Journal of Theoretical and Applied Information Technology
15th March 2022. Vol.100. No 5

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

INTERNET OF THINGS CONCEPT IMPLEMENTATION FOR MICROGREEN FARMING AUTOMATION WITH GAMIFICATION PRINCIPLES

[1]ALBERT SEBASTIAN, [2]RIYANTO JAYADI

[1,2]Information Systems Management Department, BINUS Graduate Program – Master of Information Systems Management, Bina Nusantara University, Jakarta, Indonesia

E-mail: [1]albert.sebastian@binus.ac.id, [2] riyanto.jayadi@binus.edu

ABSTRACT

Food security is one biggest challenge, especially in a big city. Price of fruits and vegetables are relatively higher than other surround cities. That happens because capabilities to produce fruits and vegetables decrease along with the increasing rate of urbanization. Therefore, households in big cities have to be able to produce their own fruits and vegetables. With Internet of Things concept (IoT), we can make farming process easier. In order to increase user interest, we can use gamification principle along with information system to collect and process data. Gamification has been utilized to increase user's interest or loyalty. In this paper, researchers described a concept of gamification and IoT combination in agriculture. Researchers explain how it can be used for increasing user's farming interest, especially urban community which have limited open fields.

Keywords: *Gamification, Internet of Things, Agriculture, Farming, Automation*

1. INTRODUCTION

Big city usually identic with central of business. Therefore, it always attracts migrants to move in. Infrastructures are more advance in big cities than in suburb. Those infrastructure replace significant wide area of agricultural land. For example, in Jakarta, as the biggest in Indonesia, infrastructure developments have to keep going rapidly. As the infrastructure developments continue, the agriculture area in Jakarta decreased. Based on Lokadata website, which show data presentation of total agriculture land in Jakarta every year from Indonesia Ministry of Agriculture, since 2012 to 2017 agriculture land in Jakarta has decreased at least 32.5% (Picture 1). That also affected the production of agricultural crops in Jakarta. Based on Statistics Indonesia (BPS) survey, almost all vegetables production in Jakarta has decreased significantly year by year [1]. For Example, Jakarta in 2015 was able to produce 5,071 ton of spinach, but in 2018, the spinach production only reached 3,297 (reduced up to 35%). Similar result was shown by water spinach crops production which reduced up to 56% within same years (from 10,223 ton in 2015 and 4,524 ton in 2018). Although those crops are short duration cover crop, easy to grow and maintain in Indonesia, and don't need a large area to grow, the production keeps reduced as the urbanization increase. The reduced of Jakarta spinach and water spinach production shown in Table 1.

Table 1: Jakarta's Spinach and Water Spinach Production in 2015- 2018

Vegetables	Production (ton)			
	2015	2016	2017	2018
Spinach	5107	4843	3612	3297
Water Spinach	10223	6603	5825	4524

Like others big city, most of residential type in Jakarta has small open area or nothing at all. Therefore, Jakarta's citizen has limited space problem to grow crops for business or even just for a hobby. There are some techniques of farming which developed to solve this limited space problem such as hydroponic farming. Hydroponic is one of farming activities which uses water as the main growth media instead of soil. With hydroponic, process of planting does not require large space [2]. Although hydroponic is one of the

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

solutions for limited space problem, hydroponic technique is still not suitable for people who don't have free open space at all like people who lives in apartments. Therefore, the limited space is still the main problem of the reduced crops production in Jakarta.

Distribution cost is one of factors that affect market price. Market price will likely get higher as the distribution process continue [3]. Because of the reduce in crops production and lack of capability to produce vegetables independently, Jakarta citizen has no choice but to consumes vegetables that distributed from another region. That leads to relatively higher price for vegetables in Jakarta compare to another region in Indonesia. It has expected as one of main reason of low fruits and vegetables consumption.

Fruits and vegetables are one of the main sources of fiber, vitamins and minerals. However, based on research conducted by the Research and Development Center of Public Health, compared with WHO standards, 97.1% of the Indonesian population in all age categories do not meet the standards for fruit and vegetable consumption. According to the research, the average consumption of fruit and vegetables in Indonesia is around 108.8 g/person/day, far below the WHO standard of 400 g/person/day. The consumption rate of fruit and vegetables, which is far below the average, makes Indonesia one of the countries that have problems with lack of nutritional adequacy, especially the age group below five years old. In Indonesia, the percentage of children under five who experience hunger and malnutrition reaches 13.5%. The data was taken from the RISKESDAS Report (Basic Health Research), Health Ministry of the Republic of Indonesia in 2018 [4]. According to the same report, it was stated that malnutrition also occurred in 17.7% of children under five, 3.9% of whom experienced severe malnutrition. Jakarta, as the most developed city in Indonesia, recorded under-five malnourished under special care reaching 1692 people in 2016. Although the number of malnourished children has decreased to only 430 people in 2019, this problem remains one of the biggest concerns for the Jakarta government.

