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Enhancing Nature Engagement through Mobile Applications: A Technological Approach

Alwinfernandez Sandanasamy¹, Sumendra Yogarayan^{1, 2*}, Siti Fatimah Abdul Razak^{1, 2}, Jonathan Freddie Sandanasamy³, Afizan Azman⁴

¹ Faculty of Information Science and Technology, Multimedia University, 75450 Bukit Beruang, Melaka, Malaysia.

² Centre for Intelligent Cloud Computing, COE for Advanced Cloud, Multimedia University, 75450 Bukit Beruang, Melaka, Malaysia.

³ Software International Corporation (M) Sdn Bhd, 57000 Kuala Lumpur, Kuala Lumpur, Malaysia.

⁴ School of Computing, Faculty of Information and Technology, Taylors University, 47500 Subang Jaya, Selangor, Malaysia.

Abstract

In the recent surge of digitalization, especially in the post-COVID-19 era, people increasingly rely on technology to make their lives more efficient and reliable. While nature offers numerous benefits to humans, nature is often overlooked due to busy lifestyles. As time passes, people who are busy with their economic lifestyles often do not have time to even learn the names of the flora around them. Technology plays a crucial role in how humans interact with nature. By developing an application that could ease gardening and creating a nature-aware community around us, it can encourage people to interact more with nature. Existing nature applications are underused due to poor accessibility and difficult-to-navigate user interfaces. Moreover, none of the existing applications provide insights into plants based on Malaysia's regional and cultural relevance. The purpose of this project is to develop a nature interaction application that emphasizes human-computer interaction principles to enhance navigation for users. The application aims to offer insights into Malaysian flora to provide a localized experience, with Bahasa Malaysia included to increase accessibility for Malaysians. The application also acts as a one-stop shop for gardening tools, which eases human interaction with nature. All these features are made together with offering accessibility as a focus. The completed application was tested to evaluate its efficiency and user-friendliness. To fulfill this purpose, various studies about accessibility, user interface, and experience were made. The application named Nature Connect was developed using the React Ionic framework and backend processes using Python, TensorFlow, and Flask and using plugins such as Google Maps API and Capacitor. The developed application was then evaluated using usability testing metrics of effectiveness, efficiency, and satisfaction to ensure its user-friendliness. The results were 96.4% in terms of effectiveness, 51 seconds per task on efficiency, and 66% on satisfaction.

Keywords:

Human-Computer Interaction; Mobile Application; Nature Interaction Application; Plant Identification; React Ionic; Usability Test.

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1- Introduction

Throughout human history, the interaction between humans and plants has been deeply rooted in the primal instincts of survival. As far back as our earliest ancestors, humans have relied on nature for resources. The act of gardening is one of the interactions between nature and humans where humans recognized a mutual relationship by cultivating crops to eat. From food to medication, we rely on plants [1]. Plants also aided humans in documentation. This can be seen in ancient times in Egypt, writings and documentations were made from the pages of Papyrus Plant [2]. However, while humans have historically relied on nature for survival, recent technological advancements have led to a growing

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^{*} CONTACT: sumendra@mmu.edu.my

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disconnection between people and the natural world. In the current digital age, the pace of modernization has led to a detachment from nature. The existence of digital tools, smartphones, laptops, and the internet has shifted our focus away from gardening and interacting directly with nature. More people reside in urban cities and high-rise apartments rather than agricultural landscapes. Deforestation is occurring rapidly to accommodate housing needs [3]. This disconnection from nature causes a lack of awareness about the plants surrounding us, with the current generation struggling to recall the names of plants they grow and care for at home. Despite the existence of encyclopedias and almanacs that teach about plants, obtaining a copy or spending time at libraries can be difficult for some people.

Although existing plant identification applications and digital plant guides provide some solutions, many of these platforms are limited in scope and accessibility, especially for non-expert users, children, and the elderly [4]. Additionally, these applications are often designed for Western flora and lack regional relevance, particularly in the Malaysian region. Technology, which provides many benefits to humans, can also help revive awareness of nature. The COVID-19 pandemic gave time for many to perform gardening in their free time [5]. Gardening activities provided a solution to counter stress for people during the pandemic. Despite the temporary rise in gardening activities during the pandemic, studies show that interest often declines as normal routines resume [6]. Gardening habits should last after the COVID-19 timeline as people return to their normal lifestyles. Awareness of taking care of plants should begin early for children. Older people should also have awareness about nature as well. A gap exists in the current mobile applications that only cater to specific regional plant species and lack accessibility features for diverse user groups. Since usage of smartphones in our society is high, technology can play an important role in reconnecting humans with nature. Nature Connect fills these gaps by offering a localized and accessible solution. Nature Connect was developed as a one-stop platform, providing resources, enabling plant identification, offering plant care tips, and facilitating the easy purchase of gardening tools through online shopping. This application will close the growing gap between humans and nature, allowing us to be closer with nature.

One of the main issues is older people and children struggle navigating and making use of content within a native technology application. A root cause may be the lack of accessibility options in existing nature-interaction applications. The Nature Connect application directly addresses this problem by incorporating user-friendly features, including icons and voice narration [7]. These additions aim to enhance accessibility, providing a more inclusive experience and increasing the likelihood of older people and children connecting with nature and gardening [8]. Those who are illiterate can also use the application since illiterate people are not able to read or write but are able to understand spoken words [9]. By addressing accessibility and ease of use, Nature Connect ensures that no demographic is excluded from engaging with nature through technology. Furthermore, the implementation of plant detection introduces a unique way of building curiosity in children and encourages them to learn about plants. The objective was to design a user-friendly navigation and interface experience using Human-Computer Interaction (HCI) principles for the Nature Interaction Mobile Application. In general, human-computer interaction (HCI) is a multidisciplinary field that focuses on the interaction between humans and computer systems. One of the well-known principles is the Norman Principle, which emphasizes visibility, feedback, affordance, mapping, constraint, and consistency [10]. From a design perspective, Nature Connect follows Human-Computer Interaction (HCI) principles, ensuring that the application is intuitive and easy to use. Additionally, accessibility is crucial as it enables users of all abilities to use the application and benefit from it. From an application perspective, it also supports user retention.

