PARATANOM: AN AUGMENTED REALITY 2D FARMING TOP-DOWN SINGLEPLAYER GAME FOR AGRICULTURAL EDUCATION

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BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY

by

Jeremy Zion L. Jamer

Mark Lesther F. Nacario

Phoebe Kaye R. Crispino

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APPROVAL SHEET

This capstone entitled **PARATANOM: AN AUGMENTED REALITY 2D FARMING TOP-DOWN SINGLEPLAYER GAME FOR AGRICULTURAL EDUCATION** prepared and submitted by **JEREMY ZION L. JAMER, MARK LESTHER F. NACARIO, AND PHOEBE KAYE R. CRISPINO** in partial fulfilment of the requirements for the degree of BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY, has been examined and is recommended for acceptance and approval for oral examination.

MR. CHARLES P. JAMER
Adviser

PANEL OF EXAMINERS

APPROVED by the committee on Oral Examination on **November 28, 2025** with a grade of **97%**.

MR. SALVADOR V. BRIONES II
Chairperson

MR. ROWELL JOHN B. ARTIAGA
Member

MR. SALVADOR V. BRIONES II
Member

KENNEDY C. CUYA, DIT
Member

MR. FROILAND B. PEÑALOSA
Member

ACCEPTED AND APPROVED in partial fulfilment of the requirements for the degree **BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY.**

FROILAND B. PEÑALOSA
Capstone/Thesis Coordinator

JONI NEIL B. CAPUCAO, DIT
Department Chair
Department of Computational Sciences

ENGR. EMELINA R. PADAYAO
College Dean
College of Engineering and Computational Sciences

CAPSTONE READER CEERTIFICATION

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
Website: www.parsu.edu.ph
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CAPSTONE ABSTRACT

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2. Authors:

Jamer, Jeremy Zion Laovinia

Crispino, Phoebe Kaye Romero

Nacario, Mark Lesther Fernandez

3. Panel of Evaluators:

Rowell John B. Artiaga

Salvador V. Briones II

Kennedy C. Cuya, DIT

Froiland B. Peñalosa

4. Capstone Reader: Kennedy C. Cuya, DIT

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    8.1 **Rationale / Background of the Study**

Agriculture remains a cornerstone of the Philippine economy, ensuring food security and contributing significantly to national productivity (Golloso-Gubat et al., 2024). Despite its importance, the sector faces challenges in attracting younger generations. Many view

farming as a difficult, low-reward career, compounded by climate risks, reliance on traditional methods, and limited technical knowledge (Perception of Filipino Youth towards Agriculture, n.d.; Waje et al., 2024). This generational gap threatens the sustainability of the workforce and the continued growth of the agricultural industry.

The integration of technology in education presents a potential solution to these challenges. Mobile games and augmented reality (AR) applications have proven effective in engaging younger audiences, making learning experiences interactive and immersive. Such approaches can help reshape perceptions of agriculture, highlighting its value while providing practical knowledge and skill development opportunities. By leveraging technology, farming can be presented as an accessible, engaging, and rewarding field for youth.

Paratanom, an AR-based 2D farming mobile game, was developed to address these challenges. It combines gamification, storytelling, and educational content to introduce users to sustainable agricultural practices in the Partido region. The game allows players to identify local crops using AR, simulate farming activities, manage virtual farms, and complete educational challenges. Crop information was systematically gathered from local experts, ensuring accuracy and relevance, while 3D models and interactive mechanics enhance learning retention. By providing a fun, hands-on virtual experience, Paratanom aims to spark interest in agriculture and make farming knowledge more approachable and memorable for the younger generation.

The main objective of this study was to design and develop Paratanom, an augmented reality 2D farming adventure mobile game for Android smartphones, which educates students about sustainable farming practices based on expert knowledge. Specifically, the study sought to identify system requirements, design functional features, develop interactive gameplay and educational content, and evaluate the game’s effectiveness in improving agricultural knowledge retention using the Technology Acceptance Model (TAM).

8.2 Summary

The main objective of this study was to design and develop Paratanom, an augmented reality 2D farming adventure mobile game for Android smartphones. It took advantage of augmented reality and gaming to educate

students about sustainable farming practices that were derived from experts in the field of agriculture and farming. Specifically, it answered the following specific objectives:

1. Identify the requirements for an Android-based mobile game that utilized augmented reality (AR), which included technical specifications for crop identification, user interface and experience needs, educational content requirements, hardware specifications, and game mechanics for better learning outcomes;
2. Design the functionalities of the proposed mobile game, including the game mechanics, AR scanner, and educational content;
3. Develop the mobile game's proposed features of crop identification, 3D overlay display, game mechanics, and educational content modules; and
4. Test and evaluate the acceptability of the mobile game using Technology Acceptance Model (TAM) and assess its effectiveness in improving agricultural knowledge retention among students.

8.3 **Findings**

Based on the results of the surveys, below are the findings.

1. Paratanom integrated functional, educational, and technical requirements. Crop detection capabilities were achieved by training a YOLO model on photos of crops and using Vuforia's AR capabilities to instantiate 3D models. Gamified elements, including farming simulations, quests, and crop collections, enhanced engagement and reinforced learning. Text-to-speech supported accessibility, while local crop data were organized and verified to provide structured guidance for planting, maintenance, harvesting, and pest management. ESRB rating confirmed content was suitable for younger audiences.
2. The system design provided a clear framework integrating character management, AR crop recognition, and educational farming mechanics. Functional, use case, and swimlane diagrams mapped workflows and user interactions. Core systems included avatar creation, AR scanning with 3D visualization and audio feedback, farming simulation, quests, crop collection, and produce processing. UML diagrams illustrated interactions between character attributes, inventory, energy, and AR actions, ensuring responsive, interactive gameplay that reinforced sustainable farming knowledge;

3. Paratanom was successfully developed using Unity, Vuforia Engine, Android and Windows OS, Fire Alpaca, Blender, FL Studio, Cursor IDE, and YOLOv8n for AR crop recognition. Assets, coding, AR detection, and audio were integrated into a cohesive educational platform that combined interactive gameplay, AR-enhanced learning, and responsive design; and

4. Evaluation with 144 Agribusiness students using TAM (Perceived Usefulness, Ease of Use, Attitude Toward Use, Behavioral Intention) showed high acceptance. Weighted means ranged from 4.41 to 4.65, all interpreted as Strongly Agree. Students found the game useful, easy to navigate, engaging, and intended to continue using it, confirming the application’s effectiveness as an educational AR tool.

8.4 Conclusions

Based on the findings, the conclusions below are hereby presented.

1. Paratanom effectively combined functional, educational, and technical features to deliver a structured and interactive learning tool for agricultural students. AR technology, gamification, and inclusive design ensured engagement, accessibility, and accurate knowledge delivery;

2. The design successfully integrated character management, AR scanning, and gamified learning mechanics. Diagrams and class models guided development, producing a responsive system that reinforced local agricultural knowledge and sustainable practices;

3. Development using specialized software and AR frameworks produced a fully functional mobile game. Integration of assets, coding, and AR features met functional and technical requirements, resulting in a cohesive educational platform; and

4. High evaluation scores confirmed the game’s educational effectiveness, usability, and user acceptance. Students recognized Paratanom as a valuable, engaging, and sustainable learning tool, supporting continued adoption.

8.5 Recommendations

Based on conclusions, the recommendations below are hereby presented.

1. Building upon Paratanom's success, the team expanded the AR learning tool's deployment by strengthening its regional relevance through the incorporation of indigenous and high-value crop varieties, region-specific

farming practices, and real-time conditions;

2. Improve the trained YOLO model for more consistent crop detection, adding new gameplay features such as new locations, more non-playable character interaction, and adding more crops to collect;

3. Explore multiplayer or cooperative gameplay and broader device compatibility to enhance interactivity, inclusivity, and long-term engagement;

4. Continuously collect feedback, perform multiple internal testing, update content, and consider adaptive learning features to maintain educational effectiveness and user interest over time.

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J.Z.L.J.

P.B.R.C.

M.L.F.N.

DEDICATION

From Phoebe Kaye Crispino

I dedicate this capstone project first and foremost to the Almighty God for providing strength and wisdom. I dedicate this to my mother, Arnie R. Crispino for her love and support and to my late father, Menandro E. Crispino, whose memory continues to inspire me every day. I also dedicate this to my siblings for their care and help whenever they had extra time and resources. I dedicate this to my groupmates and classmates, thank you for your constant assistance and encouragement. Jeremy L. Jamer, your knowledge, skills, and dedication never fail to amaze me. I know how much this research means to you, and I truly admire the hard work you poured into it. Mark Lesther F. Nacario, thank you for partnering with me in all the tasks that needed to be done and for the support you provided along the way. Your presence has made the process lighter, and I hope you continue to inspire other people and make them smile as you always do. To my classmates, Benjie, Kyla, Natalie, Mark, Tristan, and others, thank you for your help and for always answering my questions whenever I needed guidance. Your kindness, patience, and genuine willingness to support me have meant more than you know. I am grateful for the laughter and the shared struggles that made this journey lighter and more meaningful. I dedicate this to Partido State University, my instructors, the panelists, and to the Department of Engineering and Computation Sciences, thank you for your commitment to our growth as students and future professionals. Lastly, I dedicate this work to myself for persevering and continuing despite all challenges.

From Jeremy Zion Jamer

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From Mark Lesther Nacario

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Chapter 1

INTRODUCTION

Project Context

Agriculture in the Philippines played an important role in making sure that both food security and substantial contribution were met *(Golloso-Gubat et al., 2024)*. This, however, faced multiple obstacles, particularly for newer generations of farmers, who found agriculture a sector that was hard to get into while also having some negative bias towards it and dismissing it because it was viewed as a hard life with little payoff *(Perception of Filipino Youth towards Agriculture: Eradicating Agri Stereotypes through Education, n.d.)*. Paired with the risks associated with climate change, traditional farming practices, and lack of technical expertise making productivity problems became worse *(Agricultural Policy Monitoring and Evaluation 2023, 2023; Waje et al., 2024)*. These factors all together deterred younger generations from pursuing careers in agriculture, which put this industry at risk of decline in workforce and weakened one of the most important industry backbones of the Philippines.

The potential for using games as a platform for education and skill development grew as technology became increasingly integrated into daily life. Mobile games and applications and augmented reality (AR) consistently attracted and retained younger audiences, encouraging education, and raising awareness in a variety of areas. This meant that the agricultural industry stood to gain from creative approaches that could have made farming much more approachable and interesting to younger generations while also removing their negative perceptions and biases towards it.

Paratanom, a mobile AR farming game, aimed to bridge the gap by combining entertainment and education, thereby capturing momentary curiosity and turning it into a lifelong educational experience. It was designed for students and introduced users to sustainable farming practices in an interactive way while also making agriculture much more approachable and fun. The game utilized augmented reality and gamification not only to provide hands-on virtual farming experiences but also to deliver structured educational guidance on common agricultural crops in Partido. The project sought to improve agricultural education, spark interest among young people, and support sustainable farming practices in the region by making agricultural knowledge easy to access, interactive, and enjoyable. This approach aligned with the government's goals of modernizing the agricultural industry while empowering communities through technology. (*Technology-Based Farms Key to Attracting New Generation of Farmers — DA Chief | Official Portal of the Department of Agriculture, n.d.*). The subsequent sections detailed the specific objectives, methodologies, and expected outcomes of the Paratanom project.

Purpose and Description

The AR 2D Farm Game, Paratanom, aimed to bridge the gap between traditional agricultural practices and modern technological learning tools while contributing to the United Nations Sustainable Development Goals, particularly SDG 4, Quality Education, and SDG 15, Life on Land. The project goal was to make agriculture more approachable to students through an engaging and interactive mobile game that promoted environmental awareness and quality educational experiences. It leveraged augmented reality and game mechanics to enhance the understanding of agricultural crops and helped in fostering interest in agriculture among the younger generation.

Paratanom was tailored exclusively to Android devices and featured interactive content revolving around agriculture. The game allowed users to identify local crops through AR image recognition, providing detailed information gathered from experts in the Partido area and

3D models of plants. Users were able to collect the plant and let it grow on their own farm while facing challenges in taking care of the plant based on the problems most farmers faced here in Partido. It had a story revolving around environmental awareness, revitalizing tourism via selling the processed products of the plants and learning more about the agricultural heritage of people in Partido. Players could expand their farms by helping an in-game NPC while also being quizzed on their knowledge so that they could unlock more of the game features, which helped in making it more engaging while increasing player retention. Paratanom's innovative approach to agricultural education made it a valuable tool for schools, communities, and individuals aiming to cultivate a deeper appreciation for farming and food production.

Objectives

The main objective of this study was to design and develop Paratanom, an augmented reality 2D farming adventure mobile game for Android smartphones. It took advantage of augmented reality and gaming to educate students about sustainable farming practices that were derived from experts in the field of agriculture and farming. Specifically, the study aimed to:

1.Identify the requirements for an Android-based mobile game that utilized augmented reality (AR), which included technical specifications for crop identification, user interface and experience needs, educational content requirements, hardware specifications, and game mechanics for better learning outcomes.

2. Design the functionalities of the proposed mobile game, including the game mechanics, AR scanner, and educational content.

3. Develop the mobile game’s proposed features of crop identification, 3D overlay display, game mechanics, and educational content modules.

4. Test and evaluate the acceptability of the mobile game using Technology Acceptance Model (TAM) and assess its effectiveness in improving agricultural knowledge retention among students.

Scope and Limitations

The project centered on developing a mobile game application exclusively for Android devices, with students as the primary target users. The game used storytelling elements, interactive challenges, and augmented reality to educate players about common agricultural exported crops in the Partido area. The geographic focus of the study was Partido, Camarines Sur, and the development was conducted within a 6-month timeframe to ensure the completion of key deliverables, including the augmented reality crop identification and educational content.

The project was limited to a single-player offline design to accommodate the limited internet connectivity in the Partido region, which was affected by insufficient infrastructure. Android was selected as the platform due to its higher adoption rate compared to iOS-based devices. The study was further constrained by the availability of AR-compatible Android devices among the intended users and by environmental factors—such as lighting and crop conditions—that could affect image recognition accuracy. The app recognized only eleven (11) common agricultural crops in Partido, specifically pili nuts, corn, coconut, taro, banana, cassava, chili, eggplant, Philippine lime, pomelo, and cucumber.

Although Paratanom was designed for students across the Partido area, testing and evaluation were limited to respondents from PSU-Salogon Campus due to accessibility and institutional approval. Feedback from PSU-Salogon Agribusiness students served as the representative basis for assessing usability and learning effectiveness.

Significance of the Study

Paratanom was a project aimed to make agriculture more approachable, interesting, and appealing to the younger generation, specifically for students. It served as a platform to further educate users about their agricultural heritage by using interactive 3D visualization of agricultural crops specific to the Partido area with the use of augmented reality (AR) and game mechanics. Furthermore, it integrated educational content into a fully developed mobile game that enhanced knowledge retention while being engaging and accessible.

Educational Institutions and Students. Educational institutions and students benefited from the application. This is because Paratanom introduced an innovative pedagogical approach that transformed the way agriculture was taught in the classroom. It worked alongside with the traditional theoretical approaches by providing an immersive and interactive way to learn about crops, making it more accessible and inclusive. Games had shown that, at their core, they enhanced cognitive skills, engagement, and retention. According to Gui et al. (2023), educational games significantly improved learning outcomes by encouraging active participation and critical thinking in students. This demonstrated that incorporating educational games into the curriculum was a powerful and effective strategy.

Agricultural Industry. Fostering an appreciation for

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local crops led to increased interest in agriculture and environmental awareness. Users gained a deeper appreciation of their agricultural heritage, which encouraged them to find their own ways to improve Partido's agricultural industry. This also developed more positive outlook and attitude towards agriculture among younger demographics. With more individuals finding the industry of agriculture less appealing, therefore inclining them to leave the industry *(Cerutti et al., 2021)*, and with a looming threat of agricultural workforce decline *(PH Farms Getting Empty: Agriculture Job Loss a Worrying Trend | Inquirer News, n.d.)*, the proposed application reinvigorated interest in the younger generation so that they could continue to carry on and innovate the agricultural sector of not only Partido but the Philippines as a whole.

<u>Future Researchers</u>. Future researchers benefited from the study by using it as a reference point for developing similar applications in education, agriculture, or mobile game development. The project provided a framework for integrating augmented reality, gamification, and agricultural content into a mobile platform, which future studies could refine, expand, or adapt to different contexts. It also served as a practical example of how emerging technologies can be applied to promote

sustainability and learning.

Definition of Terms

This section provides concise explanations for technical words, acronyms, or field-specific language used throughout the study. It helps readers better understand the terms that are used throughout the study.

Android. Android is an operating system for cellular telephones and tablet computers *(Britannica)*. In the study, Android specifically refers to smartphones utilizing this platform due to its high adoption rate and widespread usage.

Augmented Reality (AR). Augmented Reality (AR) is a technology that combines computer-generated images on a screen with the real object or scene that you are looking at *(Oxford Learner's Dictionaries)*. In the study, augmented reality is the use of mobile device cameras to recognize crops in the real world and show real-time 3D models and educational overlay.

AR Foundation. AR Foundation is a unity cross-platform framework for building augmented reality (AR) applications that run on both Android and iOS devices. In this study, AR Foundation is used to integrate AR features specifically for Android smartphones, enabling the overlay of 3D plant models in the 2D farming game. This was the framework used

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in the development of the Paratanom.

Game Mechanics. Game mechanics are how players and the rest of the fundamental interlocking pieces of a game—including rules, challenges, goals, actions, strategies, and game states—interact with each other in a meaningful way *(Game Design Skills)*. In this study, game mechanics refer to the interactive elements that facilitate learning and engagement in Paratanom, such as planting crops, harvesting, processing crops, level-up systems, questing mechanics, NPC interactions, and completing agricultural quizzes.

Mobile Game. Mobile games are digitally based games mostly played on mobile devices *(Encyclopedia of Information Science and Technology, Fourth Edition)*. In the study, mobile games refer to games developed for Android-based smartphones.

Non-player Character (NPC). Non-player Character (NPC) refers to any game character controlled by the computer rather than the player, often used to provide story, interaction, or assistance *(GameDev.net)*.

Offline Game. Offline games are games on mobile or laptop that do not require a constant internet connection *(Medium)*. In this study, offline games refer to the capability of an application to be played and used to its full functionality without the need to be connected to the internet.

<u>Operating System (OS)</u>. Operating system or OS is a collection of software that manages a computer's hardware and applications by allocating resources, including memory, CPU, input/output devices, and file storage *(IBM)*. In this study, operating system refers to the platform on which the mobile game application is developed and deployed.

<u>Single-player</u>. A Single-player game is a game with the ability to play without other real-life players *(Computer Hope)*. In this study, single-player refers to the functionality of Paratanom, which allows players to play the game without the need for internet connectivity.

<u>Unity</u>. Unity is a cross-platform game engine offering a robust environment for creating 2D and 3D interactive experiences *(PubNub)*. In this study, Unity is the game engine used to develop Paratanom for Android-based smartphones.

Chapter 2

REVIEW OF RELATED LITERATURES

This chapter reviewed studies and systems relevant to the development of Paratanom. It provided background for the project and identified the gaps that the study aimed to address.

AR Mobile Game Requirements

Designing effective augmented reality (AR) educational games requires careful consideration of platform compatibility, development tools, usability, and hardware limitations. Koumpouros (2024) conducted a systematic review of 73 AR studies in education and found that most applications used Unity (47.95%) and Vuforia (42.47%) as primary development tools, with the majority employing marker-based AR systems and targeting the Android platform (45.21%). Despite their popularity, challenges such as device compatibility, usability issues, and the absence of standardized evaluation frameworks persisted.

The dominance of Android devices in regions like the Philippines, where Android held a market share of 92.63% Mobile Operating System Market Share Philippines | Statcounter Global Stats (2025), showed the importance of focusing development on Android platforms to ensure extensive accessibility, especially in rural and impoverished areas. Abdullahi et al. (2025) supported this trend, emphasizing the growing role of mobile technology and applications in agricultural education and outreach, stating that smartphones served as effective tools for delivering farming knowledge in rural settings.

Usability was a critical concern for AR educational applications. Baki et al. (2024) evaluated four AR apps designed for children and found significant usability flaws, including unclear interface controls, insufficient feedback, screen freezing, and inconsistent system status indicators. These issues led to System Usability Scale (SUS) scores ranging from 57.70% to 63.81%, all below the commonly accepted threshold of 68%, indicating poor usability and negative user experience. These findings highlight the need for intuitive interfaces, clear instructions, and responsive feedback to enhance user engagement and learning effectiveness.

Regarding the choice between marker-based and markerless AR, Vadivu (2021) concluded that marker-based AR was more reliable for educational purposes, particularly on low-end or offline Android devices. Marker-based AR provided stable 3D content when printed markers were detected, while markerless AR demanded more advanced hardware, continuous internet access, and complex environmental tracking, limiting its use in resource-constrained or rural areas.

Antoniadi (2023) developed a marker-based AR app to teach plant parts to first-grade students using the Metaverse platform on Android tablets. While both the AR and traditional teaching groups showed improvement, there was no statistically significant difference between them. The study attributed this partly to usability problems such as small buttons and weak audio feedback. This emphasized the need for age-appropriate design, accessible controls, and effective multimedia feedback to boost engagement and learning among young users.

Gui et al. (2023) examined 86 studies to assess the impact of digital game-based learning. Their findings showed that the students who learned through educational games performed significantly better than those who used traditional instructional methods. The study further revealed that educational games were enhanced with specific game design elements such as pedagogical agents, self-explanation strategies, concept maps, feedback, and adaptation. The effectiveness of DGBL varied by game type, subject, and learning goal being more effective than the entertaining ones. This suggested that connecting the game features directly to the learning goals was important to achieve better educational results.

The PETAL project by Guerrero et al. (2025) developed an Android-based augmented reality application for plant identification using the SSD MobileNet V2 model and OpenCV. It allowed real-time plant detection with educational overlays through smartphone cameras. The app achieved a 62.97% mean Average Position and performed well under different lighting and viewing conditions. This study demonstrates the lightweight AR models can be effectively implemented in mobile environments, supporting real-time interaction while maintaining performance and usability on standard Android devices.

According to the study of Hurst et al. (2021), AR technology had shown significant potential in agriculture, particularly in precision crop monitoring. The review highlighted that AR solutions were most effective when integrated with supporting technologies such as GPS, sensors, SLAM algorithms, and AI for location awareness and real-time data rendering. In the context of crop farming, AR could overlay critical agricultural data in the user’s environment, enhancing visual recognition and interaction with plant information. The study also outlined the importance of selecting mobile-friendly hardware with adequate processing power and mobility, which was essential

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for field-based AR applications on Android platforms. However, the authors noted limitations in current research volume and suggested that future work should include usability and human-computer interaction assessments, which aligned with the need to define UI/UX requirements and educational content design. Despite these limitations, the paper affirmed that AR, when properly coupled with compatible technologies, provided strong functional and technical value for applications such as crop identification and real-time feedback in agricultural settings.

Functional and System Design

According to López et al. (2023), integrating Agile methodology with user-centered design (UCD) and usability testing enabled the effective development of Android-based educational applications. The process, which combined Scrum and Extreme Programming with iterative feedback from real users and clients, ensured that core functionalities aligned with learning objectives. Students developed functional mobile tools using clearly documented requirements, low-fidelity prototypes, and Kanban-based task management. The study emphasized that pre-production design and ongoing user input significantly enhanced usability and product quality, making Agile a suitable framework for developing mobile AR learning tools that required responsive design of educational modules, interactive interfaces, and real-time features, and interactions.

Sahrial (2025) demonstrated the use of Rapid Application Development (RAD) in creating an educational history game about the Indonesian figure Gajah Mada. The RAD approach allowed fast user-involved development through prototyping and iterative feedback. The study found that multimedia integration and interactive content significantly improved learner engagement and test scores. While effective in boosting early engagement, RAD's emphasis on speed and minimal documentation presented limitations in managing complex, evolving features—making it more suitable for short-term or fixed-scope projects rather than adaptive educational AR games.

Jiménez et al. (2021), examined the impact of two development methodologies—design-based (similar to RAD) and Scrum-based Agile—on the quality and effectiveness of educational games built by students under time constraints. Their study found that teams using the Agile Scrum approach produced better-aligned, functional educational games and experienced a more structured development process. The continuous sprint cycles, collaborative planning, and regular feedback loops helped Agile teams refine features iteratively, compared to the more static and prototype-heavy approach of the design-based model.

Agile also supported iterative documentation using UML diagrams like use case, class, and activity diagrams, helping developers visualize system behavior during each sprint. According to MethodPost (2025), Agile methodologies enhanced the utility of UML through iterative development, supporting evolving requirements and detailed object modeling. The integration of diagrams such as use case and class diagrams within Agile sprints enabled adaptive design, especially in projects involving user interaction and frequent feedback. This practice ensured that educational AR games benefited from clear system visualization and responsive development.

The study by Albaghajati & Hassine (2022) proposed a novel extension to UML use case diagrams to improve requirement understanding among game developers. The approach introduced game-specific constructs to standard UML, enabling better communication and alignment within development teams. Tested with titles like Super Mario Bros and Tetris, the method proved effective in enhancing learnability, usability, and team collaboration.

According to Visual Paradigm (2023), integrating UML

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modeling into Agile software development enhanced system visualization, design clarity, and team collaboration without compromising the iterative and flexible nature of Agile workflows. UML diagrams such as Use Case, Class, and Activity diagrams were used selectively and updated iteratively to match the evolving requirements in Scrum and Kanban teams. This practice supported clear communication, lightweight documentation, and just-in-time modeling—making it suitable for educational AR games that demanded continuous refinement of learning modules and user interactions.

Hekkala (2022) conducted a case study on how a large AAA game company adopted Agile practices, including Scrum and LeSS. The implementation followed a seven-stage process from recognition to sustaining change. The study found that Agile improved team communication and clarified responsibilities but also revealed difficulties with managing product backlogs and adapting leadership roles. Human-centered skills such as collaboration, support, and conflict resolution were shown to be critical for success. While based on a large-scale game studio, the findings were applicable to smaller development teams creating educational AR games. Agile enabled rapid iteration, better coordination, and timely adjustments to game features, which were essential in designing engaging learning experiences for young users.