The problem of limited land and the problem of nutritional adequacy is the background for the concept of microgreen agriculture become popular. Microgreens are plants that have passed the germination stage, but have not yet grown many true leaves [5]. One of the reasons why microgreens are gaining popularity is because they have a higher nutrient density than mature plants [6]. In the same amount, Microgreens can have up to 10-40x the nutrient content of a mature plant. For example, in microgreen spinach (Spinacia oleracea L.), the content of phytonutrients (including ascorbic acid, carotenoids, folate, a-tocopherol and phylloquinone) far exceeds that of mature spinach by the same weight [7]. In other words, microgreens can provide more nutrients without having to eat a lot of vegetables. This is useful to support the nutritional needs of children (toddlers) and parents (seniors) who have limitations in consuming fruit/vegetables.

Microgreen is also famous for its relatively easy planting process, does not require much space, can be done indoors and fast harvest. This can be a solution for all households who want to produce their own vegetables, but do not have much open land. In fact, the concept of microgreen farming allows planting without sunlight at all. Usually, microgreen farmers need 7-14 days to produce microgreens which ready for consumption (depending on the type of plant/seed planted) [6]. This makes the maintenance costs used much cheaper than the maintenance costs needed to harvest mature plants. Although microgreen planting is relatively easy and can be done anywhere, there are still some environmental variables that microgreen farmers must pay attention to. For example, at the germination stage, microgreen farmers must adjust the humidity and temperature at an optimal status. A dry environment causes a low percentage of germination success, while an environment that is too humid can cause mold growth that inhibits the growth of microgreens. Therefore, microgreen farmers must monitor the microgreen environment at least once or twice a day. The limited time to carry out maintenance and limited knowledge about the right way to plant microgreens make people reluctant to cultivate crops even though the process is relatively easy.

The concept of the Internet of Things or commonly abbreviated as IoT is the concept of utilizing sensors/actuators and other electronic components that have the ability to access internet networks for collecting data or running control. In recent years, the IoT concept has become a popular concept which uses in various fields such as health, electronics, agriculture and others. By using the concept of IoT, various processes can be automated and the data which collected can be viewed and controlled from everywhere. One of common usage of IoT in Indonesia is utilization IoT in the agricultural sector.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Agricultural sector commonly uses IoT for the purposes of monitoring the agricultural environment, collecting plant health data and managing the risk of crop damage (Pathak, 2019). Utilization of IoT and the concept of microgreen planting can be combined with artificial light sources, like LED lights or special lights for farming (GrowLight) to create automated farming in closed spaces. Therefore, every household, especially those in big cities, can carry out the process of planting to harvesting automatically. The main concept of using IoT in indoor farming is to minimize the effort, so that each household only needs to enter the seeds, then return when the seeds are ready to be harvested in the form of microgreens. In addition, each device in each household can send data of the planting environment to an integrated server, making it easier to monitor, analyze data and control.

People interest in farming process can be seen from many developments of popular game application which use farming activities as its concept. Each of those game have its system to attract user to play regularly. Instead of using farming concept in a game, researcher try to create a gamification concept in real-life farming.

Based on the idea of the solution to the above problems, research was conducted to use the IoT concept, the microgreen concept and LED light/Grow Light in the form of a prototype of agriculture in limited closed space, which called the Smart Farming Box. The result of this research is a concept/prototype that integrated between monitoring hardware, an information system and also basic idea of using gamification concept in that information system. The results of the research are only a prototype / concept that is expected to be developed on a larger scale in the future to increase crops production, especially in big cities that have limited open space, and support the idea of food security in various regions of Indonesia.

2. LITERATURE REVIEW

2.1 Internet of Things (IOT)

Internet of Thing, which is usually abbreviated to IoT, is a concept of things integration via internet in order to create a monitor and control system. The things that mentioned before can be categories into sensors and actuators. Sensors are any things which can be used to detect physical or chemical changes in environment. Meanwhile, actuators are any things which can be used for controlling those physical or chemical changes in order to create a desired environment. The perfect combination of sensors and actuators will support to achieve optimum condition of an environment.

In this modern era, which always demand an automation in every process, IoT is not only used in information technology fields. IoT has been used in almost every field, such as economy, business, education and even agriculture. IoT optimize human interaction with some process, further ensure minimum, effective and efficient efforts. In Agriculture, IoT used for monitoring plants' growth, environment control, crop risk and health analysis, and also to records plants' data [8]. IoT has contributed in almost every aspect of modern agriculture and ensure farmers to do farming activities in more effective way [9].

2.2 Gamification

Gamification is a concept of using game principles in other process which is not a game. Gamification is actually not a new thing. Nowadays, gamification is not only a strategic decision, but also a basic tool for business with digital users as its target user [10]. Gamification has received the most attention in business transformation situations due to its power to engage audiences [11]. Not only engage the audience, gamification also become a trend in e-commerce because company believes that gamification has potential to increase awareness and loyalty of consumers with respect to the brand [12]. Gamification give "motivation" play as important role in learning, further ensure user to learn while having fun. Therefore, application of game-based learning and gamification are often to be found in kindergarten education [13]. Those examples show how gamification concept can be used for many fields from learning, business, e-business etc.

