

Harvest Horizon: A 2D Farming Simulator Reflecting Realistic Agricultural Practices in the Philippines Using the Implementation of Cellular Automata Algorithm

Rhonnel S. Paculan, Roberto Acepcion Jr, Dan Plantar R. Curate, Dianne Krizelle M. Apor, Karyme R. Bagares, Marilette Rain Barugo

Arellano University, Philippines

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Abstract: This study addresses the issue of students understanding the complexities of farming by developing “Harvest Horizon”, a 2D farming simulation game designed to serve as both an educational tool and an engaging interactive experience. The game employs the Cellular Automata algorithm to model realistic plant growth behavior in response to environmental conditions.

The research follows an iterative Game Development Life Cycle (GDLC) methodology and is developed using the Godot Engine with GDScript for algorithm implementation, Adobe Photoshop and Aseprite for asset refinement, and Figma for user interface prototyping. The game is assessed based on the ISO 25010 software quality model. The evaluation involved two respondent groups: gamers with at least six months of gaming experience across various platforms, and technical experts with academic and professional backgrounds in computer science, information technology, or game development.

Findings indicate that Harvest Horizon effectively engages players in cognitive processes such as sustained attention, cognitive flexibility, working memory, and pattern recognition through its interactive farming mechanics. The game received an overall weighted average mean interpreted as “Strongly Agree.” These results affirm the game’s capacity to deliver an immersive educational experience while adhering to essential software quality benchmarks.

This study highlights the potential of game-based learning as an innovative approach to agricultural education. The successful integration of cognitive engagement and technical excellence underscores the viability of Harvest Horizon as a supplementary educational tool for those seeking to revitalize interest in farming among younger generations.

Keywords: 2D Platform, Farming Simulator, Cellular Automata Algorithm, ISO 25010, GDScript, Godot Engine, GDLC

I. Introduction

Agriculture plays a vital role in economic development and food distribution, both domestically and globally. However, interest in farming among younger generations is declining. As Consentino et al. note, despite the Philippines’ strong agricultural presence, many young Filipinos view farming as labor-intensive with limited financial returns. This trend is not unique to the Philippines; globally, the agricultural sector faces a demographic crisis as youth perceive it as lacking in economic opportunities and demanding in physical labor (Sutherland, 2023).

Conversely, studies show that younger generations, especially Gen Z and Millennials, are highly engaged with digital gaming. According to Newzoo (2024), around 80% of these groups are active gamers, often prioritizing gaming over traditional media. Meriläinen and Ruotsalainen (2023) found that 76.2% of individuals aged 10–19 game weekly, with nearly half playing daily, highlighting gaming’s role in identity formation and social interaction.

This intersection offers educational potential. Gui et al. (2023) emphasize that Digital Game-Based Learning (DGBL) enhances motivation, engagement, and cognitive skills, especially in STEM subjects. Chiotaki et al. (2023) further demonstrate that adaptive game-based systems, tailored to individual learners, yield higher engagement and satisfaction.

Together, these insights affirm that game-based platforms—when thoughtfully designed—can serve as effective tools for educating youth about complex topics like agriculture, bridging the gap between declining interest and the need for agricultural literacy.

II. Background of the Study

Farming and agriculture are foundational industries that significantly contribute to national economies through trade and food security. Despite their importance, there is a global trend of declining youth engagement in agriculture. In both developed and developing nations, aging farmer populations are increasingly prevalent—nearly one-third of European farmers are over 65, while only 10% are under 40. Similar trends are observed in regions like Southeast Asia, including Indonesia and the Philippines, where youth are deterred by low income prospects, limited land access, and arduous working conditions (Borda et al., 2023; Harahap & Siregar, 2018). Urbanization and the appeal of non-agricultural sectors further accelerate this decline, underscoring the need for innovation and policy reform to make agriculture more attractive to younger generations.