According to Keith (2021), Agile game development using the Scrum framework was characterized by iterative and adaptive cycles, where development was broken into time-boxed sprints with continuous refinement of requirements. This approach supported flexibility in game projects, enabling developers to respond to evolving user needs, test features incrementally, and maintain a functional prototype at each stage. Keith emphasized that the process empowered teams to build and improve game mechanics, visuals, and interactivity in short, focused development bursts—ideal for educational AR games that required usability validation and modular content delivery.

Figure 1

Agile Methodology Diagram

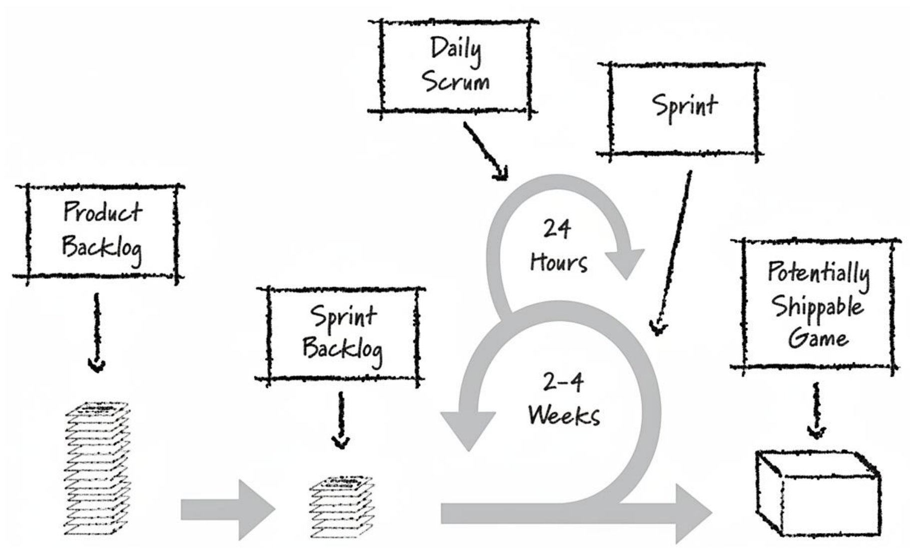

Figure 1 illustrated the Scrum workflow in Agile game development, adapted from Keith (2021). The process began with the Product Backlog, an organized list of all planned game features. During Sprint Planning, selected features—called Product Backlog Items (PBIs)—were moved into the Sprint Backlog. The team then worked on these items in a short iteration called a Sprint, typically lasting 1–3 weeks. Daily progress was tracked through Daily Scrum meetings, and each Sprint aimed to deliver a Potentially Shippable Game Increment. This iterative approach supported continuous testing, feedback, and refinement, making it especially effective for developing AR-based educational mobile games that required frequent updates and user-centered adjustments.

Keith (2021) explained that user stories helped solve communication gaps in game development by describing features from the user’s point of view (e.g., As a player, I want...). This method aligned developers and stakeholders by focusing on player value rather than technical details. User stories were brief, testable, and promoted ongoing collaboration. In AR educational games, user stories helped define features like crop scanning or learning tasks clearly and iteratively. They supported prioritization and allowed changes based on feedback. Although widely used in commercial games, their use in educational AR games remained underexplored, offering a gap for application in learning-focused development.

Weng-Lam Cheong & Hu (2022), conducted a quasi-experimental study to assess the effect of augmented reality (AR) on high school students' academic emotions during biology lessons. Two Grade-11 classes in Southern China were assigned as control and experimental groups. The experimental group used 3D AR materials to explore cell structures, supported by in-class demonstrations and after-class access. Using validated instruments, the study measured emotional responses before and after the intervention. Results showed that students who used AR reported significantly higher levels of enjoyment, pride, and hope, and lower levels of anger and boredom compared to those in the control group. Focus group interviews confirmed that AR's novelty and interactive 3D visualization enhanced students' engagement and understanding. However, technical barriers slightly limited its extended use such as the need for capable hardware and sufficient digital skills.

System Development and Tools

The development of core features such as crop identification, 3D overlay displays, game mechanics, and

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educational content modules in mobile AR games was grounded in both technical feasibility and pedagogical effectiveness.

According to Mucchiani et al. (2024), augmented reality in precision farming improved crop monitoring by overlaying real-time data through mobile AR systems. When combined with GPS, SLAM, and sensors, AR allowed farmers to identify crops, assess plant health, and view growth data in the field. The study emphasized that lightweight mobile AR tools were practical for agricultural use, supporting the development of features like crop identification and 3D overlays in farming applications.

Do et al. (2020) found that high-fidelity 3D objects with bright colors, especially red, were perceived as closer and clearer by users. This suggested that using detailed and brightly colored 3D models improved depth perception and visual effectiveness in AR applications, which was crucial for accurate object identification and engagement.

Singh & Ahmad (2024) demonstrated that the integration of AR significantly improved learners' operational proficiency and engagement. The researchers developed an AR-based learning environment (ARLE) that featured interactive 3D models linked to real laboratory hardware through Arduino. Using the System Usability Scale (SUS) and User Experience Questionnaire (UEQ), they recorded a SUS score of 80.9, classifying the system as "good." The findings indicated that AR not only enhanced user experience but also strengthens practical skills, confirming its pedagogical value in technical education.

Cai et al. (2021a) further supported the cognitive benefits of AR by reporting that AR learning games enhanced cognitive skills, emotional engagement, and information retention. The systematic review found that, compared to traditional learning methods, AR games offered more interactive and effective educational experiences. However, the study also noted challenges in designing for accessibility, especially in special education settings, emphasizing the need for thoughtful design strategies to ensure inclusivity in AR-based educational tools.

According to the study of Tobar-Muñoz et al. (2023a), AR learning games positively influenced students' cognitive performance, emotional engagement, and retention. Through a systematic review of AR applications in education, particularly in accessible learning contexts, the study found that AR game-based systems outperformed traditional approaches by encouraging active participation and improved memory retention. Despite some design challenges for

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special needs learners, the findings affirmed that AR learning games enhanced educational outcomes and should be carefully structured to maximize their instructional benefits.

Koparan et al. (2023) investigated that the use of mobile-based AR materials significantly improved students' spatial understanding and engagement. Developed using the Waterfall Model, the AR tool visualized geometric transformations, and its impact was evaluated through achievement tests, surveys, and interviews. Results showed that students accepted AR as an effective learning tool, and AR-supported instruction led to measurable improvements in learning outcomes. This suggested that well-designed AR educational modules could enhance conceptual comprehension through interactive, visual simulations on mobile devices.

Xie et al. (2022) extended the discussion to the broader food system and education sectors, noting that AR technologies—especially head-mounted displays—were being used for educational guidance, training, and interactive learning. The study affirmed that AR can facilitate real-time visual interaction with agri-based content, such as crop identification and farming techniques, and enhanced learning by simulating precision tasks. This directly supports the design of interactive AR overlays that reflected real agricultural processes and stimulate user immersion in mobile games.

Parras-Burgos et al. (2020) emphasized that the ARTID mobile AR tool enhanced students' spatial understanding and engagement in agronomy education. The tool enabled learners to visualize complex structural diagrams more effectively than traditional 2D representations. Findings showed that the AR application significantly improved comprehension of technical components and received high levels of acceptance and satisfaction among students.

Godoy (n.d.) supported the use of gamified AR content by combining augmented reality with gamification to create supplementary mobile learning tools. Built with Unity and Vuforia through the Software Development Life Cycle (SDLC), their Earth Science app engaged senior high school students through interactive AR. This case supported the development of gamified AR systems as an effective approach to improve logic, accessibility, and entertainment in science-based educational content—principles applicable to agricultural learning games targeting young users.

Lastly, Novia et al. (2024), developed augmented reality (AR) applications using Unity and Vuforia, offering an accessible and effective approach for creating interactive educational tools. Their research outlined a

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step-by-step development process that enabled educators to build AR content for teaching algorithm concepts. The findings highlighted Unity and Vuforia's ease of use, free features, and growing relevance in education, supported by a significant rise in AR-related publications—peaking in 2023. This emphasized AR's increasing adoption as a tool for enhancing digital learning.

Game Testing and Evaluation

While many educational games claimed to be effective, assessing their actual acceptability and impact on learning required a robust theoretical framework—and the Technology Acceptance Model (TAM) had consistently proven to be one of the most reliable tools for this purpose. According to Hazim Afiq Kalana & Nizam Junaini (2025a), gamification was increasingly being evaluated through TAM, with newer studies extending it to include variables such as enjoyment and engagement. Their review of 13 studies confirmed that TAM was highly effective in assessing user acceptance of gamified learning tools, especially those integrating AR.

However, user acceptance alone was insufficient without also considering how these tools impact learning. Zhang (2024) strengthened this argument by demonstrating that TAM, when integrated with game-based self-regulation strategies, not only influenced user acceptance but also

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substantially improved perceived learning and academic performance. His study involving 872 university students using Structural Equational Modeling (SEM) found that academic self-efficacy and motivation were important in boosting both technology acceptance and learning outcomes—reinforcing the claim that TAM was not just predictive of usability, but of real educational impact as well.

The consistency of these findings was further confirmed by Rong & Yu (2022), whose systematic review identified TAM as the most applied model in AR educational game evaluation. They found that perceived usefulness and ease of use were the dominant predictors of student acceptance, especially in mobile, handheld-based learning environments. These studies collectively suggest that TAM was not only valid but essential for evaluating both usability and learning efficacy in gamified AR tools.

Going beyond theoretical acceptance, Diaz & Estoque-Loñez (2024) offered quantitative evidence through a meta-analysis of 15 studies. They concluded that gamification led to significant improvements in knowledge retention and learning outcomes across different academic settings. Tools like Kahoot, which used reward-based game mechanics, showed the highest effect sizes—demonstrating how structured gamified elements drove meaningful learning beyond engagement alone.

In agricultural contexts, this became even more critical. Smartico (2025) highlighted real-world platforms such as Plantix and RiceAdvice, which used gamification to enhance sustainable agricultural practices. These tools applied challenges, reward systems, and interactive content to improve both retention and practical application of farming knowledge.

Support for this approach was also found in Oberoi et al. (2023) scoping study on gamification in rural African agriculture, which concluded that simulations and social gaming bridged the gap between information and behavior change. The research emphasized the importance of context-aware design, especially for regions with limited technology infrastructure. Findings showed that gamified interventions were effective in making abstract topics like climate insurance and sustainable farming practices more relatable and actionable.

A Likert scale was a useful tool for assessing user satisfaction in augmented reality (AR)-based game learning environments, as Liu et al. (2024) demonstrated. Students in the experimental group were given a 5-point Likert scale survey as part of their research on AR-enhanced Sanda instruction. This showed how well the Likert scale measures learning objectives, perceived usability, and engagement in game-based augmented reality applications.

Further validating the use of AR in agriculture, Garzón (2020) showed in their aquaponics case study that AR tools used alongside traditional instruction increased knowledge retention and user motivation. These results suggested that AR could meaningfully enhance cognitive engagement and understanding, especially in settings where hands-on practice may be limited.

According to Magtoto (2024a), a study titled "Perceptions and Intentions to Adopt the PhilRice PalayCheck Mobile Application of Rice Farmers from Calauan, Laguna" used an adapted Technology Acceptance Model (TAM) to evaluate farmers’ acceptance of the PalayCheck app developed by PhilRice. The study found that variables such as perceived usefulness (PU), perceived ease of use (PEOU), and social influence (SI) had moderate correlations with intention to adopt (ITA). Despite farmers' generally positive perception of the app, the lack of information awareness was a significant barrier to adoption. Only 24% were aware of the app, and just 7% had used it.

Guerrero et al. (2025), found that combining real-time AR with informative overlays increased user motivation and comprehension in their PETAL application. Their mixed-method evaluation, which included usability testing and survey feedback, showed that users found the tool engaging and effective for learning. The study highlighted the importance of combining immersive technology with educational design to improve knowledge retention and user experience in mobile learning applications.

Synthesis of the State-of-the-Art

The reviewed literature demonstrated the strong potential of augmented reality (AR) and mobile games in enhancing education, particularly in agriculture and STEM fields. Marker-based AR was frequently recommended for regions with limited resources because it operated offline and required less advanced hardware (Vadivu 2021; Antoniadi 2023). This feature made it especially suitable for the Philippine context, where most users relied on Android devices (Statcounter Global Stats, 2025). Consequently, lightweight and stable Android-friendly AR applications were considered ideal for rural communities.

Studies further emphasized the effectiveness of Unity and Vuforia as development platforms for AR-based educational applications. These tools were widely recognized for their accessibility and compatibility with marker-based AR (Koumpouros, 2024; Novia et al., 2024).

Meanwhile, advanced technologies such as SSD MobileNetV2 and OpenCV confirmed the feasibility of real-time crop identification through mobile phone cameras, demonstrating their value for agricultural education (Guerrero, 2025).

In terms of design methodologies, Agile and Scrum were consistently highlighted as effective approaches for developing AR learning applications. Their iterative nature allowed developers to integrate user feedback continuously, ensuring usability and sustained improvement (López et al., 2023; Jiménez & Ramirez 2021). Studies showed that using interactive 3D models and games enhanced learning outcomes, particularly when the design was simple, clear, and tailored to the learner’s age group. (Singh & Ahmad 2024; Koparan et al. 2023).

To evaluate learning apps, many researchers used the Technology Acceptance Model (TAM), which focused on whether users found the app useful, easy to use, and were willing to keep using it (Kalana & Junaini, 2025; Rong & Yu 2022). Some studies, such as on the PhilRice PalayCheck app (Magtoto 2024), showed how the TAM applied to agricultural tools. Tools like Likert scales measured satisfaction and learning gains (Liu et al., 2024; Guerrero et al., 2025).

However, issues remained. Many apps were not easy to use for younger users or those who are not familiar with

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technology (Baki et al., 2024). Others lacked inclusive designs, did not fully support learning, or focused too much on fun rather than education (Cai et al., 2021; Tobar-Muñoz et al., 2023). Few apps successfully combined AR plant recognition, farming lessons, and game-based tasks in one complete mobile app for rural communities. This indicated a clear need for an educational AR game that is accessible and built specifically for youth with real farming content and interactive learning tools.

Gap Bridged by the Study

While past studies illustrated strong support for using AR, mobile games, and agricultural education as separate strategies, very few successfully combined all three into a well-integrated, offline mobile app made specifically for young people in rural areas. Most existing tools focus on just one part—such as using AR for plant recognition, creating learning games without AR, or offering educational content without interaction or local relevance. Because of this, the full potential of combining these features was not fully utilized, especially in places with poor internet connection, basic phones, and unique cultural needs.

In addition, although the Technology Acceptance Model (TAM) was commonly used to measure how users accept new technology, it was not often applied to agricultural learning tools for rural youth. There was still limited research on whether AR learning apps truly improve memory, change behavior, or keep learners interested over time in areas like Partido, Camarines Sur. Many studies examined only at whether users found the tool easy or fun to use, without checking if it meets the specific learning needs of the local community.

This capstone project addressed these gaps through the development of Paratanom—a mobile, Android-based AR farming game that ran offline. It included model-driven AR recognition system, 3D educational visuals, gamified learning tasks, and farming content that was locally relevant and culturally appropriate. The app was developed using Unity and Vuforia, following an Agile process that allowed for regular improvements based on user feedback. The project applied the TAM model and Likert-scale surveys to evaluate usability, user satisfaction, and learning outcomes. Furthermore, the project aimed to promote agricultural awareness and digital literacy among rural youth. It also encourages the preservation of local knowledge about crops and traditional farming practices. By combining technology and education, Paratanom sought to make agricultural learning more interactive, enjoyable, and accessible. Ultimately, the project contributed to sustainable development by inspiring the next generation.

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Chapter 3

TECHNICAL BACKGROUND

This chapter provided a detailed overview of the technical components required to implement the project. Furthermore, it served as a foundational reference for the technologies, tools, and platforms that supported the mobile game, Paratanom.

Software Requirements

The Software Requirements section outlined the core tools and platforms used to build Paratanom from design to deployment. Unity served as the main engine for 2D gameplay and integrated seamlessly with Vuforia and Unity's inference package to achieve a model-driven AR recognition system. Android was the target platform for testing and release, while Windows provided the development environment for running the engine, IDEs, and creative applications. Blender was used to create 3D crop models that appeared during AR interactions, and FireAlpaca supported 2D art and game asset design. Coding was done in C# using Cursor IDE, which offered AI-assisted features to speed up scripting and integration. FL Studio produced the original soundtrack (OST) and sound effects (SFX) to complete the game's audio design. Together, these tools provided a complete pipeline for building, testing, and refining the mobile game.

Table 1

Software Requirements

Software	**Description**	**Version**
Unity	The game engine where the mobile 2D game is developed.	6.2
Vuforia Engine	The AR engine used to power the augmented reality feature of Paratanom.	Vuforia 11.3
Android OS	The operating system where the application is tested and used in.	Android 15 Vanilla Ice Cream
Windows OS	The operating system that is used by the desktop PC.	Windows 10/11
Blender	A 3D modeling application used to create the 3D models of the chosen 11 crops.	Blender 4.3
Fire Alpace	The art software	Fire Alpaca

	used to create the 2D elements and assets for the mobile game.	2.13.18
Cursor	An IDE used to code and added scripts, with AI integration for coding assistance.	Cursor 1.1.5
FL Studio	A Digital Audio Workstation (DAW) used for the game's OST and SFX.	FL Studio 2024 Producer Edition 24.1.2 [build 4349]
Google Collab	A cloud-based notebook environment provided by Google. Used to train the YOLO model for the game with the use of Ultralytics.	
YOLO	A real-time object detection system to recognize the selected 11 crops.	YOLOv8n

Ultralytics	The open-source framework used for implementing the YOLOv8n model to perform real-time crop identification and object detection within the mobile game and used in the development.	v8.3.184
Label Studio	A multi-type data labeling and annotation tool used to label images of crops that trained the YOLOv8n model.	Label Studio 1.20.0
Index TTS2	An open-source large-scale text-to-speech model used in the development.	V1.5.0

Table 1 outlined software requirements presented the different software used in developing the Paratanom mobile game. It included the primary game engine, AR development kit, operating systems, design tools, IDE, and audio software that supported the overall development process. Each software was listed with its specific role, highlighting how these tools worked together to build the gameplay, assets, augmented reality features, and sound design of the application.

Hardware Requirements

This section described the hardware requirements for the system. It listed the specific computer, mobile device, input, and output specifications. The hardware supported development tasks, game builds, and AR testing across desktop and mobile environments. These requirements ensured stable performance during the development of Paratanom.

Table 2

Hardware Requirements

Device	**Hardware**	**Description**
Desktop PC	Processor (CPU)	AMD Ryzen 5 3600 6-Core Processor
	RAM (Random Access Memory)	16 GB DDR4 3660 DIMM 3200MHz
	Graphics Card (GPU)	NVIDIA GeForce GTX 1650 (4 GB)
	SSD (Solid State Drive)	M.2 NVMe 500 GB

	HDD (Hard Disk Drive)	1 TB 7200 RPM
	Motherboard	Gigabyte B450M DS3H Micro-ATX (244 × 215 mm) AM4 Socket AMD B450 Chipset
	Power Supply	450 Watts Generic Powersupply
Laptop	Processor (CPU)	Intel Core i5-11400H
	RAM (Random Access Memory)	8 GB DDR4-3200 SO-DIMM
	Graphics Card (GPU)	NVIDIA GeForce RTX 3050 Laptop GPU (4 GB)
	Storage	512 GB PCIe 3.0 NVMe M.2 SSD
	Display	15.6″ (39.6 cm) Full HD (1920×1080) 144 Hz
Phone	Processor (CPU)	Octa-core (2× Cortex-A76 @ 2.2 GHz + 6× Cortex-A55 @ 2.0 GHz) MediaTek Dimensity 700
	RAM	6 GB LPDDR4X
	Graphics (GPU)	Mali-G57 MC2

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Storage	128 GB UFS 2.2
Camera	Rear: 50 MP wide (f/1.8, PDAF) 2 MP depth (f/2.4) Front: 5 MP (f/2.2), HDR
Battery	5000 mAh Li-Po

Table 2 outlined the hardware requirements, detailing the three (3) devices essential for the development of the Paratanom game application. The desktop PC functioned as the primary workstation, providing the robust hardware configuration necessary for game development, debugging, and iterative testing. The laptop served as a portable alternative, primarily supporting documentation tasks, light programming activities, and quick adjustments during collaborative or remote work sessions. Lastly, the smartphone acted as the target platform for the application. Although its specifications were less advanced compared to newer-generation devices, it served as the baseline for testing and optimizing the game to ensure compatibility and smooth performance on low-end Android-based devices. Its use also reflected realistic user conditions within rural communities, making it a practical benchmark for evaluating accessibility and usability during gameplay.

Chapter 4

METHODOLOGY

This system development focused on the design and implementation of the Paratanom mobile game, following the Agile Software Development Model. It covered the planning, design, coding, testing, and deployment stages necessary for the game to deliver its core functionalities.

Sources of Data

This section outlined the data sources used to address each research objective. Both primary and secondary data were utilized, chosen for their relevance and ability to support the analysis, design, development, and evaluation of the system.

For Research Objective 1, primary data were obtained under the guidance of the Capstone Adviser and through consultations with the project stakeholder, Dr. Jenny P. Lorio, who provided essential insights on traditional and modern farming practices, including major crops cultivated in the area. Their input ensured that the agricultural content in the game was accurate, locally grounded, and culturally appropriate. Secondary data were gathered through literature reviews from academic databases such as Google Scholar and ProQuest, focusing on sustainable farming education, AR-based learning tools, and Android-compatible system requirements.

For Research Objective 2, both primary and secondary data guided the design and prototyping of the game. The user interface (UI) design was inspired by visual references from Pinterest, which served as a creative source for layout, color schemes, and visual flow. The final design concept followed the Software Development Life Cycle (SDLC) model and was initially structured using Canva before refinement for functionality and coherence. The Capstone Adviser validated the chosen design elements to ensure they aligned with the project’s objectives and usability standards. Secondary data were drawn from existing AR game design frameworks and usability case studies to strengthen the design rationale.

For Research Objective 3, the focus was on the development and integration of the Paratanom game’s core features. Primary data were obtained through system logs, developer observations, and iterative prototype testing sessions. Continuous testing refined the crop identification module, 3D overlay display, and gameplay mechanics to ensure smooth performance on AR-compatible Android devices. Secondary data were sourced from technical documentation and tutorials from AR development platforms such as Vuforia and Unity, which provided guidance throughout the implementation and troubleshooting process.

For Research Objective 4, the evaluation and validation phase employed the use of Technology Acceptance Model (TAM). Primary data were collected through surveys, pre-tests, post-tests, and validation sessions involving student participants and expert evaluators. These instruments measured perceived usefulness, perceived ease of use, and behavioral intention to use the application. Expert validators ensured that all assessment procedures aligned with academic and usability research standards. Due to time constraints caused by the cancellation of face-to-face classes during a typhoon, all data collection for Objective 4 was conducted exclusively online. Surveys and testing instruments were deployed through Google Forms to maintain research continuity and ensure participant safety. A total of 144 students participated, representing the accessible Agribusiness student population during the data-gathering period. This sample size was sufficient for reliable computation of weighted means and for validating user acceptance of the application. Secondary data included related TAM-based evaluation studies, which provided comparative benchmarks for analysis.

Data Instrumentation

This section presented the instruments and tools used to collect, analyze, and validate data for each research objective, ensuring systematic development and assessment of Paratanom.

For Research Objective 1, data collection included semi-structured interviews and surveys. Interviews with local elders and agriculturists provided culturally and technically accurate agricultural content, while surveys among students identified user preferences and feature expectations. Secondary data from literature reviews informed hardware and design requirement analysis.

To address Research Objective 2, design validation surveys and expert reviews were conducted to evaluate the game's user interface, visual layout, and mechanics. Design inspiration was drawn from Pinterest, serving as a creative guide for visual consistency and engagement, while Canva was used for the initial layout and visualization of SDLC stages. The Capstone Adviser validated the design to ensure usability and educational relevance.

For Research Objective 3, beta testing served as the primary tool for assessing system performance and functionality. Selected users tested prototype versions of the game and provided structured feedback through surveys and gameplay observation. System logs and developer notes documented performance issues and user responses, enabling iterative improvement before the final release.

For Research Objective 4, the instruments consisted of pre-tests, post-tests, and a TAM-based survey. The tests evaluated students' agricultural knowledge before and after using the application, while the TAM survey measured perceived usefulness, ease of use, and intention to use the system. All testing instruments were administered online through Google Forms due to weather-related time constraints. Expert validators reviewed these tools to ensure accuracy, clarity, and alignment with academic research standards.

Table 3

Likert Scale Metrics

Numeric Value	**Mean Range**	**Interpretation**
1	4.21 – 5.00	Strongly Agree
2	3.41 – 4.20	Agree
3	2.61 – 3.40	Neutral
4	1.81 – 2.60	Disagree
5	1.00 – 1.80	Strongly Disagree

Table 3 outlined the Likert scale metrics used in evaluating the students' responses toward Paratanom. The table established the numerical values, mean ranges, and verbal interpretations that guided the analysis of responses. Higher mean scores corresponded to more positive perceptions, with 4.21 to 5.00 was interpreted as Strongly Agree. This scale served as the basis for interpreting the weighted means across all TAM constructs.

The weighted means derived from the TAM questionnaire provided a comprehensive view of student perceptions regarding Paratanom. Using the Likert scale metrics in Table 3, each TAM construct was evaluated to determine the overall acceptance of the application. The computed mean scores consistently fell within the "Agree" to "Strongly Agree" range, which indicated that the students found the application both useful and easy to use. These results supported the conclusion that Paratanom aligned with the design principles emphasized in TAM, effectively encouraging user intention and potential adoption.

High weighted mean values for Perceived Ease of Use showed that the students were able to navigate and utilize the game without difficulty, even with limited prior exposure to AR-based applications. Similarly, strong ratings for Perceived Usefulness suggested that the game successfully demonstrated agricultural concepts in an accessible manner. The results collectively reinforced the educational value of the application and validated its suitability as a supplemental learning tool for agricultural instruction.