2.3 Urban Farming

Urban farming is term used for represent farming concept in big cities. It always symbolized with a scheme or technique of farming which uses small area to its max potential. Examples of those techniques are vertical farming, hydroponics, aeroponics, etc.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

2.4 Microgreens

Microgreen is a new class of vegetables [6]. It's a vegetable that harvested after cotyledons, the first couple of leaf from seeds, fully grown and the true leaf start to grow [5]. Microgreen also called micro herbs or vegetable confetti. It comes in 3-10 cm height [14], has rich flavors and colorful splash of colors [15]. Because of its tender texture, Microgreens can be served as one of salads ingredient, additional vegetables for sandwiches or burgers and even a main dish [16].

Microgreens can be produced from vegetables seeds like peas, chard, beets, spinach, kale, cilantro, any salads crop and even sunflower seeds [17]. They usually grown inside a tray [5], [14], [17] with any plant medium such as cocopeat, soil, or rockwool. One of the reasons why microgreen farming became popular is the ability to grow microgreens indoor (indoor gardening).

2.5 Prototype

Prototype is an early state of the real product which used for investigating system functionalities [18]. Not only for testing purposes, prototype often created for final product approximations, verifying early design of a product or decisions making needs [19].

2.6 Microcontroller

Microcontroller is a chip that can be used for controlling electronics instruments and save logic / code of a program inside. In general, microcontroller consists of central processing unit (CPU), random access memory (RAM), memory drive, input / output pin, and several signal converters, both analog to digital converter or digital to analog converter. Some of the most popular microcontrollers in the market nowadays are Arduino, Raspberry Pi, AVR ATMega Series, etc.

3. RELATED WORKS

IoT design in agriculture knowledge area is not a new thing. Several projects have been conducted to create an optimal IoT usage in agriculture. IoT concept for monitoring plant growth parameters has been studied by Pathak, et al [8]. That research showed how IoT can be utilized to monitor farming environment and also control its variable. In this research, researcher will follow the principles which create automation in monitoring plant growth parameters but focus on seeds' germination process and growth of couples of true leaves (until seeds become microgreens). Several "Smart Farm" also has been created to ensure the effectivity of IoT usage in farming processes. They connected the IoT system to clouds in order to make monitoring process easier and to create optimum environment for plants to grow [20]–[22]. They used hydroponic farming system combined with IoT to make a modern farming [20]. In this research, data also saved in cloud too for monitoring purposes.

Beside IoT concept, this research will provide basic idea of gamification concept in IoT implementation, which rarely found in farming or IoT research before. Most of the research focus in automations of farming process in general. This research will be focused on farming automation in closed space and using gamification in its application.

This study will combine what other researchers has done to analyze how to make IoT system specifically for microgreen and indoor farming along with gamification idea in the information system. Scope of this study is to provide a concept design or a prototype design to create an idea of indoor farming automation. Prototype design will be built in a form of box with IoT system inside and can contain 1 tray of microgreens. Further research is needed in order to create a real IoT environment which ready for commercial use.

4. RESEARCH METHODOLOGY

In this research, a prototype of microgreen farming in a closed space is developed that is integrated with an Internet of Things (IoT) based automatic monitoring and control system. The research flow is planned in accordance with Figure 3.1.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

