



# An Interactive Mobile Application for Gardening Education and Community Empowerment Developed Using the Waterfall Method

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**Abstract**—Indonesia is currently facing a food crisis exacerbated by climate change, which disrupts agricultural patterns and causes crop failures. These disruptions lead to increased food prices and reduced purchasing power, particularly affecting the lower-income population. One sustainable solution is home gardening, which can enhance food availability and reduce household expenses. However, not everyone has the knowledge or resources to start gardening. To address this gap, the PANENKU application was developed as a mobile-based platform aimed at educating users on how to grow essential food crops such as chilies, shallots, and ginger. PANENKU integrates interactive learning through simulation games that guide users step-by-step, from planting to harvesting. The application leverages the Waterfall development model for systematic design and includes features such as AR (Augmented Reality) experiences, informative articles, and a community forum. These elements foster engagement, support peer-to-peer learning, and enhance users' gardening knowledge. By incorporating educational gameplay and expert interaction, PANENKU not only supports individual self-sufficiency but also promotes environmental sustainability and strengthens local economies. System testing using black box testing, which tests four features, shows that the features can run well and the System Usability Scale (SUS) shows a result of 86%. The results of this test show that the app is particularly beneficial for housewives and beginner gardeners, offering an innovative and accessible approach to addressing food security challenges in Indonesia. Ultimately, PANENKU aspires to be a positive, inclusive platform for agricultural education and community empowerment.

**Keywords:** Augmented Reality; Game; Mobile Application; PANENKU; Waterfall

## 1. INTRODUCTION

Food crisis strangles Indonesia. Climate instability causes Indonesian agriculture and plantations to experience crop failure. According to [1], climate change affects food security because it causes a shift in the rainy season which affects the pattern and time of planting food crops. According to data from the Badan Pangan Nasional (Bapanas), the average price of chili on February 1, 2025 reached IDR 72,778 per kilogram (kg). This price increased by 81.91% compared to the previous week, which was IDR 40,008 per kilogram (kg). The decline in agricultural production will trigger an increase in food prices which will then affect the decline in food purchasing power. If not addressed, the Indonesian people, most of whom are middle to lower class, will have difficulty meeting their daily food needs. On the other hand, the unevenness of food prices in several regions also needs to be considered. Gardening is one solution to the challenge of increasing food prices. Gardening does not necessarily require a large area of land and sunbathing. Small-scale gardening such as planting chili plants or planting spring onions in the yard is also included in gardening activities. In addition to reducing daily shopping costs, people can meet nutritional needs and food availability from their harvest, and can even sell the harvest to other people or local markets. However, not all people have the knowledge to garden. Therefore, the PANENKU application can help people prepare tools, materials and good and correct gardening methods. The PANENKU application is a mobile-based software designed to educate people on how to plant food crops, such as shallots, chilies, ginger, and spring onions, correctly.

In addition, one of the latest innovations in the world of software development is mobile application development technology that allows the creation of applications with high efficiency and effectiveness. Application is a program or piece of software created to carry out specific tasks on electronic devices, like computers, smartphones, or tablets [2]. Applications for today's technology are quite varied, spanning many industries and requirements. With applications, various jobs and activities can be completed more efficiently. In this application, PANENKU there are different features from other applications, where there are games on how to plant starting from tools and materials and community features for discussing gardening with each other. Playing in this case refers to the meaning of intellectual skills (intellectual playing ability). A certain level is a measure of the extent to which the game is optimally interesting to play [3]. One of the methods used in designing a system is Waterfall. The creation of interactive mobile applications for community empowerment and education has attracted a lot of interest, and many approaches are being used to guarantee successful deployment. Projects like [4] mobile learning app, which aims to help moms identify and solve early children eating disorders, have made use of the Waterfall technique. In educational app development, when precise goals and phases are required, this method's emphasis on a sequential development process enables organized planning and methodical implementation. Waterfall methodology extends beyond educational contexts into community development initiatives. For structured system planning and design, the waterfall method works well for projects whose needs have been established from the beginning [5]. This strategy takes a methodical and sequential approach [6]. This procedure is carried out in phases, beginning with the planning stage and ending with the administration stage (maintenance) [2], [7]. Beside that, waterfall is more suitable for generic systems or software and the most frequently used software development model [8]. So, waterfall is suitable for applications that focus on education and community [4].

