An Interdisciplinary System for Educating Children: Hydroponics-based Smart Education System (HSES)

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ABSTRACT

In this thesis, a novel smart system based on hydroponics is proposed. It is aimed to educate children by contributing to their improvement on cognitive domain, affective domain and psychomotor domain. This hydroponics-based smart education system is task oriented, does not interfere children's daily life and includes instant child control. It is an interdisciplinary system which consists of Android application, Raspberry Pi, Web server, MySQL server and Hydroponics system components. Self-improvement of children in terms of cognitive, affective and psychomotor could be contributed with this system's various features.

Keywords: Smart system, Mobile application, embedded system, Web, MySQL, hydroponics system, children, education, cognitive domain, affective domain, psychomotor domain.

ÖZ

Bu tezde, hidroponik temelli yeni bir akıllı sistem önerilmiştir. Bu çalışma ile çocukların bilişsel, duyuşsal ve psikomotor alanlarına katkıda bulunabilmek amaçlanmıştır. Bu hidroponik temelli akıllı eğitim sistemi görev odaklı ve çocuğun günlük yaşantısını etkilemeyecek şekilde tasarlanmıştır. Ayrıca, aile tarafından çocuk kontrolü de sağlanmaktadır. Android uygulaması, Raspberry Pi, Web sunucusu, MySQL sunucusu ve hidroponik sistem bileşenlerinden oluşan disiplinler arası bir sistemdir. Sistemde bulunan çeşitli özellikler ile çocukların kendilerini bilişsel, duyuşsal ve psikomotor alanlarında geliştirebilmesi mümkündür.

Anahtar Kelimeler: Akıllı sistem, mobil uygulama, gömülü sistem, Web, MySQL, hidroponik sistem, çocuk, eğitim, bilişsel alan, duyuşsal alan, psikomotor alan.

To my family and friends

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LIST OF ABBREVIATIONS

HSES	Hydroponics-based Smart Education System
IDE	Integrated Development Environment
LCD	Liquid Crystal Display
MySQL	My Structured Query Language
NW	Nutrient Water
PHP	Hypertext Preprocessor
REST API	Representational State Transfer Application Programming Interface
RW	Regular Water
TS	Task Score
Wi-Fi	Wireless Fidelity

Chapter 1

INTRODUCTION

With the rapid development of technology, technological products have been used in every part of human life in general. Education is one of them. There are various technology related works for education. Some recent ones are as follows: Yang et al. [1] developed a smartphone application which uses image recognition in order to improve children's mathematics. Sandman and Antonius [2] developed a mobile application that teaches the alphabet to children with more fun. Nouwen et al. [3] developed a fun and educational mobile application that teaches children how to use musical instruments. Kourakli et al. [4] introduced Kinect learning games for children in order to improve their cognitive, motoric and academic skills. Carrozzo et al. [5] developed a hydroponics system, Idropo, to educate children by gardening and playing. Idropo is like a toy. It has two LCD displays as eyes. One expresses whether the water is low and the other one expresses whether the brightness is low. In addition, it has four buttons. One is used to introduce Idropo and how to use the system by talking, second one gives some information about nature by talking, third one initialize the date and the last one says how many days passed.

Other than the Carrozzo et al.'s work, any hydroponics related academic and/or industrial work that is for children education was not encountered.

In our work, we aimed to develop a smart system based-on-hydroponics for educating children in the way of contributing to their improvement on cognitive [6, 7], affective [8] and psychomotor [9] domains. This system is called Hydroponics-based Smart Education System (HSES) (also called "Happy Plants"). HSES mainly consists of hydroponics system, embedded system and smartphone application.

Hydroponics is a plant breeding method without soil. Plants are grown healthier [10]. Since hydroponics system is a clean agriculture, the child would use our hydroponics system at home without any inconvenience. This would lead the child to use HSES more reachable and more comfortable. Nowadays, embedded systems are popular. Embedded systems are cost effective and provides easier communication between the electronic parts. Furthermore, embedded systems, such as those that includes Raspberry Pi, are small in size and allow us to have more useful and more elegant designs. Smartphones have become a part of our lives. The world population was 7.59 billion in January 2018 and 68% of them were using mobile devices [11]. It is estimated that smartphones would be used by approximately 2.53 billion people in 2018 [12]. With the smartphone application in HSES, it is possible to form more interaction between the child and the plant. With the aforementioned three main components, HSES could also be more attractive, therefore motivational, for the child. The other components which are Web server and MySQL server support the main components.

The rest of this report is organized as follows: The next chapter describes system design of the proposed system; chapter 3 explains the implementations done for the proposed system; chapter 4 explains methodology used for the proposed system's

test; chapter 5 is results and discussion section; and the last chapter concludes our work and gives future work.

Chapter 2

SYSTEM DESIGN OF THE PROPOSED SYSTEM

2.1 System Architecture

System architecture of the proposed system HSES is given in Figure 1.

Raspberry Pi is the control unit which controls the hardware part of the system. Temperature & humidity sensor, ultrasonic distance sensor, touch screen and speaker are directly connected to Raspberry Pi. Water level sensor is also connected to Raspberry Pi but indirectly. Arduino Nano is used between since Raspberry Pi does not support Analog-to-Digital Converter. Raspberry Pi displays the following information on touch screen: The values comes from the sensors; the minimum temperature requirement of the plant taken from MySQL server via REST API; and the child's Task Score (TS) taken from Web server via REST API (Web server gets the values from MySQL server and makes score calculation). Furthermore, it processes these information and, if needed, it gives warning to the child in speech by the speaker. It also stores temperature and humidity values into MySQL server via REST API.

Android application is available for the child and the parent. It consists of “Plant Detail”, “Game”, “General Knowledge” and “Task” sections for the child and “Plant Details”, “Task”, “Children” and “Settings” sections for the parent. The application gets all the required information (except the child's TS) for each section from

MySQL server via REST APIs. For the child's TS, it gets from Web server via REST API (Web server gets the values from MySQL server and makes score calculation).

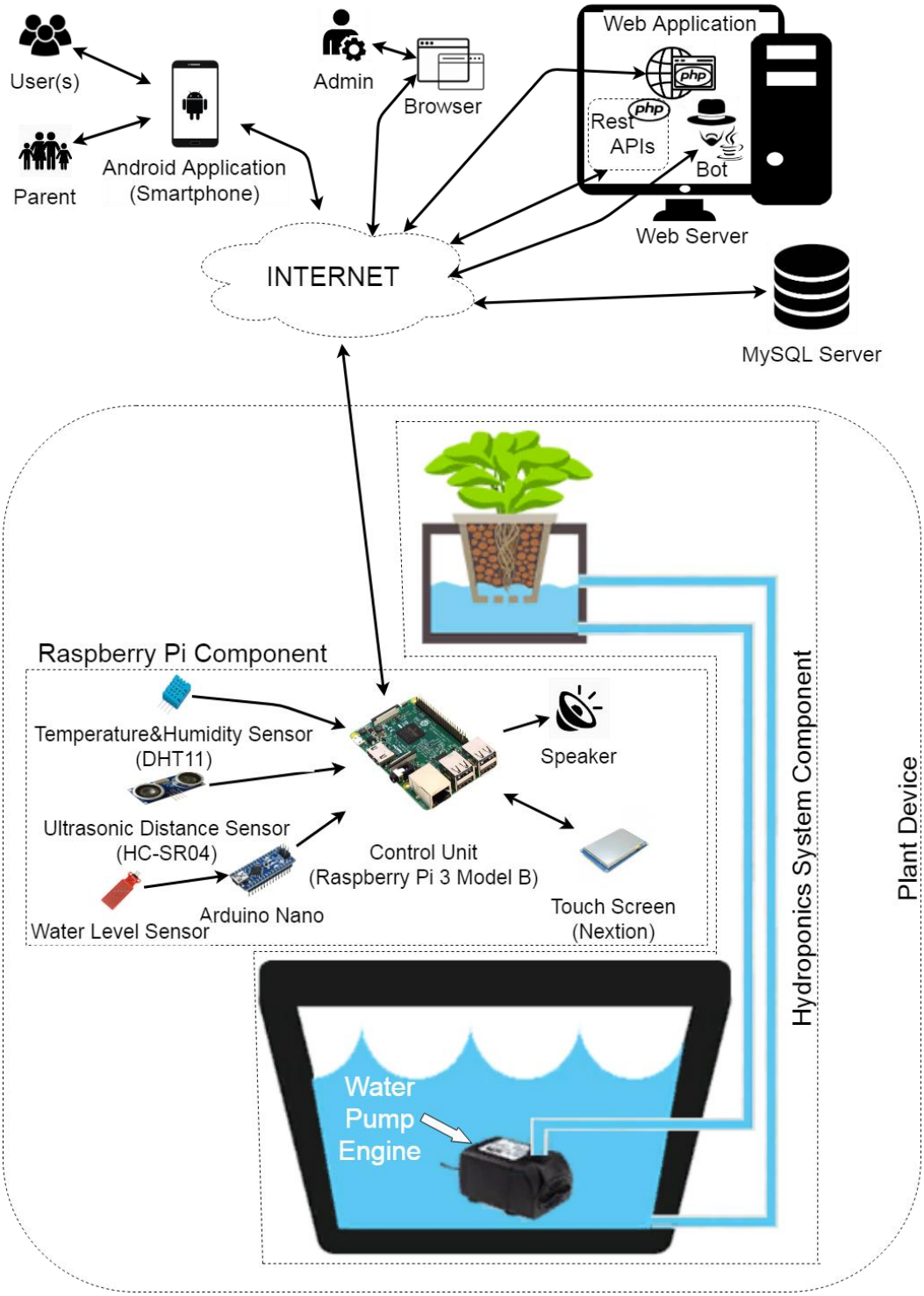


Figure 1: System Architecture of HSES

Web application is available for administrator of the system. It consists of plant device, plant and general knowledge pages. The Web application gets/stores all required information for each pages from/to MySQL Server without using REST APIs.

Bot is a software agent and runs continuously on Web server. Firstly, it gets the usernames of all children who have assigned-plant device from MySQL server. (Plant device assignment is explained below.) Then, for each child, it creates two tasks and assigns them to the child.

2.2 System Components

In HSES, there are various components as given below.

2.2.1 Android Application Component

Initialization of the system has two stages. The first one is being on Android application component and the second is being on Raspberry Pi component which is discussed in the next section. Firstly, the parent registers himself to the system by entering username, name, surname, address, telephone, e-mail and password. Then, the parent registers her/his child(ren) to the system. During the registration of the child, the parent enters her/his child's username, name, surname, gender, birthday, address, telephone, e-mail, password information of the child and free-time. (Each task is being created for a specific time period. When a task is created, the child is needed to be available for the task during that specific time period. Therefore, the free-time is required to know the available time. Note that controlling of the task completion is also being done during this specific time period.) After the registration is completed, the parent assigns the plant device which has a unique id to the child (unique id is given with plant device). Once these processes are completed, the child

can log in to the system with her/his smartphone. Note that the parent can register another her/his child with a new plant device; besides, s/he can assign another new plant device for her/his previously registered child.

In Android application component, there are various sections which are “Plant Detail”, “Task”, “Game” and “General Knowledge” for the child and “Plant Detail”, “Task”, “Children” and “Settings” for the parent. “Plant Detail” and “Task” sections are the same sections for the child as well as the parent; however, the parent sees these sections after choosing the child and the plant device and the child sees these sections after choosing the plant device.

The plant detail section shows environment temperature and humidity values, status of amount of Nutrient Water (NW) in the tank, description of the plant, the child’s TS, plant's happiness mood (decided by the application based on the child's TS) and plant's picture (a standard picture that comes with the application). In addition, this section includes description of these information.

The task section shows tasks that need to be done by the child. For each task, description, creation date, the type (such as NW-related and game types) and whether the task is completed or not are listed in this section.

The game section shows all the games the child can play. Tic-Tac-Toe is developed (with four different difficulty levels) as sample game and made available in this section.

The general knowledge section shows various information such as “meaning and significance of the day” and “today in history”. These information will be entered into MySQL server by the administrator.

The children section shows all registered children of the parent. Here, parent can add new plant devices to any one of the registered child, add new child or update any of the registered child's information.

The settings section shows personal information of the parent. Here, parent can update her/his information.

The use case diagram of Android application component is given additionally in Appendix A for better understanding.