The research team determined the sample size by first identifying the total population of Agribusiness students at the PSU Salogon campus, which was 225 (N = 225). The researcher applied Slovin's formula with a 5% margin of error (e = 0.05) to calculate the minimum required sample size for reliable results. This calculation resulted in a sample size of approximately 144.

A total of 144 students participated in the evaluation. These participants represented the accessible population of Agribusiness students who consented to take the survey during the data collection period. The selection followed Convenience Sampling due to academic scheduling and environmental constraints. The 144 respondents provided an adequate sample for measuring user acceptance and learning outcomes. This sample also offered sufficient diversity in responses to support the validity of the weighted mean analysis.

Due to the suspension of face-to-face classes caused by a typhoon that affected the region, the user testing and survey administration were conducted entirely online. All questionnaires, including the TAM instrument, pre-test, and post-test, were distributed through Google Forms. Despite these constraints, the online format allowed uninterrupted data gathering and ensured the safety of the students while maintaining the integrity of the evaluation process. The digital mode of administration also provided consistent formatting, automated data collection, and reduced the risk of missing responses, thereby contributing to the accuracy of the results. The conversion to online distribution successfully maintained the scheduled evaluation timeline despite the sudden shift in instructional delivery.

Software Development Life Cycle

Figure 2

Agile Software Development Life Cycle

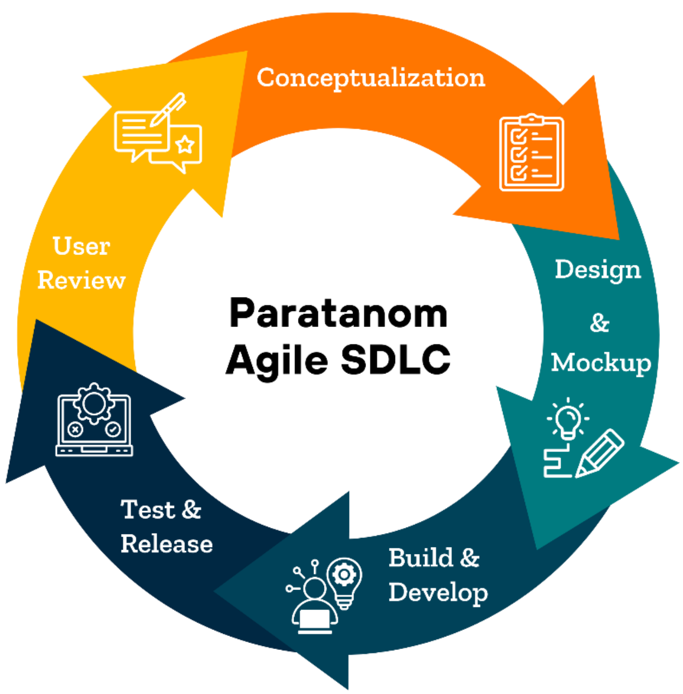

Figure 2 presented the Agile Software Development Model employed in the development of the Paratanom mobile game. The Agile approach was chosen because of its iterative and flexible nature, which allowed continuous improvement and active involvement of users. This ensured that the game remained functional, user-friendly, and engaging for students.

Conceptualization. The process began with planning, where the researchers identified the main problem: students and had limited access to interactive agricultural learning tools, and traditional methods failed to engage younger audiences effectively. To address this, initial data about the common crops in Partido, educational content, game mechanics, and AR requirements were gathered. This stage set the foundation for defining objectives, specifying game features, and creating a roadmap for development.

Design and Prototyping. In this phase, a preliminary design of the mobile game was created. This included wireframes of the user interface, mock-ups of the AR crop identification feature, and the layout of interactive and educational content. The design emphasized interactivity, intuitive navigation, and alignment with the educational objectives identified during planning.

Build and Develop. During development, the Paratanom game was built using Unity as the main game engine, integrated with Vuforia for AR functionality. Features implemented included the AR crop identification scanner, 2D and 3D plant models, interactive farm mechanics, quizzes, and NPC interactions. At this stage, the conceptual design was transformed into a functional mobile game optimized for Android devices.

Test. After development, the game underwent testing by a selected group of students. The goal was to ensure the AR scanner accurately identified crops, game mechanics operated smoothly, educational content displayed correctly, and the overall user experience was engaging. Bugs, usability issues, and errors were documented to inform further refinement.

Release. Once testing and improvements were completed, the mobile game was deployed to the primary users. Students were given access to Paratanom, allowing the researchers to observe how the game performed in real-life scenarios and how users interacted with the AR and gameplay features.

User Reviews. feedback was collected to evaluate the effectiveness and usability of the mobile game. Players provided insights regarding gameplay enjoyment, clarity of educational content, and overall engagement. This review informed subsequent iterations in the Agile cycle, supporting continuous enhancement of the Paratanom game.

Chapter 5

RESULTS AND DISCUSSIONS

This chapter presented the implementation of the study, which covered the system requirements, game design, game development, game testing, and knowledge evaluation.

AR Mobile Game Requirements

The development of Paratanom, an augmented reality (AR) 2D farming mobile game, required the integration of functional, educational, and technical components to ensure both usability and agricultural relevance. The game was designed to recognize common local crops in the Partido region through a model-driven AR object recognition approach, which was chosen for its suitability in educational contexts and reliability on mobile devices, particularly when used offline. According to Shivavarshni and Vadivu (2023), marker-based AR offered stronger performance in resource-limited environments compared to markerless alternatives, supporting its adoption in this study. Beyond crop recognition, the requirements emphasized the inclusion of farming simulation, quest systems, and crop collections to sustain user engagement. These gamified elements reinforced interactive learning, consistent with Hamari, Koivisto, and Sarsa (2014), who highlighted how game mechanics enhance motivation and learning outcomes in educational applications.

Accessibility and inclusivity were also central to the requirements. Audio feedback was delivered through text-to-speech to complement visual overlays, enabling diverse learners to interact with agricultural content more effectively. Bacca et al. (2014) found that AR applications yielded stronger educational outcomes when they provided multimodal learning experiences, which supported the integration of visual and auditory features in the game. Compatibility with Android devices was prioritized to reach the widest possible audience, as Statista (2023) reported Android as the dominant mobile operating system in the Philippines. Optimizing for low- to mid-range devices, alongside offline functionality and localized content, ensured that agricultural education remained accessible to rural youth. User interface elements were also simplified to accommodate first-time learners, ensuring that students with limited technological experience could navigate the AR features with ease. Furthermore, the inclusion of culturally familiar terms and visual cues helped strengthen user connection to the content, making the learning experience more relatable and impactful. Collectively, these requirements highlighted how AR technology, when combined with gamification and inclusive design, provided an engaging and practical tool for agricultural education in the Partido region.

Figure 3

ESRB Rating of Paratanom

This rating ensured that the game's educational content, themes, and gameplay mechanics were appropriate for younger audiences while maintaining an engaging and culturally enriching experience.

Figure 4

Data Gathering of Needed Crops

Figure 4 showed the data gathering of the researchers. The development of the Paratanom application involved a systematic process of gathering and organizing relevant crop information to ensure its practical usefulness for agribusiness students. The researcher initiated the process by identifying crops that are widely cultivated in the Salogon area, considering both staple crops and high-value or indigenous varieties that reflect local agricultural practices. This selection was guided by an understanding of the students' learning needs and the objective of making the application a practical tool for both theoretical and hands-on agricultural knowledge.

Following the identification of crops, the researcher categorized them according to growth requirements, soil compatibility, and optimal farming practices. Detailed information was compiled for each crop, encompassing planting procedures, maintenance strategies, harvesting techniques, and integrated pest management approaches. This organization ensured that the application provides a structured, accessible, and comprehensive guide for users. Verification of the information was conducted through consultation with agricultural experts and cross-referencing with authoritative sources such as government agriculture manuals and local extension services. This step was crucial to maintain the accuracy, reliability, and relevance of the crop data included in the application.

The integration of this information into the Paratanom platform emphasized user accessibility and intuitive navigation, allowing students to easily search for crops and access detailed cultivation guidelines. The careful planning and organization of crop information enhance the application's role as a learning tool, promoting not only knowledge acquisition but also the practical application of agricultural techniques. The resulting system reflects a balance between educational rigor and usability, supporting students' engagement and fostering a deeper understanding of local agricultural practices.

Functional and System Design

The system design provided a comprehensive framework that guided the creation and implementation of the mobile game, Paratanom. The developed application was fundamentally designed as a client-side, single-player experience, with its structure optimized to operate entirely offline. This decision was made to prioritize accessibility for the users based in the Partido district, where internet connectivity was often limited.

The entire application was developed using the Unity Engine, which served as the primary platform for handling the game mechanics, AR 3D rendering, neural network inference, crop recognition, and mobile development. Data persistence was managed entirely client-side, and all progress was saved to the user's mobile device using JSON files, aligning with typical mobile game practices.

An important component of the design phase was the validation of the educational content and structural integrity. The design was formally reviewed and approved by the College Dean, Dr. Jenny P. Lorio. Dr. Lorio validated the accuracy of the information, particularly within the educational module concerning local crops and appropriate agricultural processes. This important step ensured that the academic integrity of the application aligned with regional agricultural best practices before deployment.

Logical Design

The Logical Design highlighted the conceptual and functional representation of the system through diagrams that demonstrated user interactions, system workflows, and relationships between objects. These models provided a clear blueprint of how data flows across components, to ensure that all functional requirements were accurately translated into coherent and organized processes. This structure helped the team plan system behavior before moving into the technical build.

Figure 5

Functional Diagram of Paratanom

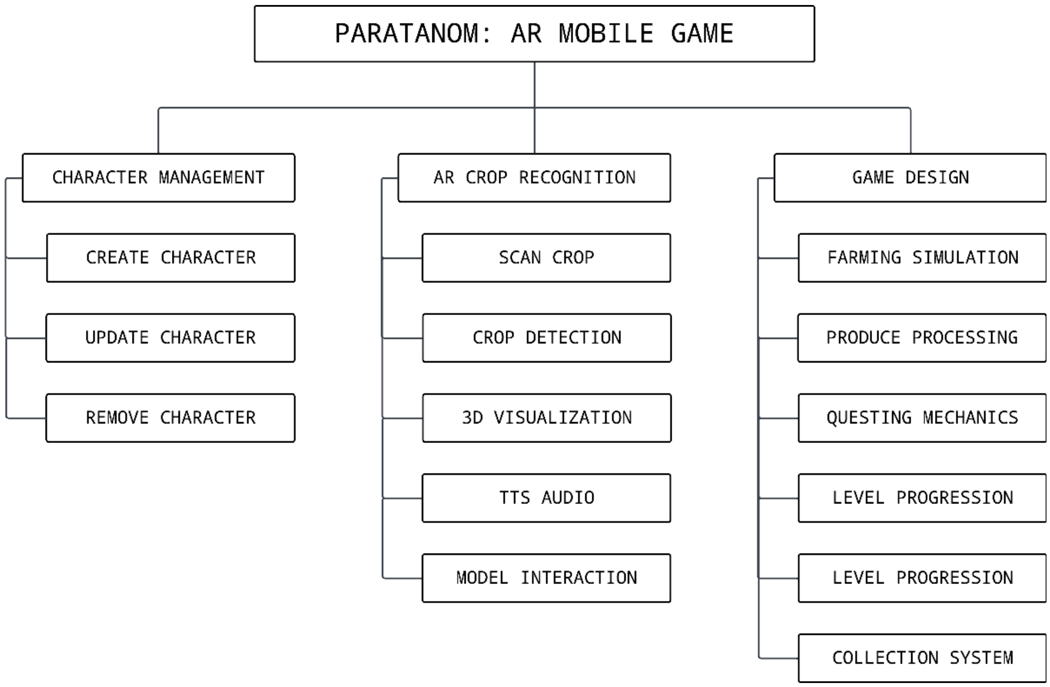

Figure 5 showed the functional diagram of Paratanom, presenting the main systems and features of the game. The game used augmented reality to teach players about local crops in the Partido region through interactive farming gameplay. The first core system was Character Management. Players created and customized a character. They saved and loaded progress, updated character details (for example, the name, clothing, and physical appearance), and removed characters if needed. The second core system was AR Crop Recognition. Players scanned real crops with their mobile device. The system detected the crop, displayed a 3D visualization, and provided audio feedback through text-to-

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speech to make it accessible. Players interacted with digital crop models to connect real plants with in-game learning. The third core system was Game Design. The farming simulation allowed players to grow and process produce. Questing mechanics provided structured tasks with educational elements. Level and story progression guided the player through learning stages, which unlocked more of the game content and story while remaining engaging. A collection system recorded crops and produce that the player had scanned and planted, allowing them to review or refresh their knowledge of the crops they had encountered. Together, these systems created a fun and educational AR farming game. Players interacted with their environment and the game world, learned about local agriculture, and progressed through farming challenges while being immersed in the game's narrative. These integrated systems not only promoted engagement but also enhanced the player's understanding of sustainable farming practices. The functional diagram illustrates how the interconnected systems work together to create educational, and engaging experience that reinforces agricultural knowledge, encourages interactive learning, and motivates players to apply sustainable farming practices both virtually and in real-life contexts.

Figure 6

Use Case Diagram of Paratanom

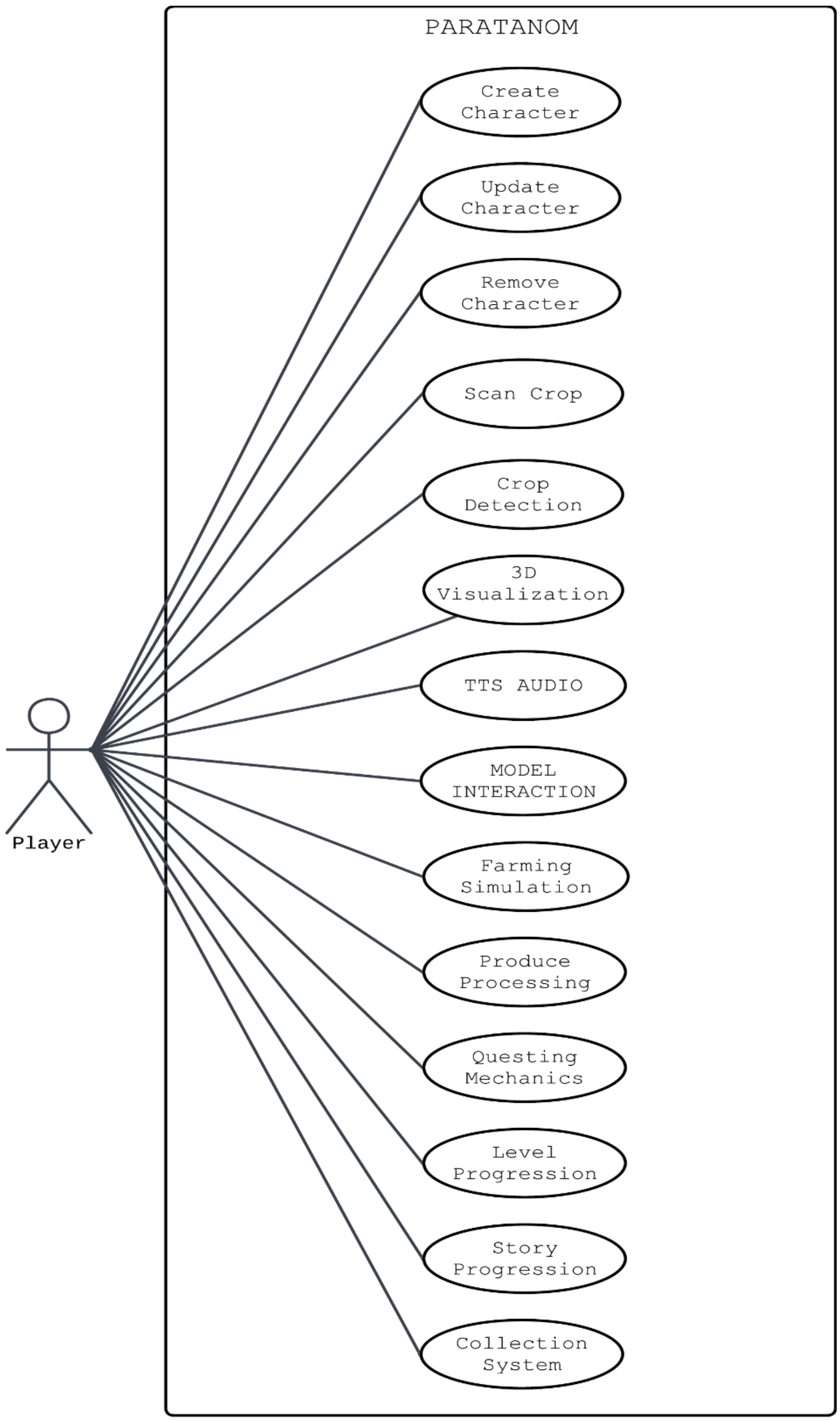


Figure 6 presented the use case diagram of Paratanom.

Each function was tied to a specific action that supported agricultural learning through an augmented reality 2D top-down game. The player managed their character by saving and loading data, creating new characters, updating details, and removing existing characters. This ensured progress tracking and personalization. The player used AR crop recognition by scanning real crops via a trained model. The system detected the crop, generated a 3D model, provided audio feedback through text-to-speech, and allowed interaction with the virtual model. This connected real crops with in-game learning. The player experienced farming simulation through the core gameplay, which included planting and nurturing plants, as well as finding ways to profit and progress through the game. They had the ability to process produce, complete quests, and advance through levels, unlocking more of the game as they played. Story progression guided them through structured learning steps, while the collection system recorded crops and produce scanned during gameplay. The diagram highlighted the direct relationship between the player and every function of the game. It showed how Paratanom linked user actions with character management, AR recognition, and farming-based learning mechanics, whilst making it entertaining for the players.

Figure 7

Swimlane Diagram of Paratanom

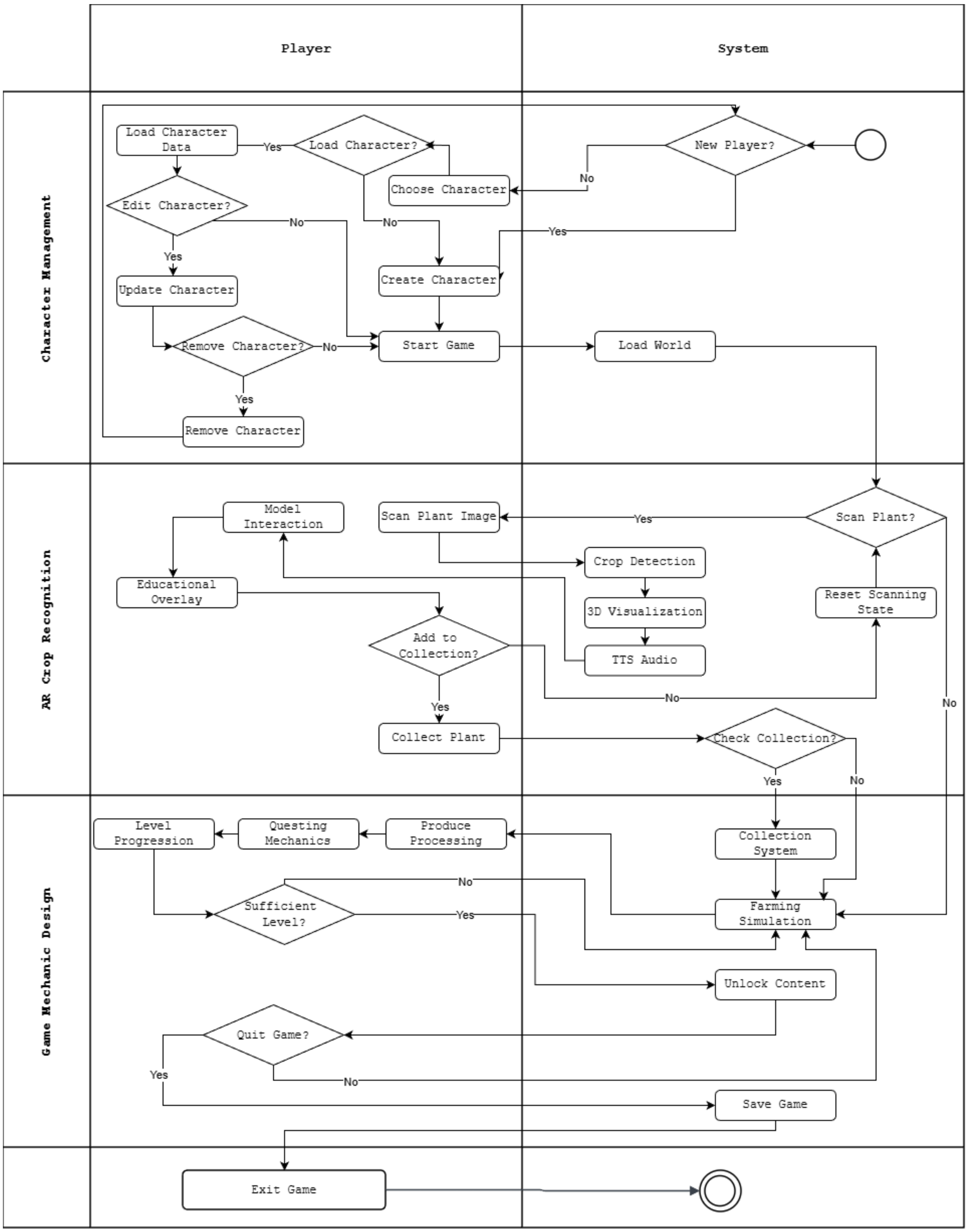
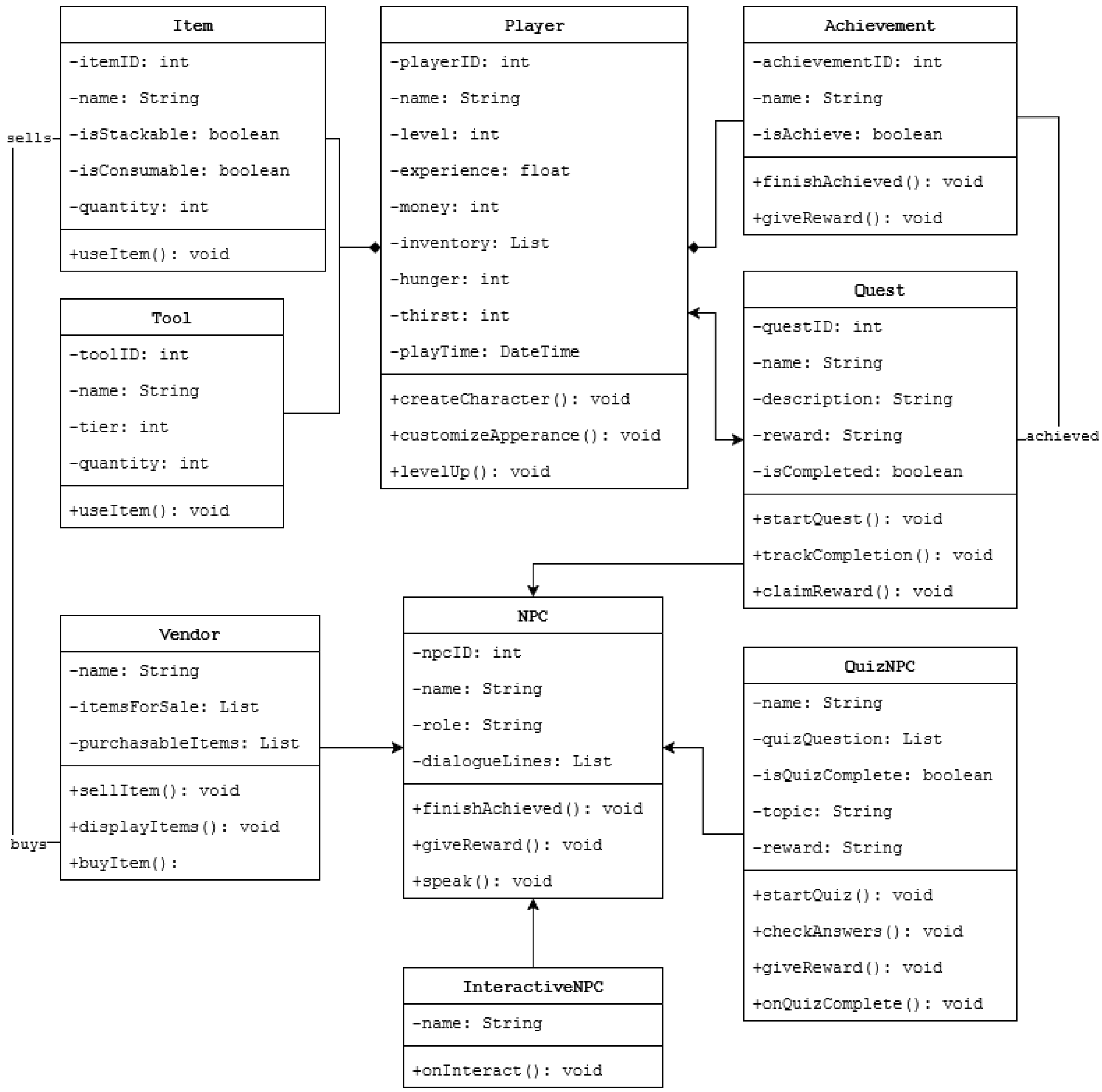


Figure 7 presented Paratanom's swimlane diagram. The lanes grouped actions into character management, AR crop recognition, gameplay systems, and saving. The session started with a check for a new player. New users created a character, while returning users loaded a character. The player could edit details or remove a character before starting the session. These steps kept progress and identity consistent across sessions. Before engaging with AR features, the system provided a brief tutorial overlay to guide new players through scanning mechanics and interface interactions, ensuring that even those unfamiliar with AR could participate effectively and confidently. Additionally, contextual prompts and visual highlights appeared dynamically during gameplay to encourage correct usage of farming tools and AR scanning, reinforcing learning objectives while maintaining user engagement. After starting the game, the world loaded and the AR flow became available. The player chose to scan a plant, then captured a plant image. The AR module performed crop detection, rendered a 3D visualization on the camera view, and played text-to-speech audio with short crop facts. Model interaction and an educational overlay supported closer inspection of leaves, fruit, and growth form. The player decided whether to add the identified plant to the collection. A positive choice created a collection entry and stored the scan for later review. The player could also open the collection at any time to check prior scans. Core gameplay ran in parallel with AR use. The farming simulation drove routine tasks such as tending plots and managing harvests. Produce processing turned harvests into outputs (for example, dried or milled products) once requirements were met. Questing mechanics set goals tied to scans, farming tasks, or processing steps. Level progression updated after task completion. A gate checked for a sufficient level, and when the requirement was met, new content became available, such as new crop entries, tools, or lessons. Story progression advanced after milestone tasks to maintain a guided learning path. Before leaving, the player saved the game to preserve progress, inventory, and collection state. A quit choice ended the session. Declining the quit prompt returned the player to ongoing tasks. The diagram highlighted handoffs across lanes: character management prepared the session, the AR module handled scanning, recognition, and overlays, gameplay systems awarded progress for scans and farming work, and the save system recorded outcomes so the next session resumed without loss. This flow kept learning focused on local crops while maintaining a simple loop of scan, learn, play, and progress.