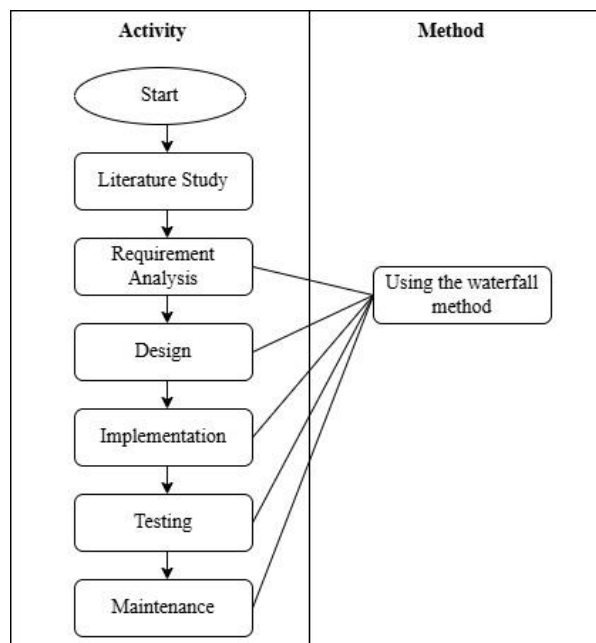


On the other hand, carrying the concept of a game, PANENKU presents interactive step by step planting of plants from the stage of sowing seeds to successful harvest. This game can be used by housewives or people who want to know how to grow food crops. Games are computer programs created with the primary goal of educating, training, or informing players through dynamic and captivating experiences, going beyond simple pleasure [9]. Mobile games are just like video games, but played on mobile devices [10]. In the game, there are targets that the players want to achieve [11]. This concept can help housewives understand information on how to plant more easily. The same thing was also revealed by [12], in his study entitled "The Effect of Education with Simulation Games on Mothers' Knowledge of Stunting in *Pemenang* District, North Lombok Regency", that counseling using the Simulation Game (GIS) method can increase mothers' knowledge about stunting. Not only that, PANENKU provides interesting information and tips related to plants through articles, 3D interactive experiences with AR, and becomes a forum that can connect the general public with experts, professionals, or experienced gardeners to share information, ask questions, expand relationships, and support each other. So, user can join the community to have discussions with plant experts on the PANENKU application. Not only community but also AR technology is used in PANENKU application. In Augmented Reality (AR) technology, users can see the real world around them with the addition of virtual objects generated by the computer [13]. AR is both interactive and registered in 3D as well as blends actual and virtual items [14]. By adding the AR feature, it can provide an overview to users who have never seen plants in real life. The principle of how to use the Augmented Reality application is to focus the android camera then point it at the marker that we have printed in paper form before and then the 3D image appears. The hope is that PANENKU can educate housewives about gardening via games, exchange information through communities and learn about real plants through AR features.

## 2. RESEARCH METHODOLOGY

### 2.1 Research Stages

In this study, the research steps can be carried out in Figure 1 for the first literature study about the waterfall method, Augmented Reality, game and mobile application. The second is design using UML, especially use cases. Then, implementation is using C# programming. The next step is testing which carried out using the black box testing and SUS (System Usability Scale) by users with task scenarios and a questionnaire.