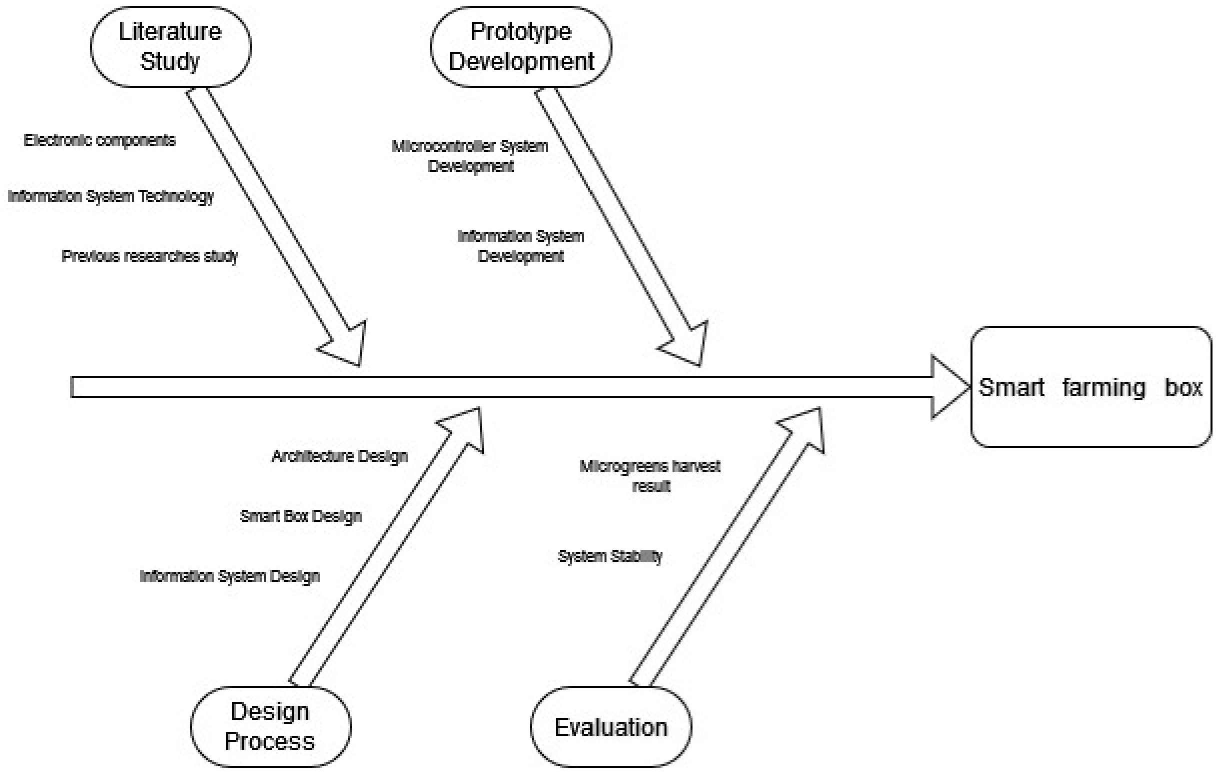

Figure 1. Research Methodology

4.1 Literature Study

This research is related to several scientific fields including agriculture, electronics and informatics. In order to support the success of the research, this research begins with a literature study which will be carried out for the first one to two months. The literature study begins by paying attention to previous similar research, understanding microgreen planting techniques and their advantages and disadvantages, understanding the use of microcontrollers, sensors and actuators to be used, understanding the characteristics of the microgreen lighting process in a closed space that will be used in research and studying supporting electronic components, etc. The literature study also includes a simple experiment to record the growth of conventionally grown microgreens, without using a prototype system. A simple trial process was carried out in Jakarta, to then be used as a reference in the evaluation stage.

4.2 System Model Plan

In this research, an agricultural technology application was developed in the form of an intelligent system for controlling and monitoring agriculture in a box as an illustration of a closed environment that does not receive sunlight. The main concept of the farming box is to combine several sensors and actuators with a microcontroller that is integrated with the esp8266 wi-fi module and connects it to a cloud-based information system. The data sent by the microcontroller will be stored into a database on the cloud which is then visualized through a display on a website page that is useful for further analysis.

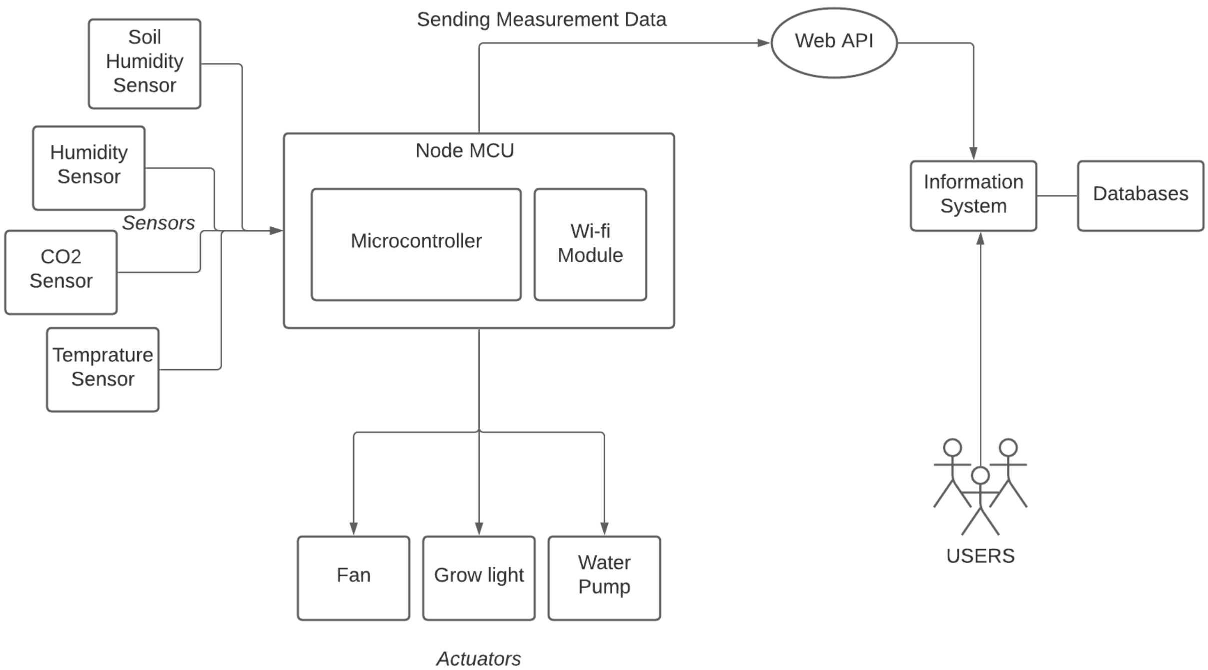

Figure 2. System Architecture

The process of sending data and control to the system is done automatically. Therefore, in this system, data is only recorded for further research needs or further system development. Not as a consideration for the system in controlling the planting environment automatically, although it does not rule out the possibility to make adjustments manually based on the data obtained. Adjustment of the control variables on the prototype system is done automatically, based on the logic that has been programmed in microcontrollers. An overview of the architecture of this system model can be seen in Figure 1. The website will be built using the PHP version 7 programming language combined with MariaDB as a database.