Figure 8

Character Class UML Diagram



As shown in Figure 8, the Character Class UML diagram illustrated the interaction between the game character and its environment through defined attributes and methods. The inventory attribute was directly connected to farming functions such as plantCrop() and harvestCrop(), as these actions updated the inventory data in real time. The energy

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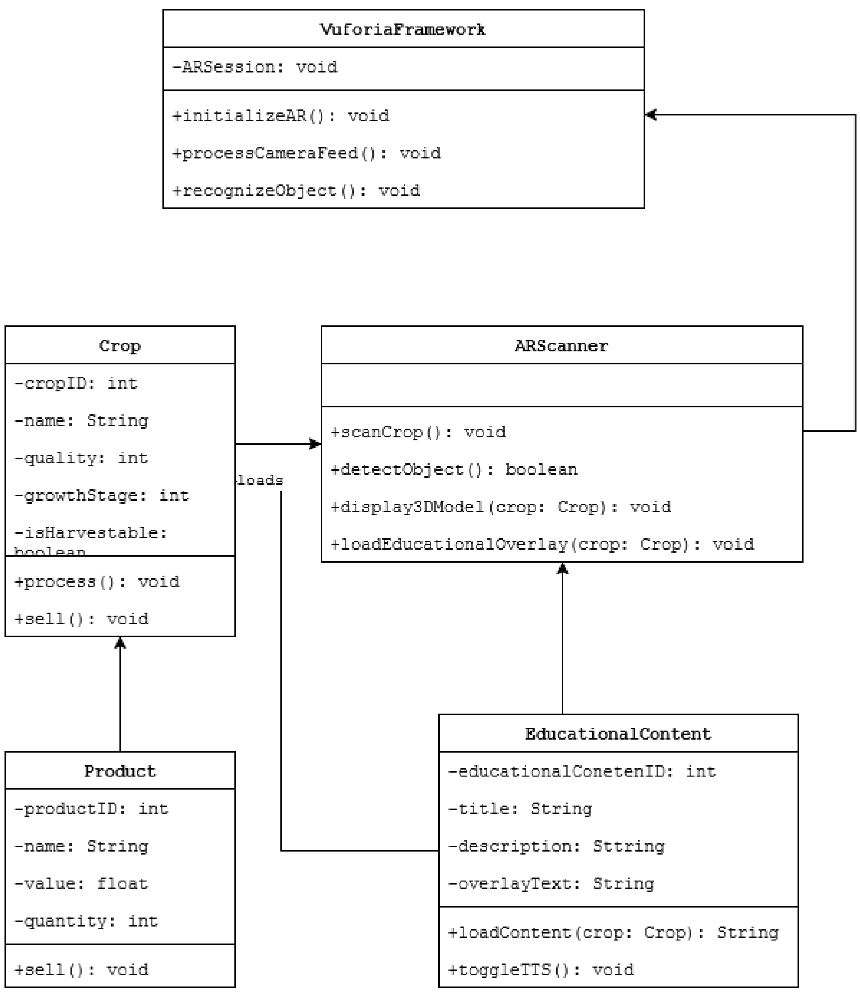
attribute was linked to action methods, emphasizing that each farming task reduced available energy, thereby simulating realistic resource management within gameplay. In addition, the AR scan method integrated crop identification into the system, embedding augmented reality functionality as part of the educational mechanics.

Figure 9

AR and Crop Class UML Diagram



The UML diagram, shown in Figure 9, explained the flow of the crop detection and AR feature in Paratanom. The process started with the AR camera. The camera captured real-world input from the field, and this live feed became the source of data for the detection system. The detection system analyzed the input and checked for crop features such as shape, color, and position. Once crops were identified, the system transformed this information into structured data that the game could use. The next part of the flow was the AR overlay. The system projected digital information on top of the real field through the device screen. The overlay highlighted the detected crops and provided information about them. This included crop type, growth stage, or actions the player needed to complete. This visual feedback made the AR system interactive and useful for both learning and gameplay. The player interacted with this system through the 2D top-down game environment. When a crop was detected by the system, the player received corresponding actions such as watering, harvesting, or checking status. The integration of AR detection and 2D controls made the gameplay both physical and digital. The game manager acted as the central controller. It loaded and updated game objects, managed the flow of information, and ensured that AR results matched player actions. The manager linked the detection system, overlays, and interaction logic. This prevented delays and kept the game responsive. This design showed a clear separation of tasks while keeping the systems connected. The AR camera handled the input, the detection system processed the data, the AR overlay displayed the result, and the player interacted with the output. The game manager tied everything together. This made crop detection efficient and ensured that AR features remained consistent with the gameplay structure of Paratanom.

System Development and Tools

This section focused on the game development and discussion of tools needed for the development.

Figure 10

<u>YOLO Model Data and Training</u>

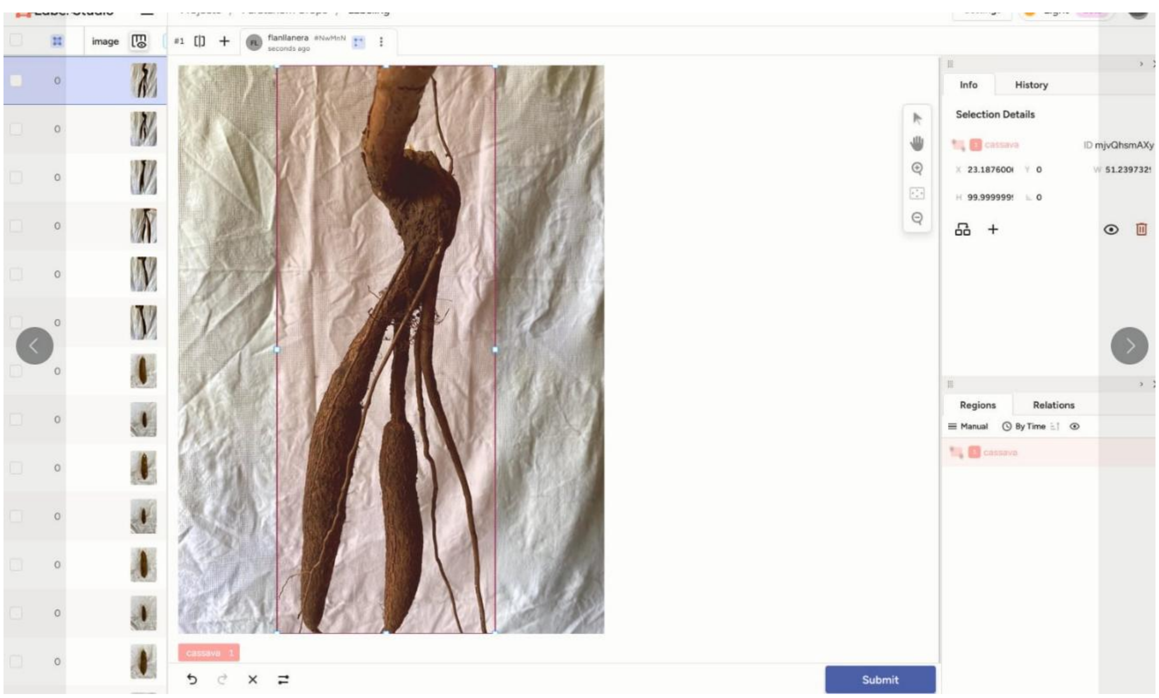
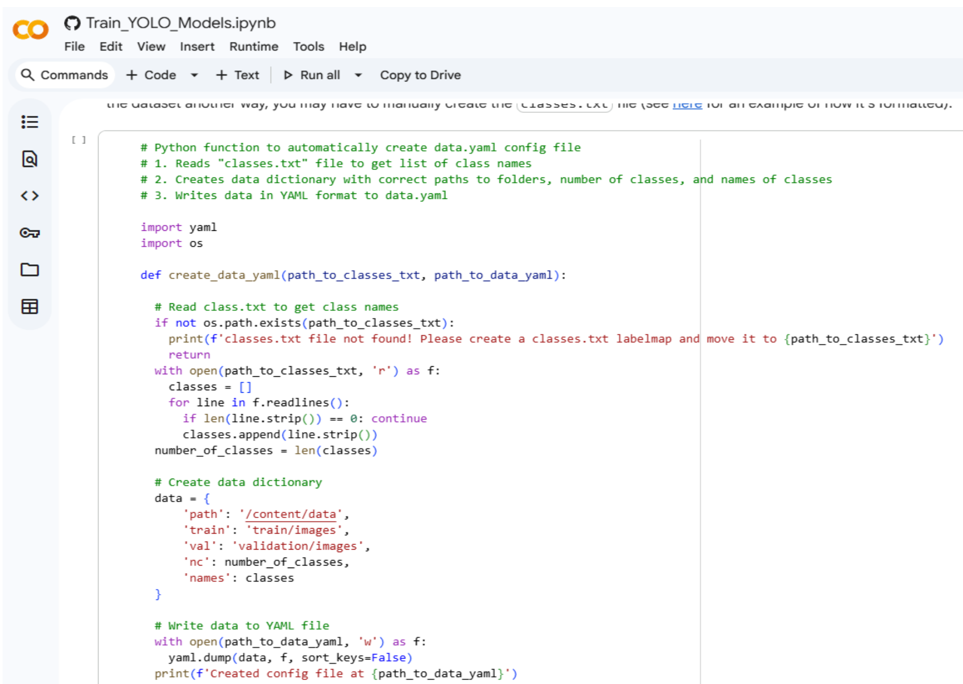


Figure 10 showed the individual labeling of the crops, illustrating the essential preliminary step for training the object detection model. The entire process began with the collection of 500 photos of various crops. These photos were prepared for machine learning by labeling them using the open-source software Label Studio.

Figure 11

YOLO Model Training in Python




```
# Python function to automatically create data.yaml config file
# 1. Reads "classes.txt" file to get list of class names
# 2. Creates data dictionary with correct paths to folders, number of classes, and names of classes
# 3. Writes data in YAML format to data.yaml

import yaml
import os

def create_data_yaml(path_to_classes_txt, path_to_data_yaml):

  # Read class.txt to get class names
  if not os.path.exists(path_to_classes_txt):
    print(f'classes.txt file not found! Please create a classes.txt labelmap and move it to {path_to_classes_txt}')
    return
  with open(path_to_classes_txt, 'r') as f:
    classes = []
    for line in f.readlines():
      if len(line.strip()) == 0: continue
      classes.append(line.strip())
  number_of_classes = len(classes)

  # Create data dictionary
  data = {
      'path': '/content/data',
      'train': 'train/images',
      'val': 'validation/images',
      'nc': number_of_classes,
      'names': classes
  }

  # Write data to YAML file
  with open(path_to_data_yaml, 'w') as f:
    yaml.dump(data, f, sort_keys=False)
  print(f'Created config file at {path_to_data_yaml}')
```

Figure 11 illustrated the Python code used for training the YOLO model, which was executed in a Google Colab notebook environment. The model training utilized the Ultralytics framework within Google Colab, and the researchers employed the YOLOv8n model as the foundation for the custom object detection system.

The successful training process produced an output file with a .pt extension. To ensure compatibility with the game's development platform, a necessary model conversion was performed. The .pt file was converted into an .onnx file format, which the Unity game engine was configured to recognize and integrate into the development environment.

Figure 12

Unity Inference Engine Overview

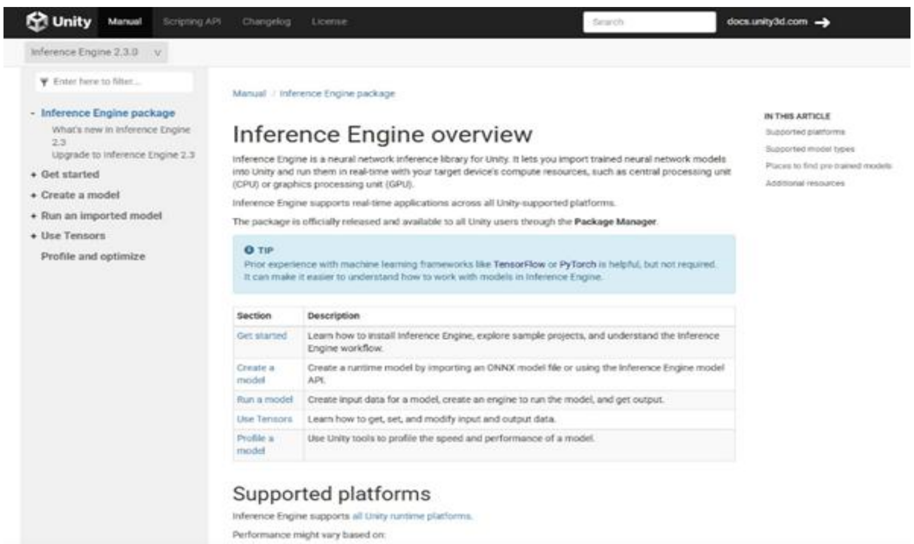


Figure 12 presents the Unity Inference Engine overview, illustrating how the .onnx file was subsequently integrated into the game environment. The application utilized Unity's Barracuda Inference package, which served as a neural network inference library, enabling the system to process data from the custom-trained model and activate the augmented reality functionalities within the final application. This entire workflow—from custom labeling to model training, conversion, and Unity integration—

culminated in the development of a customized object detection system tailored for the educational objectives of the game.

Figure 13

Landing Page of Paratanom

Figure 13 showed the main menu screen of Paratanom. The title logo was displayed at the center of a stylized mobile device, set against a rural background representing the game’s setting. Three buttons labeled PLAY, LOAD, and QUIT were presented below the logo; PLAY started a new game session, LOAD accessed existing save files, and QUIT closed the application. This screen served as the primary entry point to the game, guiding players into either a fresh experience or a continued session and establishing the mobile-focused presentation.

Figure 14

Character Customization

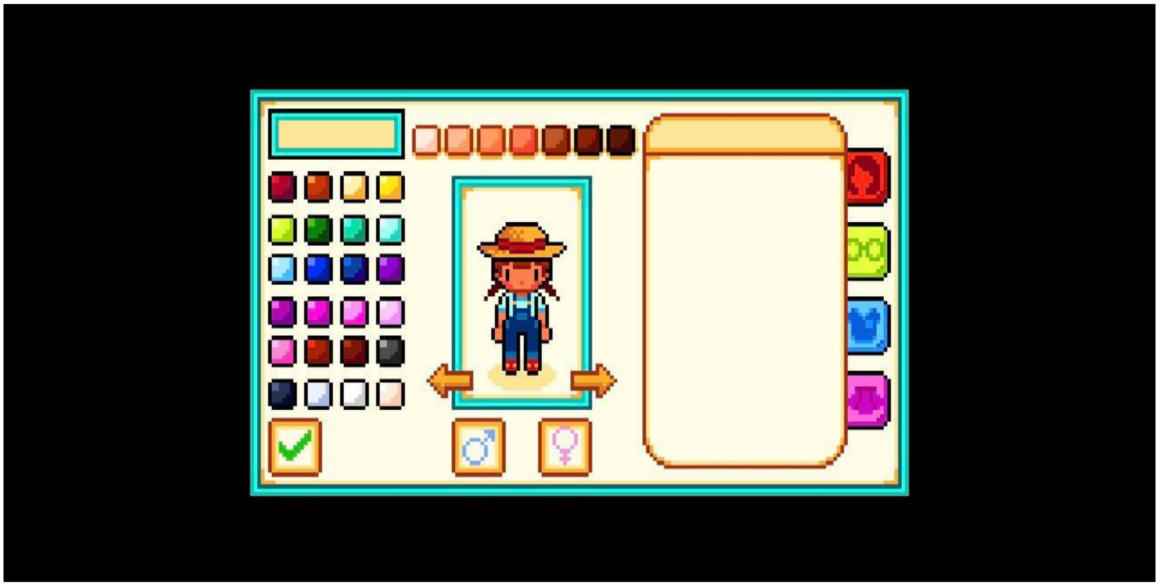


Figure 14 showcased the character customization feature of the game. Players are allowed to personalize multiple aspects of their in-game avatar, ranging from selecting a name and gender identity to adjusting sexual orientation, skin tone, hairstyles, facial features, and clothing options. Beyond appearance, customization influenced in-game interactions, as certain clothing and accessories could be displayed during quests or social interactions with NPCs, adding an extra layer of engagement. By providing a wide range of adjustable features, the system encouraged players to explore different combinations, experiment with styles, and develop a stronger sense of ownership over their avatar, making the game experience more interactive, engaging, and enjoyable.

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Figure 15

Main Gameplay of Paratanom

Figure 15 The figure presented the core gameplay screen of Paratanom, showing the player character standing in front of a house within a bright, tropical farm environment. At the top left, the day counter and time-of-day display indicated the in-game calendar and clock, which were advanced and managed by a day-night cycle system, while the adjacent coin display reflected the player's current money as tracked by a money manager. A row of red apple icons indicated the level of hunger of the player. On the left side of the screen, large arrow buttons provided touch controls for movement. Below the heads-up display, several functional icons formed the main interaction hub: the notebook icon opened a multi-tab

UI that showed active tasks, unlocked achievements, and collected crops; the backpack icon toggled the inventory system, allowing players to view and manage items; and the camera icon launched the separate crop detection scene for augmented-reality item scanning. Along the bottom, an empty hotbar reserved slots for quick-access items.

Figure 16

In-Game Crop Knowledge Quiz Interface

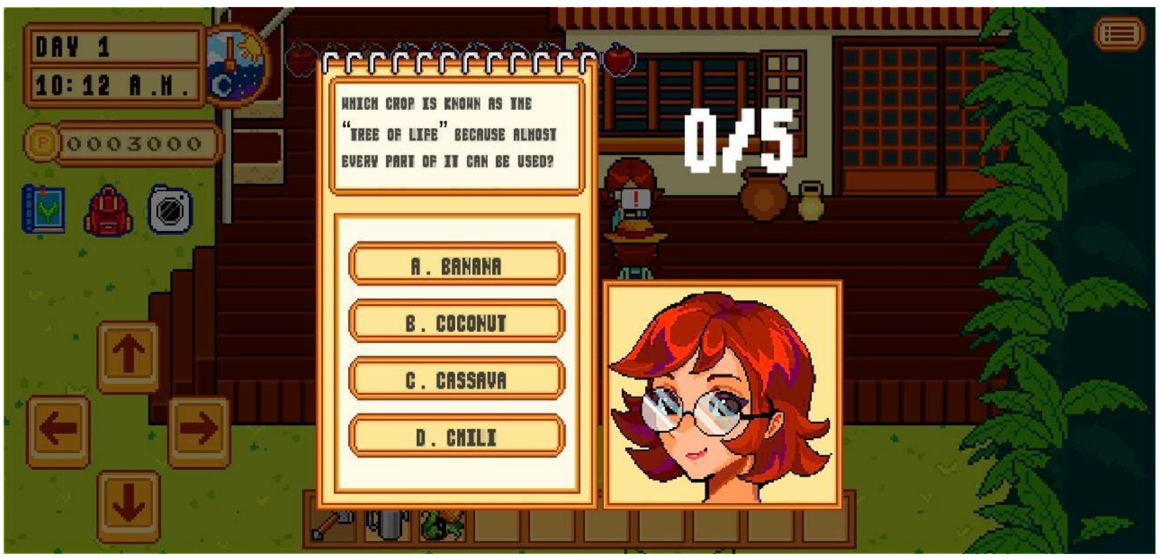

Figure 16 showed the quiz interface, a notebook-inspired UI with multiple-choice questions. The assessment appeared to players at every certain level milestone, and this interface served as the main tool for evaluating a player's understanding of local crops while integrating the learning activity into the core gameplay. Progressing through the quizzes unlocked multiple different features for the player, including in-game currency, level experience, and item rewards.

Figure 17

Save Slots UI

Figure 17 showed the save menu used to store and reload play sessions in Paratanom. A panel in the center listed several numbered slots, some filled with day and time labels and others marked empty. The game treated each slot as an entry in an internal index with a slot number, an empty flag, and metadata such as current day, in game time, and location. Whenever the player chose to save, the central save system gathered snapshots of all registered system, including player position, inventory, crops, money, tasks, quizzes, and achievements, then packed into one structured saved object assigned to the chosesn slot. After writing data to disk, the same system refreshed the index, so the menu showed up to date timestamps and progress for each row.

Figure 18

Notebook Module

The figure showed the notebook interface that the player used to review long term progress in Paratanom. The notebook opened on a spread with two pages, with the left page summarizing the player’s current level and total money, and the lower section listing active tasks with a clear prompt to tap and collect completed rewards. The right page focused on achievements, reserving dedicated slots where unlocked milestones would appear and empty frames signaled goals that had not yet been reached. Every time the player completed a task, won coins, unlocked an achievement, or advanced a level, the changes appeared here as a persistent record of progress since this notebook screen took live data from the same systems that handled saves, tasks, money, and achievements.

Figure 19

Notebook Module Crop Collection Page

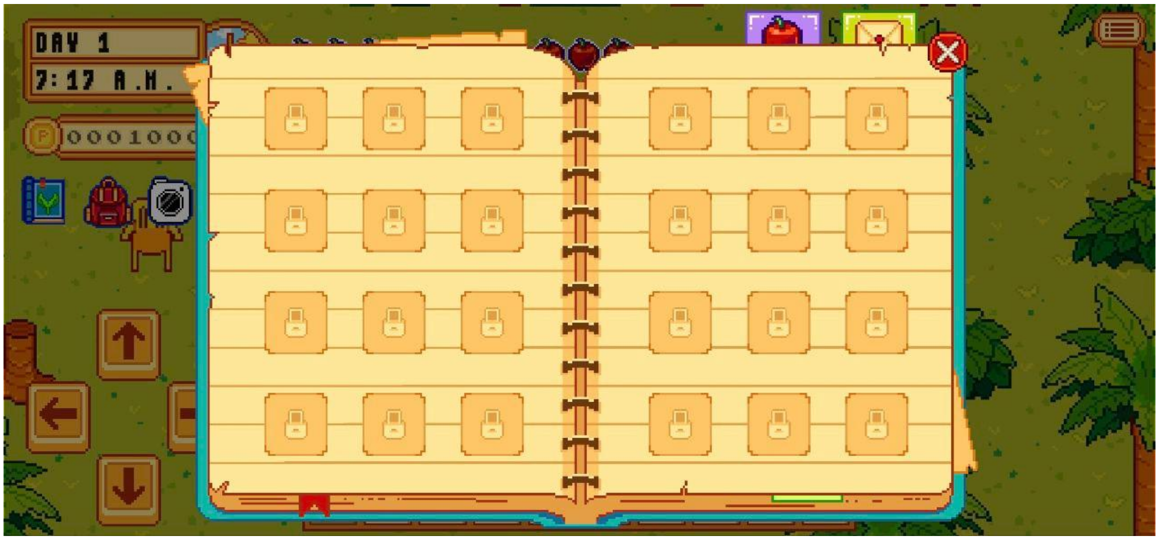

Figure 19 showed players the crop collection page wherein they saw which crops they have collected. These crops were saved and logged in the player's notebook which gave users more access to the crop's detailed information.

Figure 20

Detailed Crop Information

Figure 20 showcased a crop that has been unlocked by the player, which gave them the capability to learn more about the crop, ranging from its use case and cultural importance for the people in Partido to products made from it and how it is grown.

Figure 21

Crop Detection of Coconut Using YOLOv8n

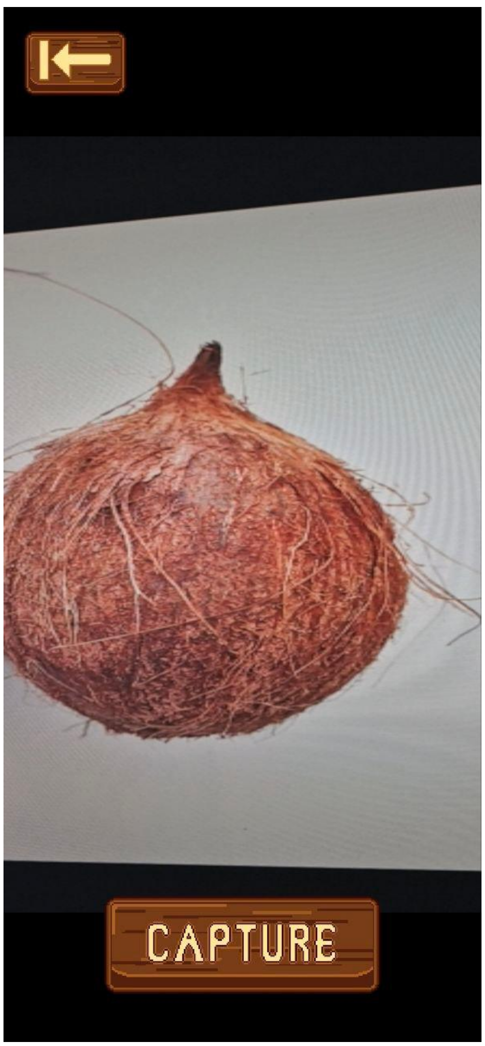

Figure 21 displayed the camera interface used for the crop detection component of the game. The central area presented the device's camera view, showing an image of a coconut framed for capture. At the bottom of the screen, a large CAPTURE button was provided, which the user pressed to capture a frame to be analyzed by the YOLO model to determine what plant the user is pointing at.