The next problem statement inspiring Nature Connect is that current applications struggle to assess the effectiveness of user interactions on each screen throughout the application. A lack of usability testing often results in buggy applications being featured on the App Store and Google Play. To address this gap, Nature Connect will incorporate usability testing, evaluating three key factors: efficiency, effectiveness, and satisfaction to understand the overall experience of users using the application [11, 12]. The next objective is to evaluate the developed application through extensive usability testing, using relevant metrics to ensure its effectiveness and user-friendliness.

The remainder of the report is organized as follows: Section 2 analyzes the literature review of technologies in humancomputer interaction and related works in nature interaction technology. In Section 3, the methodology and development technologies of the Nature Connect application are presented, while Section 4 describes functionalities and usability testing results using relevant usability testing metrics. Lastly, Section 5 concludes and discusses limitations, as well as potential future improvements.

2- Literature Review

This section discusses the current technological impact on nature interaction and provides insights on humancomputer interaction concepts revolving around mobile applications. Moreover, this section explains related works that inspire the Nature Connect application.

2-1- Technological Impact on Nature Interaction

Technology currently plays a main role in nature interactions. There are various encyclopedias and journals that exist on the internet that can be accessed by users anywhere and anytime to read about plants. Technology also allows people to buy gardening products such as plants, gardening tools, and more through online shopping [13]. Online shopping allows gardeners to no longer rely on geographical limitations to buy plants. For example, a person can buy plants from England through online shops and can get their seedlings through postage.

There are already a few plant identification and disease detection applications that are already available in the mobile market at the App Store and Google Play Store. At a glance, the existing applications fulfill the purpose of identifying plants and allowing users to get tips to care for the plants as well as having a discussion forum to build the gardening community among them. However, there are distinctive features among them and technical differences such as response time and detection accuracy.

2-2-Accessibility In Mobile Application

Accessibility plays a crucial role in enhancing the usability of software for all users. According to ISO FDIS 9241-210, accessibility is defined as "the usability of a product, service, environment, or facility by people with the widest range of capabilities." This definition broadens the concept of usability to encompass a more diverse group of users, including those with impairments. Closely related to accessibility is the concept of "design for all," which is essential for improving the user interface and user experience. When accessibility is well-implemented, it not only enhances usability but also attracts a broader range of users.

Accessibility is particularly important in Malaysia, where a notable number of individuals are illiterate. The Nature Connect application aims to address this issue by incorporating accessible features such as voice narration. According to World Bank statistics, Malaysia had 1.4 million illiterate adults in 2010, with projections indicating a concerning figure of 1.23 million in 2013 [14]. Illiteracy refers to the inability to read or write, and illiterate adults are defined as individuals over the age of 15 who are unable to write or read with understanding a short, simple statement about their everyday life.

To address this challenge, the Nature Connect application under development for this project will feature a voice narration option. Users can press a microphone button to have the application read the on-screen content aloud, enabling them to use the application and identify plants more effectively. Additionally, the use of icons throughout the application serves as another solution. Since humans have long been accustomed to communicating through images—as seen in ancient Egyptian hieroglyphics [15–17]—icons facilitate navigation and help capture user attention. Furthermore, icons help convey information more quickly on pages or screens crowded with text [18].

2-3-Related Works

The discussion below will include comparison and analysis for similarities between existing nature interaction applications on the market. Accessibility options, language options, and extra features will be analyzed for each application. From this related work, enhancements and new features can be implemented and ideated for the Nature Connect application. For this purpose, about 12 applications were tested and analyzed. The first application, Flower Checker, is available on the App Store for free. This application features a minimalist user interface with basic plant detection capabilities. Users can quickly snap and identify plants, but the accuracy is limited, often misidentifying common plants. Despite its simplicity and ad-free experience, the application lacks tutorials and advanced functionalities such as plant disease identification.

The second application is Plant Scope, designed for the Ugandan market, which offers plant disease identification. It includes a discussion forum for plant-related topics, though it is limited to Ugandan flora and lacks comprehensive plant care tips. The absence of language support and a limited plant library focusing primarily on vegetables are notable disadvantages. The third application is Cultive, which emphasizes plant disease prevention and treatment with a user-friendly interface and an urgency matrix for disease management. It performs well in navigation but is limited to vegetable plants, lacking tutorials and voice narration. Additionally, it does not offer regional care insights, which could be beneficial for Malaysian users.

Fourth was Planto, which contains a huge database of over 10,000 plants, providing detailed descriptions and a pleasant user interface. However, it falls short in offering features like voice narration and icons for easier navigation, which could enhance user accessibility. The presence of multiple advertisements and the lack of regional insights specific to the Malaysian climate are areas for improvement. The fifth application to test was PlantVision AI. The application focuses on detecting plant diseases with high accuracy through using its large dataset of images. Its minimalist homepage ensures straightforward navigation, and the absence of advertisements enhances user experience. However, it could benefit from the use of icons, language diversity, and a comprehensive tutorial for new users.

Plant Identification++ was the sixth application to be tested. It is available on the App Store, and during testing it showed a straightforward and simple user interface. It provides quick plant detection with minimal advertising but lacks additional features like detailed plant care information. The text-heavy tutorial and occasional inaccuracies in plant identification` make it less appealing. As the seventh application of testing, iNaturalist is wonderful for identifying plants

and animals, fostering a community of nature enthusiasts. It encourages user participation in recording and sharing observations, contributing valuable data for research. Despite its huge database and scientific content, iNaturalist's text-heavy user interface design and lack of real-time plant identification can be challenging for some users. It is the only application tested that supports Bahasa Malaysia.