Conversely, younger demographics—particularly Gen Z and Millennials—demonstrate high levels of engagement with video games. Research by Ipsos and Deloitte (2023) shows that individuals aged 13–34 dedicate substantial time and financial resources to gaming, using it for social interaction, emotional fulfillment, and entertainment. Educational games, or game-based learning (GBL), capitalize on this engagement by embedding instructional content within immersive gaming environments. Such "edutainment" has shown to improve motivation, retention, and critical thinking (SkillPrepare, 2023; Ziarno, 2023). These platforms accommodate diverse learning styles through visual, auditory, and kinesthetic elements, offering learners more accessible pathways to understand complex concepts.

Moreover, realistic and adaptive game design significantly enhances educational outcomes. Games that reflect real-world systems—especially those incorporating mechanics like personalized difficulty and feedback loops—improve cognitive engagement and learning efficacy (Hamari et al., 2024; Cabrera-Duffaut et al., 2024). This presents an opportunity to reframe agriculture as a compelling subject by integrating farming simulations into educational gaming.

Agricultural realism in games can be enriched by simulating core agronomic principles—such as soil types, irrigation practices, sunlight exposure, and environmental variables (Viridis Plants, 2024; Garden.org, 2024). Algorithmic models must accommodate these factors to reflect the complexity of actual farming decisions. A promising approach to this is the use of Cellular Automata (CA), which effectively model dynamic, rule-based systems such as plant growth and ecological interactions. As explained by Math LibreTexts (2024) and the IPython Cookbook (2023), CA algorithms simulate localized changes and self-organizing patterns, making them ideal for modeling growth cycles, climate variability, and crop-environment relationships in digital farming environments.

By integrating such realistic systems, educational farming games can bridge the gap between entertainment and agricultural literacy. These simulations offer a dual function: they inspire youth interest in agriculture while simultaneously cultivating knowledge of sustainable practices. In doing so, they not only address the demographic challenges of an aging agricultural workforce but also support global food security and environmental stewardship.

Ultimately, reimagining agricultural education through digital innovation can transform perceptions of farming among younger generations. This approach highlights agriculture as both a viable career path and a critical component of global sustainability. Through immersive, scientifically grounded game mechanics, educational simulators foster practical skills, ecological awareness, and a renewed appreciation for agriculture—paving the way for a more resilient and engaged future workforce.

Objectives of the Study

This study aims to address the declining interest in agriculture among younger generations by developing an educational farming simulation game that integrates entertainment with learning. The game will serve as a comprehensive digital platform that enhances awareness of agriculture's significance, fosters career interest in farming, and promotes sustainable practices. By utilizing advanced simulation techniques, such as Cellular Automata, this study seeks to create an engaging tool that not only educates but also encourages youth participation in agricultural professions, thereby revitalizing the sector.

Specifically, the project aims to:

1. Create an engaging and realistic farming simulator that offers players an interactive learning experience, utilizing the Cellular Automata Algorithm to effectively simulate plant growth behavior in response to environmental factors such as weather, soil conditions, and infestation showcasing the complexities of modern farming and its impact on sustainability.
2. Promote a deeper understanding of sustainable farming practices and the environmental challenges faced by agriculture through gaming and simulation by integrating realistic agricultural scenarios that provide both an educational and challenging gameplay environment, immersing players in real-world farming complexities.
3. Develop engaging gameplay mechanics that foster renewed interest in agricultural careers among younger generations by showcasing the significance, challenges, and rewards of farming.
4. Design a comprehensive level structure that mirrors real-world farming situations, offering players practical knowledge about crop management, farming economics, and sustainability.
5. Develop engaging gameplay mechanics that highlight the importance of agricultural careers leveraging the interactive nature of the game to merge entertainment with education, creating an accessible platform that fosters greater appreciation and curiosity for agriculture.
6. Evaluate the technical feasibility, user experience, and educational effectiveness of the game application through ISO 25010 behaviors such as Functionality, Reliability, Efficiency, Usability, Portability to ensure it meets the desired educational and engagement goals.

Conceptual Framework

The below presents the conceptual framework of the study, which functions as a guiding structure for the study's overall conduct and methodology.