Figure 22

Coconut AR Display

Figure 22 presented the result of the AR interaction. A large 3D model of a crop that was detected by the YOLO model was rendered in the foreground over the detected object. The interface showed a back button in the upper left and two buttons at the bottom labeled COLLECT and LEARN MORE. Pressing COLLECT added the coconut to the player's in-game collection, while LEARN MORE opened additional information about the crop.

Figure 23

Crop Information and Text-to-Speech Feature

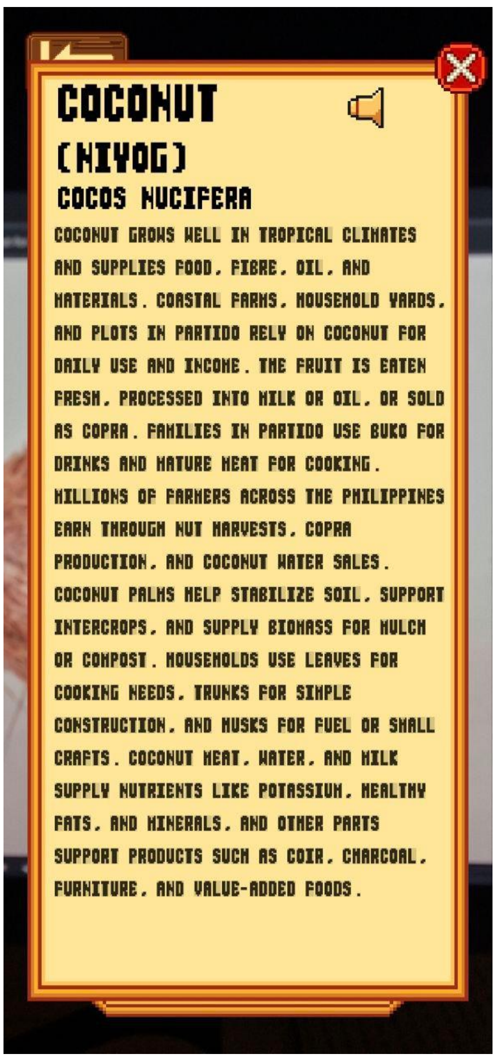

Figure 23 displayed the crop's brief description. This includes the name, local name, and scientific name of the crop. A speaker icon on the top right is a button that enables an A.I. text-to-speech recording to play that reads out the description of the crop.

Game Testing and Evaluation

The testing and evaluation of the Paratanom mobile game, an AR-based 2D farming application, focused on two main areas: user acceptance and educational effectiveness. The Technology Acceptance Model (TAM) served as the primary evaluation framework, specifically measuring the game's perceived ease of use and perceived usefulness, alongside its effectiveness in supporting agricultural learning. The target users, students, were the respondents for this evaluation. The initial procedural step involved obtaining necessary stakeholder approval from the Dean of Partido State University - Salogon Campus, Ma'am Jenny P. Lorio, before visiting the campus to formally present the game concept and secure authorization for user testing among the students, as shown in Appendix B. This ensured compliance with institutional protocols.

A key part of the evaluation was the knowledge assessment, which began with a dry run conducted with selected Agribusiness students from the Salogon Campus. The students completed a pre-test to analyze their existing knowledge about common crops. The researcher then demonstrated or ran a demo of the actual application usage before the students took the post-test.

Figure 24

Technology Acceptance Model

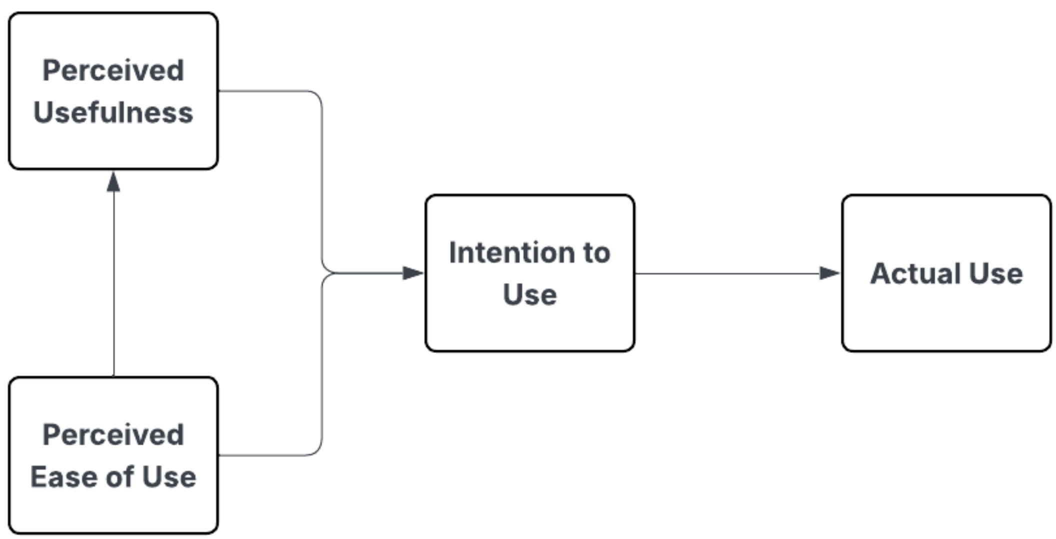

Figure 24 displayed the core relationships of the Technology Acceptance illustrating. The model illustrated how two primary variables, Perceived Ease of Use and Perceived Usefulness, directly influenced a user's Intention to Use a new technology. Specifically, Perceived Ease of Use referred to the user's belief that using the application would be effortless. This belief also directly impacted Perceived Usefulness, suggesting that an easier system was often viewed as a more useful system. Perceived Usefulness referred to the user's belief that the application would enhance their performance or learning.

Both Perceived Ease of Use and Perceived Usefulness acted as predictors of the user's desire to adopt the technology.

Figure 25

Stacked Row Chart for Pre-test and Post-test among Agribusiness Students

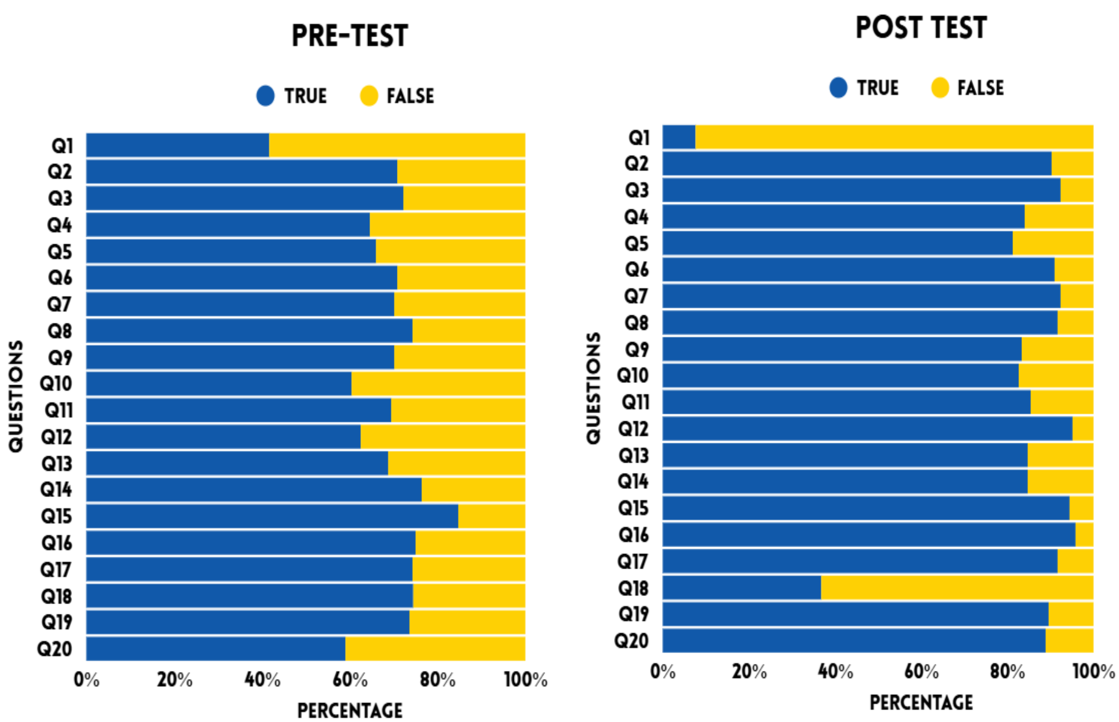

Figure 25 displayed the stacked row chart for the pre-test and post-test evaluation, visually compared the percentage of True and False responses for the twenty questions (Q1-Q20) in both assessments. The results identified that the post-test after the demonstration of the application was successful, see Appendix F for the key to correction and copy of questions. This success, evidenced by the shift toward a higher percentage of correct answers in the post-test chart compared to the pre-test chart, indicated that the use of Paratanom contributed positively to the students' knowledge acquisition regarding common crops.

Table 4

Evaluation Result for Perceived Usefulness (PU) among 144 Agribusiness Students from Salogon

Perceived Usefulness (PU)	**WM**	**Interpretation**
Using Paratanom enhances my understanding of agricultural concepts.	4.61	Strongly Agree
Paratanom helps me learn farming practices more effectively.	4.67	Strongly Agree
Paratanom contributes to improving my awareness of sustainable agriculture.	4.70	Strongly Agree
Paratanom provides useful information related to local crops and farming.	4.57	Strongly Agree
Overall, I find Paratanom beneficial for learning about agriculture.	4.71	Strongly Agree

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
Website: www.parsu.edu.ph
ISO 9001:2015 Certified

AVERAGE WEIGHTED MEAN	4.65	Strongly Agree

Table 4 presented the questions for the perceived usefulness of the application. The evaluation among 144 Agribusiness students from Salogon showed strong approval of Paratanom. The results confirmed that the team produced a useful educational tool with clear value to the students.

The first indicator had a weighted mean of 4.61, interpreted as Strongly Agree. This showed that most students improved their understanding of agricultural concepts through the application. The result indicated that the content supported clear and effective learning.

The second indicator had a weighted mean of 4.67, also Strongly Agree. This showed that the students gained practical knowledge they applied to real agricultural tasks. The finding supported the goal of strengthening both conceptual and applied learning.

The third indicator reached a weighted mean of 4.70, the highest score in the set. This showed that the platform strengthened student awareness of sustainable farming practices. The result highlighted the value of the content in promoting responsible agricultural methods.

The fourth indicator recorded a weighted mean of 4.57. This showed that the students found the information relevant to local crops and farming conditions. The score confirmed that the tool supported regional learning needs in agriculture.

The fifth indicator reached a weighted mean of 4.71, the highest individual score. The overall average for the category was 4.65, interpreted as Strongly Agree. The results showed that the students viewed Paratanom as a useful and practical tool for learning about agriculture.

Table 5

Evaluation Result for Perceived Ease of Use (PEOU) among 144 Agribusiness Students from Salogon

Perceived Ease of Use (PEOU)	**WM**	**Interpretation**
Learning how to use Paratanom was easy for me.	3.77	Agree
I find it easy to navigate and interact with Paratanom's features.	4.40	Strongly Agree
The design and layout of Paratanom make it simple to understand.	4.59	Strongly Agree

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
Website: www.parsu.edu.ph

I can use Paratanom without requiring much assistance.	4.64	Strongly Agree
Overall, Paratanom is user-friendly and easy to operate.	4.65	Strongly Agree
AVERAGE WEIGHTED MEAN	4.41	Strongly Agree

Table 5 presented the evaluation of Perceived Ease of Use among 144 Agribusiness students from Salogon. The results showed that the team created a user-friendly application. The average weighted mean of 4.41, interpreted as Strongly Agree, confirmed the success of the design approach.

The first indicator had a weighted mean of 3.77, interpreted as Agree. This was the lowest score in the set. The result showed that some students needed more support during the first use of the application. The finding signaled the need to improve the onboarding process to give clearer initial guidance.

The second indicator recorded a weighted mean of 4.40, interpreted as Strongly Agree. This showed that students found the navigation clear after they explored the interface. The result supported the strength of the layout and feature organization.

The third indicator reached a weighted mean of 4.59, also Strongly Agree. This score confirmed that the design was simple to understand. The interface supported smooth interaction and reduced confusion.

The fourth indicator had a weighted mean of 4.64. Students agreed that they used the application without much assistance. This supported the goal of promoting independent use.

The fifth indicator reached the highest score in the category with a weighted mean of 4.65. Students viewed the application as easy to operate. This showed that the initial learning curve did not affect long-term usability.

The results showed that the application was easy to use. The next step for development focused on improving the first-time user experience.

Table 6

Evaluation Result for Attitude Toward Use (ATU) among 144 Agribusiness Students from Salogon

Attitude Toward Use (ATU)	**WM**	**Interpretation**
I enjoy using Paratanom as a learning tool.	4.22	Strongly Agree

Using Paratanom makes agricultural learning more interesting.	4.58	Strongly Agree
I feel positive about using Paratanom for educational purposes.	4.72	Strongly Agree
Paratanom encourages me to explore more about farming.	4.79	Strongly Agree
I believe using Paratanom is a good idea for promoting agricultural awareness.	4.73	Strongly Agree
AVERAGE WEIGHTED MEAN	4.61	Strongly Agree

Table 6 presented the scores for Attitude toward Use of the application. The results showed strong positive engagement across all indicators.

The first indicator, which measured enjoyment in using Paratanom as a learning tool, had a weighted mean of 4.22 and was interpreted as Strongly Agree. This score showed that students felt engaged while using the platform. The finding supported the idea that the experience encouraged motivation and interest in learning.

The second indicator, which assessed whether the application made agricultural learning more interesting, scored 4.58. Students viewed the platform as an effective way to make lessons more engaging. The result confirmed that the interactive AR approach and game elements improved how students experienced agricultural topics.

The third indicator measured positive feelings toward using the application for educational purposes. This score reached 4.72. The finding showed that students felt confident using digital tools to support their studies.

The fourth indicator, which measured whether Paratanom encouraged deeper exploration of farming topics such as crop information, cultural significance, different use case of the crop, and how it is grown, recorded the highest score of 4.79. This result showed that the platform promoted independent learning. Students were motivated to seek more information outside the application and exploring on their own.

The fifth indicator, which evaluated whether Paratanom was a good idea for promoting agricultural awareness, scored 4.73. This showed that students viewed the platform as helpful not only for their personal learning but also for raising awareness in their community specifically in the Partido region.

The overall results showed that students held a strong positive attitude toward the application. The high scores supported the long-term potential of Paratanom as a tool for sustained learning while also being a fun mobile game.

Table 7

Evaluation Result for Behavioral Intention to Use (BI) among 144 Agribusiness Students from Salogon

Behavioral Intention to Use (BI)	WM	Interpretation
I plan to continue using Paratanom in the future.	4.29	Strongly Agree
I intend to use Paratanom whenever I want to learn about agriculture.	4.64	Strongly Agree
I will recommend Paratanom to others interested in farming or gardening.	4.72	Strongly Agree
I am likely to use Paratanom for further agricultural learning.	4.76	Strongly Agree
I am interested in exploring similar	4.79	Strongly Agree

educational applications like Paratanom.

AVERAGE WEIGHTED MEAN	4.64	Strongly Agree

Table 7 presented the scores for Behavioral Intention to Use. The average weighted mean of 4.64, interpreted as Strongly Agree, showed strong commitment from the students. The results confirmed that their positive views on usefulness, ease of use, and attitude led to a clear intention to continue using Paratanom.

The first indicator measured the students' plan to keep using the application. The weighted mean was 4.29. This was the lowest score in the category, but it still showed strong intent. The result suggested that regular updates and new features would help maintain long-term interest.

The second indicator asked if students intended to use Paratanom whenever they wanted to learn about agriculture. The score reached 4.64. This showed that the application was becoming part of their regular study habits. Students viewed it as a primary source for agricultural information.

The third indicator recorded a weighted mean of 4.72. Students were willing to recommend the application to others. This result reflected strong trust and satisfaction with the platform.

The fourth indicator measured the likelihood of using Paratanom for future agricultural learning. The weighted mean was 4.76. Students viewed the application as a dependable tool for ongoing study.

The fifth indicator earned the highest score in the evaluation with 4.79. This measured student interest in exploring similar educational applications. The result showed that Paratanom encouraged openness to other digital tools for agriculture.

The overall results showed strong motivation for continued use. The platform established a solid foundation for long-term engagement and consistent learning.

Table 8

Summary of TAM Evaluation Results among 144 Agribusiness Students from Salogon Campus

Technology Acceptance Model	**Average Weighted Mean**	**Interpretation**
Perceived Usefulness (PU)	4.65	Strongly Agree
Perceived Ease of Use (PEOU)	4.41	Strongly Agree

Attitude Toward Use (ATU)	4.61	Strongly Agree
Behavioral Intention to Use (BI)	4.64	Strongly Agree
TOTAL AVERAGE WEIGTHED MEAN	4.57	Strongly Agree

Table 8 of showed that all four TAM dimensions reached high scores. The Total Average Weighted Mean was 4.57 and was interpreted as Strongly Agree. This result confirmed strong acceptance of Paratanom among the 144 Agribusiness students from Salogon Campus. The evaluation showed that the tool was useful, engaging, and suitable for sustained educational use.

Perceived Usefulness recorded the highest score with a mean of 4.65. Students viewed the application as helpful in improving their understanding of agricultural concepts. They also valued the focus on sustainable practices and local farming knowledge. The strong score showed that the content met their learning needs.

Attitude Toward Use followed with a weighted mean of 4.61. Students reported strong interest in using the application. The results showed that they found the learning experience more engaging and were encouraged to explore more about farming.

Behavioral Intention to Use recorded an average score of 4.64. Students planned to continue using the application for their future studies. They also showed strong willingness to recommend the platform to others, which reflected solid trust and satisfaction.

Perceived Ease of Use recorded a weighted mean of 4.41. Students found the interface clear and simple to follow. The score suggested that the design supported independent use, although the onboarding process needed slight improvement for new users.

The overall results showed strong acceptance across all dimensions. The high scores confirmed that Paratanom supported its objectives and provided value for long-term agricultural learning.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary of findings, conclusions and recommendations of the study.

Conclusions

Based on findings, the conclusions below are hereby presented.

1. Paratanom, an augmented reality (AR) 2D farming mobile game, integrated functional, educational, and technical requirements to create a practical learning tool for agricultural students in the Partido region. The system employed a model-driven AR approach, where a YOLO-based object detection model identified crops directly from the camera feed, enabling reliable recognition on low- to mid-range Android devices even without ARCore support. Vuforia was utilized solely as the AR camera provider to ensure broad device compatibility. Gamified elements such as farming simulations, quest systems, and crop collections enhanced user motivation and reinforced learning. Text-to-speech features supported accessibility for diverse learners. Local crop data were systematically gathered, categorized by growth requirements, soil compatibility, and optimal farming practices, and verified through expert consultation and authoritative sources. The application

presented structured, easy-to-navigate information on planting, maintenance, harvesting, and pest management. Content review following ESRB guidelines confirmed appropriateness for younger audiences while maintaining cultural relevance. By combining AR, gamification, and inclusive design, Paratanom delivered an interactive educational platform that promotes agricultural knowledge and practical skills.

2.The system design of Paratanom provided a structured framework for implementing its augmented reality 2D farming gameplay, integrating character management, AR crop recognition, and educational farming mechanics. Logical design components, including functional, use case, and swimlane diagrams, detailed user interactions, system workflows, and relationships between objects, guiding development and ensuring usability. Character management allowed creation, customization, and progress tracking of player avatars, while the AR crop recognition module enabled real-world plant scanning, 3D visualization, and text-to-speech audio feedback. Core gameplay systems included farming simulation, quest progression, crop collection, and produce processing, all structured to promote engagement and learning. UML diagrams for character and crop classes demonstrated the interactions of attributes and methods with game actions, linking inventory, energy, and AR scanning to gameplay mechanics. The AR camera, detection system, overlay, and game manager functioned together to provide responsive, interactive, and educational experiences. This design ensured seamless integration of learning objectives, gamification, and AR technology, creating an immersive system that reinforced knowledge of local crops and sustainable farming practices.

3. The Paratanom mobile game used a focused set of tools for gameplay and AR features. Unity served as the main engine and supported the 2D farming system and player interactions. Vuforia provided the AR camera and delivered stable tracking on Android devices, including devices without ARCore support. A YOLO-based model handled crop recognition from the live camera feed and triggered the correct AR prefab inside Unity. Android OS and Windows OS supported testing and deployment. Fire Alpaca produced the 2D art. Blender produced the 3D models. FL Studio produced the audio. Coding took place in Cursor IDE with AI support. YOLOv8n training used Label Studio and Google Colab to reach reliable crop detection. These tools worked together to deliver an educational platform with stable gameplay, AR learning, and responsive design.

4.The evaluation of the Paratanom mobile game demonstrated high user acceptance and educational effectiveness among 144 Agribusiness students from Salogon Campus. Using the Technology Acceptance Model (TAM), the game was assessed across four dimensions: Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Attitude Toward Use (ATU), and Behavioral Intention to Use (BI). For PU, weighted means ranged from 4.57 to 4.71, with an average of 4.65, indicating that students strongly agreed that Paratanom enhanced understanding of agricultural concepts, supported learning of farming practices, promoted awareness of sustainable agriculture, and provided relevant information about local crops. PEOU scored an average weighted mean of 4.41, reflecting that students found the interface intuitive, easy to navigate, and manageable, with minor initial guidance required. ATU achieved an average of 4.61, showing strong positive engagement, motivation, and confidence while using the platform. BI obtained an average of 4.64, highlighting students' intention to continue using the application, recommend it to others, and explore similar digital learning tools. The overall total average weighted mean across all TAM dimensions was 4.57, interpreted as Strongly Agree. These results indicate that Paratanom was highly effective in delivering agricultural knowledge, engaging users, and promoting sustained adoption, confirming the game's success as both an educational and interactive AR-based learning tool.

Recommendations

Based on the conclusions presented, the following recommendations are hereby provided.

1. By successfully executing the process, design, and testing compilation, Paratanom showed the possibility of creating an effective mobile AR learning tool through the alignment of its functional, educational, and technical requirements. The team prepared the application for wider use in the Partido district through planned deployment on public platforms like the Google Play Store. This expansion required immediate updates to strengthen regional relevance. The team expanded the crop list and focused on indigenous and high-value varieties found across Partido. They added region-specific farming practices, seasonal changes, and real-time conditions to match local needs.

2. The design effectively combined character management, AR crop recognition, and gamified learning, but further enhancements improved usability and interactivity, especially on low- to mid-range Android devices. The team optimized the AR module for offline functionality, reduced loading times, and improved navigation and visual cues to make the system accessible to a wider range of users. They expanded game mechanics, expanding quest and tasks,

storyline expansion, and collection rewards to sustain engagement while reinforcing learning objectives. Regular testing of the interface and educational overlays ensured a seamless balance between gameplay, AR functionality, and instructional content.

3. The integration of multiple software tools and engines allowed Paratanom to operate as a cohesive educational platform. The team focused on sustaining high user engagement confirmed by the evaluation. They introduced optional multiplayer and cooperative learning modes to encourage collaboration among students on simulated farming tasks. They added interactive elements such as leaderboards and digital cosmetic rewards earned through completing challenges and tasks to maintain long-term engagement. They ensured the application remained compatible with a wide range of Android devices and operating systems. This approach made the learning experience more inclusive and extended the application's reach among rural learners.

4. The evaluation results confirmed high user acceptance and educational effectiveness, but the team recognized that continuous monitoring and iterative improvement were crucial to maintain these outcomes. They gathered feedback from a broader range of learners,

including younger students and community members, to identify areas for refinement. Periodic usability assessments, content updates, and feature expansions ensured the game remained engaging, educational, and relevant. They incorporated adaptive learning elements, where the game adjusted difficulty or content based on the user’s knowledge level, to enhance learning outcomes and sustain interest over time.

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Appendices

APPENDIX A

TURNITIN PLAGIARISM REPORT

Turnitin-Paratanom_Group_14

Turnitin-Paratanom_Group_14

Turnitin

Document Details

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APPENDIX B

USER TESTING LETTER

Republic of the Philippines
PARTIDO STATE UNIVERSITY
Camarines Sur

BAGONG PILIPINAS

November 6, 2025

Dr. Jenny P. Lorio
Partido State University (Salogon Campus)
Salogon, Camarines Sur

Dear Ma'am Jenny,

Greetings!

We, the undersigned incoming fourth-year Bachelor of Science in Information Technology (BSIT) students from Partido State University, are currently enrolled in CAP2 – Capstone and Research 2 as part of our academic requirements.

Our group is presently conducting a research project titled "*Paratanom*: An Augmented Reality 2D Farming Top-down Singleplayer Game for Agricultural Education." As part of our study, particularly Objective No. 4 – to test and evaluate the effectiveness of the developed system, we respectfully request permission to conduct a survey among one hundred (100) students of Partido State University – College of Agribusiness and Community Development, Salogon Campus. The purpose of this survey is to gather user feedback and evaluate the system's performance and usability.

All information to be collected will be used solely for academic and research purposes and will be treated with the utmost confidentiality.

We sincerely hope for your favorable consideration of this request. Should you need further information, you may reach us at pkcrispino517.pbox@parsu.edu.ph.

Thank you very much for your time and support.

Mabalos pong maray!