The child can access the game and general knowledge sections during the free-time only while s/he can access the plant detail and task sections at any time. Note that Android application controls game and general knowledge tasks’ completion within the free-time. The parent has no the game and general knowledge sections but, like her/his child, s/he can access the plant detail and task sections at any time. The parent access the plant detail and task sections for controlling her/his child’s status. Being able to control the child’s status at any time is called instant child control.

2.2.2 Raspberry Pi Component

Raspberry Pi component is a part of plant device as shown in Figure 1.

As it is mentioned earlier, the second stage of initialization of the system includes filling-the-tank-first-time with the NW, placing the plant on to plant device, and

setting Raspberry Pi. After filling the tank and place the plant, the parent enters Wi-Fi login information via touch screen in order to connect Raspberry Pi to the Internet. Then, over touch screen, the parent selects the plant to be grown and restarts Raspberry Pi. With the aforementioned processes: if it is re-initialization and there is stored data regarding the child and her/his plant device on the database, these data will be erased; and, then, the system will be initialized and activated.

Raspberry Pi displays the minimum temperature requirement for the plant (taken from MySQL server) and the child's TS on touch screen. Raspberry Pi compares the environment's current temperature value taken from the sensor with the minimum temperature requirement of the plant to find out if the temperature is higher or lower. It does this in every 20 seconds and, if the temperature is higher or lower, it gives a corresponding message (if temperature is high, the message is "Heey! Burası çok sıcak oldu beni biraz serinletir misin?" ("Heey! It became too hot, would you please cool me down a little?"); if temperature is low, the message is "Heey! Burası çok soğuk oldu beni biraz ısıtılır mısın?" ("Heey! It became too cold, would you please warm me up a little?")) in speech via speaker for asking help. Raspberry Pi compares the current NW level taken from the sensor with the pre-defined ranges. It does this in every 20 seconds and, if the level is lower than the required amount, it gives a corresponding message (if 100 ml NW is missing, the message is "Heey! Suyum azaldı lütfen kontrol eder misin?" (Heey! My water level is reduced, would you please check it?); if 200 ml NW is missing, the message is "Heey! Suyum biraz azaldı lütfen kontrol eder misin?" (Heey! My water level is slightly reduced, would you please check it?); if 300 ml NW is missing, the message is "Heey! Suyum çok azaldı lütfen kontrol eder misin?" (Heey! My water level is much reduced, would you please check it?)) in speech via speaker for asking help. Raspberry Pi displays

current temperature, current humidity and current NW level in every 20 seconds on touch screen. It reads these from the corresponding sensors. Furthermore, it sends the last values of these to MySQL server in every 10 minutes in order to be stored for further usage.

Raspberry Pi controls movement in front of ultrasonic distance sensor. If there is a movement in the range of 30 centimeters, it gives the related message “Heey! merhaba benimle ilgilenmeye mi geldin?” (Heey! hello, do you came to take care of me?) in speech via speaker for drawing attention. This is called draw attention function.

Raspberry Pi calculates how many days passed since the plant was planted by taking the difference of the time of the second phase initialization and the present time and, then, displays it on touch screen.

Raspberry Pi decides plant’s happiness mood based on the child's TS and displays it on touch screen.

Raspberry Pi displays the date of the day on touch screen.

Note that, over touch screen, the Wi-Fi network change can be done by the parent/child and starting of the second stage’s re-initialization process can be done by the parent.

2.2.3 Web Server Component

Web server has three parts which are Web application, Bot, and REST APIs.

With Web application, the administrator can make add, update, delete and list operations for plant device, plant and general knowledge. The administrator adds unique ID of every produced plant device, the minimum temperature requirements, NW change period, description of the plant and the information for general knowledge task (e.g. “meaning and significance of the day” and “today in history”). The administrator can update, delete, and list these. Note that the previously stored information for general knowledge task are used every year by the system.

Bot creates as well as assigns two tasks for each child, after it gets the usernames of all children who have assigned-plant device. One task is for the game section and the other one is for the general knowledge section. Bot do this in every 24 hours.

REST APIs in our system provide communication between components via HTTP protocols. Android application and Raspberry Pi components makes request to the corresponding REST API and the API makes process with MySQL server component and returns the result to the component which made the request. In our system, all requests except Web application’s are provided with REST APIs.

One of the requests is for the child’s TS. When the request comes, the Rest API calculates the child’s TS for the time starting from beginning of the current week to until then. The formula of the child’s TS is as follows:

$$\mathrm{TS} = \frac{\mathrm{TPET} * 1000}{\mathrm{TPE}} \quad (1)$$

where TPET is Total Points Earned from the Tasks done and TPE is Total Points can be Earned. Game and general knowledge related tasks are 1 point each. Temperature

and NW related tasks are 3 points each. If there is no assigned task for the considered time range, the child's TS is being 1000 points directly.

2.2.4 MySQL Server Component

There are two triggers in MySQL server. The temperature-task-trigger finds out if the temperature is high or low. It compares each of the last two temperatures stored in MySQL server with the minimum temperature requirement of the plant. If both comparisons show the temperature is increased or decreased, then the trigger assigns a corresponding task (i.e. "high temperature" task or "low temperature" task). The water-adding-task-trigger finds out if the NW level in the tank is low. It compares each of the last two NW levels stored in MySQL server with the pre-defined level ranges. If both comparisons show the NW level is in the same range but lower than the required amount, then the trigger assigns a corresponding task ("Add 100 ml", "Add 200 ml" or "Add 300 ml" water task) which guides the user to add the required amount. (In order to keep the nutrient balanced in the NW in the tank, different water type (i.e. regular or nutrient) is needed for different time ranges (see Appendix B). The user will be asked to add the corresponding water type based on the time range.) Note that; other than adding water, there is a filling-the-tank-first-time (with the NW) process in the second initialization stage and there is a changing-the-NW-in-the-tank task which is assigning by Raspberry Pi. Task created by the trigger is checked by the same trigger to see if the task is completed.

In addition, there are procedures in this component. They are responsible to register, retrieve, update and delete data to/on MySQL server.

2.2.5 Hydroponics System Component

There are 3 main parts which are plant, water tank and water pump engine. NW in the tank contains the nutrients that the growing plant needs. As long as energy is

available, the water pump engine in the tank provides NW flow through the plant's roots.

Hydroponics system component is a part of plant device as shown Figure 1.

2.3 Database

The database of the HSES is called “marulcuk” and designed in accordance with 1nF, 2nF, 3nF and 3.5nF. It consists of 12 tables, 2 triggers and 40 procedures. Figure 1 shows the database's entity relationship diagram.

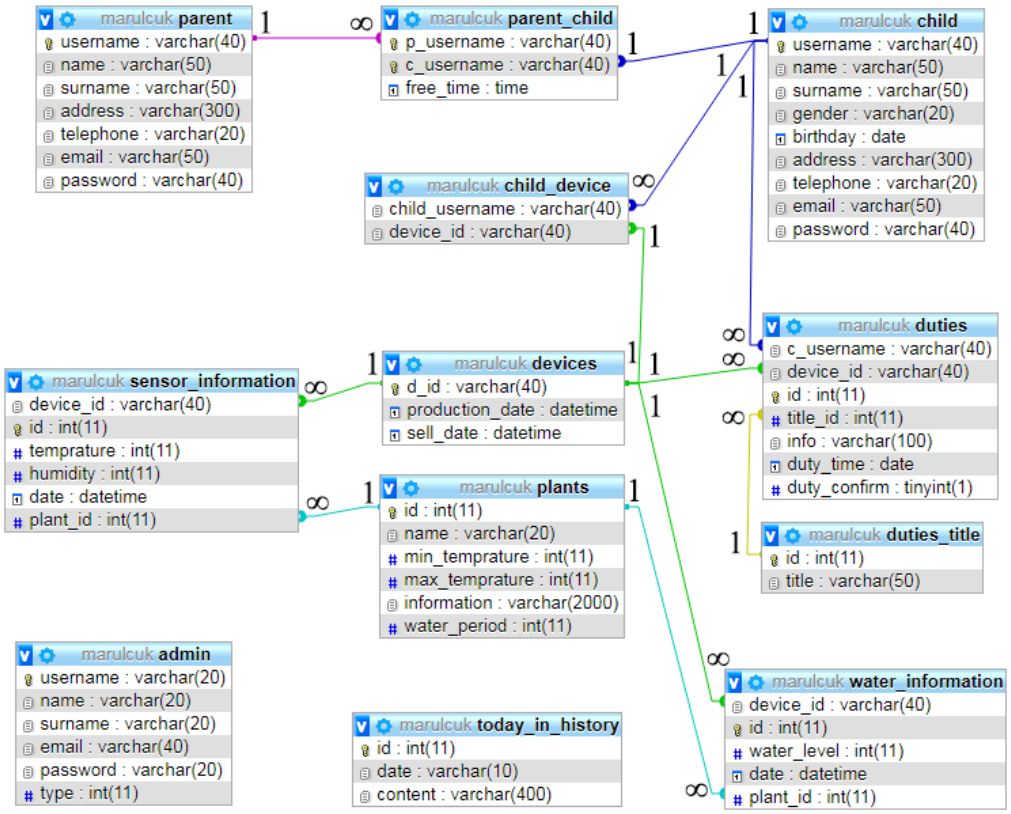


Figure 2: The marulcuk database’s entity relationship diagram

As shown in Figure 1, there are 12 tables in the database. These are; “admin”, “child”, “child_device”, “devices”, “duties”, “duties_title”, “parent”, “parent_child”, “plants”, “sensor_information”, “today_in_history” and “water_information”.

The admin table is designed to keep the system administrator's information. “admin” table has 6 columns. These are “username”, “name”, “surname”, “email”, “password” and “type”. Table 1 shows description and type for every column.

Table 1: The admin table of “marulcuk” database

Column	Description
username	Unique name specified by the administrator for login. This column is a primary key (Varchar).
name	Admin`s first name (Varchar).
surname	Admin`s last name (Varchar).
email	Admin`s e-mail address (Varchar).
password	Admin`s password (Varchar).
type	Authorization level for admin (Number).

The child table is designed to keep the children's personal information. “child” table has 9 columns. These are “username”, “name”, “surname”, “gender”, “birthday”, “address”, “telephone”, “email” and “password”. Table 2 shows description and type for every column.

Table 2: The child table of “marulcuk” database

Column	Description
username	Unique name specified by the child for login. This column is a primary key (Varchar).
name	Child`s first name (Varchar).
surname	Child`s last name (Varchar).
gender	Child`s gender (Varchar).
birthday	Child`s birthday (Date).
address	Child`s address (Varchar).
telephone	Child`s phone number (Varchar).
email	Child`s e-mail address (Varchar).
password	Child`s password (Varchar).

The child_device table is designed to keep plant devices assigned to the child. “child_device” table has 2 columns. These are “child_username” and “device_id”. Table 3 shows description and type for every column.

Table 3: The child_device table of “marulcuk” database

Column	Description
child_username	The “child_username” column is the foreign key to “username” in the “child” table.
device_id	The “device_id” column is the foreign key to “d_id” in the “devices” table.

The devices table is designed to keep the all plant devices. “devices” table has 3 columns. These are “d_id”, “production_date” and “sell_date”. Table 4 shows all columns’ descriptions and types.

Table 4: The devices table of “marulcuk” database

Column	Description
d_id	Keeps the unique id of plant devices that are ready (Varchar). This column is a primary key.
production_date	Device's production date (Datetime).
sell_date	Device's sell date (Datetime).

The duties table is designed to keep all tasks assigned to children by the system. “duties” table has 7 columns. These are “c_username”, “device_id”, “id”, “title_id”, “info”, “duty_time” and “duty_confirm”. Table 5 shows all columns’ descriptions and types.

Table 5: The duties table of “marulcuk” database

Column	Description
c_username	The “c_username” column is the foreign key to “username” in the “child” table.
device_id	The “device_id” column is the foreign key to “d_id” in the “devices” table.
id	This column was defined as an identity column (Integer and Auto Increment). When the inserted a new row in the table, id value is increased 1 by automatically. Thus, it is created a unique column on the table. This column is a primary key.
title_id	The “title_id” column is the foreign key to “id” in the “duties_title” table.
info	Task`s information (Varchar).
duty_time	It's date for assign of task (Date).
duty_confirm	Task is done or not (Tinyint).