The eighth application was Flora Incognita, which offers a unique and engaging user interface, ideal for younger audiences. It provides accurate plant identifications and valuable regional insights. However, the application could improve by including Bahasa Malaysia support, enhancing plant care information, and incorporating voice narration features to enhance its accessibility. RootSnap Plant Identification had significant technical issues during testing, making it non-functional. The minimalistic interface is appealing, but the application needs improvements to make it compatible with Mate 10, as during testing it was unresponsive to user interaction.

Nature Detect-Plant Identify was the 10th application to test, which allowed identifying insects, flowers, and mushrooms with reasonable accuracy. The user interface is decent, but the overload of advertisements. It also lacks detailed plant care tips, limited identification accuracy, and comprehensive language support. Blossom is a premium plant care guide with a beautiful user interface and features like care reminders and discussion forums. It offers climate-specific tips, enhancing plant care. However, the absence of Bahasa Malaysia and voice narration limits its accessibility. The premium price tag can act as a disadvantage for some.

Lastly, the twelfth application was Doctor P, which aims to detect and treat plant diseases, offering traditional care methods alongside modern techniques. Its accuracy in plant detection is acceptable, but the application has its small plant library and language support restricted to English and Russian. Expanding its plant database and language options would greatly benefit users.

Application Name	Things To Learn	Weaknesses			
	1. Simple, user-friendly interface	1. Limited Plant Identification Accuracy			
Flower Checker	2. Fast Response	2. No extra Features			
	3. Accessible to beginners	3. No Tutorial Provided			
	1. Connection with agronomist	1. Limited To Ugandan Region only			
Plant Scope	2. Free with advertisement.	2. Lack Of Plant Care Tips			
	3. Has discussion forum	3. Lack Of Accessibility Options			
	1. Urgency Matrix Feature	1. Focuses On Vegetables Only			
Cultive	2. Categorized plant care information	2. No Tutorial Provided			
	3. Good User Interface	3. No Regional and Seasonal Care			
	1. Large Database	1 Too much advartisament in Free Version			
Planto	2. High Accuracy of Identification	2. No regional insists for Malauria			
	3. Detailed Plant Care Information	2. No regional insignt for Maraysia			
	1. Simple And Minimalistic Design	1. No Tutorial for Beginners			
Plant Vision Al	2. High Accuracy of Identification	2. Small Plant Library			
	1. Fast Response	1. Less Identification Accuracy			
Plant Identification++	2. Minimal Advertisement	2. Too much of Texts			
iNaturalist	1. Wide Database	1. No Plant Identification Feature			
	2. Has Information on Flora and Fauna	2. No regional care based on Malaysia			
	3. Strong Community Engagement	3. Lack of Voice Narration			
	3. Detailed Tutorials	1. Limited Plant Care Information Upon Identification			
Flora Incognita	4. Unique User Interface	2. No regional care based on Malaysia			
	5. High Plant Identification Accuracy	3. Lack of Voice Narration			
	1. Free To Use				
RootSnap Plant Identification	2. Simple User Interface	1. Application Did Not Work during Testing			
	1. Insect Identifier Feature	1. Setting Option Made Application Unresponsive			
Nature Detect – Plant Identify	2. Good User Interface	2. Lack Of Language Support			
Blossoms	1. Detailed Tutorials	1. Pro Model Expensive			
	2. Wide Database	2. Lack Of Regional and Language for Malaysia			
	1 Detailed Tutorials				
Doctor P	2 Free To Use	1. Limited Plant Library			
DOCIONI	2. Traditional Diant Care Time Included	2. Lack Of Regional and Language for Malaysia			
	5. Traditional Plant Care Tips Included				

Table 1. Existing Nature Interaction Application

After numerous hours of testing the existing detection applications, none of the applications had voice narration to help those with illiteracy, and there was only one (1) application with a Bahasa Malaysia language option. Moreover, very limited applications focus on Malaysian culture and provide insights into plant care specific to Malaysia's climate. These applications provide valuable insights into the strengths and weaknesses of current plant identification and care applications, which inspires and allows issues to be addressed in the Nature Connect application that was developed under this project.

3- Research Methodology

The Nature Connect application adopted Agile Methodology for its development due to the dynamic and challenging characteristics of building software applications. Agile allows seamless adaptation to changes, allowing the project to revisit the ideation phase or adjust during testing without stopping the ongoing development [19, 20]. The iterative approach of Agile aligns well with the complex application development, offering the flexibility needed to refine and enhance the project as it progresses [21]. The agile methodology used for this project involves planning, design, development, testing, release, and feedback. The hardware specification for the project is as follows: The application was developed on an MSI laptop model with 4GB of RAM and 256 GB of ROM. The chipset of the laptop was Intel I3 10th Generation. The Huawei Mate 10 was used as the testing device during the usability test, which has a screen size of 5.9 inches with a resolution of 1440×2560 pixels.

3-1-Use Case Diagram

The use case diagram illustrates the interactions between users and the Nature Connect application. As shown in Figure 1, the diagram outlines various user interactions with the application, including plant identification, reading about plants, language translation, viewing tutorials, locating nearby nurseries, utilizing voice narration, and shopping for essentials. Each function is seamlessly integrated within the Nature Connect application. Figure 1 comprehensively captures all interactions between the user and the application.