San Juan Bautista St., Goa, Camarines Sur 4422 Philippines
Contact Nos.: 09696087792 (Smart)
Website: www.parsu.edu.ph Email: op@parsu.edu.ph

Republic of the Philippines
PARTIDO STATE UNIVERSITY
Camarines Sur

BAGONG PILIPINAS

Yours truly,

Jeremy Zion L. Jamer
Researcher, BSIT4A

Phoebe Kaye R. Crispino
Researcher, BSIT4A

Mark Lesther F. Nacario
Researcher, BSIT4A

Endorsed by:

Mr. Charles P. Jamer
Paratanom, Adviser

Noted by:

Dr. Kennedy C. Cuya
CAP2, Instructor

Approved

Dr. Jenny P. Lorio
College Dean, College of Agribusiness and Community Development – Salogon Campus

San Juan Bautista St., Goa, Camarines Sur 4422 Philippines
Contact Nos.: 09696087792 (Smart)
Website: www.parsu.edu.ph Email: op@parsu.edu.ph

APPENDIX C

TOTAL POPULATION DATA

Republic of the Philippines
PARTIDO STATE UNIVERSITY
Camarines Sur

Office of the Registrar
ParSu Salogon Campus

SUMMARY OF ENROLMENT
Bachelor of Science in Agribusiness and
Bachelor of Science in Community Development
1st Semester, AY 2025-2026

Year Level	Male	Female	Total
BS Agribusiness (BSAB)	104	121	225
BS ComDev (BSCD)	32	74	106
TOTAL	136	195	331

Prepared by:

ANGELICA C. CANTALEJO
Campus Registrar- Designate

Certified Correct:

ARIEL N. DELFINO, MSc, MBA
BSCD Department Chair

MARIA MELANIA T. SANGALANG, PhD
BSAB Department Chair

Approved:

JENNY P. LORIO, PhD
College Dean

APPENDIX D

APPROVAL OF CROPS DATA DESCRIPTION

Republic of the Philippines
PARTIDO STATE UNIVERSITY
Camarines Sur

BAGONG PILIPINAS

November 6, 2025

Dr. Jenny P. Lorio
Partido State University (Salogon Campus)
Salogon, Camarines Sur

Dear Ma'am Jenny,

We, the undersigned fourth-year Bachelor of Science in Information Technology (BSIT) students from Partido State University, are currently enrolled in CAP2 – Capstone and Research 2 as part of our academic requirements.

Our group is conducting a research project titled "Paratanom: An Augmented Reality 2D Farming Top-down Singleplayer Game for Agricultural Education" As part of this study, we have prepared the descriptions of crops that will be included in the game and accompanying research paper. These crops include banana, coconut, calamansi, corn, cucumber, eggplant, okra, pili nuts, and pomelo.

We respectfully request your approval of the crop descriptions to ensure the information is accurate, suitable for educational purposes, and can be used in both the game and our research documentation. All data will be used solely for academic purposes.

We appreciate your time and consideration.

Yours truly,

Jeremy Zion L. Jamer
Researcher, BSIT4A

Phoebe Kaye R. Crispino
Researcher, BSIT4A

Mark Lesther F. Nacario
Researcher, BSIT4A

Approved:

Dr. Jenny P. Lorio
College Dean, College of Agribusiness and Community Development – Salogon Campus

San Juan Bautista St., Goa, Camarines Sur 4422 Philippines
Contact Nos.: 09696087792 (Smart)
Website: www.parsu.edu.ph Email: op@parsu.edu.ph

APPENDIX E

CROPS DATA DESCRIPTION

Banana / Saging (Filipino)

Scientific Name: *Musa spp.*

<u>Description</u>

Banana (*Musa spp.)* is a tropical fruit widely grown and consumed all over the world. It belongs to the family Musaceae and is cultivated in over 130 countries, with both dessert (sweet) and cooking varieties. Globally, bananas are a staple food and a major export commodity, providing energy, nutrients, and income to millions of people. They grow as herbaceous plants with a pseudostem that produces clusters of fruits called "hands." Popular types include Cavendish (exported internationally), Saba (cooking), Lakatan (dessert), and Latundan. In the Philippines, especially in Camarines Sur and the Partido area, bananas are an important crop for both home consumption and local markets, contributing to household nutrition and smallholder livelihood (FAO, 2022; DA-BPI, 2025; PCAARRD, 2021).

<u>How it is Grown (Locally)</u>

In Philippines like smallholder farms of Partido, Camarines Sur, banana plants are mostly grown from healthy suckers or tissue-cultured plantlets. Farmers choose sites with well-drained, fertile soils and partial wind protection. Proper spacing, mulching, and fertilization are essential for strong growth, while regular pruning and sanitation help prevent pests and diseases. Harvesting usually occurs 9–12 months after planting. Extension agencies, including the Agricultural Training Institute (ATI) and the Bureau of Plant Industry (BPI), provide guidance on integrated pest management, Philippine Good Agricultural Practices (PhilGAP), and postharvest handling to ensure quality fruit and income for local farmers (DA-HVCDP, 2022; ATI, 2024).

Food Use

Bananas are eaten fresh or cooked, depending on the variety. Saba is boiled, fried, or made into snacks like banana cue, turon, and maruya, while dessert types such as Lakatan and Latundan are eaten raw. In Partido, banana provides a readily available food source for households and schools.

Livelihood

Bananas are a key source of income for farmers. They can be sold in local markets or supplied to traders for wider distribution. Banana farming provides jobs along the value chain, from planting to harvest, processing, and marketing (PCAARRD, 2021).

Agricultural Benefits

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Banana plants help reduce soil erosion with their wide leaves, provide organic matter when pruned or decomposed, and can be intercropped with vegetables or root crops, making them a sustainable choice for small farms in Partido.

Cultural and Household Use

Banana leaves are used in Filipino cuisine for wrapping rice cakes and as eco-friendly plates. The pseudostem and other plant parts are used as feed or mulch. In local traditions, bananas are also offered in community rituals and festivals.

Nutritional Value

Bananas are rich in carbohydrates, potassium, vitamin C, vitamin B6, and dietary fiber. These nutrients provide energy, support heart health, and aid digestion (FAO, 2022).

Other Uses

Aside from food, banana parts are used in many practical ways. Banana trunks can be processed into fibers for handicrafts or packaging materials. The leaves and stems can also be used as organic fertilizers or animal feed. Some researchers have explored using banana peel waste for making vinegar, wine, or even bioplastics, showing that the plant is useful from root to fruit.

Calamansi / Kalamansi (Filipino)

Scientific Name: *Citrofortunella macrocarpa*

<u>Description</u>

Calamansi, also called Philippine lime, is a small citrus fruit widely grown in Southeast Asia and tropical regions worldwide. It belongs to the Rutaceae family and produces tiny, round, green-to-orange fruits known for their sour taste. Globally, calamansi is valued for its culinary, nutritional, and medicinal uses. In the Philippines, especially in Camarines Sur and the Partido area, calamansi is a common backyard and farm crop. The fruit is used for cooking, beverages, and as a natural preservative. It is easy to grow in tropical climates, making it a popular fruit for smallholder farmers and households (FAO, 2022; DA-BPI, 2023; PCAARRD, 2021).

<u>How it is Grown (Locally)</u>

In Philippines, calamansi is usually grown from seeds or grafted seedlings. Farmers select well-drained, fertile soils with good sunlight. Planting is done with enough spacing to allow air circulation and sunlight for fruit development. Regular watering, mulching, pruning, and fertilization are important to maintain healthy trees. Local extension services, such as the Agricultural Training Institute (ATI) and the Bureau of Plant Industry (BPI), promote Integrated Pest Management (IPM) and Philippine

Good Agricultural Practices (PhilGAP) to control pests like citrus leaf miner, fruit flies, and diseases, ensuring high-quality fruit for markets and home consumption (DA-HVCDP, 2022; ATI, 2024).

Food Use

Calamansi is widely used in Filipino cuisine. Its juice adds sourness to dishes like kinilaw, sinigang, and pancit, or is mixed with water and sugar as a refreshing beverage. It is also used in marinades, dipping sauces, and as a natural preservative for meat and fish. In rural households of Partido, calamansi is harvested regularly and used as a fresh ingredient in daily meals.

Livelihood

Calamansi farming provides income for smallholders. The fruit is sold fresh in markets or processed into juice, jams, concentrates, and essential oils. Its year-round production allows farmers to supply both local and regional markets. Value-added processing of calamansi products contributes to income diversification and livelihood resilience in the Partido area (PCAARRD, 2021).

Agricultural Benefits

Calamansi trees improve soil stability and provide shade for understory plants in agroforestry systems. By growing calamansi alongside vegetables or other fruit trees, farmers can increase land productivity and sustainability. Pruned branches and fallen leaves can be composted, enriching farm soils naturally.

Cultural and Household Use

Calamansi is integral to Filipino households and traditions. The juice is used for cleaning, whitening teeth, and removing odors. Leaves and peels are sometimes used in folk remedies. Calamansi trees are often planted near homes in Partido, serving as both food source and ornamental plant.

Nutritional Value

Calamansi is rich in vitamin C, antioxidants, flavonoids, and essential minerals. These nutrients support immunity, help prevent scurvy, and improve skin health. Regular consumption of calamansi juice provides hydration and natural detox benefits (FAO, 2022).

Other Uses

Beyond food, calamansi extracts are used in cosmetics, cleaning products, and aromatherapy. Essential oils from the peel have antimicrobial and fragrant properties. Research also explores using calamansi waste in natural preservatives, eco-friendly packaging, and other bioproducts (CBSUA, 2021).

Cassava / Kamoteng Kahoy (Filipino)

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Scientific Name: *Manihot esculenta*

Description

Cassava (Manihot esculenta) is a tropical root crop grown widely in Asia, Africa, and Latin America. It is known for its starchy tuberous roots, which are a major source of carbohydrates worldwide. Cassava is drought-tolerant and grows well in poor soils, making it an important staple food for millions of people, especially in rural areas. In the Philippines, cassava is widely grown in the Bicol Region, including the Partido area of Camarines Sur, both for household consumption and as a cash crop. Varieties include sweet and bitter cassava, which differ in cyanogenic content and require appropriate processing before consumption (FAO, 2022; DA-BPI, 2023; PCAARRD, 2021).

How it is Grown (Locally)

Locally, cassava is usually propagated from stem cuttings. Farmers prepare the soil by clearing weeds and lightly plowing the land. Cuttings are planted directly into the soil at recommended spacing to allow enough room for root development. Cassava grows best in well-drained soils under full sunlight. Fertilizers and mulching are used to maintain soil fertility and moisture. Pest management, including control of mealybugs, scales, and mosaic virus, is promoted through Integrated Pest Management (IPM) practices. Harvesting typically occurs 8–12 months after planting, depending on the variety and intended use (DA-HVCDP, 2022; ATI, 2024).

Food Use

Cassava is primarily used as a source of carbohydrates. Its roots can be boiled, baked, or fried and are often processed into chips, flour, or starch for various food products. In Partido, cassava is commonly prepared as boiled or steamed roots for snacks, or made into cassava cake and other traditional Filipino delicacies.

Livelihood

Cassava cultivation provides income for smallholder farmers in rural areas. Its year-round cultivation and low input requirements make it a reliable source of cash. Processed products such as flour, chips, and starch offer additional livelihood opportunities through small-scale enterprises. In the Partido area, cassava contributes to household income and local trade (PCAARRD, 2021).

Agricultural Benefits

Cassava improves soil cover, reducing erosion and maintaining soil organic matter. Its adaptability to poor soils and drought conditions makes it an ideal crop for marginal lands. Residues from the plant can be composted, providing organic fertilizer for other crops.

Cultural and Household Use

In Filipino households, cassava is a staple snack and ingredient for traditional dishes. Leaves are sometimes cooked as a vegetable, while roots are used in everyday meals. Cassava is also part of local festivals and celebrations in some communities, highlighting its cultural importance.

Nutritional Value

Cassava is rich in carbohydrates, providing energy for daily activities. It also contains small amounts of vitamins and minerals, including vitamin C and calcium. Proper preparation, especially of bitter varieties, is necessary to remove naturally occurring cyanogenic compounds (FAO, 2022).

Other Uses

Besides food, cassava can be used as animal feed, biofuel, and raw material for starch-based industries. Leaves and stems can be composted, while industrial applications include paper, adhesives, and biodegradable plastics (CBSUA, 2021).

Chili / Siling Labuyo or Siling Haba (Filipino)

Scientific Name: *Capsicum frutescens*

Description

Chili (Capsicum spp.) is a small fruit-vegetable belonging to the nightshade family (Solanaceae). It is widely grown across tropical and subtropical regions and is cultivated both as a vegetable and spice. Globally, chili fruits are valued for their pungent flavour due to the compound capsaicin, as well as for their rich nutrient and bioactive compound content (Chakrabarty et al., 2017; Kaveh et al., 2024). In the Philippines — including small farms and backyard gardens in the Partido area of Camarines Sur — both hot types (such as siling labuyo) and milder long types (siling haba) are grown for household use and local markets (Picardal et al., 2022).

How it is Grown (Locally)

Chili is generally planted from seeds in nursery trays at about 1 cm depth, then transplanted after roughly 30–40 days when seedlings show 2–3 true leaves (ATI/DA, 2022). Fields should be well-drained and receive full sunlight; plants are spaced to allow air circulation and prevent disease (DA-RFO2, 2017). Farmers mulch, fertilize, irrigate (especially during dry spells), and manage pests and diseases using integrated pest management (IPM) strategies promoted by extension services. Harvesting begins about 70–120 days after transplanting depending on variety and market use (ATI/DA, 2022)

Food Use

Chili is a staple flavouring in Filipino cuisine: it is used fresh in dishes like sinigang, Bicol Express, pickles, sauces, and condiments. In the Partido region, chilies grown

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
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at home or on small farms provide readily available spicy produce. Chilies are also dried, powdered or transformed into sauces to extend shelf-life and increase value.

Livelihood

Chili production offers income-earning opportunities for smallholder farmers. Since chili can be grown on relatively small plots and harvested multiple times per year, it offers flexibility for household cropping systems in places like Partido. Furthermore, value-added production (such as chili powder or sauces) enhances income potential (Picardal et al., 2022).

Agricultural Benefits

Chili plants are relatively quick to grow and can be intercropped with other vegetables or legumes, thus improving land-use efficiency. Their residues (old plants, leaves) can be composted to enrich farm soil. Because they require only moderate inputs and fit well into small-farm systems, chilies are suitable for small-scale farming in rural areas.

Cultural and Household Use

Beyond cooking, chili plays a cultural role: it is often grown in home gardens for convenience, and varieties like siling labuyo are strongly tied to the food heritage of the Bicol region (including Partido). The leaves may also be used in traditional cooking stews or soups, making chili both a culinary and household plant.

Nutritional Value

Chili fruits and leaves are rich in vitamins A and C, minerals such as iron, calcium and potassium, dietary fiber, and phytochemicals including capsaicin and flavonoids. One Philippine study found that chili pepper leaves contained ~243 µg β-carotene, 6.9 mg iron and 550 mg calcium per 100 g fresh leaves (Abilgos-Ramos et al., 2017). Globally, chili peppers are recognized as nutrient-dense and helpful in addressing micronutrient deficiencies (Kaveh et al., 2024).

Other Uses

In addition to culinary use, chili and its extracts have other uses: capsaicin is used in medicinal and pest-repellent products, dried chilies and leaves are used in agro-industrial products, and small-scale processing into sauces or flakes offers further livelihood options.

Coconut / Niyog (Filipino)

Scientific Name: *Cocos nucifera*

<u>Description</u>

Coconut (Cocos nucifera) is a tropical palm widely known globally as the "tree of life" because nearly every part of the plant can be used for food, fibre, oil, beverage and materials (Agricultural Training Institute [ATI], 2024). Internationally it thrives in coastal, tropical zones and supplies major products like coconut oil, desiccated coconut, coconut water and fibre. In the Philippines — including the Partido area of Camarines Sur — coconut palms are common on farms, household yards and coastal plots, contributing to both food security and local economies (Philippine Coconut Authority [PCA], 2019; Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development [PCAARRD], 2022). The Philippines is the second largest producer of coconuts globally and the top exporter of many coconut-based products (Department of Agriculture [DA], 2023; PCAARRD, 2022).

<u>How it is Grown (Locally)</u>

Coconut palms are grown from seedlings or nut propagules planted in well-drained soils, often in coastal or slightly inland locations where salt spray and wind are moderate. Farmers select tall or dwarf varieties depending on land and use; dwarf varieties bear sooner (3-4 years) while tall types take 5-7 years but last longer (ATI, 2024). Good spacing (about 8-10 m or more) allows intercropping of vegetables, bananas or root crops, which is a recommended practice for smallholders in rural Philippines (PCAARRD, 2022). Recent Philippine policy emphasises replanting ageing coconut stands, fertilisation and diversification of coconut-based farming as part of the national strategy to boost productivity and income for farmers (DA, 2023; PCA, 2019).

Food Use

Coconut is used in many forms: young "buko" (coconut) is eaten fresh or its water drunk as a refreshing beverage; mature meat is eaten fresh or processed into coconut milk, cream, oil and desiccated coconut. In your local context in Partido, households often harvest coconuts for daily use (fresh meat, buko juice) or supply to market for processing into copra (dried meat) and other value-added products. The multifunctional nature of coconut means it is a central food source in many Filipino homes (PCAARRD, 2022).

Livelihood

Coconut farming supports livelihood for millions of smallholder farmers in the Philippines; approximately 2.5 million farmers are engaged in the industry and coconut covers about 3.6 million hectares of the country (PCAARRD, 2022). In Camarines Sur, and by extension the Partido area, coconut farming offers income from nut harvests, copra sales, coconut water and processed products. National programmes such as the "Massive Coconut Planting and Replanting Project" highlight how improving tree productivity and adding value can uplift farmer incomes (DA, 2023).

Agricultural Benefits

Coconut palms help stabilize soils (especially on coastal slopes), provide shade and micro-climate for intercrops, and yield biomass (leaves, husk, trunk) that can be used for mulch, compost or other farm uses. Because coconut trees live many decades and require relatively low maintenance once established, they suit small-holder mixed farming systems typical of rural areas like Partido (PCA, 2019).

Cultural and Household Use

In Filipino culture, coconut palms are deeply ingrained: their leaves serve as roofing and roofing materials, their trunks used in construction or furniture, and husks/fibres used in mats and ropes. At the household level in the Partido region, families may use coconut water for refreshment, young meat for snacks, mature meat in cooking (e.g., coconut milk in dishes) and husks for domestic fuel or small craft. Coconuts are part of local traditions, fiestas, and the everyday rural household landscape.

Nutritional Value

Coconut meat, water and milk supply nutrients such as potassium, vitamins, minerals and healthy fats. For example, fresh coconut flesh contains about 203.7 mg potassium per 100 g and mature coconut flesh has 18.83-37% fat by weight in some analyses (PMC, 2022). Coconut water offers hydration, electrolytes and low calorie refreshment. These nutrients make coconut a useful component of diet especially in rural Filipino settings where access to diverse foods may be limited.

Other Uses

Beyond food, coconut parts are used: husk fibre (coir) for mats, ropes and growing media; shells and husks for charcoal or biofuel; trunk and wood for furniture and house posts; the oil industry uses coconut oil for cosmetics, biodiesel and food; and coconut by-products (sap, sugar, flour) are increasingly used in value-added enterprises (PCAARRD, 2022; ATI, 2024).

Corn / Mais (Filipino)

Scientific Name: *Zea mays*

Description

Corn (Zea mays L.), known internationally as maize, is one of the world's most important cereal crops, grown in tropical, subtropical, and temperate zones for human food, animal feed, and industrial uses (Department of Agriculture [DA], 2022). In the Philippines, corn is considered the country's second staple after rice, with white corn primarily consumed by humans and yellow corn used for animal feed and industrial purposes (Philstar.com, 2024). In rural areas such as the Partido area of Camarines Sur, corn is grown both for home consumption and sale,

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contributing to food security and livelihood (MIMAROPA Region – Department of Agriculture, n.d.).

How it is Grown (Locally)

In Partido, corn is typically planted after land preparation, which includes clearing and ploughing (DA, 2023). Farmers select fertile, well-drained soils and ensure adequate sunlight. Seeds are either sown directly or transplanted depending on the farming system. Proper spacing and variety selection are emphasized, whether growing white or yellow corn. The National Corn Program provides improved seeds, fertilizers, training, and post-harvest support to raise yields (Philippine Statistics Authority [PSA], 2025a). Crop rotation, pest and disease management, and proper harvesting and drying practices are also encouraged to maintain quality and marketability (PSA, 2025b).

Food Use

White corn is consumed by humans in many forms such as boiled, roasted, or processed into grits and snacks (MIMAROPA Region – Department of Agriculture, n.d.). In Partido, home-grown white corn may be eaten fresh or stored as dried kernels for later cooking. Yellow corn is mainly processed into animal feed for poultry and livestock, and industrial products such as corn starch, syrup, and oil (Philstar.com, 2024).

Livelihood

Corn farming provides income for rural farmers since both white and yellow corn have market demand (DA, 2022). Smallholder farmers in Partido can supplement family income through corn production. Government support through programs such as the National Corn Program demonstrates the importance of corn for livelihood and economic stability (Philstar.com, 2024).

Agricultural Benefits

Corn plants contribute to diversified farmland and can reduce risks compared to monocropping. Residues such as stalks and leaves can be used as fodder or incorporated into soil to improve fertility. Corn's relatively quick growth cycle allows flexible farm planning and intercropping opportunities (MIMAROPA Region – Department of Agriculture, n.d.).

Cultural and Household Use

Corn holds cultural significance in rural Filipino communities. Family gardens often include white corn for household consumption, while roasted corn-on-the-cob is a traditional snack. Corn is also part of local festivals, snacks, and small trade in rural settings like Partido (DA, 2023).

Nutritional Value

Corn is a good source of carbohydrates, providing energy for daily activities. It contains dietary fiber, B-vitamins such as niacin, and minerals including magnesium and phosphorus (PSA, 2025a). Some varieties are being biofortified to improve micronutrient content and address deficiencies (Philstar.com, 2024).

Other Uses

Corn has various industrial uses including production of starch, corn oil, syrups, ethanol (biofuel), and biodegradable materials. Corn stalks and husks can also serve as mulch, fodder, or handicrafts. Dual-purpose corn systems (for human food and animal feed) are significant in integrated farming systems (MIMAROPA Region – Department of Agriculture, n.d.).

Cucumber / Pipino (Filipino)

Scientific Name: Cucumis sativus

Description

Cucumber (Cucumis sativus L.) is a globally cultivated vine in the Cucurbitaceae family, grown for its crisp, water-rich fruits which are often treated as vegetables in cooking (Infonet Biovision, n.d.). In the Philippines, cucumber is grown in small plots or backyard gardens, contributing both to household food supply and local market sales (Helgi Library, 2024).

How it is Grown (Locally)

Cucumber plants are typically started in nursery beds or directly seeded in well-prepared, well-drained soils with trellising or vertical support for vine growth. Research from Philippine institutions such as University of the Philippines Los Baños (UP LB) has produced locally adapted varieties like 'Pilmaria' which is harvestable in about 40 days and suited for wet and dry seasons (UP LB OVCRE, 2024). Good practices including proper spacing, pest and disease-resistant varieties, and mulching are recommended to maintain healthy plants and maximise yield (Elmundo et al., 2024).

Food Use

Cucumber is commonly eaten fresh in salads, pickled, or added to fresh vegetable dishes because of its crisp texture and mild flavour; in the Philippines, pipino is a common home-garden vegetable used for quick salads, side dishes, or snacks. It can also be processed or preserved as pickles for longer shelf life.

Livelihood

For smallholder farmers in areas like Partido, cucumber offers a quick-turnaround crop compared with larger trees or perennial crops, which means more frequent harvests and cash flow. The development of improved local varieties and linkages to value-chains help farmers earn from production and supply to local markets (UP LB OVCRE, 2024).

Agricultural Benefits

Cucumber vines provide ground cover early on, helping suppress weeds; their relatively short growth cycle allows farmers to rotate crops or fit cucumber into mixed-crop systems, which is advantageous for small farms in rural settings like Partido. Furthermore, the availability of shorter-duration improved varieties encourages efficient land use (Elmundo et al., 2024).

Cultural and Household Use

In Filipino households—including those in the Partido region—pipino is valued for its quick harvest and frequent use in everyday meals, making it a practical garden crop. It is often grown near homes for easy access and fresh consumption.

Nutritional Value

Cucumbers are about 96 % water and very low in calories, making them excellent for hydration and light eating (Infonet Biovision, n.d.). They also provide vitamins (such as vitamin K) and minerals (such as potassium and magnesium) which contribute to bone health and overall wellness (National Nutrition Council [NNC], 2025).

Other Uses

Beyond fresh consumption, cucumber plants and fruits have other applications: cucumber pickle manufacturing, fresh produce trade, and as part of mixed-crop systems which contribute to overall farm productivity. Improved varieties with disease resistance (such as those from UP LB) reduce losses and improve sustainability (UP LB OVCRE, 2024).

Eggplant / Talong (Filipino)

Scientific Name: *Solanum melongena*

<u>Description</u>

Eggplant (Solanum melongena L.) is a warm-weather vegetable in the nightshade family (Solanaceae), widely cultivated in tropical and subtropical regions across the world. It is one of the most economically important solanaceous crops after potato, tomato and pepper, with global production in the tens of millions of tonnes annually (Daunay & Janick, 2007; Ghader, 2017; as cited in Frontiers, 2017). The crop originated from India and South China and today more than 90 % of its production is concentrated in Asia, particularly China and India (Frontiers, 2017). Eggplant is grown in smallholder and commercial farming systems alike, and its many varieties show wide variation in shape, colour and size of fruit (Horticulturae; 2021).

How it is Grown (Locally)

Eggplant thrives in well-drained soils, warm temperatures, full sun, and regular moisture; high temperatures (above optimum) reduce growth and yield (Alam & Salimullah, 2021). Organic inputs (mulching, compost, bio-fertilisers) and good cultural practices (nursery, proper spacing, pest management) have been shown to improve yields and sustainability of eggplant cultivation across various countries (Erwita et al., 2025). For place like Partido, these best practices can be adapted: plant seedlings after nursery stage, ensure soil fertility, manage pests (such as fruit-and-shoot borers), and harvest when fruits are mature shining.

Food Use

Eggplant is used internationally in many cuisines: it can be roasted, stewed, fried or grilled; its skin and pulp absorb flavours and oils, making it popular in dishes like ratatouille, moussaka, baba ganoush, and in the Philippines as "tortang talong", ensaladang talong, or mixed into vegetable stews. As a household crop in rural areas, growing eggplant offers fresh vegetable supply and culinary diversity.

Livelihood

Eggplant cultivation provides income for farmers globally, especially smallholders in tropical countries. For example, Bt-eggplant adoption in Bangladesh found significantly higher net returns per hectare compared to conventional varieties (Rashid et al., 2016). In areas like Partido, inclusion of eggplant in the cropping system can provide quick turnover vegetable harvests, access to local markets, and supplement household income.