The duties_title table is designed to keep all duties title. “duties_title” table has 2 columns. These are “id” and “title”. Table 6 shows all columns’ descriptions and types.

Table 6: The duties_title table of “marulcuk” database

Column	Description
id	This column was defined as an identity column (Integer and Auto Increment). When the inserted a new row in the table, id value is increased 1 by automatically. Thus, it is created a unique column on the table. This column is a primary key.
title	Main title of the task (Varchar).

The parent table is designed to keep the parent's personal information. “parent” table has 7 columns. These are “username”, “name”, “surname”, “address”, “telephone”, “email” and “password”. Table 7 shows all columns’ descriptions and types.

Table 7: The parent table of “marulcuk” database

Column	Description
username	Unique name specified by the parent for login. This column is a primary key (Varchar).
name	Parent`s first name (Varchar).
surname	Parent`s last name (Varchar).
address	Parent`s address (Varchar).
telephone	Parent`s phone number (Varchar).
email	Parent`s e-mail address (Varchar).
password	Parent`s password (Varchar).

The parent_child table is designed to keep free time for each child. “parent_child” table has 3 columns. These are “p_username”, “c_username” and “free_time”. Table 8 shows description and type for every column.

Table 8: The parent_child table of “marulcuk” database

Column	Description
p_username	The “p_username” column is the foreign key to “username” in the “parent” table.
c_username	The “c_username” column is the foreign key to “username” in the “child” table.
free_time	Child`s free time (Time).

The plants table is designed to keep information about plants that can be planted. “plants” table has 6 columns. These are “id”, “name”, “min_temprature”, “max_temprature”, “information” and “water_period”. Table 9 shows description and type for every column.

Table 9: The plants table of “marulcuk” database

Column	Description
id	This column was defined as an identity column (Integer and Auto Increment). When the inserted a new row in the table, id value is increased 1 by automatically. Thus, it is created a unique column on the table. This column is a primary key.
name	Plant`s name (Varchar).
min_temprature	The minimum temperature value the plant needs (Integer).
max_temprature	The maximum temperature value the plant needs (Integer).
information	Description of plant (Varchar).
water_period	Water change time for plant (Integer).

The sensor_information table is designed to keep the values from the temperature and humidity sensor on the raspberry pi. “sensor_information” table has 6 columns. These are “device_id”, “id”, “temperature”, “humidity”, “date” and “plant_id”. Table 10 shows description and type for every column.

Table 10: The sensor_information table of “marulcuk” database

Column	Description
device_id	The “device_id” column is the foreign key to “d_id” in the “devices” table.
id	This column was defined as an identity column (Integer and Auto Increment). When the inserted a new row in the table, id value is increased 1 by automatically. Thus, it is created a unique column on the table. This column is a primary key.
temperature	Temperature value sent from the sensor (Integer).
humidty	Humidity value sent from the sensor (Integer).
date	Time of temperature and humidity values sent from the sensor (Datetime).
plant_id	The “plant_id” column is the foreign key to “id” in the “plants” table.

The today_in_history table is designed to keep information indicating the significance of the day. “today_in_history” table has 3 columns. These are “id”, “date” and “content”. Table 11 shows all columns’ descriptions and types.

Table 11: The today_in_history table of “marulcuk” database

Column	Description
id	This column was defined as an identity column (Integer and Auto Increment). When the inserted a new row in the table, id value is increased 1 by automatically. Thus, it is created a unique column on the table. This column is a primary key.
date	Day and month for information indicating the significance of the day (Varchar).
content	Information indicating the significance of the day (Varchar).

The water_information table is designed to keep the values from the water level sensor on the raspberry pi. “water_information” table has 5 columns. These are “device_id”, “id”, “water_level”, “date” and “plant_id”. Table 12 shows all columns’ descriptions and types.

Table 12: The water_information table of “marulcuk” database

Column	Description
device_id	The “device_id” column is the foreign key to “d_id” in the “devices” table.
id	This column was defined as an identity column (Integer and Auto Increment). When the inserted a new row in the table, id value is increased 1 by automatically. Thus, it is created a unique column on the table. This column is a primary key.
water_level	Water level value sent from the sensor (Integer).
date	Time of water level value sent from the sensor (Datetime).
plant_id	The “plant_id” column is the foreign key to “id” in the “plants” table.

There are 40 procedures in the database. They are responsible to register, retrieve, update and delete data to/on MySQL server. Table 13 shows all procedures and their descriptions.

Table 13: All procedures of “marulcuk” database and their description

Procedure Name	Description
addChildDeviceProcedure	This procedure is used by the Android application for assigning plant device to the child.
addChildProcedure	This procedure is used by the Android application for child registration to the system.
addDeviceProcedure	This procedure is used by the Web server for adding a new plant device to the database.
addGameDutyProcedure	This procedure is used by the bot for assigning the game task to the child.
addGeneralKnowledgeDutyProcedure	This procedure is used by the bot for assigning the general knowledge task to the child.
addGeneralKnowledgeProcedure	This procedure is used by the Web server for adding a new general knowledge information to the database.
addParentChildProcedure	This procedure is used by the Android application for assigning parent to the child and assign free time to the child.
addParentProcedure	This procedure is used by the Android application for registration to the system.
addPlantProcedure	This procedure is used by the Web server for adding a new plant to the database.
addSensorDataProcedure	This procedure is used by the Raspberry Pi for adding a new temperature and humidity value to the database.
addWaterChangeDutyProcedure	This procedure is used by the Raspberry Pi for assigning the water change task to the child.
addWaterSensorDataProcedure	This procedure is used by the Raspberry Pi for adding a new water level value to the database.
childUpdateProcedure	This procedure is used by the Android application for update of child's information in the database.

dutiesUpdateProcedure	This procedure is used by the Android application to update exist task in the database.
gameDutyUpdateProcedure	This procedure is used by the Android application to update exist game task in the database.
gkDutyUpdateProcedure	This procedure is used by the Android application to update exist general knowledge task in the database.
parentChildUpdateProcedure	This procedure is used by the Android application for update of child's free time.
parentUpdateProcedure	This procedure is used by the Android application for update of parent's information in the database.
selectChildAllDevicesInfoProcedure	This procedure is used by the Android application to select all information for selected plant device from the database.
selectChildDeviceIDControlProcedure	This procedure is used by the Android application to checks whether the plant device with the child matches or not in the database.
selectChildDevicesProcedure	This procedure is used by the Android application to select all plant devices for selected child from the database.
selectChildFreeTimeDeviceIDProcedure	This procedure is used by the Android application to add 2 hours to free time for selected child from the database.
selectChildFreetimeProcedure	This procedure is used by the Android application to select free time for selected child from the database.
selectChildProcedure	This procedure is used by the Android application to select all information for child from the database.
selectChildWithoutPasswordProcedure	This procedure is used by the Android application to select all information for child without password from the database.
selectDeviceControlProcedure	This procedure is used by the Android application to control of existing all plant devices in the database.

selectDeviceSensorInfoProcedure	This procedure is used by the Android application to select all information for selected plant device from the database.
selectDutiesProcedure	This procedure is used by the Android application to select all duties for selected child and plant device from the database.
selectDutyInfoProcedure	This procedure is used by the Android application to select all information for selected task from the database.
selectParentChildNameProcedure	This procedure is used by the Android application to select all child's information for selected parent from the database.
selectParentDeviceIDControlProcedure	This procedure is used by the Android application to checks whether the plant device with the parent matches or not in the database.
selectParentProcedure	This procedure is used by the Android application to select all information for parent without password from the database.
selectParentWithoutPasswordProcedure	This procedure is used by the Android application to select all information for parent from the database.
selectPlantDetailsProcedure	This procedure is used by the Raspberry Pi and android application to select all information for selected plant from the database.
selectPlantsProcedure	This procedure is used by the Android application to select all plants in the database.
selectTodayInHistoryProcedure	This procedure is used by the Android application for showing general knowledge to the child from the database.
selectUserControlProcedure	This procedure is used by the Android application to control of existing all username in the database.
selectUserNameDeviceProcedure	This procedure is used by the Android application to list all plant device and all child from the database.
updateChildPasswordProcedure	This procedure is used by the Android application to update child`s password in the database.
updateParentPasswordProcedure	This procedure is used by the Android application to update parent`s password in the database.

Works of two triggers are explained in detail in chapter 2.2.4 (MySQL server component).

2.4 System Requirements

Main hardware requirements: Raspberry Pi 3 Model B, temperature & humidity sensor (DHT11), water level sensor, ultrasonic distance sensor (HC-SR04), Arduino Nano, speaker, Nextion 4.3” LCD touch screen and water pump engine.

Software requirements: For Raspberry Pi 3 Model B, Raspbian Stretch (June 2018 version) was used as operating system; for sensors, touch screen and speaker control, Python (Version 2) programming language with 2.7, 3.0 and 3.5 Python libraries was used; Arduino IDE was used for programming of Arduino Nano; smartphone application was developed with Android Studio 3.0.1 by targeting the Android 8.0 (API Level 26, but application compiled with last Android 9.0 (API Level 27)) (note: the smartphone must have at least Android 4.0.3 (API Level 15));MySQL version 10.1.31-MariaDB was used as database management system; phpMyAdmin 4.7.9 was used for MySQL; Web application and REST APIs was programmed with PHP 7.1.15 scripting language and they complied by Apache 2.4.29; and Bot was coded in NetBeans IDE 8.2 with Java programming language.

2.5 System Cost

The system cost based on main parts is given in Table 14.

Table 14: List of the item's price

Item	Price
Raspberry Pi 3 Model B (Full Kit)	70$
Touch Screen (Nextion 4.3 Inch)	60$
Sensors + Arduino Nano	21.1$
Hydroponics system parts	11.5$
Nutrient solution for lettuce	3.8$
Production of Plant device	28.8$
Total	**195.2$**

Chapter 3

IMPLEMENTATION OF THE PROPOSED SYSTEM

HSES has three different type of implementations. These are Web application, Android application and plant device.

3.1 Web Application

Web application is developed for the administrator of the system. On the Web application, the administrator can make add, update, delete and list operations for plant device, plant and general knowledge.

Figure 3 shows the first page that the user can login to the system. The user enters username and password and cliks, “Submit” button. If the wrong username and/or password are/is entered, an error message will be displayed by the system as shown in Figure 4. When the correct username and password are entered, the system will be redirected to the main page as shown in Figure 5. Also, the system keeps the username and password in the session for the next entry. In the top menu of this page, there are “Home”, “List”, “ADD Device”, “ADD General Knowledge”, “ADD Plant”, “Sign Out” and “⚙” tabs.

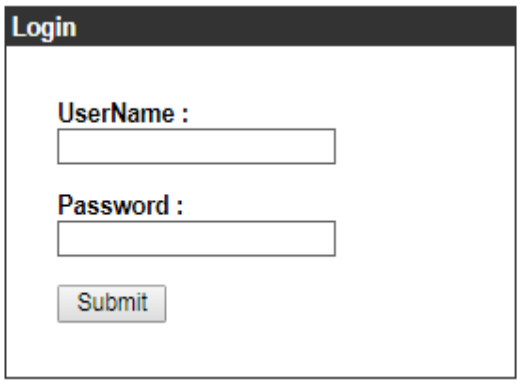


Figure 3: Login page

Figure 4: Error message of login page

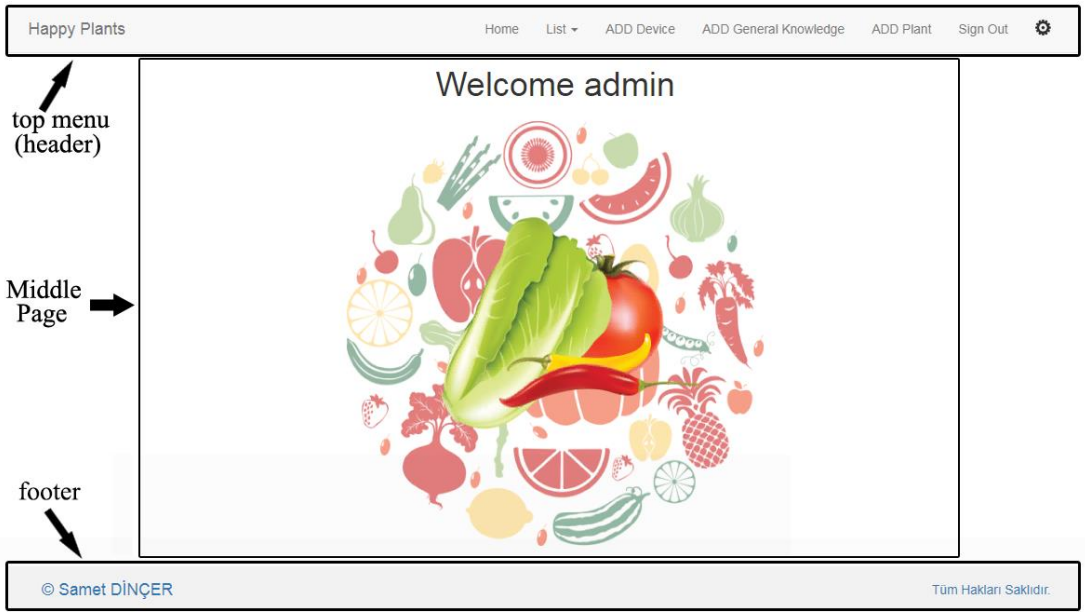


Figure 5: Main page of Web application

When the “Home” tab is clicked, the main page comes. For the rest of all pages, the top menu and the footer are always visible and the pages are loading into the middle page. From the list tab, “All Devices”, “All General Knowledge” and “All Plants” information stored in the database can be listed.