**Figure 1.** The Research Stage

During the test, 10 housewives were involved. Black Box testing is a testing method that focuses on testing software functionality without needing to see the structure of the program code used [15]. The requirement analysis based on initial questionnaire and competitor application like *Plantix*, *Agrio*, *Petani Full Power*, *Petani Sawit Pro*, and *Ekosis* for referencing in designing new designs and feature which has games and AR. The comparing similar applications can be seen in Table 1. Comparison feature. The waterfall method describes a coherent and systematic approach through stages [16], [17] namely:

- a. Requirement analysis: the goal of this step is to compile the system needs required to efficiently support the gardening education. These specifications initial questionnaire cover both functional (what the system should perform) and non-functional (such security, speed, or user interface) elements. In order to achieve the goal of the PANENKU software on the urgency of planting food crops, a survey was conducted on 10 people with a background of housewives to find



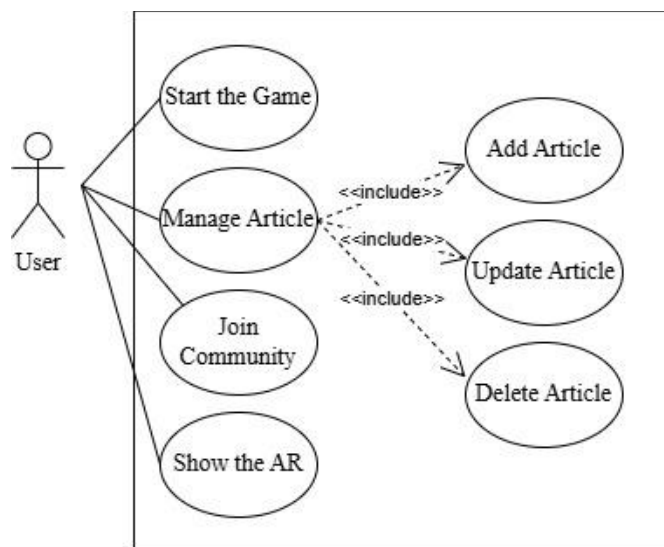
out the needs and desires of users for the PANENKU application. From the results of the initial survey, 73.3% said that they had never received digital education on planting food. Based on the survey results presented previously, the researcher concluded that an educational application related to how to plant food crops needs to be created. In this case, the researcher used an interactive game as a means of conveying information related to good and correct planting procedures based on the real experiences of garden farmers. In addition, from the results of the researcher's observations of other similar applications that were used as a comparison, an AR feature was created to view plants in 3D, an article feature for a detailed explanation of the procedures for materials, tools, and steps accompanied by recommendations for certain materials, and a community feature to bring together users of the PANENKU application. Beside that, the research use the data from the comparison feature from similar application.

**Table 1.** Comparison feature

Application	Community	Article	Game	AR
Plantix	√	√	X	X
Agrio	X	X	X	X
Petani Full Power	X	√	X	X
Petani Sawit Pro	X	X	√	X
Ekosis	√	X	X	X
Panenku	√	√	√	√

The comparison with other applications is that there are games that focus on the stages, tools and materials for planting food crops such as chili, onion and ginger. Based on Table 1, the Plantix Application only has community and article features. The Agrio Application does not have all four features. The Full Power Farmer Application only has article features while the pro palm oil farmer application only has game features. Likewise, with the Ekosis Application which only has communities. While in the PANENKU application, all four features are available in the PANENKU application.

- b. Design: this phase entails developing a technical design in accordance with the requirements that have been examined. The user interface and UML (Unified Modelling Language) like use case diagram are all included in this design. UML is used to model systems visually [18]. Designing At the designing stage, use UML, specifically use case diagrams. In the design of user interface is used low fidelity prototypes.
- 1. Use Case Diagram : describes the type of interaction between a user of a program (system) with the system itself [19]. The actors in this system consist of one actor, namely the user, which can be seen in Figure 2. Users can be housewives or people who want to learn gardening and plant or agricultural practitioners.



**Figure 2.** Use Case Diagram

- 2. Low Fidelity Prototype : uses frequently employed in preliminary user interface design assessments [20]. This design will be used by users to understand and evaluate whether the expected needs have been met [21]. At the low fidelity stage, the author will present an initial version of the visual interface that is simple and easy for users to understand [22]. One of three technologies is usually used by user interface designers to create low fidelity prototypes: basic art supplies (like pen, paper, and scissors); general-purpose graphics and presentation software that isn't made especially for low fidelity prototyping (like PowerPoint and Photoshop); and custom software made especially for creating low fidelity prototypes [23]. As shown in Figure 3, the basic art supplies employed in this study were paper and pens.