Meanwhile, the initial hardware design of the prototype follows the model in Figure 3.3. The box will be created by minimizing the light entering, as an example of a closed and low light environment. At the top, a growlight will be installed as the main light source instead of sunlight. On the side of the box will be installed a fan that acts as an actuator in adjusting the humidity in the system and controlling air flow. The bottom of the box will be the room that holds the water. A water pump will be placed in the container as an actuator which is used to adjust the water content in the growing media. Plants will be planted using planting media in a tray and placed in a box. Meanwhile, other sensors will be installed in the system, to control each actuator. These sensors include humidity sensors, temperature sensors and CO_2 sensors.

4.3 System Development Process

The system will be created within 3-4 months after the literature study is completed. The system created will focus on 2 developments: development of hardware and development of software (simple information system).

The development of hardware includes the development of:

a. Microcontroller Box: Create a box that will be a place for the IoT system consisting of a microcontroller, wi-fi module, sensors, actuators, and other required electronic components.

b. Microgreen Devices: The concept of planting microgreens that will be made is planting microgreens in trays.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

The growing media is maintained by the system so that it always contains water/moist for germination process can be optimal. This process will be discussed further in chapter 4.

Meanwhile, the development of software will be divided into:

a. Making automation programs on the microcontroller.
b. Design and develop databases to store microgreen monitoring data.
c. User interface of the website to show the collected data from IoT system.

4.4 Evaluation

The evaluation in this research will focus on evaluate microgreen yields. The quality of microgreen planting will be assessed with parameters such as: leaf color, microgreen taste, and the number of microgreens produced as well as the obstacles faced.

5. RESULTS

5.1 Pre-Design Analytics

The term "microgreen" in Indonesia is still a term that is rarely heard. Therefore, research on microgreens in Indonesia is still difficult to find. The literature study begins by determining what seeds are suitable for use as testing material in this study. These seeds must meet the following criteria: do not contain pesticides and other chemicals, can grow in the climate of Indonesia, easy to find and have relatively affordable prices. Based on articles found from various sources, several choices of seeds that meet the criteria are mung beans, spinach, and choy sum. Researchers chose mung bean seeds as vegetables that will be used as the main research material in this study. Mung beans were chosen because they have a relatively faster microgreen planting time than other seeds, which is about 4-5 days.

Microgreens can grow in various ways, as long as the water needs for seeds to germinate (germination) are met. Therefore, the main goal is to always provide enough water in growing media. There are many ways to ensure that the planting medium is always wet/moist. Some of the technique options are NFT (Nutrient Film Technique) method, the bottom watering method, and the drip system. NFT is a watering system that is also used for hydroponics. In NFT, water flows continuously through the plant roots. The surface of the water became thin, as thin as a sheet of film. This system ensures that the seeds always get water, but it is less applicable if space is very limited, in this study it was a box. Meanwhile, the bottom watering system is the system most widely used by microgreen farmers who plant manually (without an IoT system). Microgreens are planted in perforated trays. The tray is stacked on top of another tray filled with water. If watering is required, the bottom tray is filled with water, then the top tray is stacked again so that the planting medium absorbs water from below. Meanwhile, the drip method is a watering method that ensures plants get water by watering little by little in a certain time. In this study, researchers chose the drip method as a microgreen planting method because the system uses sensors that allow watering to be made automatically.

Researchers need a proper microcontroller to retrieve environmental variable data from each sensor and send it to the database. There are several microcontrollers that can be considered including NodeMCU, Arduino Uno and Raspberry Pi. NodeMCU is chosen because it already has an integrated wi-fi module, making it easier to program in the microcontroller. In addition, the price is also relatively cheaper. The number of input output pins on the NodeMCU Microcontroller is also sufficient to run all actuators and sensors in this study.

The information system is made by utilizing hosting services as a server. The information system must have an API (Application Programming Interface) address to receive sensor data from each smart box. The data is then processed into several simple graphs/calculations that are presented in the form of a website page.

5.2 Pre-Design Analytics

Microgreens are grown by the drip method. The pump will automatically provide water into the tray if the planting media is deemed to be short of water. Therefore, unlike most microgreen farmers, this system only requires one tray without holes, which holds the growing media. The size of the tray used in this study has a length of 35 cm, a width of 25 cm and a height of 10 cm. The growing media used in this study were rockwool and cocopeat. 100-150 grams of mung bean seeds were randomly distributed on the planting medium.

5.3 Microcontroller Design

NodeMCU was chosen as the microcontroller in this study. Sensors and actuators are designed according to the design in Figure 4.2. Lamps, pumps and fans require a voltage greater than the maximum voltage that can be generated by the NodeMCU, so a relay is needed to connect lamps, pumps and fans to direct voltage. By using a relay, the light is controlled via a signal on digital pin number 3, while the pump is on digital pin number 4, and the fan is on digital pin number 5. While the humidity sensor is connected to digital pin number 6, soil moisture sensor is on digital pin number 6 and CO2 sensor on digital pin number 1 and 0 because it requires 2 inputs / outputs.