When “All Devices” is clicked, “All Devices” page (Figure 6) that shows all plant devices' “ID”, “Production Date” and “Sell Date” registered in the database is shown.

On this page, the information of an existing plant device can be updated or deleted. When “Edit” link is clicked, “Update Device” page comes for the clicked device as it seen in Figure 7. On “Update Device” page, the production date and/or sale date of the device will be updated, when “Update” button is pressed. On “All Devices” page, when the “Delete” link is clicked, the clicked plant device will be deleted.

Device ID	Production Date	Sell Date		
00:00:00:00:00	2018-03-27 00:00:00	2018-03-28 00:00:00	Edit	Delete
00:00:00:00:01	2018-04-18 00:00:00	2018-04-18 00:00:00	Edit	Delete
01:MS:44:ES:06	2018-03-21 23:47:41	2018-03-21 23:47:41	Edit	Delete
12:24:2B:BF:53	2018-03-18 07:24:21	2018-03-20 15:24:17	Edit	Delete
202481592806689	2018-06-22 19:36:30	0000-00-00 00:00:00	Edit	Delete
98:M8:48:8S:80	2018-03-15 00:00:00	2018-03-14 00:00:00	Edit	Delete

Figure 6: “All Devices” page

UPDATE DEVICE	
* required field.	
Device ID	00:00:00:00:00
Production Date	2018-03-27 00:00:00 *
Sell Date	2018-03-28 00:00:00 *
	UPDATE

Figure 7: “Update Device” page

When “All General Knowledge” link is clicked on the “List” tab, it shows all general knowledge as in Figure 8. This page gives general knowledge information based on day and content which are stored in the database. Also, update and delete links exist on this page. When “Edit” link is clicked, “Update General Knowledge” page related with the clicked general knowledge will be shown. On “Update General Knowledge” page (Figure 9), the day, the month and/or the content of the general knowledge will be updated, when “Update” button is pressed. On “All General Knowledge” page, when “Delete” link is clicked, the clicked general knowledge will be deleted.

Day	Content		
11-07	1964 - Cumhurbaşkanı Cemal Gürsel, ömür boyu hapse mahkûm eski cumhurbaşkanı Celal Bayar ı affetti.	Edit	Delete
11-07	1942 - Türk İnkılap Enstitüsü kuruldu.	Edit	Delete
11-07	1920 - Türk ordusu Gümrü yü ele geçirdi.	Edit	Delete
11-07	1917 - I. Dünya Savaşı: İngiliz kuvvetleri Osmanlı Devleti idaresindeki Gazze yi ele geçirdi.	Edit	Delete
11-07	1971 - Kâzım Koyuncu doğum tarihi, Karadenizli, Laz şarkıcısı	Edit	Delete
11-06	1494 - Kanuni Sultan Süleyman doğum tarihi, Osmanlı padişahı (ö. 1566)	Edit	Delete
11-06	1918 - Çanakkale Boğazı, İngiliz ve Fransızlarca işgal edildi.	Edit	Delete
11-06	1936 - İzmit te kâğıt ve karton fabrikası açıldı.	Edit	Delete
11-06	1955 - Kayseri Şeker Fabrikasında üretime başlandı.	Edit	Delete
11-06	1981 - YÖK Yasası yürürlüğe girdi.	Edit	Delete
11-05	1840 - Afganistan, İngilizlere teslim oldu	Edit	Delete
11-05	1919 - Gaziantep, Fransızlar tarafından işgal edildi.	Edit	Delete
11-05	1930 - İlk televizyon reklamı Londra da gösterildi.	Edit	Delete
11-05	1934 - Devlet Tiyatroları kuruldu.	Edit	Delete
11-05	1615 - Osmanlı padişahı I. İbrahim doğum tarihi (ö. 1648)	Edit	Delete
11-05	2006 - Bülent Ecevit ölüm tarihi, Türk siyaset adamı ve şair.	Edit	Delete
11-05	1948 - William D. Phillips doğum tarihi, Nobel Ödülü sahibi ABD li fizikçi	Edit	Delete
11-04	1922 - Osmanlı devletinin resmi gazetesi Takvimi Vakayi yayınını durdurdu.	Edit	Delete
11-04	1950 - Türkiye, Avrupa İnsan Hakları Bildirisi ni imzaladı.	Edit	Delete

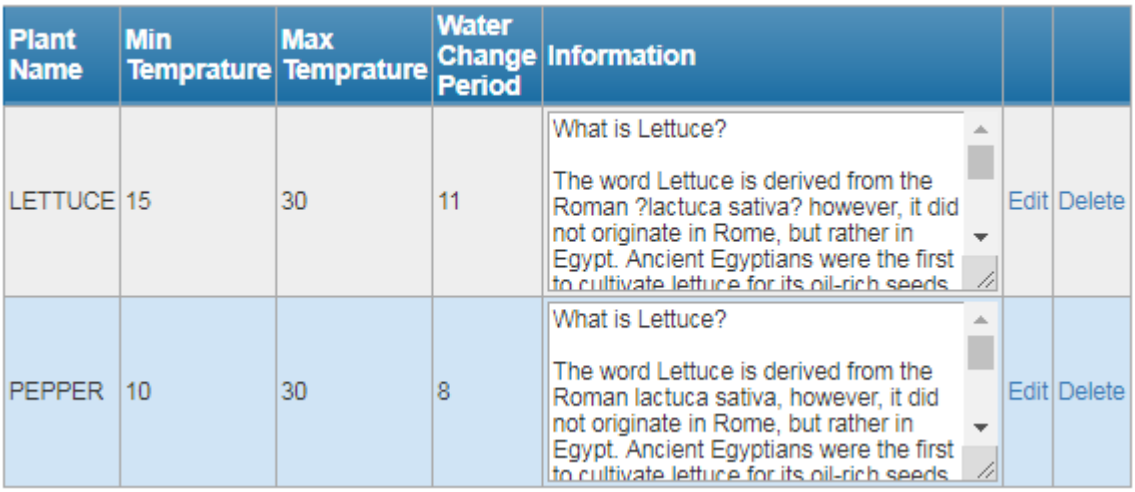
Figure 8: “All General Knowledge” page

UPDATE GENERAL KNOWLEDGE

* required field.	
Date	07-07
Day	Choose Day ▼ *
Month	Choose Month ▼ *
Content	1985 - Boris Becker won the Wimbledon tennis tournament (the first German to win the tournament and 17 years old).
	UPDATE

Figure 9: “Update General Knowledge” page

When “All Plants” link is clicked on the “List” tab, it shows all plants as in Figure 10. This page shows all plants' “Plant Name”, “Min. Temperature”, “Max. Temperature”, “Water Change Period” and “Information” stored in the database. Also, update and delete links are available on this page. When “Edit” link is clicked, “Update Plant” page related with the clicked plant will be shown. On “Update Plant” (Figure 11) page, plant name, minimum temperature, maximum temperature, water change period and information of the plant will be updated and when “Update” button is pressed. On “All Plants” page, when “Delete” link is clicked, the clicked plant will be deleted.



Plant Name	Min Temprature	Max Temprature	Water Change Period	Information		
LETTUCE	15	30	11	What is Lettuce? The word Lettuce is derived from the Roman ?lactuca sativa? however, it did not originate in Rome, but rather in Egypt. Ancient Egyptians were the first to cultivate lettuce for its oil-rich seeds	Edit	Delete
PEPPER	10	30	8	What is Lettuce? The word Lettuce is derived from the Roman lactuca sativa, however, it did not originate in Rome, but rather in Egypt. Ancient Egyptians were the first to cultivate lettuce for its oil-rich seeds	Edit	Delete

Figure 10: “All Plants” page

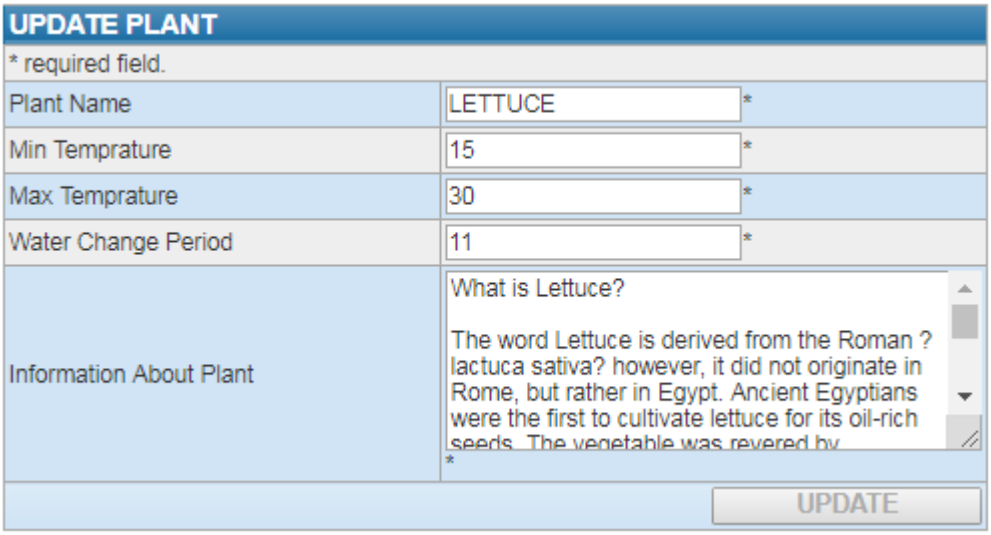


Figure 11: "Update Plant" page

When "ADD Device" tab is clicked on the top menu, "New Plant Device" page will be opened as in Figure 12. On this page, "Product Date" will be automatically take by the system, "Device ID" enters and "ADD" button will be pressed. After new plant device is added, the information message will be displayed on the page as in Figure 13.

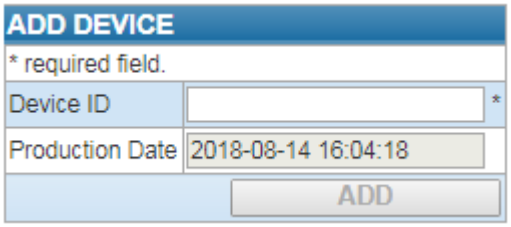


Figure 12: "New Plant Device" page

Figure 13: Successful new plant device addition

When "ADD General Knowledge" tab is clicked on the top menu, "Add New General Knowledge" page will be opened as in Figure 14. On this page, "Day" and "Month" will be chosen and "Content" will be entered then "ADD" button will be pressed. After the addition, the information message will be displayed as in Figure 15.