Agricultural Benefits

As a relatively short-cycle vegetable, eggplant allows more flexible land use compared to tree crops. Its cultivation can be integrated with other crops or in rotation to reduce risk. Using organic fertilisers and mulching has been shown to enhance soil fertility and yield stability in eggplant systems (Erwita et al., 2025). Improved varieties and greenhouse/shade management can mitigate stress in challenging climates (Alam & Salimullah, 2021).

Cultural and Household Use

Eggplant holds many roles in household gardens: it is planted near homes for ready harvest, used in family meals, and often grown on small plots by women or household-based producers. Culturally, eggplant appears in folk recipes and is part of vegetable diversity in many rural home gardens.

Nutritional Value

Eggplant has low calorie content but packs dietary fibre, minerals and bioactive compounds. For example, 100 g raw eggplant yields about 26 kcal, contains ~5.4 g carbohydrates, ~2.4 g fibre and about 222 mg potassium (Healthline, 2024).

Additionally, eggplant fruits and their bio-residues are rich in phenolic compounds and anthocyanins (e.g., nasunin) which provide antioxidant benefits (Silva et al., 2021). A review of its nutritional and medicinal value shows presence of flavonoids, alkaloids and sterols which may have anti-inflammatory or antioxidant effects (Naeem & Ugur, 2019).

Other Uses

Besides food use, eggplant bio-residues (peel, pulp waste) are being researched for use as sources of nutrients, bioactive compounds, and natural colourants in food technologies (Silva et al., 2021). On-farm crop residues can be composted to return nutrients to soil. Improved varieties and protected culture systems (greenhouse/shade) enhance productivity under climate challenge (Alam & Salimullah, 2021).

Okra / Lady's Finger

Scientific Name: *Abelmoschus esculentus*

Description

Okra (Abelmoschus esculentus L. Moench) is a warm-season vegetable crop valued for its edible pods and is grown widely in tropical and subtropical regions, including the Philippines. According to the Department of Agriculture, fresh green okra pods are now being prepared for export from accredited Philippine farms. (Department of Agriculture [DA], 2019) In the Philippines, okra is considered a convenient vegetable crop for smallholder and backyard production, and is adaptable to warm conditions and simple farming systems (Agricultural Training Institute [ATI], 2022).

How it is Grown (Locally)

In Philippine production systems, okra is typically planted via direct seeding in warm soils because seeds will not germinate well at low temperatures (DA Regional Field Office 02, 2018). The Agricultural Training Institute's Production Guide notes that okra begins flowering 40 to 75 days after planting, and tender fruits are harvested 4 to 6 days after flowering (ATI, 2022). Seed soaking overnight helps achieve more uniform germination (DA RFO2, 2018). Plant spacing, mulching, and good drainage are recommended to maximize yield and reduce pest and disease issues (ATI, 2022). Export-oriented farms must be accredited under the Bureau of Plant Industry (BPI) phytosanitary requirements (DA, 2019).

Food Use

Okra pods are eaten fresh, lightly cooked, or added to stews, soups and vegetable dishes. The slimy mucilage is often used as a thickening agent in soups. In

Philippine households, okra provides a quick-harvest vegetable for daily meals and can also be incorporated into processed forms for value addition.

Livelihood

Okra offers livelihood opportunities for Filipino smallholders because it can be grown in small parcels, has short harvest intervals, and fetches market premiums for fresh export-quality pods. The Department of Agriculture notes that accredited Philippine farms supply fresh green okra for export, indicating growth in the value chain (DA, 2019).

Agricultural Benefits

Because okra adapts to warm tropical conditions and is relatively tolerant of poorer soils compared with some crops, it fits well into mixed and small-farm systems typical of many Filipino rural areas. Good agronomic practices (such as mulching and appropriate seeding) reduce weed pressure and help optimize production under small-holder conditions (DA RFO2, 2018).

Cultural and Household Use

In many Philippine households, okra is grown in backyards or near the home for easy access. It also features in local vegetable mixes and home gardens where quick-turnover crops support food and nutrition security. The plant's ease of culture makes it culturally acceptable as a "quick vegetable" crop.

Nutritional Value

Philippine research has shown that okra pods are an affordable, nutritious vegetable choice. For example, a study in the Philippines found that okra seed powder had measurable effects in reducing fasting glucose levels in people with impaired fasting glucose, indicating its potential nutritional/functional value (Adversario et al., 2017). The mucilage of okra has also been studied for its health-benefit potential.

Other Uses

Beyond fresh consumption, Philippine studies have explored okra pods for novel uses: for example, pods were used to produce a low-cost ultrasound gel alternative in medical applications in the Philippines (Alipio et al., 2021). This shows that okra's usefulness extends beyond food into industrial or value-added agricultural by-products.

Pili

Scientific Name: *Canarium ovatum*

<u>Description</u>

Pili nut (Canarium ovatum) is an indigenous tree crop of the Philippines, especially prominent in the Bicol Region where it has become a signature or "flagship" commodity. It grows into a large evergreen tree (averaging around 20 m) and produces drupe fruits that consist of a thin skin, a fibrous pulp, a hard shell, and a kernel inside. (Imperial, 2012) The Bicol Region produces about 90% of the country's pilinut output and approximately 84% of the national production volume, making this area the major center of pili cultivation in the Philippines. (Department of Agriculture [DA], 2023)

How it is Grown (Locally)

Pili trees are often grown on volcanic soils in the provinces of Camarines Sur, Albay, Sorsogon, and other surrounding areas. (Imperial, 2012) The crop is managed over longer time horizons than vegetables: trees start bearing fruit after several years. A demographic study among Bicol farmers found that production capacity and profitability are high when trees are well maintained, though many farmers still rely on wild or semi-domesticated stands rather than intensive orchard planting. (Lirag, Foronda, Ativo & Estrella, 2023) Good agronomic practices include site selection on well-drained slopes, maintaining tree health (pruning, thinning), and timely nut harvest. The regional offices emphasise upgrading processing and post-harvest systems (e.g., cracking machines, sorting) to improve quality of kernels. (Department of Agriculture-Bicol, 2024)

Food Use

Pili nuts are eaten as whole kernels, roasted or toasted, used in candies, brittles, pastries and other confections. In Bicol households, it is common to find pili candy and other local sweets made from pili kernels. Seeds and kernels can also be processed into oils or used in other food-based value-added products. (Philippine Center for Postharvest Development & Mechanization [PhilMech], 2010)

Livelihood

Pili cultivation and processing provide significant livelihood opportunities for Bicol farmers. A study found that pili production in selected Bicol provinces yielded high financial returns (about 127%) when properly managed. (Lirag et al., 2023) The fact that the Bicol region supplies most of the national output and is now exporting kernels to markets such as the EU, USA, Canada and Japan underlines its livelihood importance. (DA, 2023)

Agricultural Benefits

As a tree crop, pili offers benefits such as soil stabilization (especially on sloped volcanic terrain of Bicol), shade and potential agroforestry integration with other crops beneath the canopy. The durable nature of the tree means relatively lower annual planting labour compared to annual crops. Upgraded processing technologies (nut-cracking, sorting) developed in Bicol help reduce post-harvest losses and improve kernel value. (DOST-PCAARRD, 2024)

Cultural and Household Use

In Bicol, the pili tree is part of cultural identity: many households maintain one or more pili trees near homes or in backyards, and festivals (such as the Pili Festival in Sorsogon) celebrate the nut's importance. The nut and its derivatives (candies, butter, pastries) are embedded in local culture and hospitality.

Nutritional Value

Studies on pili kernel show high oil content, quality fatty acid profiles, and protein potential. For example, an article in The Philippine Agricultural Scientist reported on the antihypertensive and antioxidative activity of protein hydrolysates from pili kernel. (UP LB et al., 2023) These nutritional attributes, along with strong export demand, raise pili's status as a "super-nut" from Bicol.

Other Uses

Beyond food, all parts of the pili tree and nut have uses: the hard shell is being explored for charcoal or briquettes, the pulp for oil extraction and skincare product use, and the shell and pulp wastes for bio-products. (Imperial, 2012) Processing innovations in Bicol (nut-cracker machines, sorting machines) are helping turn pili into more market-ready value-added items. (DOST-PCAARRD, 2024)

Pomelo / Suha (Filipino)

Scientific Name: *Citrus maxima*

<u>Description</u>

Pomelo (Citrus maxima) is one of the largest citrus fruits in the world, widely grown in Southeast Asia, East Asia, and tropical regions globally, and valued for its sweet to mildly sour segmented flesh and thick rind. Internationally, it is recognized for its role in citrus breeding (e.g., as a parent of grapefruit) and as a fresh-fruit commodity in global markets (Iplantz, 2025). In the Philippines, pomelo is locally known as "suha" and is grown across many provinces; it contributes to domestic consumption, local trade and export potential (Acta Medica Philippina, 2018).

<u>How it is Grown (Locally)</u>

In the Philippines, pomelo trees are typically established on deep, well-drained soils with full sunlight and moderate rainfall; they begin bearing fruit after several years of growth. For example, a Philippine study on the 'Magallanes' variety found that applying higher potassium (K) fertilisation improved flowering, fruit-set and yield of pomelo trees under local conditions (Magbalot-Fernandez & De Guzman, 2019). Research on nematode infestation in pomelo roots in Luzon likewise indicates that root-soil health is critical for sustained production (Almasco et al., 2024). Proper spacing, nutrient management, pest and disease monitoring (especially in the Philippine context) are key practices for smallholder or commercial pomelo orchards.

Food Use

In the Philippines, pomelo is commonly eaten fresh, often peeled and segmented, or used in salads, fruit mixes and festive dishes. The thick rind is sometimes candied or processed into marmalades. Its sweet-sour flavour and large fruit size make it a popular household fruit during harvest season.

Livelihood

Pomelo cultivation offers livelihood opportunities for Filipino farmers, especially those in provinces suited to citrus production. A production-chain study in the Philippines found that inefficiencies (in marketing, technical knowledge, quality control) still limit income gains for some producers (Cosrojas, Abao & Piquero, 2023). Nevertheless, improved variety adoption and better post-harvest handling can increase returns for growers.

Agricultural Benefits

As a perennial tree crop, pomelo contributes to agroforestry and long-term land use stability. In the Philippine setting, it provides landscape cover, root stability and opportunities for intercropping in the early years. Additionally, research in the Philippines has shown that its peels have by-product potential (e.g., pectin extraction), offering added value beyond the fruit itself (Arollado et al., 2018).

Cultural and Household Use

In many Filipino households (including rural regions), pomelo trees are part of the home garden or family orchard—providing fruit for personal consumption, local barter/trade, and sometimes for special occasions or celebrations. The fruit's size and seasonality also mean it features in household traditions and gift-giving.

Nutritional Value

Pomelo is rich in vitamin C, fiber and water content; it offers a refreshing low-calorie snack option. Although specific Philippine nutritional surveys are less frequent, citrus fruit such as pomelo are recognised locally for supporting immunity and hydration.

Other Uses

In the Philippines, research has shown that pomelo fruit peels can be used to extract pharmaceutical-grade pectin (Arollado et al., 2018) and have antibacterial properties when used in peel extract soaps (Ochate et al., 2023). These studies highlight extra-fruit uses which add value and reduce waste for Filipino producers.

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
Website: www.parsu.edu.ph
ISO 9001:2015 Certified

Taro / Gabi (Filipino)

Scientific Name: *Colocasia esculenta*

Description

Taro (*Colocasia esculenta*) is a tropical root crop grown for its starchy corms and edible leaves; it is cultivated across Asia, Africa and the Pacific and is valued both as a staple and as a specialty food (Ferdaus, 2023). In the Philippines, taro is an important rootcrop in household gardens and small farms and has many local cultivars adapted to upland and wetland conditions (Philippine Root Crops Research & Training Center—PhilRootcrops, n.d.; Pasiona, 2021). Philippine research describes taro as a resilient, multi-purpose crop that performs well in humid tropical climates and in soils with reasonable moisture retention (Vasquez, Contero & Ferraren, 2020).

How it is Grown Locally

Locally, taro is usually planted by setting whole corms or cormels directly into prepared soil and is often grown in both upland (rainfed) and lowland/paddy systems; wetland systems require water retention (PhilRootcrops, n.d.). Farmers in the Philippines typically plant taro between the start of the rainy season and early wet months so corms develop with steady moisture, and they harvest between about 7–10 months after planting depending on variety and whether the crop is upland or wetland (Department of Agriculture — HVCDP, n.d.). In Bicol and similar provinces (including Partido in Camarines Sur), taro is commonly part of mixed home gardens and is grown near the homestead for easy harvest and leaf access (Pasiona, 2021). Best practices promoted by PhilRootcrops and DA include using healthy seed corms, good land preparation, regular weeding, incorporation of organic matter, and proper curing/drying before storage to reduce rot (PhilRootcrops, n.d.; DA-HVCDP, n.d.).

Food Use

Taro corms are boiled, mashed, or used in stews and desserts (e.g., ginataan, halaya-type preparations), while leaves (commonly called "dahon ng gabi") are a key ingredient in regional dishes such as Bicol's laing (PhilRootcrops, n.d.; Pasiona, 2021). Taro can also be processed into chips, flour, and other value-added snacks — Philippine studies and product trials have tested taro-based ensaymada and taro chips for local markets (Research article — proximate analyses; PhilRootcrops event reports, 2021–2024).

Livelihood

Taro provides quick-turn harvests compared with tree crops and offers income through local markets and small-scale processing (PhilRootcrops, n.d.). In regions like Bicol and Cordillera, taro products (chips, packaged halaya, value-added flours) have been developed to increase farmer returns and support small agro-enterprises (CIP/partner reports; PhilRootcrops activities, 2014–2022). Research and government extension (DA/BAR, PhilRootcrops, DOST-PCAARRD) encourage linking farmers to processors and markets to raise profitability (DOST-PCAARRD, 2021).

Agricultural Benefits

Taro stabilizes soils where planted, provides ground cover that reduces erosion, and returns organic matter when residues are composted (PhilRootcrops, n.d.). Because taro fits both upland and wetland systems, it helps diversify farm risk in smallholder landscapes, and its relative tolerance to shade makes it compatible with agroforestry or intercropping under coconut/banana stands (Pasiona, 2021; PhilRootcrops, n.d.).

Cultural and Household Use

Taro is deeply embedded in Philippine food culture: households plant taro near kitchens for ready access to leaves and corms, and regional dishes (notably Bicol's laing) feature gabi leaves as essential ingredients (Pasiona, 2021). Festivals, local markets and household foodways in Bicol and other regions celebrate taro as both food and cultural identity (local university reports; regional DA features).

Nutritional Value

Taro corms are a good source of carbohydrates, dietary fiber, and some minerals, while the leaves contain vitamins and minerals (e.g., vitamin A precursors, iron) and bioactive antioxidants; recent reviews and Philippine studies report that taro is nutrient-dense and has promising functional food properties (Ferdaus, 2023; Vasquez et al., 2020). Some Philippine trials and proximate analyses have explored taro's suitability in bakery products and found it contributes carbohydrates, fiber and acceptable sensory attributes when formulated correctly (proximate analysis studies, 2024–2025).

Other Uses

Beyond food, taro corm and leaf biomass have potential in animal feed (after proper processing), starch extraction, and as raw materials for small food industries. Philippine researchers have also examined the antioxidant properties of taro leaf extracts and explored taro flour as an alternative ingredient for gluten-free foods (Vasquez et al., 2020; Ferdaus, 2023). Community enterprises in the Philippines have trialled taro chips and flours as income diversification products (PhilRootcrops, DOST-PCAARRD, DA extension reports).

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Website: www.parsu.edu.ph
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
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APPENDIX F

PRE-TEST AND POST TEST QUESTIONS

Pre-test

Instruction: Read each statement carefully. Write T if the statement is True and F if it is False.

___ 1. Bananas in the Philippines are commonly grown from seeds. (False)

___ 2. Banana leaves are traditionally used in Filipino cuisine for wrapping rice cakes.

___ 3. Calamansi is widely used in marinades, dipping sauces, and beverages in Filipino households.

___ 4. Chili contains capsaicin, which gives it its spicy flavor.

___ 5. Cassava is propagated using stem cuttings in local farms.

___ 6. Coconut is known globally as the "tree of life" because almost all its parts can be used.

___ 7. Corn is considered the second staple crop of the Philippines after rice.

___ 8. Cucumber varieties like 'Pilmaria' can be harvested in about 40 days.

___ 9. Bananas contribute to soil erosion control because their wide leaves help protect the soil.

___ 10. Calamansi trees are often planted near homes for both food and ornamental use.

___ 11. Chili is grown both in small farms and backyard gardens in the Partido area.

___ 12. Cassava roots can be boiled, baked, fried, or processed into flour and starch.

___ 13. Coconut farming supports millions of smallholder farmers in the Philippines.

___ 14. Corn stalks and leaves can be used as fodder or turned into soil-improving organic matter.

___ 15. Cucumber is commonly eaten fresh, added to salads, or pickled.

___ 16. Chili leaves contain nutrients such as iron, calcium, and beta-carotene.

___ 17. Coconut husk fibers can be used to make ropes, mats, and other products.

___ 18. Cassava grows best in shaded, water-logged areas with very little sunlight. (False)

___ 19. Calamansi is rich in vitamin C and antioxidants, supporting immunity.

___ 20. Bananas are harvested about 9–12 months after planting.

Post-test

Instruction: Read each statement carefully. Write T if the statement is True and F if it is False.

___ 1. Bananas in the Philippines are commonly grown from seeds. (False)

___ 2. Banana leaves are traditionally used in Filipino cuisine for wrapping rice cakes.

___ 3. Calamansi is widely used in marinades, dipping sauces, and beverages in Filipino households.

___ 4. Chili contains capsaicin, which gives it its spicy flavor.

___ 5. Cassava is propagated using stem cuttings in local farms.

___ 6. Coconut is known globally as the "tree of life" because almost all its parts can be used.

___ 7. Corn is considered the second staple crop of the Philippines after rice.

___ 8. Cucumber varieties like 'Pilmaria' can be harvested in about 40 days.

___ 9. Bananas contribute to soil erosion control because their wide leaves help protect the soil.

___ 10. Calamansi trees are often planted near homes for both food and ornamental use.

___ 11. Chili is grown both in small farms and backyard gardens in the Partido area.

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___ 13. Coconut farming supports millions of smallholder farmers in the Philippines.

___ 14. Corn stalks and leaves can be used as fodder or turned into soil-improving organic matter.

___ 15. Cucumber is commonly eaten fresh, added to salads, or pickled.

___ 16. Chili leaves contain nutrients such as iron, calcium, and beta-carotene.

___ 17. Coconut husk fibers can be used to make ropes, mats, and other products.

___ Cassava grows best in shaded, water-logged areas with very little sunlight. (False)

___ 19. Calamansi is rich in vitamin C and antioxidants, supporting immunity.

___ 20. Bananas are harvested about 9–12 months after planting.

Pre-test

Instruction: Read each statement carefully. Write T if the statement is True and F if it is False.

_T_ 1. Bananas in the Philippines are commonly grown from seeds. (False)
_F_ 2. Banana leaves are traditionally used in Filipino cuisine for wrapping rice cakes.
_T_ 3. Calamansi is widely used in marinades, dipping sauces, and beverages in Filipino households.
_T_ 4. Chili contains capsaicin, which gives it its spicy flavor.
_T_ 5. Cassava is propagated using stem cuttings in local farms.
_T_ 6. Coconut is known globally as the "tree of life" because almost all its parts can be used.
_T_ 7. Corn is considered the second staple crop of the Philippines after rice.
_T_ 8. Cucumber varieties like 'Pilmaria' can be harvested in about 40 days.
_T_ 9. Bananas contribute to soil erosion control because their wide leaves help protect the soil.
_T_ 10. Calamansi trees are often planted near homes for both food and ornamental use.
_T_ 11. Chili is grown both in small farms and backyard gardens in the Partido area.
_T_ 12. Cassava roots can be boiled, baked, fried, or processed into flour and starch.
_T_ 13. Coconut farming supports millions of smallholder farmers in the Philippines.
_T_ 14. Corn stalks and leaves can be used as fodder or turned into soil-improving organic matter.
_T_ 15. Cucumber is commonly eaten fresh, added to salads, or pickled.
_T_ 16. Chili leaves contain nutrients such as iron, calcium, and beta-carotene.
_T_ 17. Coconut husk fibers can be used to make ropes, mats, and other products.
_F_ 18. Cassava grows best in shaded, water-logged areas with very little sunlight. (False)
_T_ 19. Calamansi is rich in vitamin C and antioxidants, supporting immunity.
_T_ 20. Bananas are harvested about 9–12 months after planting.

Post-test

Instruction: Read each statement carefully. Write T if the statement is True and F if it is False.

_T_ 1. Bananas in the Philippines are commonly grown from seeds. (False)
_F_ 2. Banana leaves are traditionally used in Filipino cuisine for wrapping rice cakes.
_T_ 3. Calamansi is widely used in marinades, dipping sauces, and beverages in Filipino households.
_T_ 4. Chili contains capsaicin, which gives it its spicy flavor.
_T_ 5. Cassava is propagated using stem cuttings in local farms.
_T_ 6. Coconut is known globally as the "tree of life" because almost all its parts can be used.
_T_ 7. Corn is considered the second staple crop of the Philippines after rice.
_T_ 8. Cucumber varieties like 'Pilmaria' can be harvested in about 40 days.
_T_ 9. Bananas contribute to soil erosion control because their wide leaves help protect the soil.
_T_ 10. Calamansi trees are often planted near homes for both food and ornamental use.
_T_ 11. Chili is grown both in small farms and backyard gardens in the Partido area.
_T_ 12. Cassava roots can be boiled, baked, fried, or processed into flour and starch.
_T_ 13. Coconut farming supports millions of smallholder farmers in the Philippines.
_T_ 14. Corn stalks and leaves can be used as fodder or turned into soil-improving organic matter.
_T_ 15. Cucumber is commonly eaten fresh, added to salads, or pickled.
_T_ 16. Chili leaves contain nutrients such as iron, calcium, and beta-carotene.
_T_ 17. Coconut husk fibers can be used to make ropes, mats, and other products.
_F_ 18. Cassava grows best in shaded, water-logged areas with very little sunlight. (False)
_T_ 19. Calamansi is rich in vitamin C and antioxidants, supporting immunity.
_T_ 20. Bananas are harvested about 9–12 months after planting.