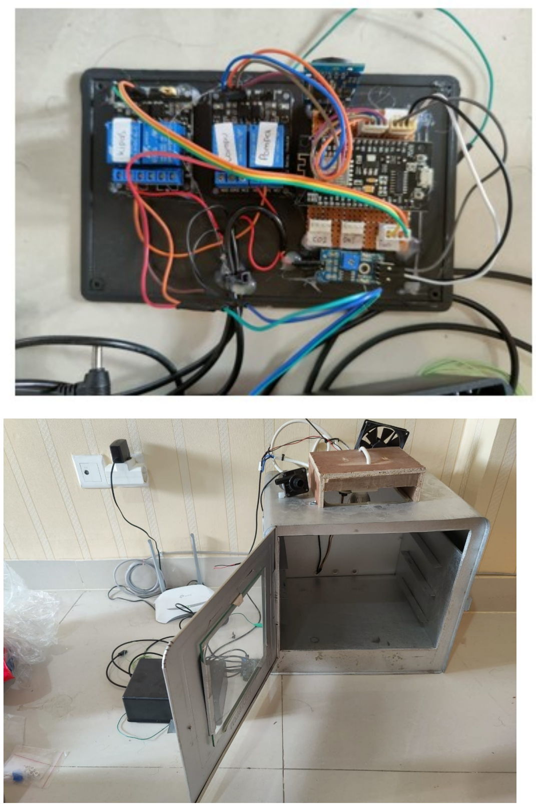

Figure 4. Smart Box (Prototype)

5.4 Gamification Implementation

In this paper, researchers made a design concept of gamification in IoT to improve urban communities farming experience based on Six Steps to Gamification by Werbach and Hunter (2012) and commonly known as 6D. This is a basis for several other gamification framework [23].

5.4.1. Define Business Objectives

System should be developed according below business objectives:

- Simplified farming process with IoT.
- Collect and centralized farming data within an information system.
- Increase user interest in farming process.
- Increase crops productivity, especially for big cities.

5.4.2. Delineate Target Behaviors

In this concept design users are expected to:

- Use Smart box to grow selected plant seeds.
- Have internet connection and read measurement data from Smart box in information system in order to monitor plant growth via Information system.
- Interact with other users which have Smart box in different place via application and real life.
- Harvest microgreens in designated time and regrow the microgreen inside Smart box.

5.4.3. Describe Your Players

Users in this concept design will use the system as an Achiever and a Socializer. As an achiever, user will be encouraged to do some tasks to achieve rewards. For example: harvesting will give user 3 points, share data progress for 2 points, etc. Meanwhile, as a Socializer, user expected to interact with other user in order to achieve the same goal: successful harvest. User can also show and share their achievement to others.

5.4.4. Devise Activity Loops

Activity loop in this concept design is re-grow activity. The final task of the concept is microgreen harvest. After that harvest, user have to re-plant the crops in Smart box and follow the same tasks as before. Every harvest will give user some point, which will be used to give user a title such as: newbie, expert, or master in farming.

5.4.5. Don't Forget the Fun

The fun factors that will encourage user to use the system are mentioned below:

- Users can eat real vegetables after harvest process.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

- Users can interact and brag about achievements that they achieved.
- System equipped with several automation process with IoT to ensure simplicity and convenience of the farming process

5.4.6. Deploy Appropriate Tools

In order to achieve "the fun" with activity loops and achieve the goals, system have to designed with combination of real-world IoT device (Smart Box) that sends sensor data to Web API (Fig. 1). User can access that information by interact with user interface of information systems to check their Smart box environment condition or other user smart box condition.

5.5 Evaluation

During testing there were several problems that made significant changes to the system. Some of these changes are:

5.5.1. Soil Moisture Sensor Removed.

Figure 6. Usage of Aluminium Sheet as Water Indicator

After trying to use cocopeat and rockwool, the soil moisture sensor was less reliable in detecting the water content in the growing media. Researchers suspect that this is caused by the planting media that is not too thick and the need for very much water from the planting media makes the planting media not only damp, but wet / waterlogged. Because of this problem, the automatic irrigation system was changed. Two aluminum sheets are placed on the sides of the tray and the bottom of the tray respectively as shown in Figure 4.16. The two aluminum sheets are connected by a cable that is connected to the input output pin on the microcontroller. If water enters the tray, an electric current will flow from the bottom aluminum sheet through the water and touch the aluminum sheet on the side of the tray. If the water manages to touch the aluminum sheet on the side of the tray, the pump will stop dispensing water. Based on the watering algorithm, soil moisture sensor can be removed.

5.5.2. Molds on Planting Media

A moist, small and enclosed environment makes it easy for mold to grow. Molds/fungal problems are the main problem that hinders the germination process. In the three initial experiments conducted by the researchers, the molds grew on the surface of the growing media so that the seeds failed to germinate / only small parts were able to germinate. As a solution to the problem of fungal growth, the lighting time was made longer to 8 hours, from the previous 5 hours. The irradiation time of 8 hours succeeded in preventing the fungus from growing on rockwool growing media. Meanwhile, for cocopeat growing media, the molds continue to grow. Therefore, the suitable planting medium for the SmartBox system is rockwool.

Figure 5. Microgreens Harvest Result

Although it succeeded in overcoming the mold problem, the length of the lighting time made the microgreens shorter than they should be, making them more difficult to harvest.