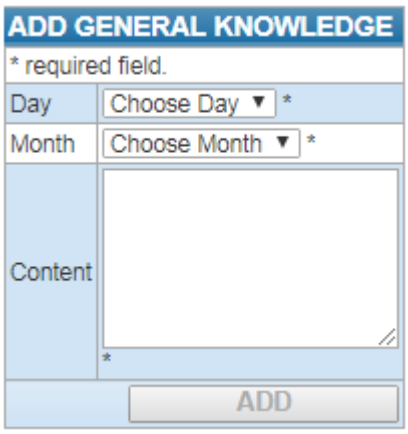


Figure 14: "Add New General Knowledge" page

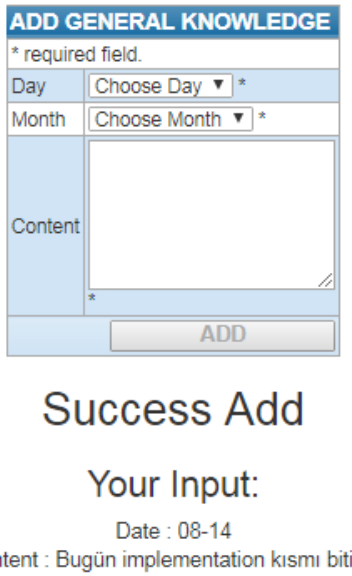


Figure 15: Successful new general knowledge addition

When “ADD Plant” tab is clicked on the top menu, “Add New Plant” page will be opened as in Figure 16. On this page, “Plant Name”, “Min. Temperature”, “Max. Temperature”, “Water Change Period” and “Information About Plant” will be entered then “ADD” button will be pressed. After the addition, the information message will be displayed as in Figure 17.

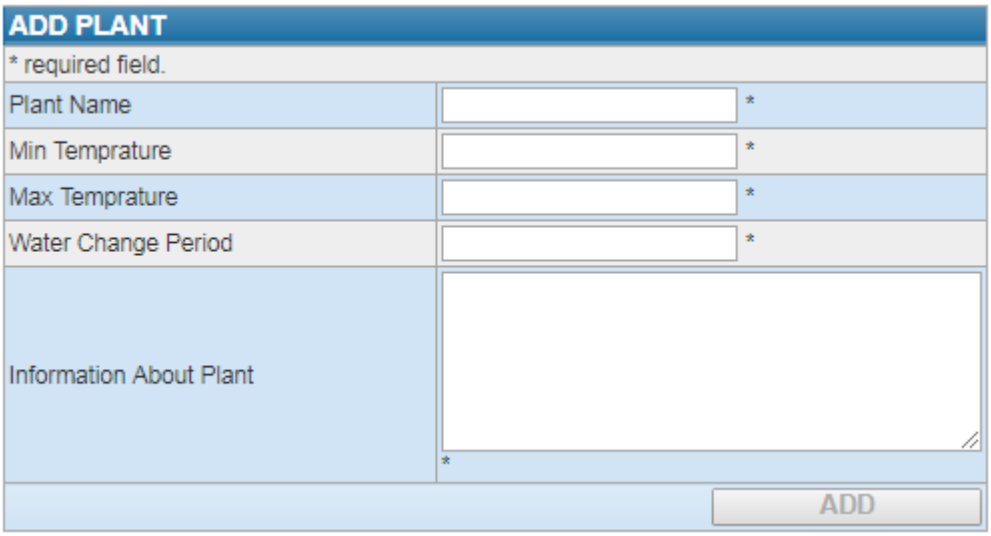


Figure 16: “Add New Plant” page

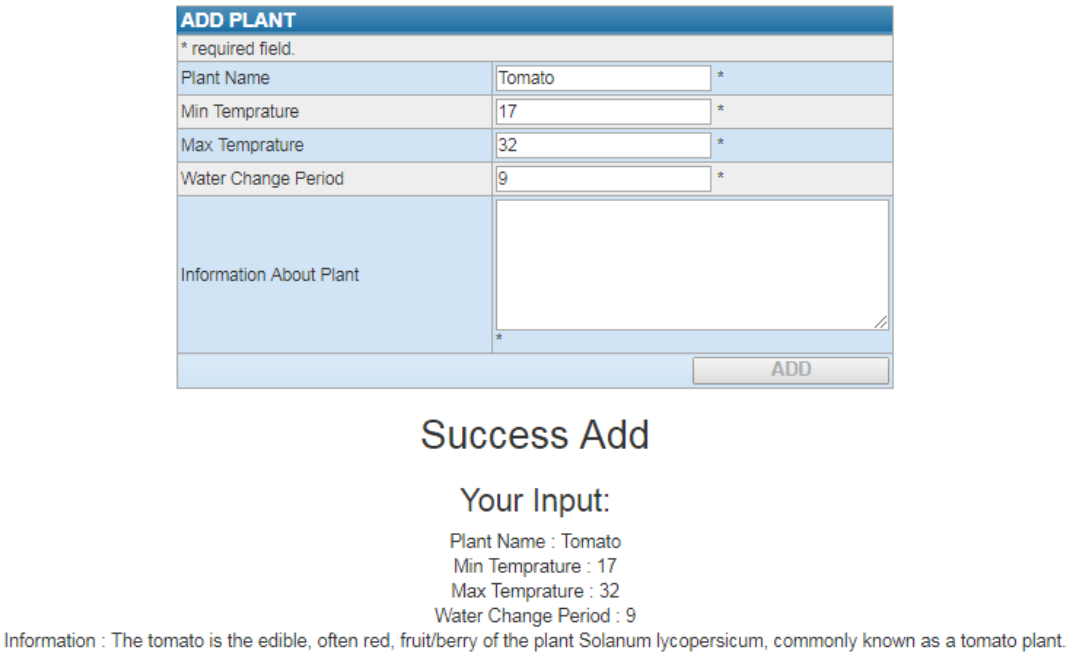


Figure 17: Successful new plant addition

On all addition and all update pages, the fields marked with * are required fields. When the required fields are not entered or wrong format is entered, warning message(s) will be given on each pages. As in Figure 18, the "Plant Name" field must be contain only alphabetic characters, temperature fields must contain only numbers and all the fields are required to be filled.

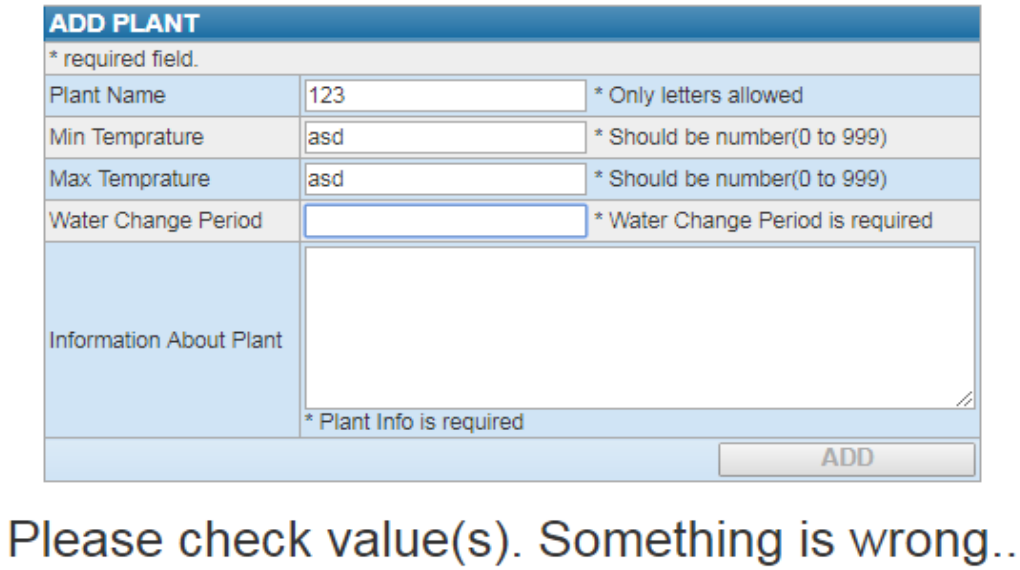


Figure 18: Error messages of addition and update pages

When the “Sign Out” tab is clicked on the top menu, session will be closed and login page will be opened as in Figure 3.

When “⚙” tab is clicked on the top menu, “Settings Page” will be opened as in Figure 19. On this page, password update could be performed. All required fields indicated by * must enter. The “Current Password”, “New Password” and “Confirm New Password” will be entered then “Submit” button will be pressed. If the current password is entered incorrectly, system will be displayed an error message as in Figure 20(a). If “New Password” and “Confirm New Password” fields are not matched, system will be displayed an error message as in Figure 20(b). If fields are matched correctly, system will be displayed a success message as in Figure 20(c) and the password will be updated.

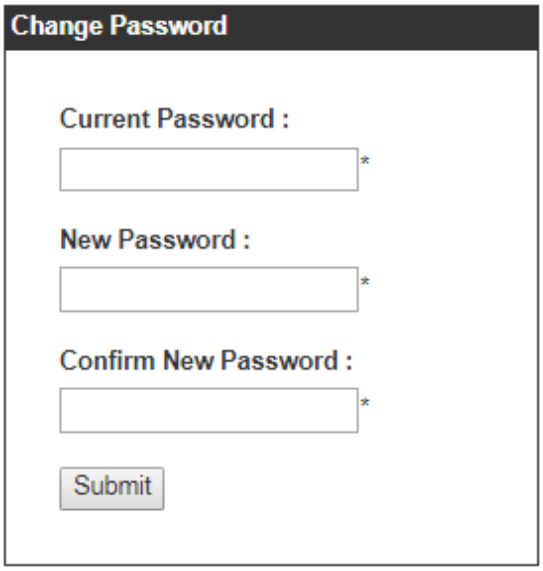
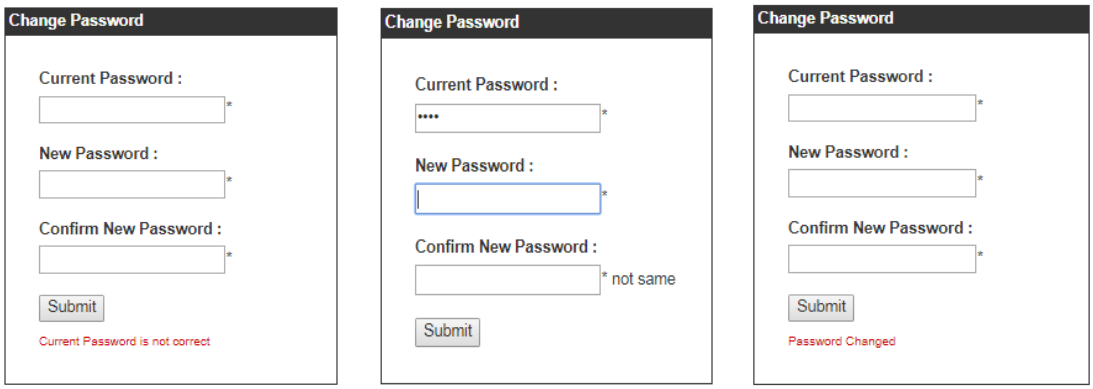


Figure 19: Settings page



(a) (b) (c)

Figure 20: Error and success messages of "Settings" page

3.2 Android Application

Android application is developed for the parent and the child. Both users use the system over the same application. First of all, the application will be installed on the smartphone. After the installation, "Happy Plants" icon will be shown and the user will be open the application by pressing it. When the application is started, the "Sign-In" activity will be opened as in Figure 21.

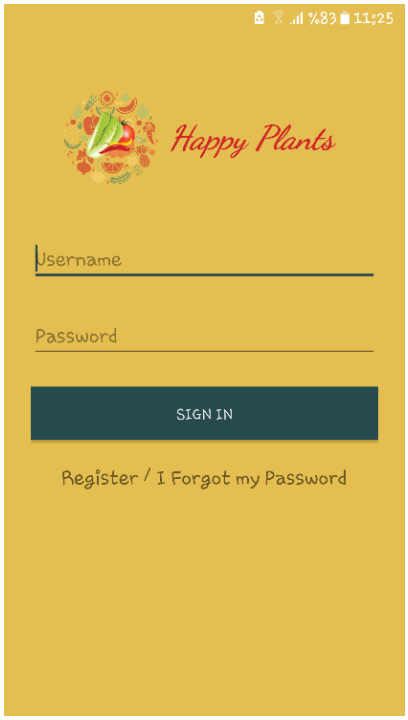


Figure 21: "Sign-In" activity

In order to be able to login to the application, it is necessary to register on the system first. When “Register” link that appears in Figure 21 is pressed, “Registration” activity will be opened as shown in Figure 22. “Registration” activity is designed for the parent.

All fields in “Registration” activity must be completed for registration. If the fields to be entered are left empty and “REGISTER” button is pressed, the system automatically gives a message that the empty fields must not be empty. An example is shown in Figure 23.