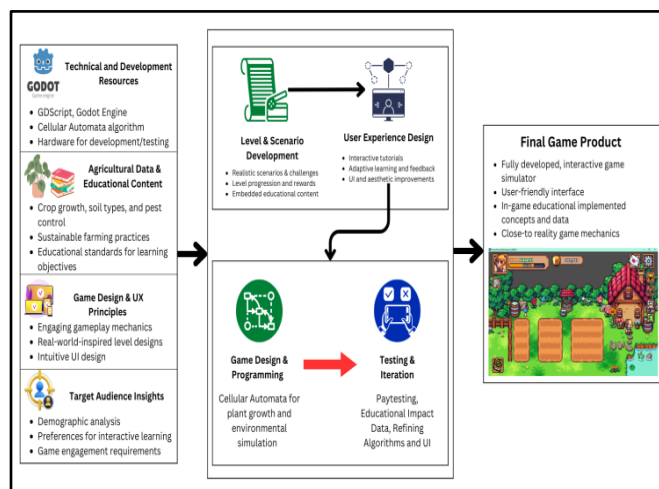


Figure 1: Input-Process-Output Model

The Input phase on figure 1 focuses on gathering resources essential for the game's development, including GDScript and the Godot Engine for programming, Cellular Automata algorithms for simulating plant growth, and data on agricultural practices. This phase also considers the target audience's educational needs, user interface design, and the inclusion of real-world farming data to align gameplay with sustainable agricultural practices.

In the Process phase, the game is developed through stages that include crafting farming scenarios, designing engaging user experiences, and implementing realistic plant growth simulations. Iterative testing and feedback help refine gameplay mechanics, ensuring the game is educational, engaging, and responsive to player performance.

The Output phase results in a fully developed farming simulator that integrates realistic gameplay mechanics with educational content. The game features plant growth, environmental simulations, and sustainable farming practices, presented through an intuitive user interface tailored for younger audiences. It also provides structured learning pathways and real-time feedback to promote critical thinking and awareness of agriculture.

Synthesis

Incorporating the principles of cellular automata (CA) together with the educational potential inherent in digital gaming, thereby establishing an engaging two-dimensional farming simulator that authentically represents agricultural practices in the Philippines. By employing CA algorithms, the game aspires to replicate complex agricultural dynamics, facilitating an immersive experience that allows players to navigate the multifaceted realities of farming through interactive gameplay.

The framework of cellular automata will be utilized such that each crop or land tile within the game operates as an individual cell, which dynamically transitions between states in response to localized rules that consider critical environmental factors, including soil quality, environment, and pest presence. This methodological approach is informed by the work of White and Engelen (1993), which elucidates the capacity of localized interactions to generate intricate patterns within urban land-use modeling. Such a concept is readily applicable to agricultural environments, thereby creating intricacies of crop behaviors and interactions that reflect the complexities of real-life agricultural ecosystems.

Moreover, leveraging insights from Liu et al. (2008) and Tien Bui et al. (2019), the game will feature scenarios that examine a variety of agricultural strategies, allowing players to observe the repercussions of their decisions within a risk-free environment. By modeling the dynamic interactions among crops, resources, and environmental conditions, participants will engage in decision-making processes that emulate the challenges confronted by farmers. This design not only promotes an understanding of sustainable agricultural practices but also cultivates a nuanced appreciation for the decision-making intricacies involved in farming.

The educational dimension of the simulator will be further augmented through the implementation of gamification strategies, as advocated by Hamari et al. (2014) and Palao and Alilay (2021). This will involve the incorporation of elements such as achievement badges and resource management challenges, which serve to enhance active engagement and motivation. Such features encourage players to delve into agricultural concepts in a meaningful context. Through fostering critical thinking and situational awareness, the simulator aspires to function not merely as a source of entertainment but also as a robust pedagogical tool, thereby reinforcing the societal significance of agriculture and the imperative for sustainable practices.

Additionally, the integration of local studies, such as those conducted by Alcantara and Ramos (2022) and Dela Cruz and Santos (2020), underscores the relevance of interactive gaming as an educational medium within the context of Philippine agriculture. By

simulating real-world farming challenges, the game aims to offer players practical learning experiences that effectively bridge the gap between theoretical knowledge and practical application.

