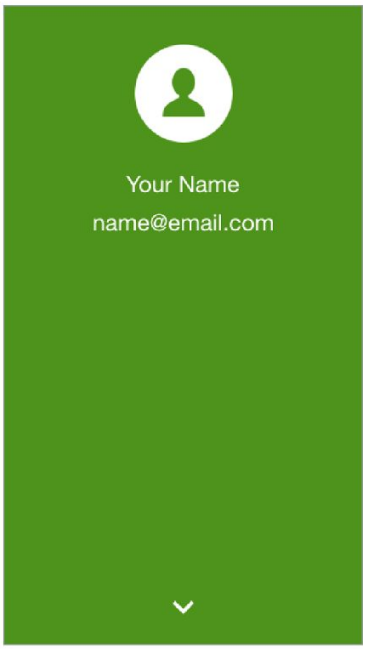
Appendix H - High Fidelity Mock-Ups

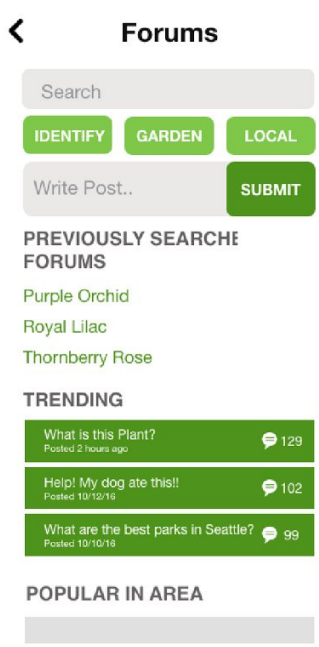
Prototype found at: https://xd.adobe.com/view/9d806d8a-9eef-4c96-9ecd-57ba53e27b34/

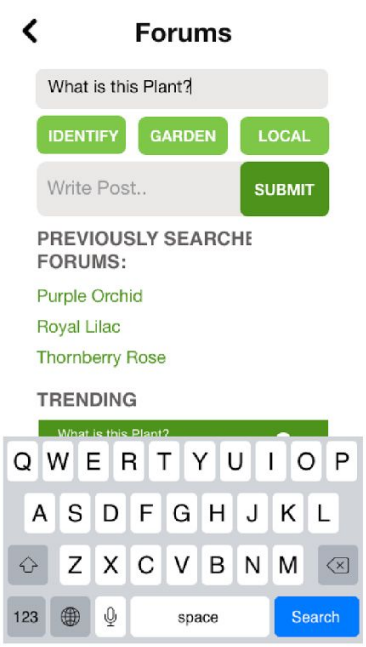


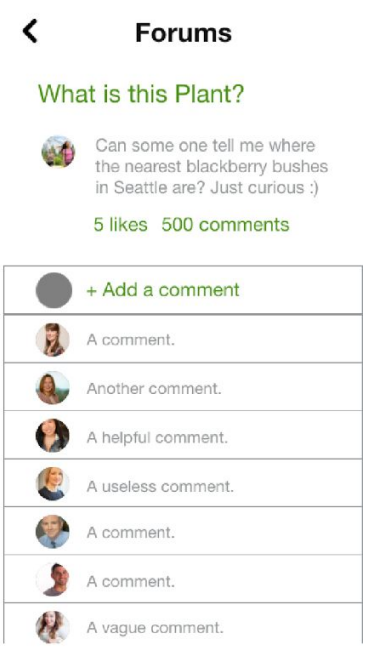

Search
Search
Databases
Download offline databases when traveling to remote areas
PREVIOUSLY IDENTIFIE PLANTS
Purple Orchid
Royal Lilac
Thornberry Rose
TRENDING
Spiral Cactus Shrub
600 searches
Purple Swirl Weed
200 searches


Offline Databases
DOWNLOAD ALL DATABASES
Poo Poo Point
Mount Si
Rattlesnake
SUBMIT


Your Name
name@email.com

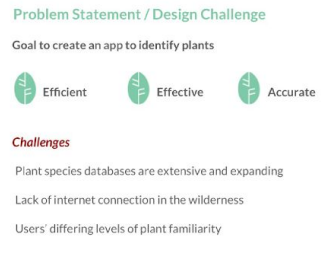

Forums
Search
IDENTIFY
GARDEN
LOCAL
Write Post..
SUBMIT
PREVIOUSLY SEARCHE FORUMS
Purple Orchid
Royal Lilac
Thornberry Rose
TRENDING
What is this Plant?
Posted 2 hours ago
129
Help! My dog ate this!!
Posted 10/12/16
102
What are the best parks in Seattle?
Posted 10/10/16
99
POPULAR IN AREA

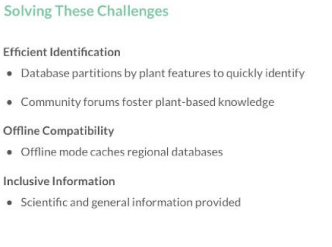

Forums
What is this Plant?
IDENTIFY
GARDEN
LOCAL
Write Post..
SUBMIT
PREVIOUSLY SEARCHE FORUMS:
Purple Orchid
Royal Lilac
Thornberry Rose
TRENDING
Q W E R T Y U I O P
A S D F G H J K L
Z X C V B N M
123
space
Search

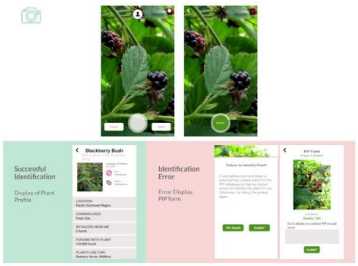

Forums
What is this Plant?
Can some one tell me where the nearest blackberry bushes in Seattle are? Just curious :)
5 likes 500 comments
+ Add a comment
A comment.
Another comment.
A helpful comment.
A useless comment.
A comment.
A comment.
A vague comment.

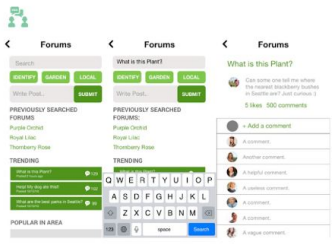
Appendix I - Presentation

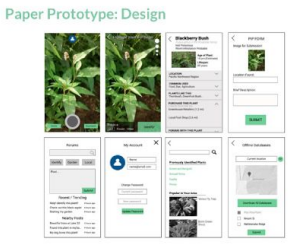
Promotional Video: https://youtu.be/n1BQxgfsEn4











Evaluation Category	P1	P2	P3	P4	P5	Average (Hi-Fi)	Average (Lo-Fi)	Std Dev (Hi-Fi)	Std Dev (Lo-Fi)
Time to complete Task #1	68s	11s	18s	11s	12s	22.2s (-7.6s)	29.8s	20.7s (-0.9s)	21.6s
Time to complete Task #2	79s	44s	38s	42s	29s	46.6s (-25.0s)	70.6s	20.1s (-1.4s)	21.5s
Time to complete Task #3	104 s	34s	30s	62s	32s	52.4s (+11.8s)	40.6s	31.7s (+18.2s)	13.5s
Errors made	5	0	0	2	1	1.6 (-0.4)	2	2.1 (-0.2)	2.3
Ease of use 1 (hard) - 10 (easy)	7.5	7.5	10	9	6	8 (-0.8)	8.6	1.5 (+0.9)	0.6
Likeability 1 (dislike) - 10 (like)	7	7.5	10	6	7	7.5 (+0.7)	6.8	1.5 (+0.4)	1.1