Figure 1. User interaction with Application visualized through Use Case Diagram

3-2-Development Technologies

The development of the Nature Connect application involved several advanced technologies, each contributing to different aspects of the application's functionality. Firstly, React Ionic was the primary framework utilized as it provides cross-platform mobile application development [22, 23]. Combining React with Ionic's UI toolkit, it enabled the creation

of mobile-based applications [24]. The integration with the Capacitor plugin allowed the use of native device features, such as the camera, important for the plant identification feature. React Ionic components like IonTitle, IonHeader, and IonGrid ensured a responsive application, while its debugging capabilities enhanced development efficiency. The Capacitor Plugin for React Ionic provided native functionality, allowing applications to run natively on iOS and Android devices. Additionally, the Text-To-Speech plugin supported the Voice Narration feature, enhancing user interaction with the application.

The backend of the application was powered by Flask, a lightweight and flexible framework that integrated seamlessly with React. Flask handled API calls, processed image data, and interacted with machine learning models for plant identification. Its simplicity and effectiveness in serving machine learning predictions made it a suitable choice for Nature Connect [25, 26]. I18next was employed to translate content from English to Bahasa Malaysia, ensuring the application was accessible and engaging for the Malaysian target market. I18next facilitated seamless language switching and content translation for every screen in the application. Due to its efficiency and simplicity, it is well known that i18next can enhance user experience for applications and websites [27].

TensorFlow, developed by Google, played a central role in the backend logic of Nature Connect [28]. It was employed to train the plant identification model, which was later exported in the HDF5 format. This model ran on the Flask backend, processing images captured by users to predict plant species. The training process was conducted in Jupyter Notebook, an interactive computational environment. Jupyter Notebook allowed for the writing of Python code, real-time debugging, and visualization of training data using tools like Matplotlib. Its integration of documentation and visualization made the model training process more efficient.

Python was the primary language used for training the prediction model and running the backend script. Python has been a widely used technology in backend development [29]. It seamlessly integrated with Flask and utilized powerful libraries such as TensorFlow and Matplotlib to enable efficient plant identification based on user-captured images. Python's versatility and robust libraries were essential in developing and deploying the prediction models for Nature Connect. The Google Maps API further enhanced the application's functionality by allowing users to locate nearby nurseries. This feature provided an easier way for users to find local nurseries, supporting the project's goal of promoting gardening and plant care.

Lastly, Android Studio was a crucial part of the development environment for Nature Connect. It enabled the deployment and export of the React Ionic application as an Android application as an APK file. Android Studio provided necessary components and plugins for building, testing, and exporting the application. It allowed for configuring essential permissions, such as network access and camera functionality, and debugging. The integrated logging features provided insights into the application's performance and made troubleshooting and testing more efficient.

4- Implementation and Result

This section explains the implementation of Nature Connect application development. Below, each function in Nature Connect is discussed as well as the brief explanation of Nature Connect design. In summary, Nature Connect aims to offer an experience that bridges the gap between nature and technology. The primary target audience for the Nature Connect application is the Malaysian public, encompassing individuals of all ages, physical abilities, and literacy levels, ensuring everyone can enhance their gardening journey and expand their plant knowledge. Nature Connect was designed very straight forward, most tasks or functions can be completed with minimal effort within 4 to 5 taps on the screen. It also has icons throughout the screens to quickly navigate, as humans have been familiar with navigating with images since ancient times [15, 30]. Icons were imported from the React Ionic library known as Ionicons. Moreover, implementation of accessibility features such as voice narration and the option to switch between Bahasa Malaysia and English supports the human-computer interaction in Nature Connect. Voice narration aids the user experience by allowing individuals, particularly those with visual impairments or literacy challenges, to easily navigate the application by hearing and access plant care information without relying on text. Icons simplify navigation by providing universally recognizable visual cues, reducing the cognitive load and making it easier for users to find and understand functions quickly. Offering content in both Bahasa Malaysia and English helps overcome language barriers, ensuring that users from diverse linguistic backgrounds can engage fully with the features inside Nature Connect. These accessibility features were evaluated for their effectiveness through usability testing, where participants' impressions and measurable metrics, such as ease of navigation, were recorded using Google Forms.

The application also has Light Mode and Dark Mode settings, which can be toggled from the device display setting (Figure 2). With that, the font color, the footer tabs, and the overall design will be adjusted to a light or dark color template. Dark mode provides extra comfort, particularly for users with eye strain [31]. Dark mode provides relief for older users who have trouble seeing bright screens. The design also adheres to Norman's Principle of Human-Computer Interaction, which includes visibility, feedback, constraints, mapping, consistency, and affordance [32]. It is enabled with a footer that allows quicker access to the homepage, identifying plants, reading about plants, shopping, and locating nurseries on any screen the user is at, and it is visualized in fonts and icons as it improves the visibility aspect according to Norman's Principle [33]. Icons and fonts do play a big role in visual aesthetics as well [34, 35].

For example, all buttons share a consistent light green color, while the fonts appear black in dark mode and white in light mode, maintaining visual consistency (Figure 3). The buttons are uniformly rounded across the application, avoiding variations such as square or other shapes that could potentially confuse users [36]. Additionally, most features can be accessed with fewer than four taps during page transitions. For instance, voice narration or content translation can be activated with a single click on any screen, consistently located in the footer area of each page, aligning with Norman's principle of mapping. Identifying plants can be completed in just four steps: navigating from the homepage to the identification page, then to the camera module, and finally to confirming the image and reaching the result screen—keeping user actions minimal. Moreover, the buttons incorporate a tactile press animation, effectively demonstrating the feedback aspect of Norman's principles. Accessing the "View/Shop Essentials" section involves only three actions: from the home page to the essentials tab, clicking the buy button, and being redirected to Shopee.



Figure 2. Homepage in Light Mode

Figure 3. Homepage in Dark Mode

Regarding the voice narration feature, the icon used is a speaker, which is universally recognized as being associated with producing an output when clicked (Figure 4). Additionally, the buttons animate upon being clicked, adhering to the feedback principle [36]. Feedback in user interfaces is crucial, as studies have shown that it can enhance user acceptance, satisfaction, and intention to continue using applications or websites [37]. When the voice narration feature is activated, a red speaker icon with a mute symbol appears. The color red typically signifies "stop" in daily life, and the mute symbol also indicates stopping audio. Together, these visual cues make it easier for individuals with lower literacy levels to understand the feature and navigate the application effortlessly.