Ultimately, this project aspires to forge a comprehensive educational tool that amalgamates the principles of cellular automata, gamification, and authentic agricultural practices. This synthesis seeks to enrich players' understanding of farming within the Philippine context, simultaneously enhancing their engagement and enjoyment through interactive gameplay. This project not only aims to educate players about sustainable agriculture but also endeavors to inspire future generations to recognize the significance of farming and the complexities inherent in agricultural management

III. Methodology

Game Development Life Cycle

This study employs the Game Development Life Cycle (GDLC) methodology, a structured and iterative framework that ensures the efficient development of high-quality game applications by balancing quality, cost, and time. The GDLC divides the development process into distinct, repeatable phases—requirement gathering, design, implementation, testing, and deployment—which are iteratively revisited to incorporate continuous feedback and facilitate incremental improvements.

Overall, the application of the GDLC methodology ensures the systematic integration of functional and educational objectives throughout the development lifecycle. The iterative nature of this approach facilitates continuous improvement, resulting in a game that is both pedagogically effective and technically robust.

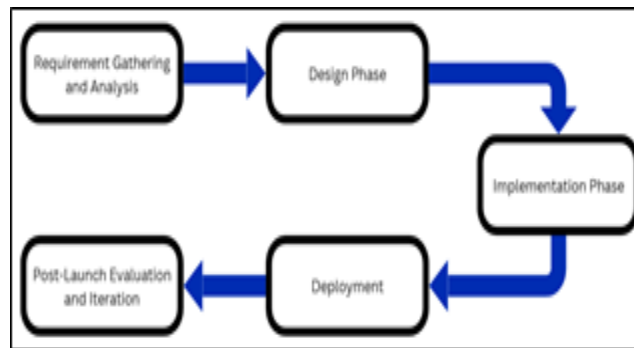


Figure 2: GDLC Model

Development Tools

- I. Adobe Photoshop and Aesperite for asset improvement
- II. Figma for prototyping user interface design and simulating game screens
- III. Godot as the game engine
- IV. Integration of cellular automata into the GDScript code

```

# Growth logic
func process_growth():
    if condition in [Condition.DROUGHT,
Condition.DROWN]:
        print("Growth halted due to poor
condition:", condition)
        return

    growth_timer += $Timers.wait_time
    if growth_timer >= max_growth_timer:
        growth_timer = 0
    if int(growth_stage) <
GrowthStage.FULLY_GROWN:
        growth_stage = int(growth_stage) + 1
  
```

```

    print("Growth stage advanced to:",
growth_stage)

    update_animation()

else:

    print("Plant is fully grown.")

```

Figure 3 GDScript Growth Logic

Logic governs the simulated progression of plant development through the `process_growth` function, which integrates environmental conditions and time-based variables to replicate realistic biological growth. This function initiates with conditional checks for adverse environmental states—specifically drought or flooding (i.e., `Condition.DROUGHT` or `Condition.DROWN`). When these conditions are present, growth is halted, effectively emulating real-world plant stress responses.

If the plant has not yet reached full maturity (`GrowthStage.FULLY_GROWN`), the system advances the growth stage by one increment and calls the `update_animation` function to visually reflect the transition. If the plant is already mature, a corresponding message is generated to indicate the cessation of further growth.

This logic encapsulates a condition-sensitive, time-driven growth model that accurately simulates plant development by incorporating both temporal progression and environmental feedback, thus contributing to the ecological realism of the farming simulator.

```

get_infestation_chance(neighbor.plant)
    if randf() <
infestation_chance:
        new_infestations.append(neighbor)

        neighbor.plant.condition =
PlantScript.Condition.INFESTED

        print("Spread infestation to cell at index:",
neighbor.get_index())

        break

        infestation_queue = new_infestations
get_infestation_chance(neighbor.plant)
    if randf() <
infestation_chance:
        new_infestations.append(neighbor)

        neighbor.plant.condition =
PlantScript.Condition.INFESTED

        print("Spread infestation to cell at index:",
neighbor.get_index())

        break

        infestation_queue = new_infestations

```

Figure 4: Cellular Automata Infestation Logic

Figure 4 Infestation Logic

Infestation Logic is implemented within the `spread_infestation` function, which models the spread of an infestation across a grid of plant cells using principles of cellular automata. This approach allows for localized, cell-based interactions that mimic the propagation of phenomena through a spatial domain.

