UGRP No. 4

A Mobile Application for Philippine Ethnobotany Integrating GIS, Plant Image Processing, and Gamification

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COMPUTER SCIENCE AND COMPUTER APPLICATIONS RESEARCH

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SCHOOL OF ACCOUNTANCY, MANAGEMENT, COMPUTING AND INFORMATION STUDIES
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CHAPTER I
INTRODUCTION

1.1 Context of the Study

Ethnobotany is a multidisciplinary field that studies the interactive connection between humans and plants, particularly emphasizing but not limited to how various societies and indigenous communities utilize plants for cultural, medicinal, and ecological purposes. Ethnobotany's importance stems from its ability to preserve ecological and ancestral knowledge regarding plant species, which is deeply ingrained in cultural traditions making it a fundamental characteristic of communities' identity and heritage (Dapar and Alejandro, 2020). Gaining insight into plant utilization's cultural and ecological context is a compass for promoting sustainable agricultural practices and effective plant species management. Preserving this knowledge provides valuable insights into the history and traditions of communities, furthering our understanding of cultural, medicinal, and therapeutic plant uses (Faruque et al., 2018).

The preservation of this knowledge is difficult due to ethnobotany's slow rate of development and the loss of traditional knowledge, which is essential for human progress. According to Vandebroek and Balick (2012), factors like the depletion of biological resources, the impact of a globalized society, cultural homogenization, and the desire for modernization are to blame for the decline in cultural knowledge. Books are out-of-date sources with little information and high costs (Reyes, 2018). Furthermore, even for botanists, identifying plants takes time (Marasigan, 2016). Since improvements in information technology have enabled users to complete laborious, time-consuming tasks in a matter of seconds, technology-assisted strategies can address these issues and offer efficient solutions. Fortunately, the use of technology offers a variety of solutions. By enabling efficient data collection, analysis, and presentation in ethnobotany, it fills the gap of slow pace development. An example of said technology is bioinformatics, a field of study for the application of advanced tools and methodologies to gather, analyze, and present ethnobotanical data efficiently (Thomas, 2008). Other studies have also applied different forms of the use of technology in relation to Ethnobotany. With some studies applying technologies that enables automated plant identification/classification to simplify the process of documenting and identifying plant species (Roslan, et al., 2023; Dileep and Purnami, 2019), Geographic Information Systems (GIS) to visualize ethnobotanical data spatially (Qayum, et al., 2014), and Gamification to engage users to learn more about plants (Borsos, 2018).

Image processing is a helpful tool when used in conjunction with ethnobotany because it makes it possible to identify different plant species by retrieving specific features from images. Swu et al. (2020) investigated various image processing techniques that could be combined with machine learning algorithms to identify plants. The study came to the conclusion that it is more accurate to identify a plant by its leaves. Wang (2017) talked about how Image Processing for Plant Identification in Mobile Applications is used, emphasizing how it encourages students to be interested in learning about plants. The difficulties that ethnobotany faces in maintaining and expanding knowledge about plant species can be addressed with the aid of this technology. The "LeafSnap" application from Kumar et al. (2012) uses image processing techniques. The area and arc length of the leaf were the main research areas, with partial leaf curvatures serving as features. There is a hole in their research because they only took partial curvatures into account. The researchers intend to include the leaf's total curvature as a feature in their analysis in order to enhance the performance of their model.

Alongside Image Processing, studies on ethnobotany have made use of the technology known as Geographic Information Systems (GIS). GIS makes it possible to gather, examine, and display data from a particular location. For instance, Biswas et al. (2019) used GIS to map medicinal plants and promote conservation measures, while Qayum, Lynn, and Arya (2014) used GIS to create spatiotemporal maps of antimalarial plants. The visual learning environment offered by this technology improves user engagement and learning. To enhance data collection, analysis, and presentation, ethnobotanical studies have also used other technologies like image processing and bioinformatics. These technologies can help us improve sustainable agricultural practices and learn more about how to best use plants.

Gamification should be used to make learning about ethnobotany more interesting and enjoyable. According to Alsawaier (2018), gamification uses game elements to encourage learning, motivation, and engagement, which in turn boosts user activity and productivity. The quiz game app Kahoot was used in a study by Yapici and Karakoyun (2017) that showed positive engagement and motivation. Motivation is a key factor in determining how engaged and involved application users are, and it is essential to the success of gamification. The development and preservation of traditional knowledge can be enhanced by the effective application of gamification in the field of ethnobotany (Yapici & Karakoyun, 2017).

Recent years have seen the emergence of ethnobotanical applications, including a mobile application, but due to a lack of technological integration, their popularity has been constrained (Ibrahim, Mohd, & Tengku, 2016). The factors that make applications popular, such as consistent user-interface design (Jiang et al., 2018) and user engagement (Dela Riva, 2021) should be taken into account when developing a successful application. For instance, Ozkan & Topsakal (2019) discovered that engaging in enjoyable and educational activities, experiments, and observations while learning ethnobotany can have a positive impact on attitudes and thoughts about learning about plants. Therefore, creating an interactive learning environment where users are constantly engaged and involved is essential for producing successful ethnobotanical applications.

Examples of successful plant applications can be found with Swann, A (2023) of Brightly and Baker, P (2023) of CNN listing their best plant applications. All of their listed applications were inclined to plant identification. Some of the listed applications have the feature of GIS that helps in the presentation of data for the plants. However, gamification is not present into these applications which may lessen the motivation of users to use the applications consistently. Though there is no gamification aspect among the listed applications, there are plant applications that focus on gaming. These games are focused on gardening, simulation, and knowing how to take care of a certain plant (Edelmayer, 2020).

Applications of technology like Plant Image Processing, GIS Mapping, and Gamification have been used in studies and applications in ethnobotany. To enhance the look and feel of the "LeafSnap PH" application, GIS mapping was suggested. Gamification features were added to the plant application in the study by Nagda et al. (2020) in order to boost user engagement. They noted that their application has quite a few gamified features, such as plant leveling, goals, and in-game rewards. These were improvements based on the results of their previous work, "gardening kits for Children," which did not incorporate gamification and led to boredom and lower user engagement. In contrast, the web application "Medicinal Plants in the Philippine Cordillera Region" (Balangcod, Licnachan, & Gueco, 2018) provides a database of ethnomedicinal plants and their uses but excludes image processing and gamification elements.

Despite these significant progress in ethnobotanical research, as we have seen there is a void in integrating all three (Image Processing, GIS, and Gamification) in preserving ethnobotanical knowledge. While other researchers explored these technologies separately, the combined application of these technologies in ethnobotany still needs to be explored, as integrating these technologies can create a comprehensive framework that enables a more efficient, engaging, and interactive approach to preserving ethnobotanical knowledge. To make the most of the discovery and the conservation of plants, this research paper aims to integrate plant image processing, GIS, and gamification in an application to capitalize on the discovery and preservation of plants while maintaining users' engagement toward the application.

1.2 Research Objectives

The objective of this study is to develop an Ethnobotanical Mobile Application for the different kinds of indigenous plants found in the country of Philippines with the intent of preserving the knowledge online and teaching the public with the use of different engagement tools, specifically GIS Mapping, Plant Image Processing, and Gamification. In line with these objectives are the following in aiding the research study, with regards to:

A. Application Design
   1. Create a design for the ethnobotanical mobile application in line with the core features and engagement tools.
      i. Determine the core features of the ethnobotanical mobile application.
      ii. Determine the software architecture to be utilized for the application
      iii. Determine the design of the different user interfaces to be used in the ethnobotanical mobile application
   2. Designing the gamification aspect
      i. Determine interactive gamification elements, within the mobile application to enhance user engagement, retention, and active participation regarding indigenous plants.
      ii. Determine how to implement the gamification elements to the ethnobotanical application.