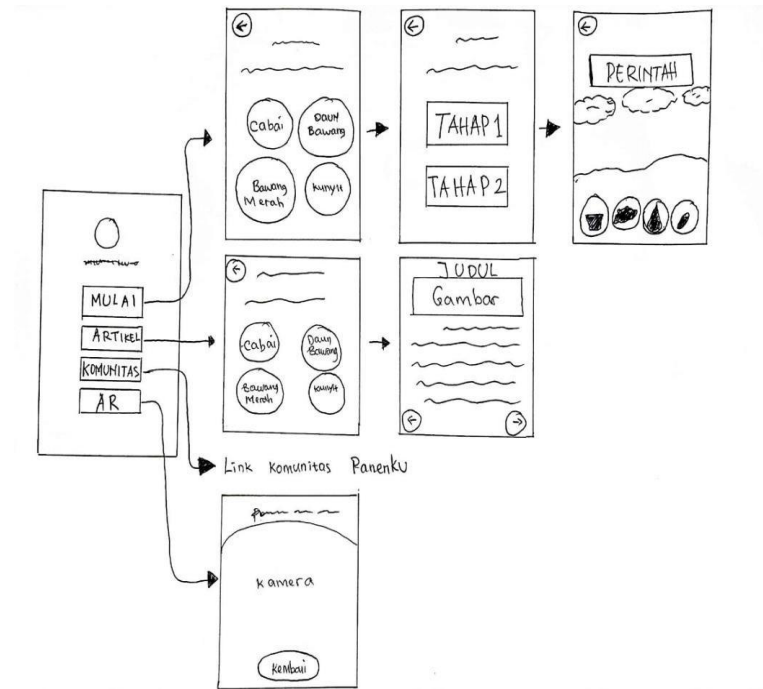


Figure 3. Design PANENKU

After conducting a needs analysis, design prototype was created to represent the menu design layout and functions in the PANENKU software. The dashboard display contains the PANENKU logo, game features, article features, community features and AR features. The game displays a selection of plants that you want to know how to plant. The article page displays news about plants that you want to know the latest news about. While on the community page, users enter a WhatsApp group where they can discuss gardening. On the AR page, it is a scan to the marker to display images in 3D.

- c. Implementation: The process of creating a system based on the developed design is known as this step. To implement all of the system's features and capabilities, the programmer creates code.
- d. Testing: his phase makes sure the system functions as intended and is free of errors. System performance, and functionality are all validated throughout testing. In addition, at the testing stage using blackbox testing and SUS carried out by users, namely housewives in the form of task scenarios to measure effectiveness and SUS questionnaires to determine user satisfaction. There are 5 task scenarios that must be completed by 10 housewives as in Table 2. In addition, users will also fill out the SUS questionnaire. There are 10 questions that will be answered by users as in Table 3 with answers on a scale of 1 to 5.

Table 2. Task scenario

Number	Task Scenario
T1	Displays the dashboard
T2	Playing stage 1 and stage 2 games
T3	Displays the article
T4	Join the community
T5	Displays the AR

Table 3. Questionnaire of SUS

Number	Question
Q1	I think that I would like to use PANENKU frequently
Q2	I found PANENKU unnecessarily complex.
Q3	I thought PANENKU was easy to use.
Q4	I think that I would need the support of a technical person to be able to use PANENKU.
Q5	I found the various functions in PANENKU were well integrated.
Q6	I thought there was too much inconsistency in PANENKU
Q7	I would imagine that most people would learn to use PANENKU very quickly.
Q8	I found PANENKU very cumbersome to use.
Q9	I felt very confident using PANENKU
Q10	I needed to learn a lot of things before I could get going with PANENKU



- e. Maintenance: The last phase, in which the system is kept up to date following deployment to guarantee its continued viability. This covers bug patches, feature upgrades, and adaptations to new requirements.