Respondents of the Study

The study employed a purposive and stratified sampling method to recruit two distinct groups of respondents—gamers and technical experts—to facilitate a comprehensive evaluation of the game application.

Categories	Total
Gamer w/ 13 years and older	50
Technical (profession, BSIT, BSCS students)	50
Total	100

Figure 4 categories of respondents

Statistical Tools

The statistical tools employed in this study are as follows:

Sample Size :

The sample size formula (n) is used to determine the minimum number of respondents needed in a study to ensure that the findings are statistically reliable and valid.

Finite Population Correction (FPC)

The Finite Population Correction (FPC) is used to adjust the calculated sample size when the target population is finite and relatively small.

Weighted Mean

The weighted mean, also referred to as the average mean, serves as a crucial statistical tool for assessing the level of agreement or disagreement across multiple items or statements in a questionnaire.

Frequency Percentage

This statistical tool is utilized to analyze the distribution of respondents based on their grade level, with the results expressed in percentage terms.

Likert Scale

A Likert scale serves as a quantitative data collection tool employed in evaluations and research to gauge individuals' attitudes, opinions, or perceptions. This scale presents respondents with a series of statements or questions, to which their responses are assigned numerical values, facilitating quantitative analysis of the resulting data.

IV. Discussion of Results

Project Description

The outcome of this study is the development of Harvest Horizon, a 2D farming simulation game that authentically represents real-world agricultural practices in the Philippines through the application of the Cellular Automata algorithm. This digital platform is designed to serve as both an educational tool and an engaging interactive experience, effectively merging entertainment with learning. The primary objective of *Harvest Horizon* is to address the declining interest in agriculture among younger generations by providing an immersive environment that showcases the complexities of farming, sustainable agricultural methods, and the impact of environmental factors on crop growth.

Game Interfaces (GIs) and Algorithms

	<pre>func _on_no_button_pressed(): _play_no_button_sound() if modal_manager:</pre>
<pre>modal_manager.close_modal()</pre>	

```

else:

    print("Error:ModalManager not found!")

func _on_yes_button_pressed():

    _play_yes_button_sound()

    await yes_button_sfx.finished

# Wait for sound to finish before quitting

    get_tree().quit()

```

Figure 5: Exit confirmation modal script

Figure 5 presents the implementation of the confirmation modal's button event handlers within the Graphical Interface (GI) of the HUD, managing user responses to critical in-game prompts such as quitting the game. These functions handle the "Yes" and "No" button interactions, ensuring an intuitive and responsive user experience.

	<pre> func _ready(): if not has_save_file(): continue_button. disabled = true # Disable if no save found if new_button: new_button.pressed.connect(_on_new_pressed) if continue_button: continue_button. pressed.connect(_on_continue_pressed) if exit_button: </pre>
--	--

Figure 6: Game start/saved initialization script

Figure 6 presents a fundamental component of the main menu interface within the Graphical Interface (GI) of the HUD, designed to facilitate seamless game state management by enabling or restricting user interactions based on the availability of saved game data. The `_ready()` function serves as the initialization routine, wherein it first invokes the `has_save_file()` function, which leverages

`FileAccess.file_exists(SAVE_PATH)` to verify the existence of a saved game file. If no prior game session is detected, the "Continue" button is programmatically disabled, ensuring that players cannot attempt to load a non-existent save state, thereby preventing erroneous interactions. Furthermore, the function establishes signal connections for the "New Game," "Continue," and "Exit" buttons, directing user inputs to their respective event handlers. Specifically, upon pressing "New Game," the `_on_new_pressed()` function is executed, triggering an auditory feedback mechanism via `_play_button_sound()` to enhance user experience, printing "Starting New Game..." for debugging purposes, and subsequently setting `SavingComponents.is_new_game = true` to indicate that the game should initialize as a fresh session. Finally, the function transitions the game to "main_scene.tscn", effectively launching a new gameplay instance. This structured implementation ensures a robust and user-friendly game initialization process, mitigating potential usability issues while reinforcing state-dependent interaction control, which is critical for the development of scalable and immersive gaming applications.