B. Application Development
   1. Image Processing Model
      i. Determine the Training and testing processes
      ii. Determine the Evaluation metrics used to ensure the accuracy of the model.
   2. Determine how to develop the application.
      i. Determine the software development model to be followed for the development of the application

ii. Determine the software development tools and frameworks to develop the application

1.3 Research Questions

The study aims to answer the following question: How will the researchers design the ethnobotanical mobile application to engage with the use of GIS Mapping, Gamification, Plant Image Processing as the engagement tools while also being educational with contents comprising the different indigenous plants within the Philippines? From here, the following sub-questions will help in answering the main question:

A. Application Design
1. How will the researchers develop the design for the Ethnobotanical Mobile Application that integrates the engagement tools?
    i. What are the core features of the Ethnobotanical Mobile Application?
    ii. What software architecture will be used for the Ethnobotanical Mobile Application
    iii. What will be the design of the user interfaces to be used in the Ethnobotanical Mobile Application?
2. How will the design of the gamification aspect be developed?
    i. What interactive gamification elements will be implemented to enhance user engagement, retention and active participation regarding indigenous plants?
    ii. How will the implementation of the gamification elements to the ethnobotanical application be conducted?application?

B. Application Development
1. How will the Image Processing Model be developed?
    i. What training and testing methods will be used?
    ii. What evaluation metrics are appropriate for the image processing model developed
2. How will the Ethnobotanical Mobile Application be developed?
    i. What is the software development life cycle model used for the development of the application?
    ii. What are the software development tools and frameworks used in order to make the application?

1.4 Scope and Limitations

This research is a component of a team-based study that aims to create a mobile ethnobotanical application that will provide information on native Philippine plants. To keep users interested and help them remember information, the app will have features like GIS mapping, plant image processing, and gamification. To design the application, the researchers looked at the efficacy of engagement tools and how they were used in mobile applications. The leaf of the plant is the only registered and identified feature in the image processing model, and the dataset used in this study is from the open source leafsnap with ready-made segmented leaf images. The data needed for the final application will be gathered by additional research teams.

1.5 Significance of the Study

Traditional medicines are found through ethnobotany, but unrecorded discoveries may be lost (Qureshi et al., 2016). Plants and traditional knowledge may both become extinct as a result of the loss of oral tradition (Dapar & Alejandro, 2020). Through electronic word of mouth and mobile applications, the internet enables more significant knowledge sharing, even with distant or like-minded individuals (Yang, 2016; Ahmed et al., 2021). Rose et al. (2021) found that gamification in technological applications can increase information accessibility, preserve local and indigenous knowledge, and increase interest in ethnobotany. User engagement can be increased by incorporating gamification, GIS, and plant image processing into the suggested application (Rose et al., 2021). The study's results can benefit ethnobotany professionals and researchers studying the technological applications' impact on the Philippines (Rose et al., 2021).

1.6 Research Framework

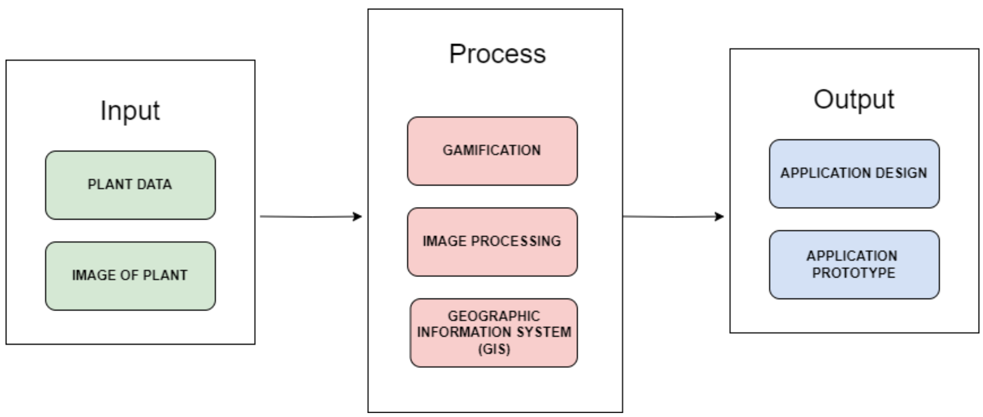

Figure 1. Framework

CHAPTER 2
METHODOLOGY

This chapter discusses the methods utilized in answering the research questions. Section 3.1 discusses the Ethnobotanical Mobile Application design and the methods used in selecting the features. Section 3.2 discusses the methods in the development of the Application.

2.1 Application Design

This section outlines the methodology and tools used in the design process, and discusses the methods how the researchers found and utilized the resources gathered from their review of related literature and review of similarly built applications.

2.1.1 Design

With the intent of incorporating an educational game-based learning approach to the application design, to promote active learning and increase user engagement (Asniza et al., 2010). The researchers reviewed related literature, previous studies, and mobile applications to determine the appropriate design for the said approach. In addition, focus groups and meetings with stakeholders will be conducted, in order to determine the relevance of the features taken from the studies for the desired application. This will allow the researchers to determine whether the selected features are beneficial to promoting active learning, increasing user engagement, and retaining information.

2.1.1.1 Core Features

The core features for the applications are essential in creating an engaging ethnobotanical mobile application, with the focus on preserving ethnobotanical knowledge and increasing user interest. This section presents the various studies that the researchers reviewed in tabular format, with each study presented along with the features that they have utilized.

Researches	**Authors**	**Feature/s Applied**
Web GIS Based Identification and Mapping of Medicinal Plants	Biswas, B., Walker, S., & Varum, M. (2017).	GIS
LeafSnap	Kumar, N. et al. (2012)	Image Processing
LeafSnap PH	Marasigan, M. C. (2016, May)	Image Processing
iNaturalist	Matheson, C. A. (2014)	Image Processing and GIS
Pl@ntNet Mobile App	Goëau, H. et al. (2013, October 1)	Image Processing
Gamification in Plant Education for Children	Nagda, M., Mehta, P., Lamba, S., & Kanani, P. (2020, June)	Gamification

Table 1. Different Ethnobotanical Applications with their main feature/s.

2.1.1.2 Application Software Architecture

Software architecture serves as the system's blueprint, influencing an application's performance and quality. With the cruciality of choosing appropriate architecture, the researchers reviewed literature that evaluates the performance of the three commonly used architectures for android application development, namely, Model View ViewModel (MVVM), Model View Presenter (MVP), and Model View Controller (MVC) Architectures.

2.1.1.3 User Interface Designs

The researchers reviewed similar applications that focused on ethnobotany or plants. Also, the design will be based on the general target audience who are not tech savvy. With that, the researchers will look for simple and consistent user interface designs to draw inspiration from then integrate it to the application.

2.1.2 Gamification Design

This section discusses how the researchers determined the gamification elements to be used for the application and their implementations. Through reviews of studies and applications related to ethnobotany, Section 3.1.2.1 discusses how the elements were determined and 3.1.3.2 discusses the implementation.