Figure 4. Voice Narration Enabled

4-1-Application Functions

The application includes seven key functions: viewing tutorials, identifying plants, reading about plants, translating content, providing voice narration, locating nearby nurseries, and viewing/shopping for gardening essentials. Below,

each function is detailed to highlight the flow of interaction between the user and Nature Connect. The first function is viewing tutorials, which users can access from the homepage by clicking the "View Tutorial" button (Figure 5). This presents tutorials for each feature, with explanations and images. Users can translate the content between Bahasa Malaysia and English. Additionally, a speaker icon allows for voice narration in either language, enhancing accessibility. The tutorials comprehensively guide users through features like identifying plants, reading about plants, translating content, and more. This ensures that users can quickly understand and utilize Nature Connect to enhance their gardening experience. The second function is voice narration, accessible from the homepage by selecting the "Voice Narration Speaker" icon at the footer of each screen, further enhancing accessibility (Figure 6). This feature reads aloud any text content, aiding users who prefer listening over reading. Users can toggle between English and Bahasa Malaysia narrations, and a mute option allows for instant cessation of the narration. This feature, powered by the Text-To-Speech plugin from Capacitor, significantly improves accessibility for users with reading difficulties and those with illiteracy (Figure 7).



Figure 5. View Tutorial



Figure 6. Voice Narration Enabled and Mute Button Visible



Figure 7. Voice Narration Process

The third function, content translation, allows users to switch between English and Bahasa Malaysia with the "Translate Content" button at the footer of each screen (Figure 8). The button's label indicates the current language, ensuring users can easily read and understand plant care information in their preferred language. This feature, implemented through the i18next plugin, ensures seamless language transitions, making Nature Connect accessible to a wider audience.



a) Read About Plants in English

b) Read About Plants in Bahasa Malaysia

Figure 8. Read About Plants Landing List

The fourth function is plant identification. Users can start from the homepage and click the "Identify Plants" button or use the identify footer icon. With the screen providing guide, users can snap a clear picture of a plant, which the application processes to provide detailed information about the plant. Currently, Nature Connect can identify four common plants in the Malaysian climate: Rose, Aloe Vera, Sunflower, and Daisy. This functionality, achieved through a combination of Capacitor's camera plugin and Python's TensorFlow model, makes plant identification easy and informative (Figure 9).

The fifth function of Nature Connect, "Read About Plants," showcases the application's commitment to integrating Malaysian cultural aspects into its design and content. Accessible from the homepage through the "Read About Plants "button or the flower icon in the footer, this feature allows users to browse a list of ten plants, including notable species such as Sunflower, Hibiscus, Orchid, Rose, Daisy, Mint, Bougainvillea, and Aloe Vera. Each plant entry comes with a detailed description and care instructions tailored specifically for the Malaysian context. For example, Nature Connect provides information on flowering months, common pests relevant to Malaysia, and recommendations for sunlight exposure based on Malaysia's climatic conditions. These insights not only assist in meeting the practical needs of gardeners but also highlight the unique flora of Malaysia. Moreover, the application includes a special facts section for each plant, which displays aspects that are culturally significant. For instance, the Hibiscus, recognized as Malaysia's national flower, is featured with relevant historical and cultural insights. This section promotes a deeper understanding of its significance within Malaysian culture among the application's users. During the content development of "Read About Plants," Nature Connect reviewed various blogs and write-ups focused on Malaysian plant care and gardening traditions to validate cultural appropriateness and relevance, ensuring that it resonates with local users and reflects their cultural practices in gardening (Figure 10).

The sixth function is viewing and shopping for essentials. Users can select the "View/Shop Essentials" button from the homepage or use the shop icon in the footer. This opens a list of gardening products with descriptions and prices. Users can easily purchase items through Shopee, making it convenient to find and buy necessary tools and supplies for gardening (Figure 11). The application adapts to the current global trend of increasing online shopping, which provides various benefits to users [38]. In the Malaysian context, items are sold on Shopee Malaysia, with all pricing displayed in Ringgit Malaysia. This integration not only simplifies the shopping experience but also promotes and boosts local sellers in Malaysia, nurturing a stronger connection between consumers and their local gardening suppliers.



c) Loader Animation

d) Result for Aloe Vera

Figure 9. Identification of Plant and Result Process



a) List of Plants



c) Care Tip

d) Care Tip in Bahasa Malaysia



e) Malaysian Based Insight and Extra Fact





a) List of Products to Shop

b) Prompted To Shopee Platform

Figure 11. List of Products to Shopee Process

The seventh function, locating nearby nurseries, can be accessed from the homepage by selecting the "Locate Nearby Nurseries" option or pressing the nursery icon in the footer. This feature uses Google Maps API to display nurseries across Malaysia. The Google Maps API offers 4 types of map modes, which include roadmap, satellite, terrain, and hybrid [39]. As of Nature Connect, users can view the map in standard or satellite mode, use Street View, and see markers for nearby nurseries. A tutorial below the map guides users on navigating this feature, which also includes a "View on Google Maps" option for directions. This function, developed with Google Maps API services, ensures users can easily locate and visit local nurseries, supporting both their gardening needs and local businesses by increasing visibility (Figure 12).



e) Street View Mode



g) Full screen View

Figure 12. Locating Nearby in Various View Process

4-2- Comparison of Nature Connect Application With Existing Nature Interaction Application

Table 2 presents the comparison of the existing nature application with the Nature Connect application. A comparison was made according to its feature offerings. The features are evaluated according to initial personal impressions during testing.