### 3. RESULT AND DISCUSSION

In this study, the data used is the initial stage questionnaire data in the requirements analysis in the form of functional and non-functional needs distributed to 10 housewives and a comparison of similar applications as in Table 1. Stages in research based on the waterfall method, there are:

#### 3.1 Implementation Result

In developing PANENKU software, the programming language used is C# programming language by utilizing Unity IDE. Unity IDE has AR Foundation feature that supports the creation of augmented reality (AR) so that it can enable the creation of 3D objects. The results of the implementation of the design stage are as follows:

##### a. Dashboard

On the dashboard, there are start (game), info (article), AR, community and exit buttons. Each button has its own function. The start button is placed at the top compared to the other buttons because the PANENKU mobile application prioritizes games as the main educational feature in gardening. The info button provides information on how to plant in the form of articles and the latest information on how to garden. The AR button will take users to see the harvest in 3D. The community button, users are invited to enter into a discussion with housewives who want to garden and agricultural practitioners to provide information and tricks on how to plant properly. In addition, exit button to exit the PANENKU application.



Figure 4. Dashboard PANENKU

##### b. Game



Figure 5. First Page of the Game



Figure 6. Second Page of the Game

On the game page the user selects one of the plants they want to plant. In the game has some of plants like chili, spring onions, shallots, turmeric as in Figure 5. If user choose of one of this plant, user will enter to the second page as in Figure 6. There are two buttons, namely stage 1 and stage 2. Stage 2 can be played if the user has completed stage 1. In stage 1 the focus is on how to plant and the tools and materials needed as in Figures 7 and 8. For the first user is educated with prepare the soil. The size of the good land is also explained in this game. Then the plant seeds are ready to be planted. And finally, the user is advised to give water as much as the measurement stated in this game. In addition, there are additional tips and tricks at the end of the game that provide advice so that plants can grow well.



Figure 7. Third Page of the Game



Figure 8. Fourth Page of the Game



Figure 9. First Page of Stage 2



Figure 10. Second Page of Stage 2

In stage 2, focus on the fertilization stage. Starting from the type, method and time of giving fertilizer. There are several steps until the user completes the game and at the end of the game is given an article so that the plants that have been planted can grow thickly and harvest quickly. In stage 2 also shows that the game of one of the plants is finished which can be seen in Figure 9 and 10. Not only artificial fertilizers are explained in this game, but also natural fertilizers that can be given to plants. If stage 1 is finished, the padlock in stage two is no longer there. In other words, stage 2 can be played by the user.

c. Article

In the article feature there are several plant options that can be selected as in Figure 11. When the user clicks on one of the plants, for example leeks, the user is taken to the next page, namely the leek page in Figure 12. Apart from the description there is information about tools, materials, processes, tips and video links. Video about how to plant these plants until harvest. So, if users do not have time to read the article, users can watch a short video tutorial on how to plant the plant. So that it is easier for users to learn how to plant the food crop.



Figure 11. First Page of Article

TANAM DAUN BAWANG



Daun bawang adalah tumbuhan yang sering sekali dijumpai pada masakan. Meskipun daun bawang hanya dipakai sebagai bahan pelengkap saja pada makanan, tumbuhan ini tetap diusahakan untuk ada pada masakan. Bukan tanpa alasan, cita rasa yang khas dapat menambah selera makan.

Selain itu keberadaan daun bawang ini juga dapat mempercantik masakan. Tanaman daun bawang ini dapat dibudidayakan. Selain untuk memenuhi kebutuhan sehari-hari, daun bawang juga dapat dibudidayakan dalam jumlah yang banyak untuk dijual.

Proses penanaman dan pemeliharaan daun bawang ini juga tergolong murah dan sederhana. Berikut ini adalah bahan, alat, tips,

Figure 12. Second Page of Article



d. Community

In the community feature, when the user clicks the community button, the user will enter the WhatsApp application. In the community group there are discussions, information webinars about gardening. Apart from that, the group has experts who can educate members. The latest information regarding gardening is also discussed in the group. Not only expert people but also practitioner of gardening.

e. Augmented Reality (AR)

Augmented Reality (AR) is used to see the shape of the plants being planted. Apart from being useful for housewives regarding the shape of the plant, it can also be used to educate children. This AR feature requires two devices. One device is used to display markers in the PANENKU application in Figure 13. One more device, used for barcodes.