2.1.2.1 Gamification Elements

In order to identify the gamification elements that can enhance user participation, knowledge retention, and motivation within an application, the researchers will conduct a literature review of the application of gamification elements in various studies. The review will be focused on analyzing existing studies that explore the effectiveness and benefits of gamification elements. Alongside existing studies, the researchers will also be reviewing other applications that implemented gamification, specifically educational based applications, ethnobotanical/plant based applications, and popular applications.

2.1.2.2 Implementation of Gamification Elements

To determine the implementation approach for the gamification elements, the researchers will draw inspiration from existing game applications. More specifically, applications that have implemented a daily activity cycle. As this allows for the most efficient and effective manner of creating daily participation from the user. With this in mind, the researchers will examine and analyze how these game applications have successfully incorporated gamification elements and adapt those strategies to suit their own context and objectives.

2.2 Application Development

This section discusses the development and implementation of the designs that are mentioned from Section 3.1.1. The possible tools and libraries that may be used in the development process were also discussed.

2.2.1 Image Processing Model

The researchers comprehensively analyzed existing technologies and techniques that leverage image processing as a key feature. The researchers discovered numerous innovative applications throughout their investigation, including the distinguished LeafSnap application. After evaluating the various image processing methods underpinning LeafSnap, the researchers decided to adapt the image processing methods used by LeafSnap to suit their research objectives, which proved to be a highly effective approach. In order to make a significant contribution to the advancement of ethnobotanical applications, the researchers recognized the need to build upon existing methods and practices that have been proven efficacious in this field. The researchers set out to further improve the measures employed by LeafSnap in their image processing method.

$$K = \int\_C k(s)\, ds$$
$$\kappa = |d\theta/ds|$$
$$\kappa = |T(s)\ x\ A(s)|\ /\ |T(s)|\text{^}3$$

$$Let\ r(s) = [x(s),\ y(s)]$$

$$where\ T(s) = r'(s) = [dx/ds,\ dy/ds]$$
$$A(s) = T'(s) = [d\text{^}2x/ds\text{^}2,\ d\text{^}2y/ds\text{^}2]$$

Integral Curvature Formula

While LeafSnap initially employed area measures to calculate curvature values at each contour point, the researchers decided to use integral curvature, a more accurate and informative measure of curvature.

Calculating the integral curvature starts with calculating the curvature of a plane curve, the algorithm used is seen in Fig _____. K corresponds to the value of the curvature, $d\theta/ds$ is the rate of change of the tangent angle with respect to the symbol s which means the arc length. The formula can be further broken down to fit our objective in calculating curvature in each point of the shape contour(see Fig ______). The unit tangent vector T(s) is a unit vector that gives the direction of the curve at a given point, and it is defined as the first derivative of the position vector r(s) with respect to s. The tangent vector has a length of one since it is a unit vector. The formula for the unit tangent vector T(s) is T(s) = [dx/ds, dy/ds], where x(s) and y(s) are the x and y coordinates of the curve at point s. The curvature vector A(s) has the form A(s) = T'(s) = [d^2x/ds^2, d^2y/ds^2], which represents the curvature of the curve at point s. The magnitude of the curvature vector is the second derivative of r(s) with respect to s, and it measures the rate of change of the tangent vector with respect to the curve's parameter s.
In summary, the curvature κ of a curve at a point s can is expressed as κ = |T(s) x A(s)| / |T(s)|^3. The integral curvature is then computed by $K = \int\_C k(s)\, ds$, where the total curvature K can be computed by integrating the curvature function over the parameter domain of the curve.

2.2.1.1 Training and Testing Methods

By carefully designing and implementing the training and testing processes, this study aims to develop an accurate and reliable model for identifying plant species based on their features, with potential applications in plant identification. This study aims to make a significant contribution to this effort by developing a machine learning model that could accurately and efficiently identify different plant species based on their distinct physical attributes.

2.2.1.2 Evaluation Metrics

To ensure that the model's predictions are reliable and accurate, various evaluation metrics are employed as a means of assessing the model's performance and determining its efficacy in accomplishing the intended task. In looking for the correct evaluation metrics, the researchers will follow different related researches and use it as an inspiration to evaluate the model.

2.2.2 Development of the Mobile Application

This section will discuss the methods and the tools used to develop the application for the ethnobotanical application. The application development process is specially made to address the application's peculiarities. The researchers reviewed different native tools and frameworks in developing the ethnobotanical mobile application for the Android Mobile Operating System (AndroidOS) in Section 3.2.2. In order to choose the appropriate development approach, the researchers did a comparative analysis between traditional and agile methodologies in section 3.2.1. A comparative analysis was also conducted between the common software architectures in section 3.2.3 to determine the appropriate software architecture.

2.2.2.1 Software Development Life Cycle Model

With the use of a software development model, the application development process can have a foundation supported by a detailed plan and sets of guidelines. Creating a development process with the total control of the researchers and providing appropriate time-frames for the planning, implementation, review, and evaluation steps. The researchers reviewed different software development methodologies, determining which methodology will be appropriate for the researchers and the development process.

2.2.2.2 Software Development Tools and Frameworks

The development process is supported by various platforms ranging from tools, frameworks, and Programming APIs and Languages, each having their respective implementations that will help the process to be more efficient while not sacrificing the quality. With the proper tools, the application's development process and team productivity can be improved. In this particular study, the researchers will use a design tool to envision the design of the application then later on apply it using a full-stack framework together with its functionalities. With multiple User Interface (UI) and User Experience (UX) prototyping tools on the market, it is essential to determine which ones provide the best and most appropriate tools and features. Sharma & Tiwari (2021) discussed the relevance of UI/UX to the users with brief discussion on the current UI/UX tools, specifically; Figma, Adobe XD, and Sketch. To implement the design into a working mobile application, an appropriate framework needs to be established. As the research is focused on the development of a mobile application, the framework needs to be a native framework. Additionally, the mobile application should be able to adapt itself in two different platforms, these being Android and iOS. As such, the framework should be cross-platform while also having the flexibility in developing in one platform and converting to the other. Wu (2018) discusses the comparison between two cross-platform frameworks, namely React Native and Flutter.

CHAPTER 3
RESULTS

This chapter shows and discusses the findings of the study. Section 4.1.1 discusses the design of the ethnobotanical mobile application. Section 4.2.2 discusses how the ethnobotanical mobile application was developed using the methods under Section 3.2.2.

3.1. Designing the Ethnobotanical Mobile Application

The section discusses in detail on how the design of the ethnobotanical application was finalized. The design is based on the core features, software architecture, and the application's user interfaces.

3.1.1 Application Design

This section describes the designs that researchers have developed in relation to the development of the mobile application. 3.1.1.1 discusses the features that the researchers have chosen in implementing in the application. 3.1.1.2 describes the architecture that the researchers have followed in conducting the application. 3.1.1.3 showcases the various designs that the researchers have developed for the application.

3.1.1.1 Determine the core features

Through the different related literature the researchers studied and read on, the various features seen and considered were GIS, Plant Image Processing, and Gamification. These features were seen in different studies, some incorporating two of these features at the same time but no current study incorporates these three features altogether. Through further examination of these studies, the benefits and contributions of incorporating these features were seen and considered in creating an ethnobotanical application that is engaging and educational.