After the problem is successfully solved, the following results are obtained:

1. Microgreen mung beans have grown well and are ready to harvest within 4 days.
2. The color of the leaves is dark green, the same as the leaves of plants in the sun.
3. The stem grows quite long, so that when harvested, the microgreen height is about 15cm (Figure 4.19).

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

4. From 150 grams of green beans, about 600-750 grams of microgreens are obtained.
5. The taste of normal microgreens, no bitter taste when eaten directly or cooked first.

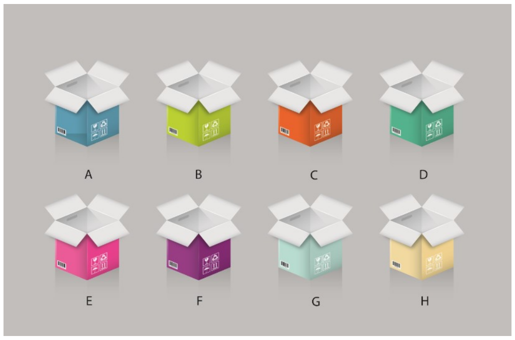

Figure 7. Smartbox Interface Example

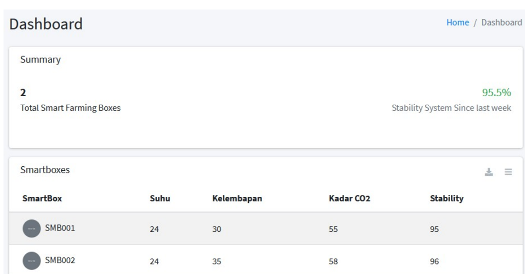

Figure 8. Example Page Which Shows Measurement Data

5.5.3. Information System

Information system show user multiple box which represent Smartbox of each user. When clicked, user can see measurement data that collected in database as can be seen in Figure 7 and Figure 8.

6 CONCLUSION

6.1 Does Gamification Applicable?

Smartbox have some limitations such as:

- Availability of electricity: all of IoT component needs electricity to works. So, with that limitation, human interference still needed. System should be able to inform users if something wrong with electricity of the devices.
- Not all of the activity can be automated process, for example crop harvest and re-plant activity. Smartbox in this concept did not have capabilities to do those activities.

With those limitations, gamification still have potential to increase user engagement and user interest. Gamification will create a reason for users to do the activity loop and willing to prevent those limitations. But, the actual implementation and how much gamification needed vary according to the system design.[20]

6.2 Final Verdict

Final results of the research on making prototypes of agriculture in closed spaces using IoT technology, which are then called Smart Farming Boxes, are as follows:

- Researchers have succeeded in proving that the farming process can be automated in a small and closed space by utilizing IoT. In this research, the process of microgreen farming is the main focus and implement gamification concept to encourage user for re-planting.
- The prototype can produce microgreens with relatively good quality. During the test period there was a problem with the growth of mold. But at the end of the test, microgreen was able to grow well. The replanting process also did not find the same problem again with the use of rockwool as a planting medium. The prototype is able to produce microgreen mung beans within 4 days without user assistance.
- The results of this study are far from perfect to be applied on a larger scale. However, the prototype that was built, has succeeded in showing how to farm in a closed and narrow room using the IoT concept Therefore, this research is expected to be an alternative for urban communities to grow vegetables independently albeit limited space to support food security in big cities.

6.3 Further Research Ideas

This research was conducted to build the SmartBox in form of a prototype which acts like a more comprehensive idea but far from final product form. The future research can be conducted to make this prototype more applicable in daily use. This research did not analyze cost efficiency or cost comparison with traditional farming process.

Hence, cost analytics to determine how profitable this automation is, can also be future research idea.

REFERENCES

[1] B. P. Statistik, "Produksi Tanaman Hortikultura," *Website Badan Pusat Statistik Indonesia*, 2020. https://www.bps.go.id/subject/55/hortikultura.html (accessed Feb. 17, 2020 21:30:00).

[2] I. S. Roidah, "Pemanfaatan Lahan Dengan Menggunakan Sistem Hidroponik," *J. Univ. Tulungagung BONOROWO Tahun*, vol. 1, no. 2, pp. 43–50, 2014.

[3] S. Santoso and Suharmiati, "Pengaruh Biaya Saluran Distribusi Terhadap Volume Penjualan," *Akuisisi J. Akunt.*, vol. 14, no. 1, pp. 34–43, 2018, doi: 10.24127/akuisisi.v14i1.239.

[4] Kementrian Kesehatan Indonesia, "Hasil Utama RISKESDAS 2018," *www.kemkes.go.id*, 2018. http://www.kemkes.go.id/resources/download/info-terkini/hasil-riskesdas-2018.pdf (accessed Aug. 18, 2020 22:16:00).

[5] Danielle D. Treadwell;Robert Hochmuth; Linda Landrum;Wanda Laughlin, "Microgreens: A New Specialty Crop," *Hortic. Sci.*, no. April 2010, pp. 1–3, 2016.

[6] E. Pinto, A. A. Almeida, A. A. Aguiar, and I. M. P. L. V. O. Ferreira, "Comparison between the mineral profile and nitrate content of microgreens and mature lettuces," *J. Food Compos. Anal.*, vol. 37, no. 3, pp. 38–43, 2015, doi: 10.1016/j.jfca.2014.06.018.