APPENDIX G

CROP DETECTION MANAGER CODE SNIPPET

```
using System;
using System.Collections;
using System.Collections.Generic;
using System.IO;
using Unity.InferenceEngine;
using UnityEngine;
using UnityEngine.SceneManagement;
using UnityEngine.UI;
using UnityEngine.InputSystem;

public class CropDetection : MonoBehaviour
{
    public ModelAsset modelAsset;

    public TextAsset classesAsset;

    public Button captureButton;

    public Camera displayCamera;

    [SerializeField] private float displayDistance = 5f;

    public string arSceneName = "ARScene";

    const BackendType backend = BackendType.GPUCompute;

    private Worker worker;
    private string[] labels;
    private RenderTexture targetRT;

    private const int imageWidth = 640;
    private const int imageHeight = 640;

    private WebCamTexture webcamTexture;
    private bool isDetecting;

    [SerializeField, Range(0, 1)]
    float iouThreshold = 0.5f;

    [SerializeField, Range(0, 1)]
    float scoreThreshold = 0.5f;

    Tensor<float> centersToCorners;

    private GameObject cameraFeedPlane;
    private Material cameraFeedMaterial;
    private int lastWebcamWidth = 0;
    private int lastWebcamHeight = 0;
```

```
private float lastCameraAspect = 0f;
private int lastVideoRotation = -1;
private bool lastVerticallyMirrored = false;

void Start()
{
    Application.targetFrameRate = 60;


    labels = classesAsset.text.Split('\n');

    LoadModel();

    targetRT = new RenderTexture(imageWidth, imageHeight, 0);

    if (displayCamera == null)
    {
        displayCamera = Camera.main;
        if (displayCamera == null)
        {
            displayCamera = GetComponent<Camera>();
        }
    }

    if (displayCamera != null)
    {
        displayCamera.clearFlags = CameraClearFlags.SolidColor;
        displayCamera.backgroundColor = Color.black;
    }

    SetupInput();

    if (captureButton != null)
    {
        captureButton.onClick.AddListener(CaptureAndDetect);
    }
}

void OnEnable()
{
    if (displayCamera == null)
    {
        displayCamera = Camera.main;
        if (displayCamera == null)
        {
            displayCamera = GetComponent<Camera>();
        }
    }

    if (displayCamera != null)
    {
        displayCamera.clearFlags = CameraClearFlags.SolidColor;
```

```
            displayCamera.backgroundColor = Color.black;
        }

        if (webcamTexture != null && webcamTexture.isPlaying &&
cameraFeedPlane != null)
        {
            StartCoroutine(UpdateCameraDisplay());
        }
        else if (webcamTexture != null && webcamTexture.isPlaying &&
cameraFeedPlane == null)
        {
            StartCoroutine(SetupCameraDisplay());
        }
    }

    void LoadModel()
    {
        var model1 = ModelLoader.Load(modelAsset);

        centersToCorners = new Tensor<float>(new TensorShape(4, 4),
        new float[]
        {
            1,      0,      1,      0,
            0,      1,      0,      1,
            -0.5f,  0,      0.5f,   0,
            0,      -0.5f,  0,      0.5f
        });

        var graph = new FunctionalGraph();
        var inputs = graph.AddInputs(model1);
        var modelOutput = Functional.Forward(model1, inputs)[0];
        var boxCoords = modelOutput[0, 0..4, ..].Transpose(0, 1);
        var allScores = modelOutput[0, 4.., ..];
        var scores = Functional.ReduceMax(allScores, 0);
        var classIDs = Functional.ArgMax(allScores, 0);
        var boxCorners = Functional.MatMul(boxCoords,
Functional.Constant(centersToCorners));
        var indices = Functional.NMS(boxCorners, scores, iouThreshold,
scoreThreshold);
        var coords = Functional.IndexSelect(boxCoords, 0, indices);
        var labelIDs = Functional.IndexSelect(classIDs, 0, indices);

        worker = new Worker(graph.Compile(coords, labelIDs), backend);
    }

    private System.Collections.IEnumerator SetupCameraDisplay()
    {
        yield return new WaitUntil(() => webcamTexture != null &&
webcamTexture.isPlaying && webcamTexture.width > 16);

        CreateOrUpdateDisplay();
    }
```

```
    private System.Collections.IEnumerator UpdateCameraDisplay()
    {
        yield return null;
        CreateOrUpdateDisplay();
    }

    private void CreateOrUpdateDisplay()
    {
        if (displayCamera == null)
        {
            displayCamera = Camera.main;
            if (displayCamera == null)
            {
                displayCamera = GetComponent<Camera>();
            }
        }

        if (displayCamera == null)
        {
            Debug.LogWarning("[CropDetection] No camera found for
display. Camera feed will not be visible.");
            return;
        }

        displayCamera.clearFlags = CameraClearFlags.SolidColor;
        displayCamera.backgroundColor = Color.black;

        float currentAspect = displayCamera.aspect;
        int currentWidth = webcamTexture.width;
        int currentHeight = webcamTexture.height;
        int currentRotation = webcamTexture.videoRotationAngle;
        bool currentVerticallyMirrored =
webcamTexture.videoVerticallyMirrored;

        bool needsUpdate = cameraFeedPlane == null ||
            Mathf.Abs(currentAspect - lastCameraAspect) > 0.01f ||
            currentWidth != lastWebcamWidth ||
            currentHeight != lastWebcamHeight ||
            currentRotation != lastVideoRotation ||
            currentVerticallyMirrored != lastVerticallyMirrored;

        if (!needsUpdate && cameraFeedPlane != null)
        {
            return;
        }

        if (cameraFeedPlane == null)
        {
            cameraFeedPlane =
GameObject.CreatePrimitive(PrimitiveType.Quad);
            cameraFeedPlane.name = "CameraFeedPlane";
```

```
            Collider collider =
cameraFeedPlane.GetComponent<Collider>();
            if (collider != null)
            {
                Destroy(collider);
            }
        }

        if (cameraFeedMaterial == null)
        {
            cameraFeedMaterial = new
Material(Shader.Find("Unlit/Texture"));
            MeshRenderer renderer =
cameraFeedPlane.GetComponent<MeshRenderer>();
            renderer.material = cameraFeedMaterial;
        }
        cameraFeedMaterial.mainTexture = webcamTexture;

        Transform cameraTransform = displayCamera.transform;
        cameraFeedPlane.transform.position = cameraTransform.position +
cameraTransform.forward * displayDistance;

        cameraFeedPlane.transform.rotation = cameraTransform.rotation;

        int rotation = currentRotation;
        int rotationCompensation = -rotation;

        if (rotationCompensation != 0)
        {
            cameraFeedPlane.transform.Rotate(Vector3.forward,
rotationCompensation, Space.Self);
        }

        float mirrorX = currentVerticallyMirrored ? -1f : 1f;

        float cameraHeight = 2f * Mathf.Tan(displayCamera.fieldOfView *
0.5f * Mathf.Deg2Rad) * displayDistance;
        float cameraWidth = cameraHeight * currentAspect;

        bool needsAspectSwap = (rotation == 90 || rotation == 270);

        float webcamAspect;
        if (needsAspectSwap)
        {
            webcamAspect = (float)webcamTexture.height /
webcamTexture.width;
        }
        else
        {
            webcamAspect = (float)webcamTexture.width /
webcamTexture.height;
```

```
        }

        float quadWidth, quadHeight;
        if (webcamAspect > currentAspect)
        {
            quadHeight = cameraHeight;
            quadWidth = cameraHeight * webcamAspect;
        }
        else
        {
            quadWidth = cameraWidth;
            quadHeight = cameraWidth / webcamAspect;
        }

        cameraFeedPlane.transform.localScale = new Vector3(quadWidth *
mirrorX, quadHeight, 1f);

        lastCameraAspect = currentAspect;
        lastWebcamWidth = currentWidth;
        lastWebcamHeight = currentHeight;
        lastVideoRotation = currentRotation;
        lastVerticallyMirrored = currentVerticallyMirrored;

        Debug.Log($"[CropDetection] Camera feed plane updated.
VideoRotation: {rotation}°, Compensation: {rotationCompensation}°,
VerticallyMirrored: {currentVerticallyMirrored}, Aspect:
{webcamAspect}, Camera Aspect: {currentAspect}");
    }

    void SetupInput()
    {
        if (webcamTexture != null)
        {
            return;
        }
        webcamTexture = new WebCamTexture();
        webcamTexture.Play();

        StartCoroutine(SetupCameraDisplay());
    }

    private void Update()
    {
        if (Keyboard.current != null &&
Keyboard.current.escapeKey.wasPressedThisFrame)
        {
            Application.Quit();
        }

        if (displayCamera != null && cameraFeedPlane != null &&
webcamTexture != null && webcamTexture.isPlaying)
        {
```

```
            float currentAspect = displayCamera.aspect;
            if (Mathf.Abs(currentAspect - lastCameraAspect) > 0.01f)
            {
                CreateOrUpdateDisplay();
            }
        }
    }

    void CaptureAndDetect()
    {
        if (isDetecting)
        {
            return;
        }
        if (webcamTexture == null || !webcamTexture.isPlaying ||
webcamTexture.width <= 16)
        {
            Debug.Log("Webcam not ready yet.");
            return;
        }

        isDetecting = true;

        float aspect = webcamTexture.width * 1f / Mathf.Max(1,
webcamTexture.height);
        float targetAspect = 1f;

        if (aspect > targetAspect) {
            float scale = targetAspect / aspect;
            Graphics.Blit(webcamTexture, targetRT, new Vector2(scale,
1), new Vector2((1 - scale) * 0.5f, 0));
        } else {
            float scale = aspect / targetAspect;
            Graphics.Blit(webcamTexture, targetRT, new Vector2(1,
scale), new Vector2(0, (1 - scale) * 0.5f));
        }

        using Tensor<float> inputTensor = new Tensor<float>(new
TensorShape(1, 3, imageHeight, imageWidth));
        TextureConverter.ToTensor(targetRT, inputTensor, default);
        worker.Schedule(inputTensor);

        using var output = (worker.PeekOutput("output_0") as
Tensor<float>).ReadbackAndClone();
        using var labelIDs = (worker.PeekOutput("output_1") as
Tensor<int>).ReadbackAndClone();

        int boxesFound = output.shape[0];
        if (boxesFound <= 0)
        {
            Debug.Log("No objects detected above threshold.");
            isDetecting = false;
```

```
            return;
        }

        int labelIndex = Mathf.Clamp(labelIDs[0], 0, labels.Length -
1);
        string predictedLabel = labels[labelIndex].Trim();
        if (string.IsNullOrEmpty(predictedLabel))
        {
            Debug.Log("Predicted empty label.");
            isDetecting = false;
            return;
        }

        DetectionResult.DetectedLabel = predictedLabel;
        Debug.Log($"Detected: {predictedLabel}. Loading AR scene:
{arSceneName}");

        SceneLoader.SwitchModalScene(arSceneName);
    }

    void OnDestroy()
    {
        if (webcamTexture != null && webcamTexture.isPlaying)
        {
            webcamTexture.Stop();
        }

        if (cameraFeedPlane != null)
        {
            Destroy(cameraFeedPlane);
        }

        if (cameraFeedMaterial != null)
        {
            Destroy(cameraFeedMaterial);
        }

        centersToCorners?.Dispose();
        worker?.Dispose();
    }
}
```

APPENDIX H

PROOF ON THE CONDUCT OF TESTING

APPENDIX I

PERCEIVED USEFULNESS RAW DATA

Perceived Usefulness (PU)	5	4	3	2	1	WM	Interpretation
Using Paratanom enhances my understanding of agricultural concepts.	116	13	9	0	6	4.61	Strongly Agree
Paratanom helps me learn farming practices more effectively.	105	34	3	1	1	4.67	Strongly Agree
Paratanom contributes to improving my awareness of sustainable agriculture.	109	28	6	1	0	4.70	Strongly Agree
Paratanom provides useful information related to local crops and farming.	96	39	6	2	1	4.57	Strongly Agree
Overall, I find Paratanom beneficial for learning about agriculture.	107	34	2	1	0	4.71	Strongly Agree
AVERAGE WEIGHTED MEAN						4.65	Strongly Agree

APPENDIX J

PERCEIVED EASE OF USE RAW DATA

Perceived Ease of Use (PEOU)	**5**	**4**	**3**	**2**	**1**	**WM**	**Interpretation**
Learning how to use Paratanom was easy for me.	66	25	28	4	21	3.77	Agree
I find it easy to navigate and interact with Paratanom's features.	97	21	16	7	3	4.40	Strongly Agree
The design and layout of Paratanom make it simple to understand.	106	22	13	2	1	4.59	Strongly Agree
I can use Paratanom without requiring much assistance.	107	25	10	2	0	4.64	Strongly Agree
Overall, Paratanom is user-friendly and easy to operate.	108	28	4	3	1	4.65	Strongly Agree
AVERAGE WEIGHTED MEAN						4.41	Strongly Agree

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
Website: www.parsu.edu.ph

APPENDIX K

ATTITUDE TOWARD USE RAW DATA

Attitude Toward Use (ATU)	5	4	3	2	1	WM	Interpretation
I enjoy using Paratanom as a learning tool.	90	19	22	3	10	4.22	Strongly Agree
Using Paratanom makes agricultural learning more interesting.	106	21	13	3	1	4.58	Strongly Agree
I feel positive about using Paratanom for educational purposes.	117	18	7	1	1	4.72	Strongly Agree
Paratanom encourages me to explore more about farming.	120	20	3	0	1	4.79	Strongly Agree
I believe using Paratanom is a good idea for promoting agricultural awareness.	118	19	3	3	1	4.73	Strongly Agree
AVERAGE WEIGHTED MEAN						4.61	Strongly Agree

APPENDIX L

BEHAVIORAL INTENTION RAW DATA

Behavioral Intention to Use (BI)	**5**	**4**	**3**	**2**	**1**	**WM**	**Interpretation**
I plan to continue using Paratanom in the future.	100	14	15	3	12	4.29	Strongly Agree
I intend to use Paratanom whenever I want to learn about agriculture.	109	22	10	3	0	4.64	Strongly Agree
I will recommend Paratanom to others interested in farming or gardening.	117	20	3	3	1	4.72	Strongly Agree
I am likely to use Paratanom for further agricultural learning.	116	24	3	0	1	4.76	Strongly Agree
I am interested in exploring similar educational applications like Paratanom.	119	21	3	1	0	4.79	Strongly Agree
AVERAGE WEIGHTED MEAN						4.64	Strongly Agree

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
Website: www.parsu.edu.ph
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APPENDIX M

IMPLEMENTATION PLAN

Once Paratanom is fully tested and approved by our adviser and the people who evaluated it, the next phase is the structured deployment process appropriate for a mobile game intended for release on the Google Play Store.

Figure 26

Paratanom Implementation Plan

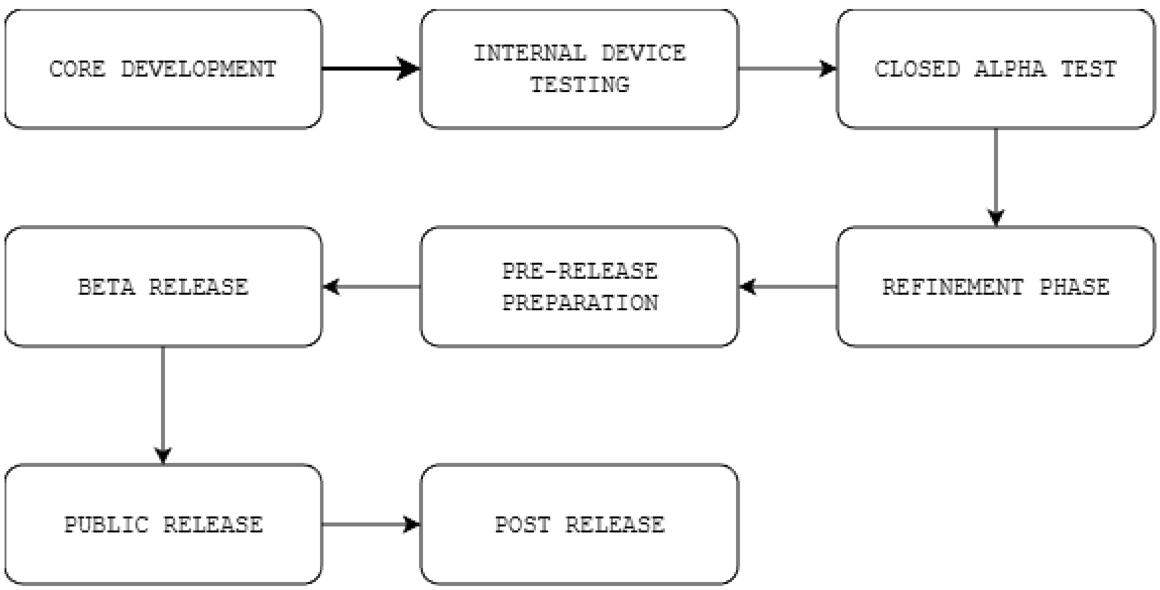

Figure 26 presents the implementation plan follows industry-aligned practices for mobile game deployment, including internal testing, alpha testing with campus participants, refinement cycles, pre-release preparation on Google Play Console, and eventual beta and public release. The game has been tested on student players from Partido State University – Salogon Campus and will undergo additional testing phases to ensure stability, compatibility, and educational effectiveness.

The development of Paratanom began with a 5-month phase focused on building the core features of the game. The team integrated Vuforia to support AR marker interactions, allowing the camera to project 3D crop models for player viewing and interaction. The team also implemented the YOLOv8n model through Unity's inference package to detect real agricultural crops. Farming mechanics, top-down movement, the user interface, and learning modules were created during this phase. The team performed continuous debugging and validation to confirm that core systems worked as intended.

After the core build was completed, the project moved into internal testing. This stage verified device compatibility on Android 10 and above and assessed the stability of AR rendering, marker tracking, and YOLO detection. Testers monitored frame rates on low-end and recommended devices. They documented bugs and inconsistencies for refinement.

The project then advanced to a closed alpha test at Partido State University, Salogon Campus. Selected students received the APK so the team could observe performance across a wider set of Android devices. Their feedback

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
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Website: www.parsu.edu.ph
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covered gameplay flow, clarity of the interface, AR responsiveness, and recurring detection issues. They also provided suggestions for stronger engagement and better educational pacing.

The team used this feedback to guide a full refinement phase. Tracking through Vuforia was improved. YOLOv8n detection accuracy was strengthened. Performance issues were resolved. Interface layouts were adjusted to support clearer guidance for new players. Farming progression was balanced, and device-specific issues were fixed to support smoother gameplay.

As the game neared release, the team prepared requirements for Google Play distribution. This step included creating builds that met publishing standards, producing icons and screenshots, writing a privacy policy, and adding safety checks for AR features. The game was uploaded to the Google Play Console under the Closed Testing track for controlled rollout.

The beta release attracted a larger tester group. Google Play provided crash logs, device analytics, and performance data. The team used these reports to identify remaining usability problems and complete final tuning.

After all optimizations are finalized, Paratanom will move to public release. Once approved in the production

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
Website: www.parsu.edu.ph
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track, the game will be available for download. A staged rollout will help ensure stability across device types.

Post-release work will focus on monitoring user reviews, crash reports, and performance metrics. Updates will address new issues, improve gameplay, and add content such as new crops or expanded learning modules. Continued maintenance will support compatibility with future Android versions and devices.

Table 9

Phone System Requirements

Specifications	**Description**
Operating System	Android 10 or higher
Memory (RAM)	4 GB minimum; 8 GB recommended
Processor	Octa-core 2.2 GHz minimum; high-efficiency multi-core recommended
GPU	Mid-range GPU capable of AR rendering
Camera	High-resolution rear camera for crop detection
Storage	At least 2 GB free space for game assets and updates

Table 9 presented both the minimum and recommended phone specifications for the game to run. The 2D nature of the game ensures that a low amount of storage is used when the game is installed, only requiring a high-resolution camera for a better outcome for the crop detection feature of the game.

San Juan Bautista, Goa, Camarines Sur, Philippines 4422
Contact No.: (054) 871-2090; +63 969 608 7792; +63 945 413 9825
Website: www.parsu.edu.ph
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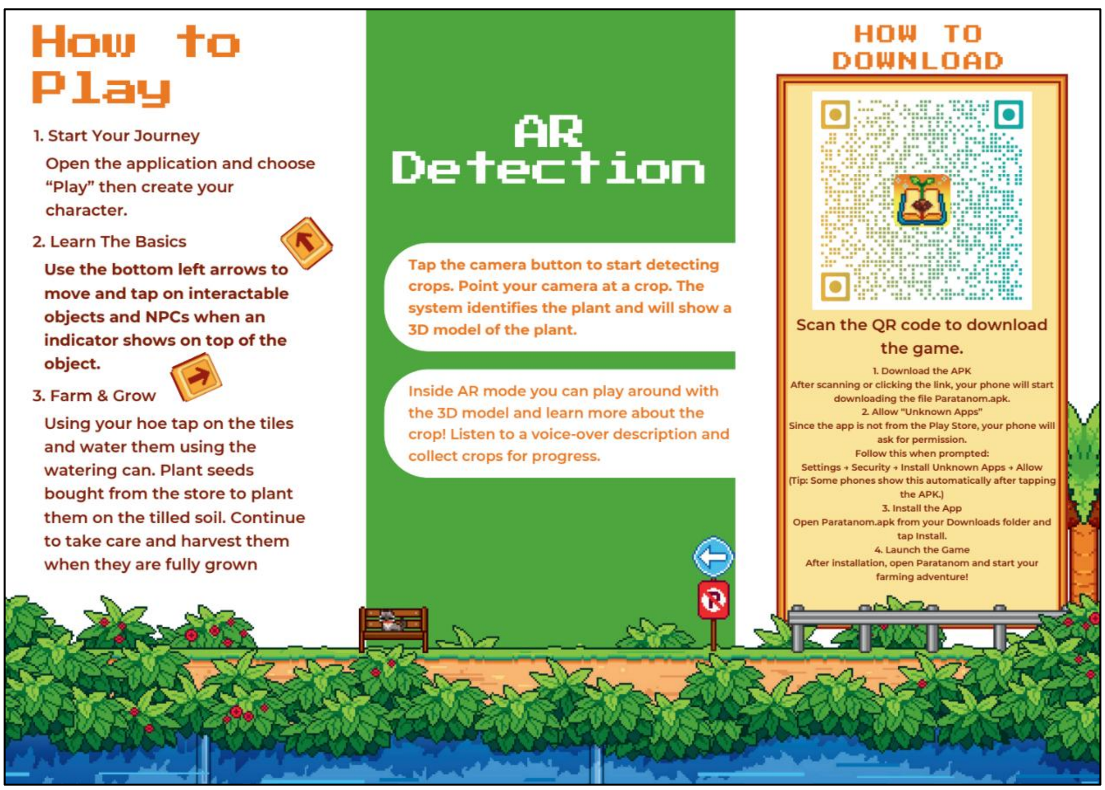
APPENDIX N

SYSTEM MANUAL

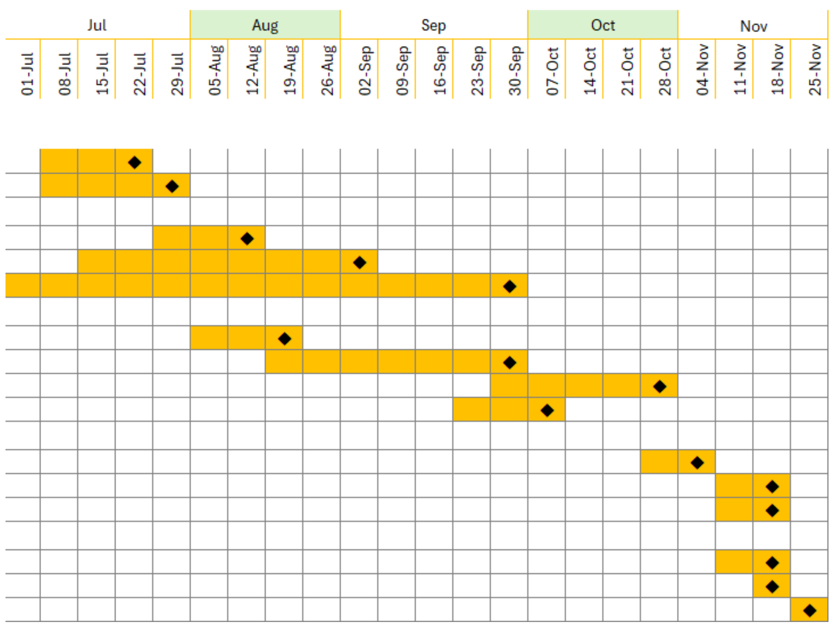


APPENDIX O

GANNT CHART

Project Name: PARATANOM
Project Start: 01-Jul
Current Date: 20-Nov

Task	Project Lead	Start Date	End Date	Days
Planning Stage				
Requirement Gathering	Phoebe Crispino	09-Jul	19-Jul	10
Game Design and Storyboarding	Jeremy Jamer	08-Jul	29-Jul	21
Desgin				
AR Scanner and Marker Design	Jeremy Jamer	29-Jul	10-Aug	12
3D Crop Modeling	Lesther Nacario	20-Jul	30-Aug	41
2D Art Assets	Lesther Nacario	01-Jul	30-Sep	91
Development				
Game Prototype Development	Jeremy Jamer	05-Aug	20-Aug	15
Programming Game Mechanics	Jeremy Jamer	20-Aug	27-Sep	38
Soundtrack and SFX Design	Jeremy Jamer	01-Oct	25-Oct	24
Integration of AR Features	Jeremy Jamer	27-Sep	05-Oct	8
Testing				
Internal Testing and Debugging	Phoebe Crispino	28-Oct	01-Nov	4
Beta Testing with Users	Phoebe Crispino	16-Nov	20-Nov	4
Data Collection (Surveys, Interviews)	Lesther Nacario	16-Nov	21-Nov	5
Finalization				
Final Revisions and Improvements	Phoebe Crispino	16-Nov	18-Nov	2
Final Documentation and Report Writing	Phoebe Crispino	19-Nov	20-Nov	1
Capstone Preparation & Defense	Jeremy Jamer	24/11/2025	28/11/2025	5



CURRICULUM VITAE

JEREMY ZION LAOVINIA JAMER
Partido State University
+63 961 111 7172
jzjamer897.pbox@parsu.edu.ph

PERSONAL INFORMATION

Birthdate:	MARCH 16, 2003
Civil Status:	SINGLE
Gender:	MALE
Religion:	CHRISTIAN

EDUCATIONAL ATTAINMENT

Tertiary:	BACHELOR OF SCIENCE IN INFORMATTION TECHNOLOGY PARTIDO STATE UNIVERSITY, 2022-PRESENT
Secondary:	CORNERSTONE CHRISTIAN ACADEMY OF QUEZON CITY, 2016-2018 VICTORY CHRISTIAN INTERNATIONAL SCHOOL, 2018-2022
Elementary:	CORNERSTONE CHRISTIAN ACADEMY OF QUEZON CITY, 2010-2016

ATTENDED SEMINARS/WEBINARS

The AI Edge: How AI Tools Are Shaping Business Efficiency (AUGUST 20, 2025), MR. MARION A. GONZALES AND MS. JONNADETH S. COJA.

Cloud and Virtualization and Data Management (August 16, 2025), MS. ETHEL GRACE VERANA AND MR. LEMUEL C. CONDES

Stay Safe Online: Cyber Security Basics "Take Control of Your Online Security (August 22, 2025), ENGR. ANTONIO EDWARD E. PADRE

Network Security for Cyber Security and Penetration (August 12, 2025), MS. ETHEL GRACE VERANA

Information Sessions on Data Awareness, ATTY. EUNICE BUSTANTE, August 22, 2025

CURRICULUM VITAE

PHOEBE KAYE ROMERO CRISPINO
Partido State University
+63 9631 177 3939
pkcrispino517.pbox@parsu.edu.ph

PERSONAL INFORMATION

Birthdate:	NOVEMBER 7, 2003
Civil Status:	SINGLE
Gender:	FEMALE
Religion:	ROMAN CATHOLIC

EDUCATIONAL ATTAINMENT

Tertiary:	BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY PARTIDO STATE UNIVERSITY, 2022-PRESENT
Secondary:	GOA SCIENCE HIGH SCHOOL GOA, CAMARINES SUR, 2016-2022
Elementary:	GOA CENTRAL SCHOOL, GOA, CAMARINES SUR, 2010-2016

ATTENDED SEMINARS/WEBINARS

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Stay Safe Online: Cyber Security Basics "Take Control of Your Online Security (August 22, 2025), ENGR. ANTONIO EDWARD E. PADRE

Network Security for Cyber Security and Penetration (August 12, 2025), MS. ETHEL GRACE VERANA

Information Sessions on Data Awareness, ATTY. EUNICE BUSTANTE, August 22, 2025

CURRICULUM VITAE

MARK LESTHER FERNANDEZ NACARIO
Partido State University
+63 9 278235771
mlnacario536.pbox@parsu.edu.ph

PERSONAL INFORMATION

Birthdate:	DECEMBER 29, 2003
Civil Status:	SINGLE
Gender:	MALE
Religion:	ROMAN CATHOLIC

EDUCATIONAL ATTAINMENT

Tertiary:	BACHELOR OF SCIENCE IN INFORMATION TECHNOLOGY PARTIDO STATE UNIVERSITY, 2022-PRESENT BSIT
Secondary:	GOA NATIONAL HIGH SCHOOL TAYTAY GOA, CAMARINES SUR, 2016-2022
Elementary:	GOA CENTRAL ELEMENTARY SCHOOL GOA, CAMARINES SUR. 2010-2016

ATTENDED SEMINARS/WEBINARS

The AI Edge: How AI Tools Are Shaping Business Efficiency (AUGUST 20, 2025), MR. MARION A. GONZALES AND MS. JONNADETH S. COJA.

Cloud and Virtualization and Data Management (August 16, 2025), MS. ETHEL GRACE VERANA AND MR. LEMUEL C. CONDES

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Network Security for Cyber Security and Penetration (August 12, 2025), MS. ETHEL GRACE VERANA

Information Sessions on Data Awareness, Atty. Eunice Bustante, August 22, 2025