Core Features	**Objective**
GIS	The application shall have a map that contains information related to the indigenous plants in the Philippines and the user can use.
GIS Markers	The GIS map shall contain markers of various information regarding the ethnobotany in the Cordillera region of the Philippines. The markers shall contain the name and image of the information set on the marker, and upon use will redirect the user to a screen containing the marker's detail.
Image Processing	The application shall have a functionality that utilizes the camera and the user can use it to identify a plant they take a picture of.
Gamification Elements	The application shall have gamification elements that incentives the user to keep using the application daily. The gamification elements will be conducted through daily activities set on a 24hr cycle. The gamification elements shall provide rewards based on the activities set.
Daily Activities	The Application shall contain a page containing the daily activities for the day. The Daily Activities shall shuffle after a 24hr cycle. Upon completion of the activities, it shall update the profile page with the rewards it will provide.
Library	The application shall have a library that contains information regarding the indigenous plants found in the Cordillera region of the Philippines.

	The library shall contain the description, usage, and location of the indigenous plants.

Table 2. List of Core Features

3.1.1.2 Software Architecture

In this research, the researchers utilized the MVC pattern to create an ethnobotanical mobile application, which is designed to provide users with information on the traditional uses of plants. The MVC pattern provided clear separation between the application's Model, View, and Controller, which allowed the researchers to manage each component independently. The Model component was responsible for handling the application's data and business logic, the View component was responsible for presenting the data to the user interface, and the Controller component acted as the mediator between the Model and View, handling user input and updating both accordingly. This separation of concerns helped the researchers to maintain the application's functionality and organization throughout the development process.

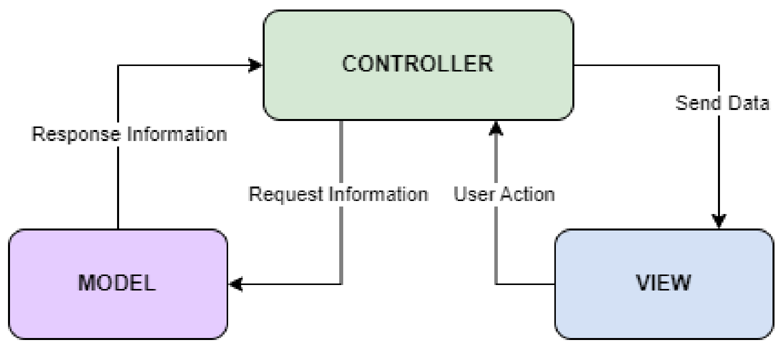

Figure 2. Model-View-Controller design pattern

3.1.1.3 Design of User Interfaces

The visual representation of information is a vital communication medium between users and researchers. The present study aims to create a minimalist user interface (UI) design that presents a vibrant representation while ensuring an easy-to-use and non-overwhelming experience. To achieve this, the researchers drew inspiration from multiple free and commercially available UI designs, including undraw. Co for illustrations and feathericons.com for icons while developing the UI design. The researchers also included all the necessary front-end frameworks and appropriate libraries from react-native while developing the user interface.

When the user first opens the application they are greeted with the default welcome screen seen in figure 3. As they navigate through the welcome screen, they will be redirected towards the login screen (see figure 4), and if they currently don't have an account they are able to register through the registration screen as seen in figure 5.

Upon logging in, users will be greeted by the home screen (See figure 6), which contains clickable icons which are the scan that leads the user to the camera screen, the locate that leads the user to the map screen, the library that leads the user to the plant library screen, and guide. Additionally, the home screen features a navigation bar for easy navigation, presenting icons such as home for returning to the home screen, a star for accessing the daily quest screen, and a profile icon for accessing the profile screen.

Figure 4. Welcome Screen

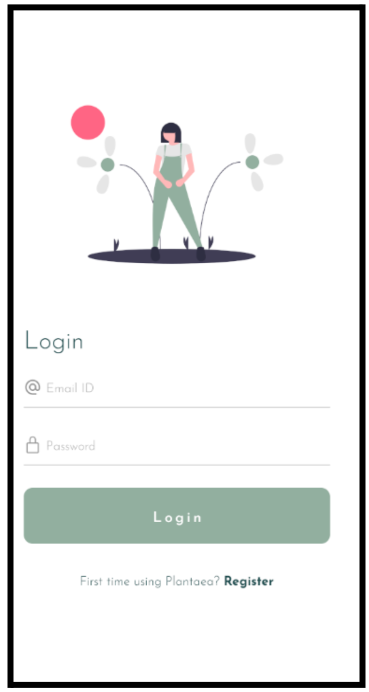

Figure 5. Login Page

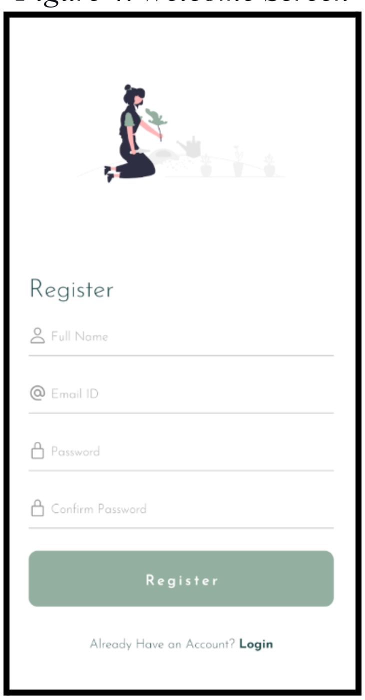

Figure 6. Registration Page

Figure 7. Home Screen

Exploring the functional icons at the home screen will lead the user to the following screens:

- *Scan* - Upon clicking the scan it will direct the user to the camera screen (See figure 7), where they can utilize the application's camera feature to identify a plant. Subsequently, the user will be presented with another screen (See figure 8) that provides options to save, discard, share, or scan the captured plant

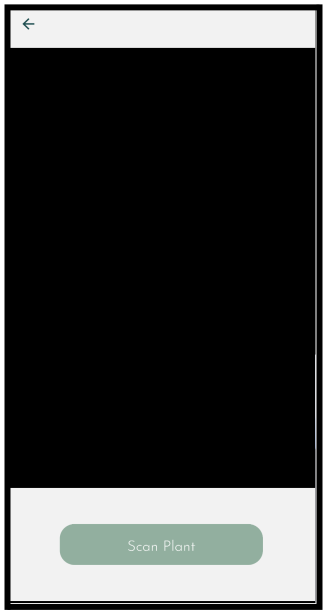

Figure 8. Camera screen

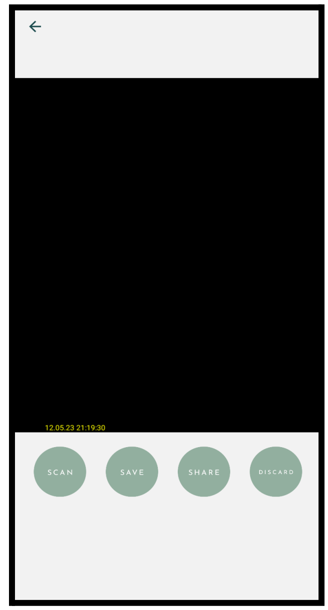

Figure 9. Camera Screen w/ other options

- *Locate* - Upon clicking the locate, it will direct the user to the map screen(See figure 9), where they can utilize the application's map feature to locate plants and establishments such as plant markets and department of agriculture offices. The screen also provides a filter option(see figure 10) that enables users to selectively display map markers for medicinal(See figure 10.1), ornamental (See figure 10.2), and consumable plants (See figure 10.3) and establishments(See figure 10.4). Moreover, when clicking on any plant markers, a clickable prompt will appear showing the plant's name and a sample picture. Clicking on the prompt will direct the user to the plant library, where they can access the plant description.