Figure 22: “Registration” activity

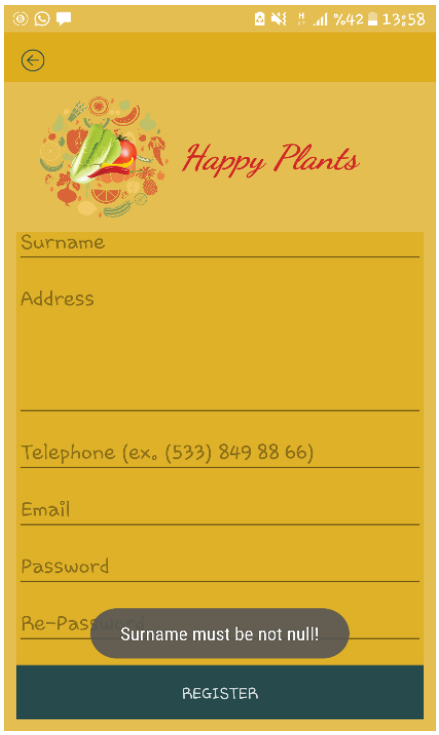


Figure 23: Error message for empty field

During registration, each field must be entered in accordance with its own format. Username must contain at least one alphabetic character, cannot start with a number and cannot contain any special character. Name and surname fields must not contain any number and special character. Otherwise an error message will be displayed.

Telephone field must be in the format shown. E-mail field must be in standard email format. For password, 4-10 character long password that includes one capital letter, one number and one symbol are required. For the aforementioned fields, if there is an error, an appropriate error message will be shown such as given in Figure 24.

(a)

(b)

(c)

(d)

Figure 24: Error messages for field format(s)

If a successful registration is performed, the success message will be displayed and "Main" activity for parent will be shown (Figure 25). This activity contains links for "LOGOUT", "PLANT DETAIL", "CHILD TASK", "CHILDREN" and "SETTINGS".

When "SETTINGS" link is pressed, "Settings" activity will be opened as shown in Figure 26. On this activity, the information entered during registration can be updated. All information entered during registration here is appeared in the related fields (excluding username and password). In order to be able to change the information, password fields will be entered then "UPDATE" button will be pressed. All fields must be entered in their own format as in during parent registration otherwise the same error messages will be encountered.

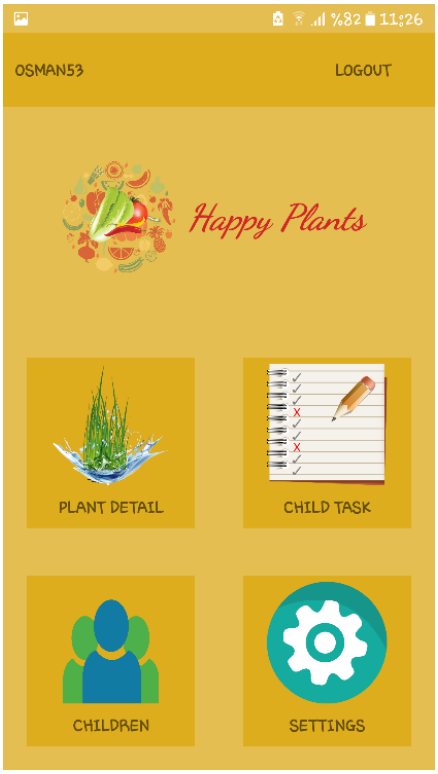


Figure 25: "Main" activity for parent

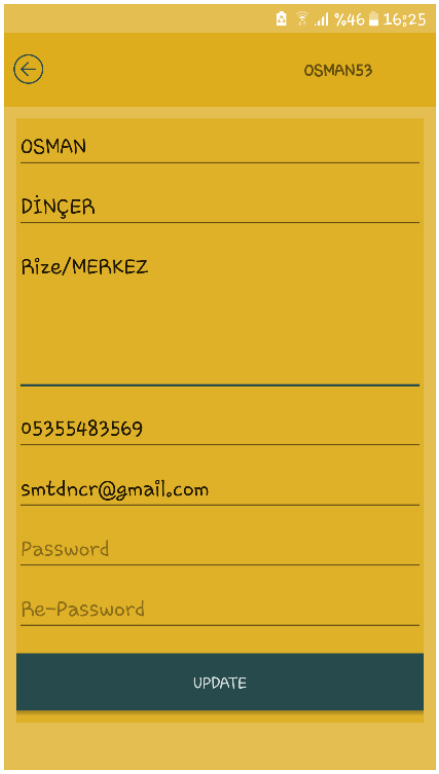


Figure 26: "Settings" activity for parent

When "CHILDREN" link in Figure 25 is pressed, "Children" activity will be opened as shown in Figure 27. On this activity, the children that registered by the parent will be displayed, a new child can be registered, the child's information can be updated and the plant device can be assign to the child. For adding a new child to the system, "ADD CHILD" button is pressed. When this button is pressed, the "Child Registration" activity will be opened as shown in Figure 28.

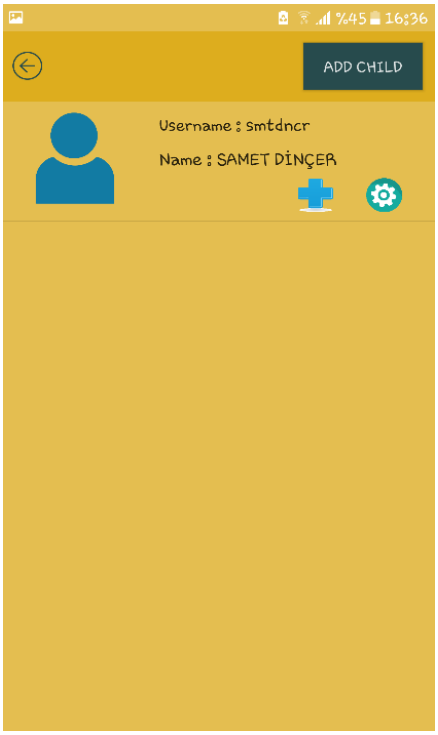


Figure 27: “Children” activity

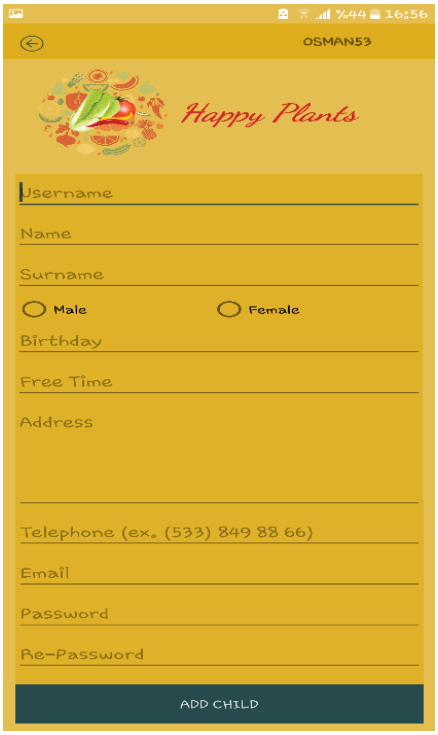
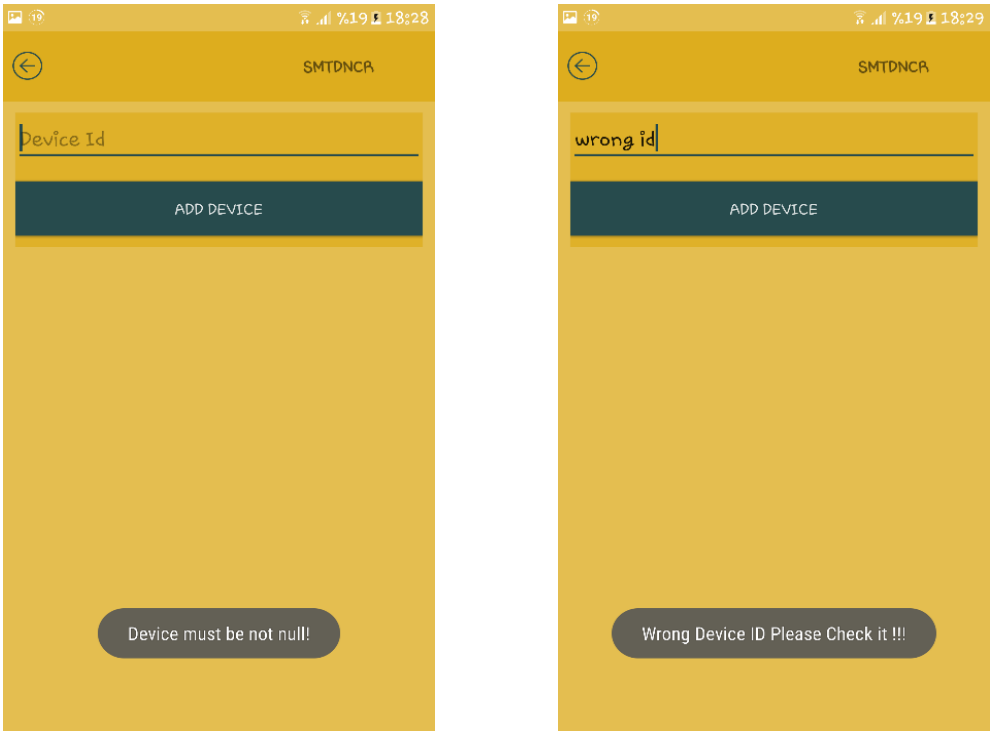


Figure 28: “Child Registration” activity for parent

All fields must be entered in their own format as in during parent registration otherwise the same error messages will be encountered. When all fields are entered correctly, “ADD CHILD” button will be pressed and child registration will be completed. Now that the child is registered, parent can be assign plant device to the child. For assign plant device to the registered child, “✚” icon will be pressed in Figure 27. “Device ID” will be entered in the opened activity and then “ADD DEVICE” button will be pressed. Thus, the plant device will be matched with the child. If the field is left blank, application will be displayed an error message as in Figure 29 (a), if the wrong plant device id is entered, application will be displayed an error message as in Figure 29 (b).



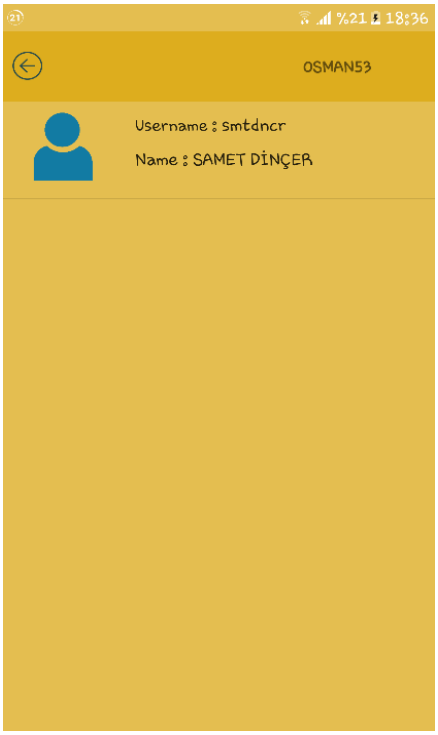
(a) (b)

Figure 29: Error messages for plant device assign activity

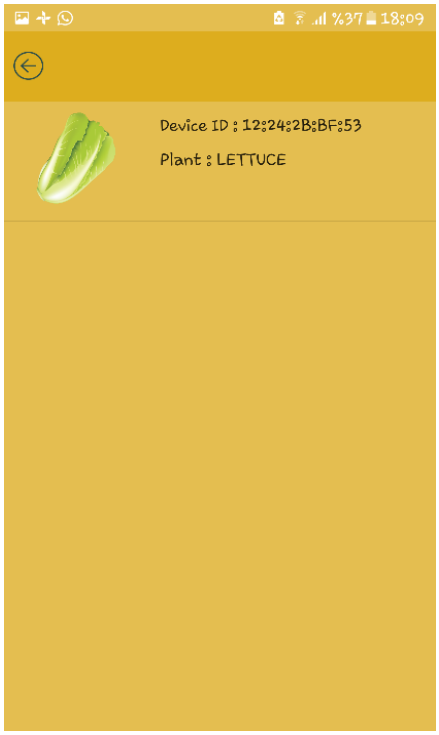
When "⚙" icon in Figure 27 is pressed, "Child Settings" activity will be opened as shown in Figure 30. On this activity, the information entered during child registration can be updated. All information entered during registration here is appeared in the related fields (excluding username and password). In order to be able to change the information, the password fields will be and "UPDATE" button will be pressed. All fields must be entered in their own format as in during parent registration otherwise the same error messages will be encountered.