Project Evaluation Results

The evaluation of the game application is conducted through a dual-assessment framework, encompassing two distinct respondent groups: (a) gamer respondents and (b) technical respondents or professional group. The assessment by the gamer cohort primarily emphasizes the acceptability and usability of the game application, drawing insights from their experiential engagement and overall gameplay satisfaction. Conversely, the technical respondents focus on evaluating the system's technical robustness, performance efficiency, and architectural integrity, ensuring the application meets industry standards from a software engineering perspective. The ISO 25010 software quality model serves as the evaluative criterion for the respondents, systematically analyzing the application's functional suitability, reliability, maintainability, and overall software quality attributes.

Summation of Gamer and Technical Respondents Evaluation

Table 3: Average Rating of Accumulated Respondents

Respondent Group	Weighted Average Mean (WAM)	Verbal Interpretation (VI)
Gamers (50)	3.96	Strongly Agree
Technical Experts (50)	3.89	Strongly Agree
Gamers (50)	3.96	Strongly Agree

Table 3 presents the overall accumulated evaluation ratings of both Gamer and Professional respondents regarding the game's functionality, reliability, performance efficiency, usability, and portability. The Gamer respondents reported an overall Weighted Average Mean (WAM) of 3.96, which falls under the "Strongly Agree" category. This indicates a high level of user satisfaction, suggesting that the game effectively meets the expectations and usability standards perceived by the gaming community. Similarly, the Professional respondents provided an overall WAM of 3.89, also categorized as "Strongly Agree." This result underscores the game's adherence to industry standards in terms of technical robustness, system stability, and performance across different conditions. The consistency between these two respondent groups suggests that the game is not only engaging and user-friendly but also technically proficient and reliable. The slight variance between the two groups may reflect differing perspectives, wherein gamers prioritize user experience, immersion, and ease of interaction, while professionals assess the game from a more technical and structural standpoint. Overall, these findings validate the game's effectiveness in delivering a high-quality, interactive, and well-optimized experience across different user demographics.

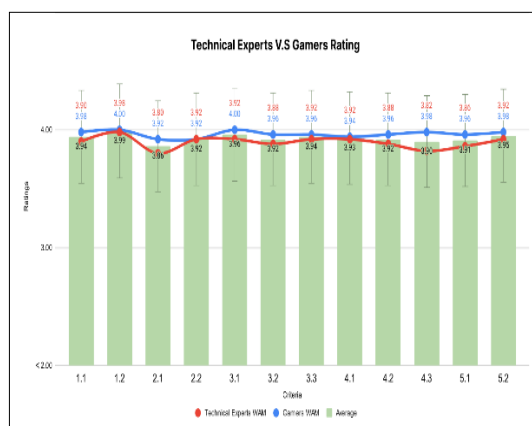


Figure 7: Technical Experts and Gamer Rating Data Chart Comparison

Figure 7 presents a data chart summarizing the evaluation results from both gamer and Technical Expert respondents, based on ISO quality standards. The chart displays the Weighted Average Mean (WAM) for each evaluation criterion, including Functionality, Reliability, Performance Efficiency, Usability, and Portability—key attributes ensuring optimal gaming experience and technical robustness.

Using a 4-Point Likert Scale, with a range of 3.01 to 4.00 indicating "Strongly Agree," the findings reveal that both groups viewed the game positively in meeting quality standards. Criterion 1.2, which pertains to the inclusion of promised features, achieved the highest average WAM of 3.99, indicating successful implementation. Conversely, Criterion 2.1, assessing system stability and crash prevention, recorded the lowest average WAM of 3.86, still within the "Strongly Agree" range, but highlighting areas for further optimization.