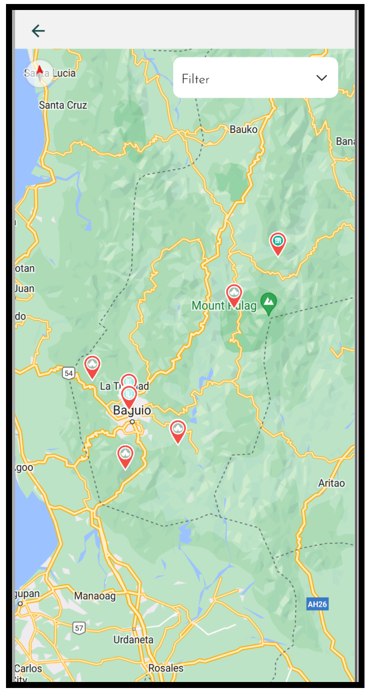

Figure 10. Map Screen

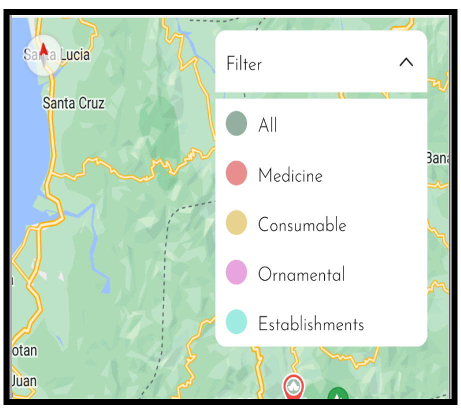

Figure 11. Map markers filter

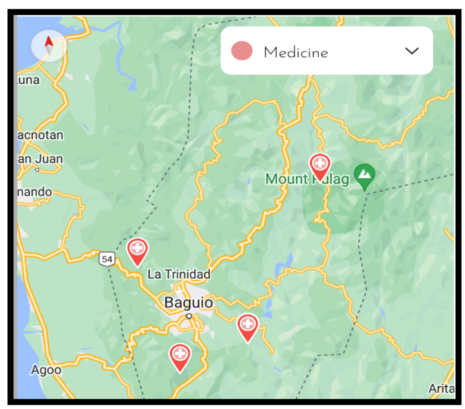

Figure 11.1. Medicinal Plant locations

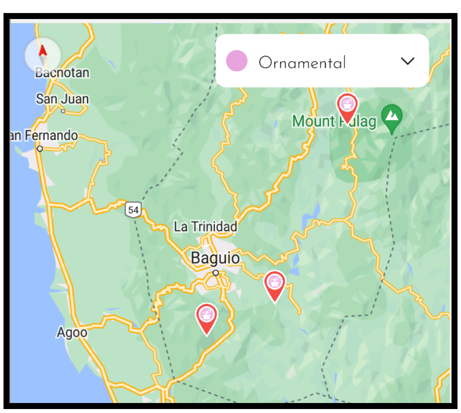

Figure 11.2. Ornamental plant locations

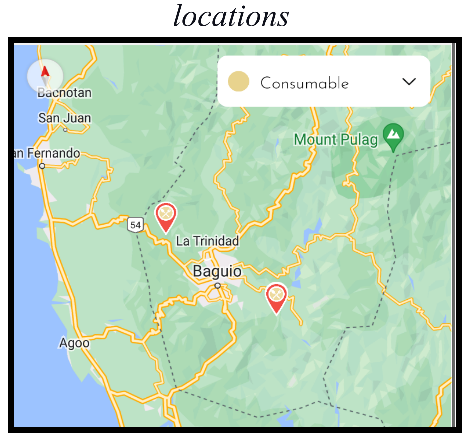

Figure 11.3. Consumable Plant locations

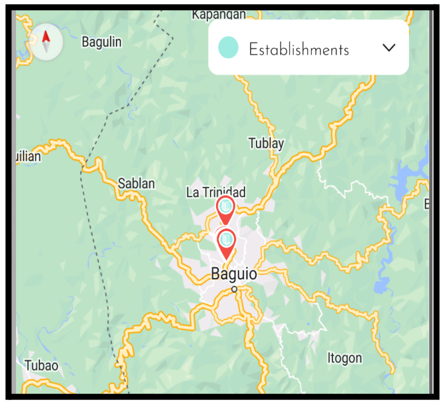

Figure 11.4. Establishment locations

- *Library* - Upon selecting the library icon, users will be redirected to the plant library screen (See figure 11) to explore and acquire knowledge about various plants. The screen has a filtering feature (See figure 12) allowing users to view medicinal, ornamental, and consumable plants. The list of plants displayed on the screen is interactive, enabling users to access detailed information about each plant on the plant details screen (See figure 13). The plant details screen presents the plant's description, category, uses, and location. Clicking on the uses button will direct users to a YouTube video demonstrating the proper preparation or utilization of the plant, while selecting the location will lead them to the map screen, specifically indicating the plants.

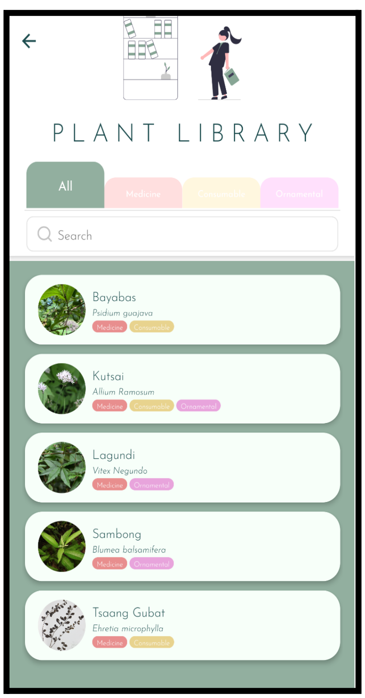

Figure 12. Plant Library Screen

Figure 13. Plant Library Filter

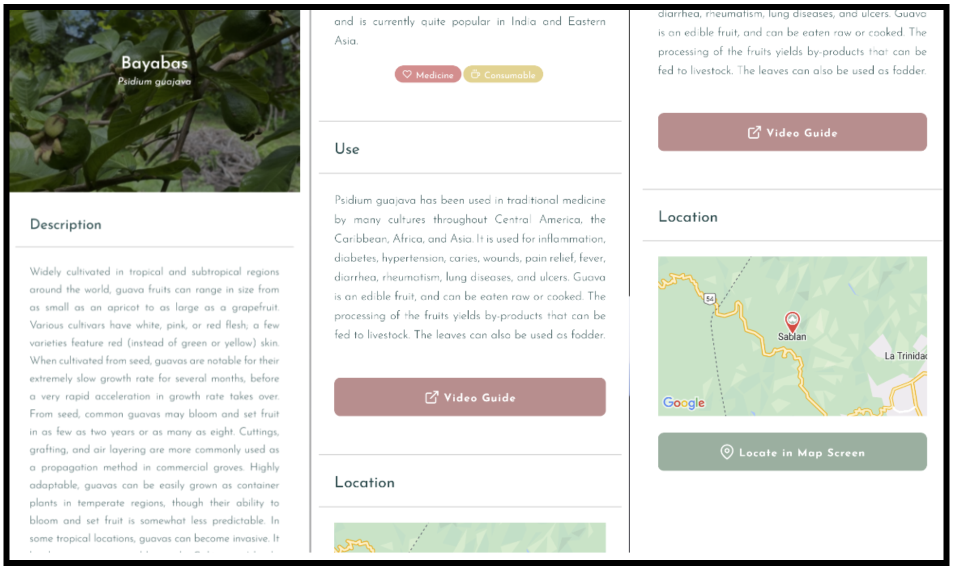

Figure 14. Plant Details Screen

By interacting with the navigation bar, it will lead the user to the following screens:

- *Dailies* - Upon clicking the star icon, the user will be redirected to the dailies screen (See figure 14), which displays the user's current progress on their daily quest.
- *Profile* - Upon clicking the profile icon, the user will be redirected to the profile screen (See figure 15), which displays the user's current points.

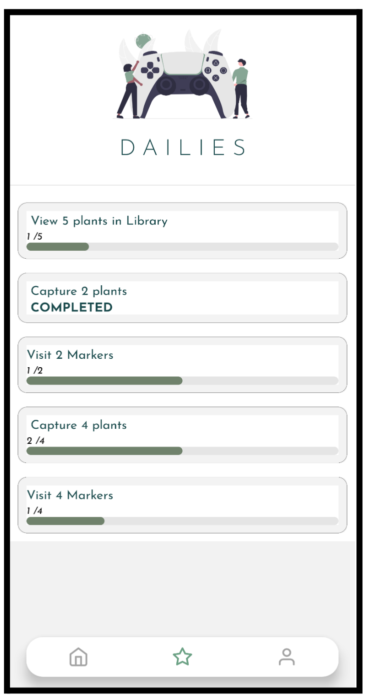

Figure 15. Dailies Screen

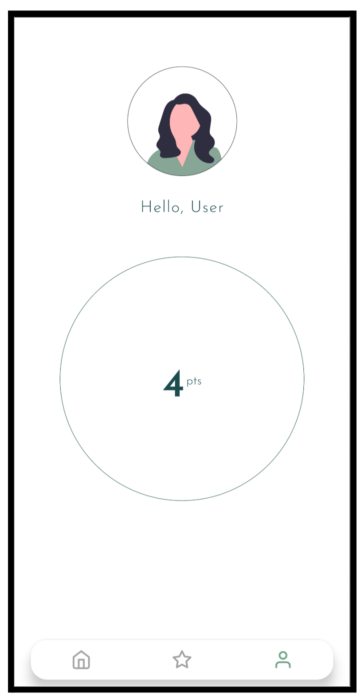

Figure 16. Profile Screen

3.1.2 Gamification Design

This section discusses the design implemented on the gamification aspect of the application. Section 3.1.2.1 discusses the gamification elements that the researchers have utilized. Section 3.1.2.2 discusses the implementation the researchers have conducted to integrate the design of the gamification elements to the application.

3.1.2.1 Gamification Elements

Upon basing from existing game applications, the researchers have finalized the elements for gamification. The elements are namely: **Leveling, Rewards, and a Mission System**

Gamification Element	**Objective**
Leveling System	A process that through the use of experience points, shall allow the user to continuously grow their account to their liking
Reward System	A system that when the user has accomplished a set of tasks, they are rewarded in various forms. As of the applications current version, the current reward set is experience points
Mission System	A daily system that is set in place of the application that shall give incentives to the user who uses the application daily and accomplish the tasks that are given.

Table 3. List of Gamification Elements

Utilizing the all three together allows for a coherent process in which the users are incentivized to continuously use the application daily and reap the rewards.

3.1.2.2 Implementation of Gamification Elements

Drawing inspiration from various gamified applications and games, the researchers have developed a blueprint showcasing the flow of the application with relation to the gamification elements. As seen on figure 17. The user interacts with the application through the various scenarios within the application, these being the scan, locate, library, and dailies. Through this interaction they are introduced to the game environment. The game environment is the daily activities that we have developed along with the total experience point counter found in the profile page. These daily activities incentivises the user from interacting with the various functionalities of the application.

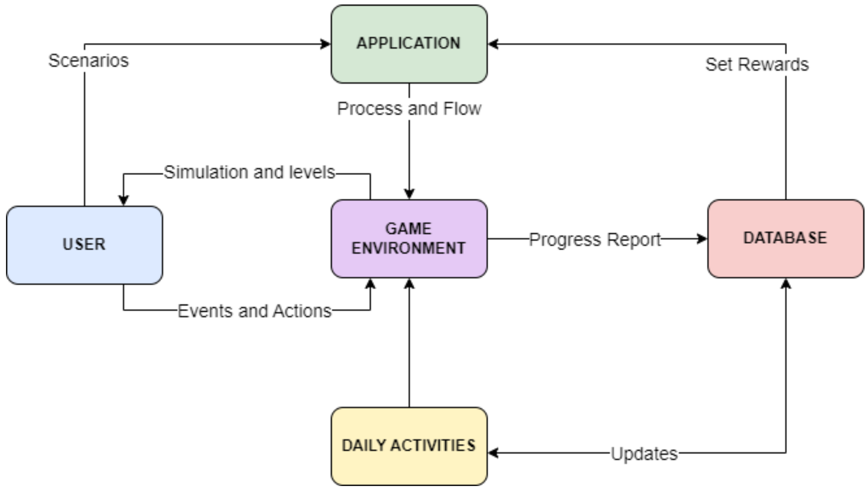

Figure 17. Gamification Blueprint

Daily Activities		
Activities	Objective	Reward
Browse Plants	This shall encourage users to browse and learn about different plants in the plant library	Experience points
Capture Plants	This shall encourage users to identify different plants immediately using our plan identification feature	Experience points
Visit Markers	This shall encourage users to utilize GIS	Experience points

Table 4. List of Daily Activities

These activities range from viewing the library to utilizing the GIS by viewing the markers. The full list can be viewed on Table 4. The daily activities are connected to the database, and through a 24 cycle the activities listed on the users screen are shuffled. As the user follows and conducts the activities, the actions they conduct will reflect on the daily screen. As they complete each activity, the reward (experience points) will reflect on the total exp count found on the profile page. As seen on Figure 17. This process is cycled till the next improvement or update the researchers will develop on the application.

3.2 Developing the Application

This section discusses in detail how the overall application was developed. It also discusses how all the core features were combined and placed into one application and satisfies the questions of Section 1.3 B.

3.2.1 Image Processing Model

In image processing, selecting appropriate methods that align with the research objectives is essential to obtain the most informative results. To this end, the researchers involved in the study thoroughly evaluated the image processing methods employed by LeafSnap. Following the evaluation, the researchers decided to customize the methods to suit their research goals, a crucial decision that could impact the accuracy and reliability of the results.One of the most significant modifications the researchers made was to change the measure used by LeafSnap to extract curvature values from images.