Figure 13. Second Page of Article

3.2 Testing Result

Black box testing will check four features, namely games, articles, communities and AR to find out whether the features are running well or not. The scenario components have valid values. The results of the games feature testing are shown in Table 2. Of all the features tested using the black box, they produce correct or valid values. This indicates that the application can run according to software requirements.

Table 4. Games Testing

Identification	BU-01		
Function Number	F01		
Test Item Name	Game Testing		
Purpose	To request stage 1 and stage 2 game permission		
Description	This function is used to make a request for game permission stage 1, namely how to plant.		
Initial Conditions	<ol style="list-style-type: none"> <li>1. Select the home menu</li> <li>2. Select the start button</li> <li>3. Select the plant you want to play</li> <li>4. Select the request Stage 1</li> <li>5. Select the request Stage 2</li> </ol>		
Test Date	21/01/2025		
Examiner	All group members		
	Test Scenarios		
	<ol style="list-style-type: none"> <li>1. Select the start button</li> <li>2. Select the plant</li> <li>3. Select Stage 1</li> <li>4. Play the game until the final stage</li> <li>5. Select Stage 2</li> <li>6. Play the game until the final stage</li> </ol>		
	Results Evaluation Criteria		
	When the correct game request form has been submitted, the request data can enter the database and the request is executed, but when only part of the fields in the request form are filled in, an error message will appear.		
	Cases and Test Results		
Input Data	Which are expected	Observation	Conclusion
All stages that must be selected are in accordance with the Stage 1 game request sequence	User permission request data can be created and entered into the database.	As expected.	[ X ] accepted [ ] rejected



format. If stage 1 is finished, you can request stage 2.

Based on Table 2, the name of testing is BU-01, function number is F01 and test item name is game testing. This test is done by seeing whether the game functionality runs according to the requirements, design and implementation that has been done. Starting from the pre-condition / initial condition to the conclusion of being accepted or rejected. The initial condition explains that before entering the game the user must do what first. It is explained that the user must select the home menu. Next start button, request stage 1 and stage 2 gradually. In addition, the test scenario is also explained to run the game until the results are accepted. There are four test scenarios and four menu features. On of them can be seen in Table 2. Based on the test, all features result in accepted. This indicates that all features can be accessed according to user requests. So, users can use the PANENKU application without error.

**Table 5.** Questionnaire of SUS

Number	Strongly Disagree	Don't Agree	Neutral	Agree	Strongly Agree
Q1	0%	0%	0%	40%	60%
Q2	60%	30%	10%	0%	0%
Q3	0%	0%	0%	30%	70%
Q4	70%	20%	10%	0%	0%
Q5	0%	0%	10%	40%	50%
Q6	60%	30%	10%	0%	0%
Q7	0%	0%	20%	40%	40%
Q8	70%	20%	10%	0%	0%
Q9	0%	0%	0%	40%	60%
Q10	70%	20%	10%	0%	0%

In addition, based on Table 5, ten respondents answered ten questions which are templates from the SUS questionnaire. The questionnaire results were 86% which were in the acceptable category. In addition, the test results using five task scenarios which were qualitative tests carried out by ten users showed that the button design was unambiguous, instructions could be followed well and easily. This shows that in terms of quantitative it shows that it is acceptable and in terms of qualitative it is easy to use and effective.

## 4. CONCLUSION

Based on the findings of the study, it can be said that the PANENKU application can be used to help housewives learn more about gardening. The implementation of the PANENKU application was tested using black box testing. This can be shown by the results of testing four features, games, community, article and AR. The resulting is accepted. This shows that no problems were found in the application that was built. In other words, the application that was created was successful and valid according to the needs and functions. In addition, from a quantitative perspective, using SUS resulted in 86% which was in the acceptable category and from a qualitative perspective, using task scenarios showed that the PANENKU application was effective for use as education in gardening. Its user-friendly dashboard provides seamless access to educational games covering planting and fertilization stages, comprehensive articles with multimedia resources, a community platform for user interaction and expert advice via WhatsApp, and an AR feature for interactive plant visualization.

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