[7] G. E. Lester, G. J. Hallman, and J. A. Pérez, "γ-Irradiation dose: Effects on baby-leaf spinach ascorbic acid, carotenoids, folate, α-tocopherol, and phylloquinone concentrations," *J. Agric. Food Chem.*, vol. 58, no. 8, pp. 4901–4906, 2010, doi: 10.1021/jf100146m.

[8] A. Pathak, M. AmazUddin, M. J. Abedin, K. Andersson, R. Mustafa, and M. S. Hossain, "IoT based Smart System to Support Agricultural Parameters: A Case Study," *Procedia Comput. Sci.*, vol. 155, pp. 648–653, 2019, doi: 10.1016/j.procs.2019.08.092.

[9] A. Khanna and S. Kaur, "Evolution of Internet of Things (IoT) and its significant impact in the field of Precision Agriculture," *Comput. Electron. Agric.*, vol. 157, no. December 2018, pp. 218–231, 2019, doi: 10.1016/j.compag.2018.12.039.

[10] S. Tobon, J. L. Ruiz-Alba, and J. García-Madariaga, "Gamification and online consumer decisions: Is the game over?," *Decis. Support Syst.*, vol. 128, no. October, p. 113167, 2020, doi: 10.1016/j.dss.2019.113167.

[11] O. Humlung and M. Haddara, "The Hero's Journey to Innovation: Gamification in Enterprise Systems," *Procedia Comput. Sci.*, vol. 164, pp. 86–95, 2019, doi: 10.1016/j.procs.2019.12.158.

[12] N. Xi and J. Hamari, "Does gamification affect brand engagement and equity? A study in online brand communities," *J. Bus. Res.*, vol. 109, no. January 2019, pp. 449–460, 2020, doi: 10.1016/j.jbusres.2019.11.058.

[13] A. Martens and W. Mueller, "Gamification - A structured analysis," *Proc. - IEEE 16th Int. Conf. Adv. Learn. Technol. ICALT 2016*, pp. 138–142, 2016, doi: 10.1109/ICALT.2016.72.

[14] M. D. Ghoora, D. R. Babu, and N. Srividya, "Nutrient composition, oxalate content and nutritional ranking of ten culinary microgreens," *J. Food Compos. Anal.*, vol. 91, no. April, p. 103495, 2020, doi: 10.1016/j.jfca.2020.103495.

[15] H. Chen, X. Tong, L. Tan, and L. Kong, "Consumers' acceptability and perceptions toward the consumption of hydroponically and soil grown broccoli microgreens," *J. Agric. Food Res.*, vol. 2, no. June, p. 100051, 2020, doi: 10.1016/j.jafr.2020.100051.

[16] Z. Xiao, G. E. Lester, Y. Luo, and Q. Wang, "Assessment of vitamin and carotenoid concentrations of emerging food products: Edible microgreens," *J. Agric. Food Chem.*, vol. 60, no. 31, pp. 7644–7651, 2012, doi: 10.1021/jf300459b.

[17] G. M. Riggio, Q. Wang, K. E. Kniel, and K. E. Gibson, "Microgreens—A review of food safety considerations along the farm to fork continuum," *Int. J. Food Microbiol.*, vol. 290, no. October 2018, pp. 76–85, 2019, doi: 10.1016/j.ijfoodmicro.2018.09.027.

[18] H. Vestad and M. Steinert, "Creating your own tools: Prototyping environments for prototype testing," *Procedia CIRP*, vol. 84, pp. 707–712, 2019, doi: 10.1016/j.procir.2019.04.225.

[19] M. Auflem, J. F. Erichsen, and M. Steinert, "Exemplifying prototype-driven development through concepts for medical training simulators," *Procedia CIRP*, vol. 84, pp. 572–578, 2019, doi: 10.1016/j.procir.2019.04.202.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[20] M. Colezea, G. Musat, F. Pop, C. Negru, A. Dumitrascu, and M. Mocanu, "CLUeFARM: Integrated web-service platform for smart farms," *Comput. Electron. Agric.*, vol. 154, no. April, pp. 134–154, 2018, doi: 10.1016/j.compag.2018.08.015.

[21] A. N. Harun, N. Mohamed, R. Ahmad, A. R. A. Rahim, and N. N. Ani, "Improved Internet of Things (IoT)monitoring system for growth optimization of Brassica chinensis," *Comput. Electron. Agric.*, no. March, pp. 0–1, 2019, doi: 10.1016/j.compag.2019.05.045.

[22] M. A. Zamora-Izquierdo, J. Santa, J. A. Martínez, V. Martínez, and A. F. Skarmeta, "Smart farming IoT platform based on edge and cloud computing," *Biosyst. Eng.*, vol. 177, pp. 4–17, 2019, doi: 10.1016/j.biosystemseng.2018.10.014.

[23] A. Mora, D. Riera, C. Gonzalez, and J. Arnedo-Moreno, "A Literature Review of Gamification Design Frameworks," *VS-Games 2015 - 7th Int. Conf. Games Virtual Worlds Serious Appl.*, 2015, doi: 10.1109/VS-GAMES.2015.7295760.