The researchers made use of the Integral Curvature. It is a measure of the curvature of an object's shape that considers the entire curve's curvature properties, providing a more comprehensive understanding of the object's shape (See figure 16).The measure is handy in object identification applications, where identifying the shape of an object is crucial. Unlike the area measures used in LeafSnap, which only consider the overlap between a disk centered at a particular contour point and the interior of the contour (See figure 16), integral curvature considers the entire curve's curvature properties, providing a more comprehensive understanding of the object's shape.

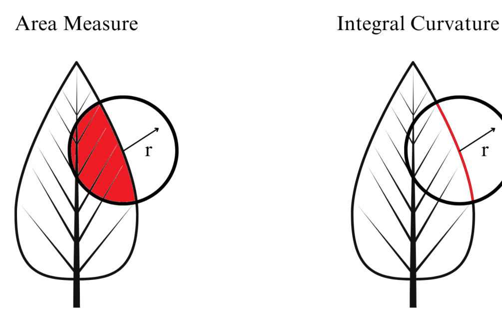

Figure 18. Curvature Measures

LeafSnap utilizes integral curvature as a measure of curvature by creating a circle at each contour point and performing calculations within that circle to obtain a more comprehensive understanding of the curvature of a shape or curve. This process is repeated multiple times, with the circle's radius gradually increasing during each iteration. Finally, for the Researchers to obtain a more comprehensive view of the curvature properties, a curvature image was created from the curvature values gathered, and based on the curvature image, the histograms of curvature values at different radii are computed and concatenated to form what is referred to as Histograms of Curvature over Scale (HOCs). These histograms offer a multi-scale representation of the curvature distribution and enable the characterization of curvature properties over different levels or scales of detail (See figure 17).

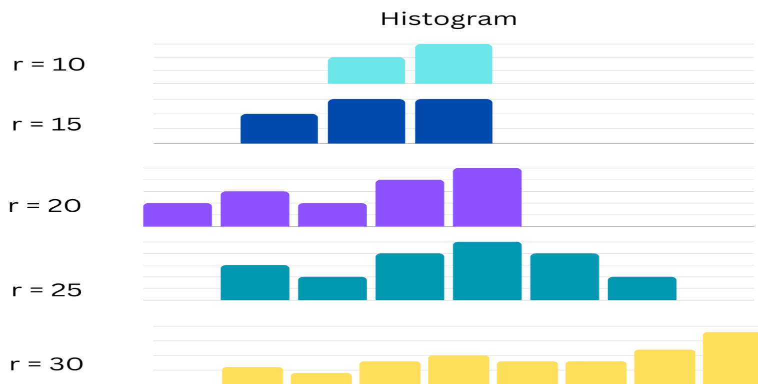

Figure 19. Hocs

3.2.1.1 Training and Testing the Model

Similar to LeafSnap, the researchers recognized the importance of quantitatively measuring the recognition performance of their proposed image processing method. In order to accomplish this, they turned to a widely-accepted technique known as leave-one-image-out species identification.

This technique involves removing one image at a time from the dataset, and then using the remaining images to train the model to recognize the species of the omitted image. The model is then tested on the omitted image to see if it correctly identifies the species. This process is repeated for all images in the dataset, allowing for a comprehensive assessment of the model's recognition performance.

3.2.1.2 Evaluation of Model

The findings show that the correct match index is among the first n results. It is important to note that similar metrics have been employed in previous research on leaf identification, indicating the practical significance of these findings.

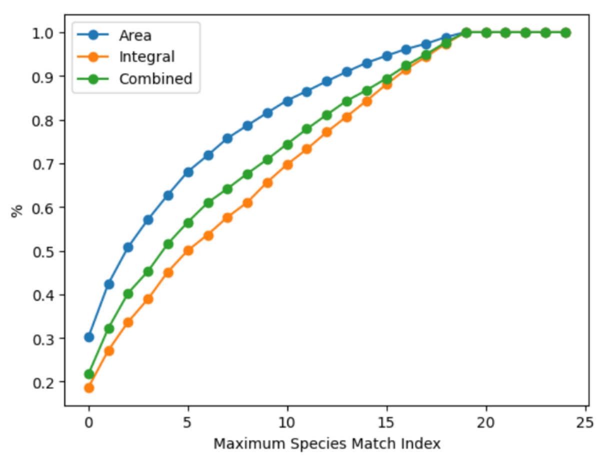

Figure 20: Maximum Species Match Index of Area, Integral, and Combined

	0	1	2	3	4	5	6	7	8	9
area	30.17	42.37	50.81	57.12	62.76	68.06	71.78	75.73	78.65	81.54
integral	18.68	27.14	33.68	38.91	45.14	50.01	53.61	57.65	61.04	65.65
mixed	21.7	32.19	40.27	45.27	51.57	56.49	60.94	64.17	67.61	70.86

Table 5: Different curvature measurement % of Maximum Species Match within N

Depending on the index, the match percentage for the area metric ranges from 30.17% for index 0 to 81.54% for index 9. The integral metric's match percentage ranges from 18.68% for index 0 to 65.65% for index 9. For the mixed metric, the match percentage ranges from 21.7% for index 0 to 70.86% for index 9. The correct prediction will be displayed among the top N results as the number of indices rises.

3.2.2.1 Software Development Model Used

The researchers chose and used the software development model that focuses on the features of the application which is the Feature Driven Development (FDD) model. This was the model chosen and utilized because the flow of the model matches the focus of the study which are the selected features namely Image Processing, GIS, and Gamification. According to Anwer (2017), the FDD model consists of five main processes. Sequentially, these processes are: Develop an overall model, Build a features list, Plan by feature, Design by feature, and Build by feature. The research group uses the FDD model as a guide in order to build the application of the study.

- **Develop an Overall Model**
  This is where the researchers defined the scope and the context of the project or application with the help of the research promoters and an expert in the field of botany. This is also the stage wherein the type of application is finalized by the research team.

- **Build a Features List**
  Upon having meetings with the research promoters, the final main features list has been decided. These features are namely: Image Processing, GIS, and Gamification. These features have also been broken down into smaller tasks since the said features have a lot of components.

- **Plan by Feature**
  After having the features listed, the researchers sorted the tasks according to features. The researchers also prioritized and assigned tasks to all the group members equally. This is also where the researchers made a schedule for each particular task to be done within a week or two.

- **Design by Feature**
  Before building the application based on the features, the researchers designed an application on how those features will be placed together in one application. The

researchers also seeked approval and guidance from the research promoters on the design of the application.

- **Build by Feature**
  In this final stage of the FDD model, the researchers implemented the design to the application with the use of different software development tools and frameworks. After each task has been done, the researchers made use of unit testing to ensure that the task has been implemented to the application successfully.

3.2.2.2 Software Development Tools and Frameworks Used

The researchers used different tools and frameworks in order to aid the creation of the application. These tools and frameworks have been used from designing to developing the ethnobotanical mobile application.

Tools	**Utilization**
Design	
Figma	Used to create the initial layout, design, and functionality of the application. Through the use of figma the researchers were able to conceptualize the designs and flow of the application.
Undraw.co	Used to create the custom designs and images for the application that are related to ethnobotanical plants and the application's features, such as plant recognition, GIS, and gamification.
Feathericons.com	Used to create the icons for the application that are consistent with the overall theme and aesthetics of the application.
Adobe Illustrator	Used to create and modify the designs of the mobile application, particularly on graphics and illustrations.
Development	
Visual Studio Code	An Integrated Development Environment (IDE) that the researchers utilized to write and test the code for the mobile application
Jupyter Notebook	A web-based computing platform that allowed the users to develop the model as well as to test the image processing used in plant recognition.
GitHub	An internet hosting service that allowed the researchers to communicate through version controls and develop the application together.