Overall, the results confirm that the game meets ISO-defined quality benchmarks, with both gamers and technical experts expressing confidence in its usability, functionality, and cross-platform compatibility. The consistently high ratings across all attributes validate the game's ability to deliver an engaging and technically proficient experience, emphasizing its potential for real-world application in educational and entertainment-based platforms.

V. Conclusion

The findings of this study affirm that Harvest Horizon successfully integrates both cognitive engagement and technical excellence, as evaluated by gamer and technical respondents. The mechanics of the game application effectively engage players in utilizing key cognitive abilities, including sustained attention, cognitive flexibility, working memory, and pattern recognition. These cognitive processes are implicitly activated as players interact with the game's farming simulation mechanics, which require strategic planning, resource management, and adaptive decision-making. The evaluation results from the gamer respondents yielded an overall weighted average mean of 3.96, interpreted as "Strongly Agree." This indicates that gamers perceive the game as cognitively stimulating and acknowledge the engagement of their cognitive abilities while playing Harvest Horizon. The technical respondents provided an overall weighted average mean of 3.89, also interpreted as "Strongly Agree," signifying that the game meets essential software quality benchmarks based on the ISO 25010 evaluation framework. This suggests that technical experts affirm the robustness, usability, and performance efficiency of the application across various technical parameters.

Overall, the combined assessment from both gamer and technical respondents resulted in an interpretation of "Strongly Agree", underscoring the effectiveness of Harvest Horizon as both an educational and entertainment platform. The game successfully achieves its objective of promoting agricultural education through an interactive and immersive digital experience while maintaining high technical standards. These findings emphasize the potential of game-based learning in fostering awareness of agricultural practices, providing an engaging platform that not only enhances players' cognitive skills but also ensures a high level of software quality and user experience.

VI. Recommendations

Based on the findings of this study, several recommendations are proposed to enhance the overall acceptability, usability, and technical performance of Harvest Horizon, ensuring its continued relevance and impact in the fields of gaming and agricultural education. Given the vast potential of the game, numerous areas can be further improved to enhance its features, expand its audience, and refine its mechanics. However, despite these opportunities for growth, Harvest Horizon remains a well-developed and effective application that successfully achieves its intended purpose—educating players about real-world agricultural practices, fostering an appreciation for farming, and promoting sustainable agriculture through an engaging and interactive digital experience.

a. Platform Expansion

Future versions of Harvest Horizon should support iOS, web, and consoles to broaden accessibility. Cloud-saving and cross-device sync can enhance user experience.

b. AI and Machine Learning Integration

Incorporate AI and ML to improve crop simulation realism, predict yields, and personalize player support via intelligent NPCs.

c. Multiplayer Features

Adding cooperative and competitive multiplayer modes can boost engagement through shared farming, trading, and strategic gameplay.

d. Adaptive Tutorial System

Develop a dynamic tutorial that adjusts to player skill levels, using interactive modules and contextual guidance for better onboarding.

e. Low-End Device Optimization

Optimize performance for devices with limited specs by reducing memory use and allowing scalable graphics to reach wider audiences.

f. Real-World Data Integration

Use real-time climate data, crop recommendations, and government advisories to increase realism and educational value.

g. Gamification Enhancements

Introduce achievements, rewards, and leaderboards to incentivize learning and sustained engagement.

h. Educational Partnerships

Collaborate with schools and agricultural institutions to implement Harvest Horizon as a formal educational tool.

i. Sustainability and Climate Awareness

Include content on organic farming, climate resilience, and environmental challenges to promote sustainable agriculture.

j. User Feedback and Iterative Updates

Implement in-game feedback systems to guide updates and improvements based on user input and gameplay analysis.

While these recommendations highlight areas for future improvement, it is important to emphasize that Harvest Horizon, in its current state, already meets its core objectives. It effectively educates players on agricultural practices, integrates real-world farming mechanics, and provides an engaging simulation experience that fosters appreciation for sustainable agriculture.

These recommendations serve as a roadmap for further refinement, ensuring that Harvest Horizon continues to evolve into a more sophisticated, accessible, and impactful educational tool in the realm of digital agriculture and game-based learning.

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