Application	Plant Identification Accuracy	Plant/Disease Journal	Plant Care Information	Overall User Interface	Use of icons	Accessibility Features	Voice Narration	Bahasa Malaysia Language	Discussion Forums/Sharing	Regional Insights about Malaysia	Nearby shops locater
Flower Checker	L	N/A	Y	L	Min	L	Ν	Ν	Ν	Ν	Ν
.Plant Scope	М	N/A	Ν	М	Max	L	Ν	Ν	Y	Ν	Ν
.Cultive	М	Small	Y	G	Max	М	Ν	Ν	Ν	Ν	Ν
Planto	Н	Huge	Y	G	Max	Н	Ν	Ν	Ν	Ν	Ν
PlantVision Ai	Н	N/A	Y	М	Min	L	Ν	Ν	Ν	Ν	Ν
Plant Identifier	М	N/A	Y	L	Max	L	Ν	Ν	Ν	Ν	Ν
iNaturalist	N/A	Huge	Y	М	Min	L	Ν	Y	Y	Ν	Ν
Flora Incognita	Н	Huge	Y	G	Max	М	Ν	Ν	Ν	Y	Ν
RootSnap Plant Identification	N/A	N/A	Ν	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nature Detect- Plant Identify	М	N/A	Y but less detail	М	Max	М	Ν	Ν	Ν	Ν	Ν
Blossoms	Н	Huge	Y and detail	G	Max	М	Ν	Ν	Y	Yes	Y but on Amazon Shop
Doctor P	Н	N/A	Y and detail	М	Min	L	Ν	Ν	Ν	No	Ν
Nature Connect	М	Small	Y and detail	G	Max	М	Y	Y	Ν	Y	Y

Table 2. Comparison with Existing Nature Interaction Application

Markers: Yes - Y, No - N, Minimal - Min, Maximal - Max, Low - L, Moderate - M, Good - G, N/A - Not Available

4-3-Usability Testing and Evaluation

The usability test involved 20 participants filling out a Google Form, which was used to systematically record their responses and feedback while using the Nature Connect application on a Huawei Mate 10. This approach facilitated the collection of both quantitative and qualitative data. Participants were selected based on a variety of criteria to ensure an insightful evaluation, including considerations of age range and literacy proficiency to capture a diverse user experience. Specifically, respondents were grouped into three distinct age categories (Figure 13): adults over 40 years old (30%, or 6 people), teenagers and children aged 19 and below (30%, or 6 people), and young adults aged between 20 to 40 years old (40%, or 8 people). Participants included individuals with both technology backgrounds and those from non-Information Technology backgrounds, as it is important to include non-experts in usability testing, as their insights can provide valuable perspectives [4].

Furthermore, the participants included individuals from various educational backgrounds, encompassing those from university settings, primary schools, and even individuals with no formal education. This diversity reflects the wide spectrum of the Malaysian population and strengthens the application's goal of being accessible to all users, regardless of their educational status.

To enhance geographic representation, participants were drawn from different regions of Malaysia, including Kedah in the north and Melaka in the south. This regional diversity ensures that the usability test addresses the cultural relevance for potential users of the application. By including participants from varied educational backgrounds and regions, the usability testing aimed to provide insights that would lead to a more user-friendly experience tailored to the needs of all Malaysians.



Figure 13. Respondent Age Range

Nature Connect was evaluated on three aspects of usability testing: efficiency, effectiveness, and satisfaction [40]. The ISO/IEC 9126-4 Metrics recommends that usability metrics should consist of these 3 aspects [41]. Effectiveness records the accuracy and completeness with which tasks are given to users. Efficiency evaluates the time taken in relation to the accuracy and completeness of a goal [37, 42]. Satisfaction measures the comfort and acceptability of use, which is based on personal impression [43]. This is the general formula that was used to calculate each aspect; however, it would be adjusted accordingly for each task.

Effectiveness can be measured using a yes-or-no checklist when a respondent attempts a specified task, and with the result, effectiveness can be calculated using:

$$Effectiveness = \frac{Number of people completed task successfully}{Total number of people perform the task} \times 100\%$$
(1)

Meanwhile, efficiency can be calculated by recording the time taken to perform a specific task. It can be calculated using:

$$Efficiency = \frac{Time \ taken \ to \ complete \ the \ task}{Total \ number \ of \ people \ perform \ the \ task} \times 100\%$$
(2)

Lastly, satisfaction is calculated by collecting responses on a scale from 1 (Very Difficult) to 5 (Very Easy) when a respondent performs a specific task. It can be calculated using:

$$Satisfaction = \frac{Number of people who gave 5 rating response}{Total number of people perform the task} \times 100\%$$
(3)

Respondents completed seven tasks, including viewing the tutorial, enabling voice narration, translating content, identifying plants, reading about plants, viewing/shopping for essentials, and locating nearby nurseries. To ensure fair testing, the content remained consistent for all respondents. This standardization included the number of plants to identify, the specific pages for enabling voice narration, the number of plants to read about, the number of products to buy, and the pages for translation. Below is discussed what the interactions a respondent performed during the test were for each task.

Before testing Nature Connect, respondents were asked general questions to assess their experiences with nature technology applications. Additionally, each respondent was asked to assess their literacy proficiency to understand their capabilities in using the application. The results from this initial section revealed that 1 respondent had low literacy proficiency, 10 had medium proficiency, and 6 had high proficiency, while 3 preferred not to reveal their proficiency level. This information helps us understand the respondents' ability to read and understand the content within Nature Connect, ensuring they can use the application as intended (Figure 14).



Figure 14. Literacy Response

Under the first section, in preparing the respondents to test Nature Connect, it was necessary to further understand respondent experience or any prior knowledge about existing plant detection applications.