Figure 30: “Child Settings” activity

When “PLANT DETAIL” link in Figure 25 is pressed, the list of the “Registered Children” activity will be opened as shown in Figure 31(a). On this activity, the child is chosen. Then, list of the matched plant devices with the child will be opened as shown in Figure 31(b). On this activity, the plant device is chosen and “Plant Details” activity will be opened as shown in Figure 32. On the “Plant Details” activity, current environment temperature and humidity values, status of amount of nutrient water in the tank, description of the plant, the child’s task score, plant's happiness mood and plant's picture are shown. In addition, this activity includes description button of these information. When this button is pressed, the “Description” activity will be opened as shown in Figure 33. “Description” activity is explained all information in “Plant Details” activity.



(a)



(b)

Figure 31: List of the registered children and matched devices with selected child

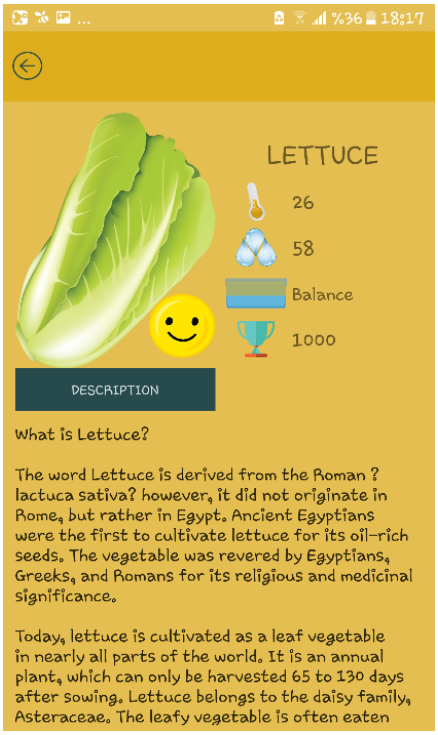


Figure 32: "Plant Details" activity

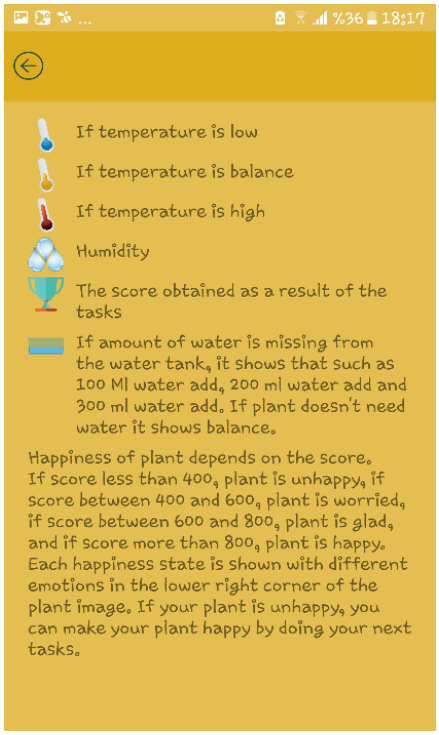


Figure 33: "Description" activity

When “CHILD TASK” link in Figure 25 is pressed, the list of the “Registered Children” activity will be opened as shown in Figure 31(a). On this activity, the child is chosen. Then, list of the matched plant devices with the child is opened as shown in Figure 31(b). On this activity, the plant device is chosen and “Child Tasks” activity will be opened as shown in Figure 34. On the “Child Tasks” activity, all assigned tasks to child, number of the task, image of the task, description of the task, date of the assigned task and picture showing whether the task has been performed are shown.

Figure 34: “Child Tasks” activity

When “LOGOUT” link in Figure 25 is pressed, session will be closed and the “Sign-In” activity will be opened. When the user wants to sign in again, the user must be entered username and password to related fields. Then, “Sign-In” button will be pressed. If username and/or password are entered incorrectly, the error message in

Figure 35 will be displayed. If fields are entered correctly, “Main” activity of parent will be opened as shown in Figure 25.

Child can sign in to his/her relevant area with created username and password by parent. If child enters incorrect username and/or password, the error message in Figure 35 will be displayed. If child is entered correctly username and password, “Main” activity for child will be opened (Figure 36). This activity contains links for “LOGOUT”, “PLANT DETAIL”, “TASK”, “GAME” and “GENERAL KNOWLEDGE”.

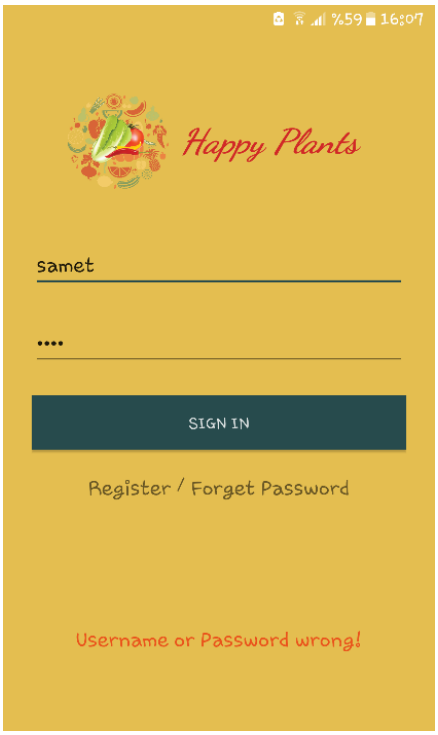


Figure 35: Error message for wrong username and/or password

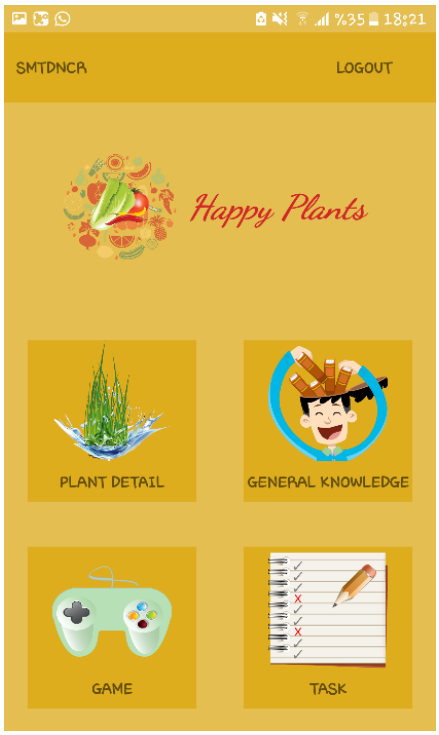


Figure 36: “Main” activity for child

When “PLANT DETAIL” link is pressed, list of the matched plant devices with the child will be opened as shown in Figure 31(b). On this activity, the plant device will

be chosen and “Plant Details” activity will be opened as shown in Figure 32. Parent and child are used same activity for this part. All steps are same with parent parent.

When “GENERAL KNOWLEDGE” link in Figure 36 is pressed, “General Knowledge” activity will opened as shown in Figure 37. On this activity, date and general knowledge information will be shown. If “GENERAL KNOWLEDGE” link is pressed “out of free-time”, the information message in Figure 38 will be displayed.

Figure 37: “General Knowledge” activity

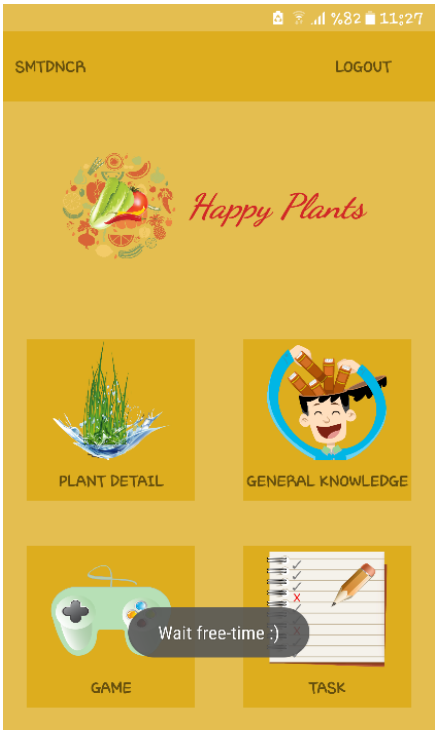


Figure 38: Information message for out of free-time

When “GAME” link in Figure 36 is pressed, “List of Games” activity will be opened as shown in Figure 39. On this activity, all games list in the application are shown. For now, the application has just one game which is Tic-Tac-Toe. When the Tic-Tac-Toe game icon is pressed, game will be opened as shown in Figure 40. When other game icons are pressed, the information message as “Please Wait Update☺“ will be

displayed. If the “GAME” link is pressed out of free-time, the information message in Figure 38 will be displayed.

Main activity of Tic-Tac-Toe shows level of game, your score and cpu's score. Also, it contains buttons for “NEW GAME”, “SETTINGS” and “SCORES”. The score information will be automatically updated when the game is won or lost.

Figure 39: “List of Games” activity

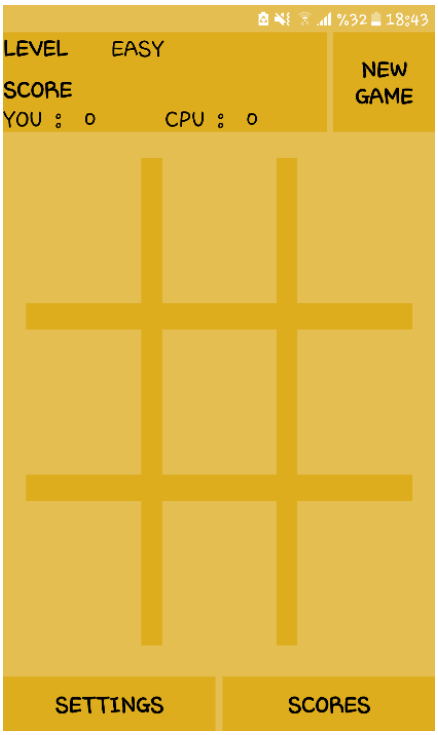


Figure 40: Main activity of Tic-Tac-Toe

When “NEW GAME” button is pressed, game is started again. When “SETTINGS” button is pressed, “Settings” activity will be opened as shown in Figure 41. On this activity, game level and graphic card can be changed. When the desired change is made, “NEW GAME” button will be pressed and game will be started again. With “BACK” button, it is exited without making change.

When “SCORES” button in Figure 40 is pressed, “Scores” activity will opened as shown in Figure 42. On this activity, all level's scores will be shown. With “CLEAR” button, all scores can be reset. With “BACK” button, it is exited without making change.

Figure 41: “Settings” activity of Tic-Tac-Toe

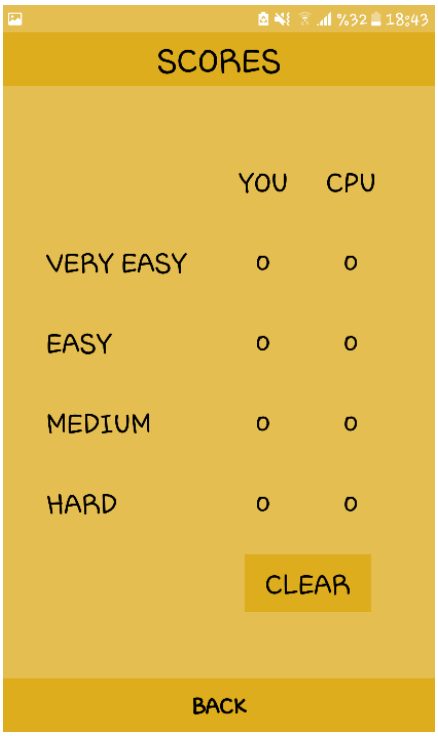


Figure 42: “Scores” activity of Tic-Tac-Toe

When “TASK” link in Figure 36 is pressed, list of the matched plant devices with the child will be opened as shown in Figure 31(b). On this activity, the plant device will be chosen and “Tasks” activity will be opened as shown in Figure 32. Parent and child are used same activity for this area. All steps are same with parent area.

When “LOGOUT” link in Figure 36 is pressed, session will be closed and the “Sign-In” activity will be opened.