Table 6. List of Tools Used

API/Framework/ Language	**Utilization**

Python	The main programming language used for developing the model that will power the plant recognition feature of the application.
JavaScript	The programming language that the researchers used to develop the mobile application.
Nodejs	The interpreter that the researchers used for the JavaScript Language to build the mobile application.
React Native	The software javascript framework the researchers used for the development of the application.
React-Native-Map	An API within the React Native Community that was used for the integration and implementation of the GIS technology, allowing for the mapping and visualization of ethnobotanical plants, markets, and plant organizations.

Table 7. List of API/Frameworks/Languages Used

CHAPTER 4
DISCUSSION

In this research paper, the researchers have presented the development of an ethnobotany mobile application designed to address the issues that affect the ethnobotanical field of study. With the aim of providing a solution for the slow rate of development of ethnobotany in relation to technology, preservation, and the spreading of knowledge and information. To achieve the objectives that the researchers have set, a systematic development process was followed, specifically the Feature Driven Development Life Cycle Model. There are several reasons why the Feature Driven Development (FDD) model was used and a variety of software development tools and frameworks. The FDD model was chosen because it fits with the study's primary focus, which are the application's chosen features of Image Processing, GIS, and Gamification. With specific goals and tasks arranged in accordance with the application's features, the researchers were able to construct the application using the FDD model. This method made sure that every feature was created effectively and efficiently, and that the finished application was functional and useful.

The development of the application required the use of numerous software development frameworks and tools. The researchers were able to collaboratively and effectively design, develop, and test the application thanks to these frameworks and tools. For instance, the application's initial layout and design were created using Figma, and its development was carried out using Visual Studio Code as the IDE. On the other hand, the image processing model was created using Jupyter Notebook, a web-based computing environment. The researchers were able to speed up the development process and guarantee that each task was successfully finished by utilizing these tools and frameworks.

The selection of the application's programming languages, APIs, and frameworks was also very important. To create the image processing model, Python was used as the programming language, and JavaScript was used to create the application. React Native served as the JavaScript framework for the software, and React-Native-Map served as the API for implementing and integrating GIS technology. These options were chosen because they are compatible with the languages and framework chosen, alongside with the fact that they are well used in the development community and have successfully produced other useful and user-friendly applications (O'Reilly). Throughout the development process, the researchers have encountered several challenges, such as incompatibility with other APIs or Libraries, the depreciation of older libraries, slow paced training and testing time of the Image Processing Model, and many more. However, through proper communication and effective problem solving, the researchers were able to find ways to address these challenges and make sure the application will be stable and usable.

The developed application offers a range of features that correlates with the identified objective. These features include the Image Processing, which is used to identify a plant through its leaves, the Geographical Information System, which allows the user to view a map with information relating to the indigenous plants, and the Gamification Elements that are implemented to create a fun learning environment and to increase user engagement. Through the implementation of these technologies/features, the researchers aimed to improve the slow rate of development of ethnobotany by incorporating it through the modernized way of utilizing the mobile phone instead of the old ways of using books and localized teachings. By utilizing the app, the spreading of knowledge is conducted through virtual means and allows individuals outside of the area of the indigenous plant to know and understand the importance of these indigenous plants. While the researchers did not perform a performance evaluation or usability assessment of the developed ethnobotanical mobile application, these aspects can be explored in future research.

As we discuss these technologies, the results of the image processing model were identified and reviewed. From the results of the Image Processing Model, the researchers are able to see that in comparison to the curvature integral measure and the combined curvature area-integral measure, the curvature area measure seems to be a better descriptor for differentiating between different leaf species. The higher percentage match indices across all maximum species match indices tested using the curvature area measure support this. This result could be explained, in part, by the fact that the curvature area measure, as opposed to the curvature integral measure, which concentrates on the local curvature of the leaf contour, captures more overall information about the leaf shape (See figure 16). This may strengthen the curvature area measure's resistance to variations in leaf shape within a particular species and improve its ability to distinguish between various species. The curvature area measure's greater sensitivity to variations in leaf size, which may be a key trait in identifying certain species, is another explanation that has been put forth (Liu et al., 2020). This is corroborated by the fact that, when compared to the other measures, the area measure had the largest percentage differences. It's crucial to remember that the specific dataset and application of the feature extraction techniques used may have an impact on the study's outcomes. These results may require confirmation by additional research and also different utilization of various open-source datasets, which should also explore the advantages of combining various features or employing various feature extraction techniques altogether.

CHAPTER 5
CONCLUSION

5.1. Conclusion

In conclusion, this research paper presented the development of an ethnobotanical mobile application that utilizes the three technologies, namely Image Processing, GIS, and Gamification Elements, to solve the issues that halt and slow the development of ethnobotany. Through a deliberate and strategic choice, the researchers chose to use the FDD model, as well as various software development tools and frameworks to create the ethnobotanical mobile application. The researchers were able to create a useful and well-rounded application using these methods, and while making sure that the development process was quick and effective, and would result in a functional ethnobotanical mobile application. This research lays a foundation for potential advancement in the field of application development, image processing

5.2. Future Directions

In order to further enhance the core features of this research, several possible future directions could be explored.

To improve image recognition, the dataset currently used by the researchers - which is similar to LeafSnap - could be evaluated to identify potential areas for improvement. Furthermore, the Philippine Ethnobotanical dataset could be utilized for further development, and plant features such as branches and fruits could be incorporated to enhance the plant recognition process. Additionally, the camera function could be adapted to work with the current Augmented Reality features and facilitate the plant recognition process during the scanning phase.

In relation to the GIS feature, as the current result represents only the initial phase of a fully-functional application, multiple sub-features could be integrated to enhance its functionality. For example, users could be enabled to add markers for specific plants to facilitate collaborative data collection. A cloud-based backend could also be integrated to handle and verify the collected data and assist with the overall process of the mobile application. Moreover, a Google API key could be generated to enable the GIS function to operate when the app is built.

Regarding gamification, sub-features could be incorporated into the application to enhance user engagement and interaction. Full-fledged games, developed with appropriate research methodologies, could be integrated, and a leaderboard could be introduced and supported by a cloud-based backend. Lastly, deploying the application to the Google Play Store and App Store could help to maximize its reach and impact.

These potential future directions could be valuable in expanding the knowledge base and functionality of the research, while also potentially enabling researchers to gain deeper insights into the benefits and limitations of the application.

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Authors' Information Page

Project Title: A Mobile Application for Philippine Ethnobotany Integrating GIS, Plant Image Processing, and Gamification

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This research paper explores the creation of a mobile application for ethnobotany that combines image processing, GIS, and gamification. The application features a user-friendly interface and offers functionalities such as plant recognition, mapping plant locations, and gamified elements like leveling and rewards. The study discusses the design process and the utilization of software development models, tools, and frameworks. Additionally, future directions are proposed, including expanding the image recognition dataset, incorporating more plant features, enhancing the GIS capabilities, and implementing advanced gamification strategies. Despite limitations and challenges, this research contributes to the field of ethnobotany and paves the way for further advancements in leveraging technology for research and conservation purposes.

Keywords: Ethnobotany, Image Processing, GIS, Gamification, Preservation, Development