From the results, about 75% of respondents (15 people) had never used a plant detection application, while 25% had prior experience with similar applications. The ease of using these applications was rated on a scale from 2 to 5, with 5 indicating excellent usability. Only one respondent rated their experience as excellent, while the highest rating, level 4, was given by two respondents.

All respondents recognized the importance of technology in plant care and gardening, with 100% agreeing that technology plays a crucial role. They also recognized the importance of accessibility in mobile applications. Accessibility features highlighted included a visually appealing user interface, voice narration, and the availability of native language options, all of which Nature Connect has now incorporated.

The usability testing for the "View Tutorial" section of Nature Connect involved a simple process. Users were asked to go to the "Tutorial" section from the homepage. Then, they browsed and read the guide, which consists of each feature that Nature Connect offers. In the test, this was placed at the beginning so that it would help the respondents to have a better understanding of navigating and using Nature Connect for other features. Time is recorded from the moment the respondent is at the homepage until the respondent has gone through each tutorial and informs them that they are satisfied. The time taken is used to measure efficiency, and their impression is used to measure satisfaction through the 5-scale rating in a Google form. Meanwhile, the ability for the respondent to complete navigating and reading through the tutorials is recorded for the effectiveness aspect. With successfully navigating and understanding the tutorial, the test will be marked as 'Yes' else 'No'. The result was very encouraging, as all 20 respondents were able to effectively perform the task. The effectiveness of View Tutorial was 100%, the efficiency was 1 minute 10 seconds, and the satisfaction was 65% (Figure 15).

The usability testing for the "Voice Narration" section of Nature Connect involved users pressing the correct button to activate voice narration at the homepage. Users must listen to the entire audio output and then try again in Bahasa Malaysia narration. Lastly, they can listen or stop the audio when they are satisfied, and their response is used for the satisfaction aspect. Time is recorded from the moment the respondent is at the homepage until the respondent has activated and stopped voice narration and informed them that they are satisfied; this metric is used for efficiency. As for the effectiveness of Voice Narration, the ability for the respondent to completely activate and listen to narration is recorded. With successfully activating and understanding the narration, the test will be marked as Yes else No. The result was very appealing, as all 20 respondents were able to effectively perform the task. The effectiveness of Voice Narration was 100%, the efficiency was 35 seconds, and the satisfaction was 90%.



Figure 15. Satisfaction Result for View Tutorial Task

The usability testing for the "Translate Content" section of Nature Connect involved users pressing the correct button to translate content on the homepage. Users must read the content on the homepage in English and retry in Bahasa Malaysia. Time is recorded from the moment the respondent is at the homepage until the respondent has activated translation, read homepage content in both English and Bahasa Malaysia, and informed that they are able to understand and are satisfied. Their impression is used for the satisfaction aspect, recorded time is used for efficiency, and as for the effectiveness of the Translate Content Feature, the ability for the respondent to completely activate translation and understand content in both languages is recorded. With successfully activating and understanding the translated content, the test will be marked as Yes else No. The result was very appealing, as all 20 respondents were able to effectively perform the task. The effectiveness of Translate Content was 100%, the efficiency was 33 seconds, and the satisfaction was 80% (Figure 16).



Figure 16. Efficiency Result for Translate Content Task

The usability testing for the "Identify Plants" section of Nature Connect involved users navigating to the identify plants tab, snapping pictures of plants in front of them (4 plants that Nature Connect can identify include Sunflower, Aloe Vera, Rose, and Daisy only), and getting the identification result. Time is recorded from the moment the respondent is at the homepage until the respondent has navigated to the tab, snapped the plant image, and received the result. Only 1 attempt was recorded for testing for each person. As for the Identify Plants Feature, the ability for the respondent to completely navigate and receive the result of identification is recorded. With successfully receiving an accurate identification result, the test will be marked as Yes else No. The result was 17 respondents performed the task completely

and received accurate results, while 3 received non-accurate results of identification. The result is recorded on the 1st attempt of accurate identification, even though some of the respondents received accurate identification on the 2nd attempt. The effectiveness of Identify Plants was 85%, the efficiency was 36 seconds, and the satisfaction was 80%.

The usability testing for the "Read About Plants" section of Nature Connect involved users navigating to the read about plants tab, selecting a plant, and reading its plant care. Time is recorded from the moment the respondent is at the homepage until the respondent has navigated to the tab, selected a plant, and read its plant care. As for the Read About Plants Feature, under the aspect of effectiveness, the ability for the respondent to completely navigate and read about a specific plant is recorded. With successfully being able to read and understand the plant care for a specific plant, the test will be marked as Yes else No. The result was all 20 respondents performed the task completely and were able to understand plant care to apply to their daily lives. The effectiveness of Read About Plants was 100%, the efficiency was 1 minute 2 seconds, and the satisfaction was 60%.

The usability testing for the "View/Shop Essentials" section of Nature Connect involved users navigating to the shop tab, reading about the product, and pressing the cart button to redirect to the Shopee application, where users can proceed to buy. Time is recorded from the moment the respondent is at the homepage until the respondent has navigated to the tab, selected an item, and been redirected to Shopee. As for the View/Shop Essentials Feature, the ability for the respondent to navigate to the shop tab, select a product, and redirect to the Shopee application is recorded. By successfully navigating and landing on the Shopee page for a specific product, the test will be marked as Yes else No. The result was that all 20 respondents performed the task completely. The effectiveness of View/Shop Essentials was 100%, the efficiency was 40 seconds, and the satisfaction was 70%.

The usability testing for the "Locate Nearby Nurseries" section of Nature Connect involved users navigating to the Locate Nursery tab, reading about the guide for using the tab, and accessing a nearby nursery by using Google Map features such as street view. Time is recorded from the moment the respondent is at the homepage until the respondent has navigated to the tab, tapped a nearby nursery, and pressed View on Maps to get directions. The effectiveness of the Locate Nearby Nurseries function was the ability for the respondent to navigate to the Locate Nursery tab, get details of a specific nursery, and launch it on Google Map view. By successfully navigating and getting nursery directions for a specific nursery, the test will be marked as Yes else No. 18 respondents, about 90%, performed the task completely without any hassle. The effectiveness of Locate Nearby Nurseries was 90%, the efficiency was 1 minute 22 seconds, and the satisfaction was 20%.

The overall effectiveness of Nature Connect can be calculated by adding all the average effectiveness percentages for each task and dividing by the total number of tasks that were given to respondents. The result is 96.4%.

$$Overall \ Effectiveness = \frac{Effectiveness \ of \ every \ task}{Total \ Number \ Of \ Task}$$
(4)
$$Overall \ Effectiveness = \frac{100\% + 100\% + 100\% + 100\% + 90\%}{7} = 96.4\%$$

Overall efficiency of Nature Connect can be calculated by adding all average efficiency for each task divided by total number of tasks that were given to respondents.

$$Overall \ Efficiency = \frac{Efficiency \ of \ every \ task}{Total \ Number \ Of \ Task}$$
(5)

$$Overall \ Efficiency = \frac{(71s+35s+33s+36s+62s+40s+82s)}{7} = 51 \ Seconds \ Per \ Task$$

Overall satisfaction of Nature Connect can be calculated by adding all the average satisfaction for each task divided by total number of tasks that were given to respondents. Which makes the average as 66% approximately 13 respondents agree Nature Connect is very satisfying and rated 5 for the satisfaction scale.

$$Overall Satisfaction = \frac{Satisfaction of every task}{Total Number Of Task}$$

$$Overall Satisfaction = \frac{(65\%+90\%+80\%+80\%+60\%+70\%+20\%)}{2} = 66\%$$
(7)

Table 3. Summary	of	Usability	Test	Result
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No.	Aspect	Results		
1	Effectiveness	96.4%		
2	Efficiency	51 Seconds Per Task		
3	Satisfaction	66%		

4-4-Interpretation and Explanation of Usability Results

The results of the usability testing for Nature Connect demonstrate an overall positive outcome, with an effectiveness rate of 96.4%, an average task efficiency of 51 seconds per task, and a user satisfaction rate of 66%. Each of these results reflects the application's strengths and areas for improvement.

The 96.4% effectiveness rate shows that nearly all users were able to successfully complete the given tasks with minimal errors. This suggests that the interface design of Nature Connect is intuitive and accessible, fulfilling the key objective of providing a user-friendly application for users of all abilities. However, there is a small percentage of users who experienced challenges, especially with the Identify Plants feature, where some users did not receive accurate results on their first attempt. The potential improvements can be focused on the plant identification algorithm, particularly in enhancing accuracy or providing clearer instructions on capturing plant images.

In terms of efficiency, users were able to complete tasks in an average of 51 seconds. This indicates that Nature Connect offers a smooth experience, with users able to navigate between screens and complete tasks quickly. The relatively fast task completion times showcase ease of use, but there may still be opportunities to further reduce task times, particularly for features like Locate Nearby Nurseries, which took over a minute to complete.

The 66% satisfaction rate notes the area for improvement. Although most users found the application easy to use and rated their experience positively, about one-third of users indicated they had some difficulty or were less satisfied. The Locate Nearby Nurseries feature, which had the lowest satisfaction score of 20%, suggests that this feature may require further refinement. Enhancing this feature, such as improving the accuracy of Google Maps integration or offering more detailed directions, could help increase user satisfaction overall and provide a better user experience on the Nature Connect application.

5- Conclusion

In conclusion, the Nature Connect application successfully achieved its primary objective of providing a user-friendly navigation and interface experience, grounded in Human-Computer Interaction (HCI) principles. This was achieved through the integration of various technologies and insights from user interface and experience research. Additionally, the application was rigorously evaluated through comprehensive usability testing using relevant metrics to assess its effectiveness, efficiency, and user satisfaction. The results showed an effectiveness rate of 96.4%, an average task completion time of 51 seconds, and a satisfaction rate of 66% among the 20 respondents, demonstrating that Nature Connect meets its design objectives effectively.

However, the application has certain limitations that could be addressed in future updates. Currently, the Flask script used for the Identify Plants function operates only in a Localhost environment, requiring the laptop and mobile device to be on the same Wi-Fi network. Additionally, the plant library in the Read about Plants feature includes only 10 plants, and the Identify Plants feature is limited to 4 plants. Future enhancements could include deploying the Flask script to the cloud to eliminate the dependency on Localhost, leveraging cloud services such as Firebase for user sign-up and real-time statistics monitoring, and expanding the plant database with more models trained in TensorFlow Python.

To determine which additional plants will be included in the Nature Connect database, several criteria will be considered. The primary focus will be on plants that have a high prevalence in Malaysia's climate, ensuring they thrive in local conditions. Popularity among Malaysians and nurseries will also be a key factor, as including plants that are widely recognized and sought after can enhance user engagement and fulfill target market demand. Furthermore, special attention will be given to plants that struggle with care due to a lack of specific plant care knowledge, allowing the application to provide tailored insights to users facing challenges in maintaining these plants. Collaboration with local botanists to verify the accuracy of plant care tips could further improve the application. Overall, Nature Connect holds promise in bridging the gap between humans and nature, offering a foundation for continued development and refinement.

6- Declarations

6-1-Author Contributions

Conceptualization, A.F.S. and S.Y.; methodology, A.F.S. and S.Y.; software, A.F.S.; validation, A.A.; investigation, A.F.S. and A.A.; writing—original draft preparation, A.F.S.; writing—review and editing, S.Y. and A.A.; supervision, S.Y. All authors have read and agreed to the published version of the manuscript.

6-2-Data Availability Statement

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6-5-Institutional Review Board Statement

Not applicable.

6-6-Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

6-7-Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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