Parent or child can be forgot their passwords. If this situation is realized, the “I Forgot my Password” link in Figure 21 will be pressed. When this link is pressed, the “Change Password” activity will be opened as shown in Figure 43. On this activity, Username, Device (Plant Device) ID, New Password and Re-New Password fields must be entered then the “CHANGE PASSWORD” button must be pressed. If the fields is left blank and the “REGISTER” button is pressed, the system will be given an error message that the empty field must not be empty. An example is shown in Figure 23. If username and Plant device ID are matched, password will be changed. Password field must be match the format in Figure 24(d). If username and device ID are not matched, an error message “Username and Device ID are not matched!” will be displayed.

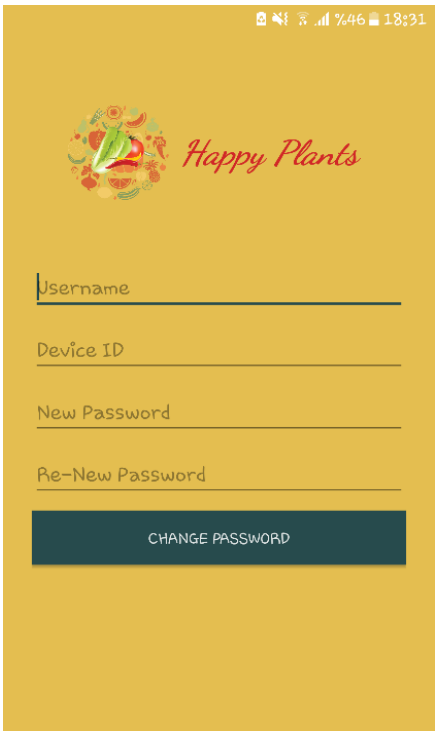


Figure 43: “Change Password” activity

Some activities has “” button. When this button is pressed, current activity will be closed and previous activity will be opened.

3.3 Plant Device

Plant device was developed for growing plant and also use of plant device by the child and parent. The general view of the plant device is shown in Figure 44.

Figure 44: General view of plant device

First of all, water tank will be filled with NW from RW/NW add point shown in Figure 45 before the system is operated. Secondly, the plant will be placed in the recess shown in Figure 46.

Figure 45: RW/NW add point

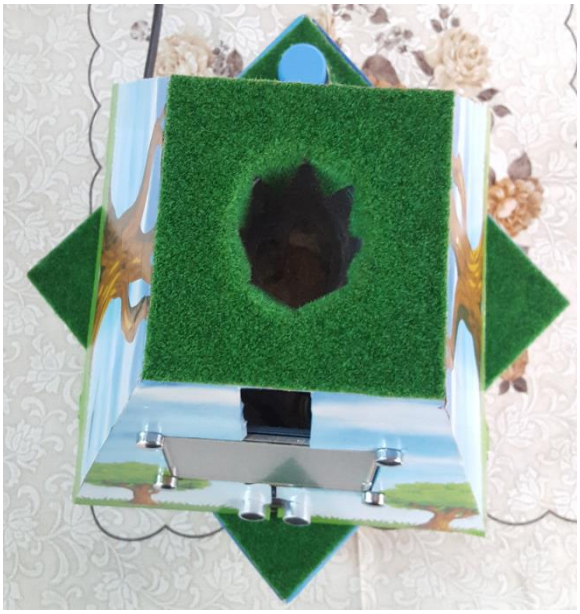


Figure 46: Plant place

Thirdly, power connection will be required for the plant device's work. After the power connection is established, the system will be started to operate automatically. When the system is turned on, "Wi-Fi Configuration" screen in Figure 47 will be opened. When Wi-Fi name and Wi-Fi password are entered to related fields, "Next" button will be pressed. After button is pressed, "Plants" screen will be opened as shown in Figure 48.

Figure 47: “Wi-Fi Configuration” screen for first initialization

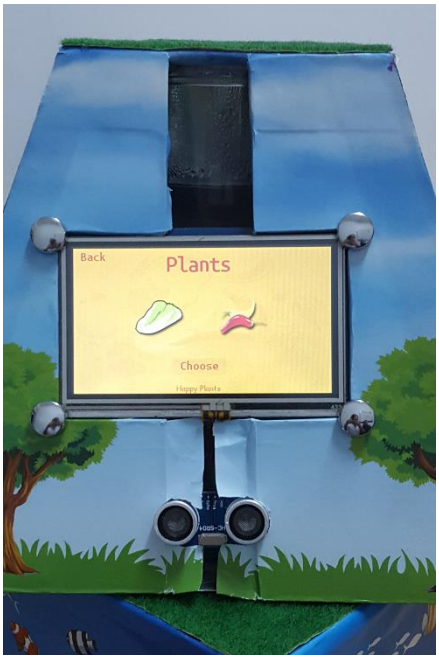


Figure 48: Screen of “Plant” selection

One of the plants registered in the system will be selected and “Choose” button will be pressed. After button is pressed, “Are you sure” screen will be opened as shown in Figure 49. If everything is gone right until here, “Yes” button is pressed to complete the system setup. If chosen plant or Wi-Fi login information are wanted to change, “No” button will be pressed for turn back. When “Yes” button is pressed, system will be restarted then the “Main” screen will be opened as shown in Figure 50.

Figure 49: Confirmation screen of plant selection

Figure 50: “Main” screen of plant device

Current temperature, current humidity, current water need, date of the day, plant's happiness mood, point bar, minimum requirements for growing plant, whether plant

device is connected to the internet and how many days have passed since the plant was planted are shown on the “Main” screen. Also, it contains “Wi-Fi” and “Settings” buttons on top right corner of the screen. When “Wi-Fi” button is pressed, “Wi-Fi Configuration” screen will be opened as shown in Figure 51. Wi-Fi login information can change on this screen. Wi-Fi name and Wi-Fi password will be entered related fields and “Connect” button will be pressed. After button is pressed, the system will be restarted. When “Back” button in Figure 51 is pressed, “Main” screen will be opened. When “Settings” button in Figure 50 is pressed, “Settings” screen will be opened as shown in Figure 52. This screen contains buttons for “Home Page”, “Wifi”, “Boş” and “Initialize”. When “Home Page” button is pressed, the “Main” screen will be opened as shown in Figure 50. When “Wi-fi” button is pressed, “Wi-Fi Configuration” screen will be opened as shown in Figure 51. When the “Boş” button is pressed, screen will be not changed.

Figure 51: “Wi-Fi Configuration” screen

Figure 52: “Settings” screen

When “Initialize” button in Figure 52 is pressed, “User Control” screen will be opened as shown in Figure 53. This screen is designed for the parent. If the system is to be re-initialized from scratch, parent must be entered his/her username and password. After entered username and password, “LOGIN” button will be pressed. After button is pressed, the system will be check username and password. If user is exist and its type is parent, the “Important Announcement” screen will be opened as shown in Figure 54. This screen contains information about re-initialize and also “Yes” and “No” buttons. When the “Yes” button is pressed, the system will be re-initialized from scratch. System re-initialization is the same as first setup. When the “No” button is pressed, the re-initialize will be canceled and the “Settings” screen will be opened as shown in Figure 52.

Figure 53: “User Control” screen

Figure 54: “Important Announcement” screen

Chapter 4

METHODOLOGY FOR THE PROPOSED SYSTEM'S TEST

The proposed system's test consists of three parts which are pre-survey, post-survey and trial. One trial that would take about one month was done with a 10 years old child. (One trial was done because of the limited time and cost.) Two pre-surveys (one for child and one for parent) and two post-surveys (one for child and one for parent) were prepared as shown in Appendix C. The purpose of these surveys are to learn effects on child and thoughts of her/his parent. Pre-surveys were filled out before the trial and post-surveys were filled out after the trial. Before filling out the pre-surveys, details about the system were given to the parent and the child. In addition, observations were done during the trial.

Note that, for this test, the necessary permissions were taken from both the child and his parent.

Chapter 5

RESULTS & DISCUSSION

The main purpose of HSES is to contribute to self-improvement of children. HSES assigns tasks, which are temperature, NW, game, and general knowledge tasks and draws attention in order to achieve this.

Every plant has certain temperature requirement for healthy growth. In case where the requirement is not provided, the system assigns the temperature task to the child by declaring that the required temperature range in the environment should be balanced. Thus, the child would consider finding a solution to compensate the environment temperature. The child would apply the method(s) s/he has found such as opening/closing the window and moving the plant device to inside/balcony. As a result, this task could contribute to the child's improvement on cognitive, affective, and psychomotor domains.

Plants need RW and certain nutrients. Because of our proposed system also includes a Hydroponics system, certain amount of RW and certain amount of the nutrients are required. The system follows NW level in the water tank and if this level is decreased, it assigns the water task to the child for adding RW/NW. After the task assignment, the child adds the necessary amount of RW/NW through "RW/NW add point" into the water tank. Furthermore, there is one more water task that changing

the NW in the tank is asked. Hence, these tasks could contribute to the child's improvement on all the three domains.

Educational, instructive, and engaging games have positive effects on children when used for educational purposes [13]. Therefore, the game task that the child would play with fun and improve himself is also added to HSES. Currently, Tic-Tac-Toe game is included in our system as a sample game. It could contribute to the child's improvement on cognitive, affective, and psychomotor domains. Other new games could also be included in HSES; however, those games that let the children to improve themselves with fun would be preferred.

The general knowledge task is included in the system with the logic of every-day-new-information. While giving this task to the child, it is aimed to contribute to the child's improvement on cognitive and affective domains.

There draw attention function is added to the system in order to attract the child's attention and, hence, motivate him to use HSES. This function tries to attract the attention of the child by speech, when s/he passes from front of the system. The child's improvement on affective domain could be contributed with this direct motivation. The system does not differs who is passing; so, it also tries to draw attention of anybody else passing from front. That person might be motivated to motivate the child to use the system actively by poking him with questions about the system such as "Did you do today's tasks?" and "Do you care with your plant?"; therefore, the child would be indirectly motivated. While giving messages via speakers about temperature and NW level troubles help the plant, the same effect with draw attention function would also be occurred.

The contributions in terms of cognitive, affective, and psychomotor domains of all tasks and draw attention function are summarized in Table 15.

Table 15: The contributions of all tasks and draw attention function

Contributed Domain / Task / Function	Cognitive	Affective	Psychomotor
Temperature Task	√	√	√
NW Task	√	√	√
Game Task (Tic-Tac-Toe)	√	√	√
General Knowledge Task	√	√	×
Draw Attention Function	×	√	×

HSES considers the free-time entered by the parent to notify tasks to the child in voice and/or written formats. The free-time is a two hours interval per day. This interval is especially limited to two hours since American Academy of Pediatrics [14] stated that children's interaction with media should be less than two hours per day. It is good to say that our system is appropriate for the duration of daily media usage of children.

To the best of our knowledge, HSES is more advanced, has more features, has wider scope, and uses more various state-of-the-art methods, according to our literature survey. Only Idropo, which is developed by Carrozzo et al. [5], was encountered as related work. A brief comparison of our system and Idropo is shown in Table 16.

Table 16: Comparison table for HSES and Idropo features

Feature \ System	HSES	Idropo
Water level status control	√	√
Water level status display	√	√
Environment temperature control	√	×
Environment temperature display	√	×
Environment brightness control	×	√
Environment brightness display	×	√
Screen	√ (One 4.3” Touch screen)	√ (Two smaller LCD screens)
Game	√	×
General knowledge	√ (Everyday new information shown)	√ (The same information repeats)
Draw attention function	√	×
Notification	√ (Audio and written)	×
The days passed information	√ (Current date also shown)	√
Multiple plant	√ (No limit (With additional plant device(s)))	√ (Maximum four plants)
Multiple child	√ (No limit)	√ (Maximum four children)
Specialized on a plant	√ (Works for lettuce and pepper)	Not known
Mobile application	√	×
Web application	√	×
Internet connection	√ (For communication of components)	×
Instant child control	√	×

Multiple Plant: One child can have one or more plant devices at the same time in HSES, while Idropo has only four plant slots to be used at the same time.

Multiple Child: HSES allows more than one child per parent (with at least one plant device per child) at the same time, while Idropo allows maximum four children under one or more supervisor(s) at the same time. Note that it is assumed that only one child would grow the plant on a slot/plant device.

Profile of the child who performed the trial is as follows: He was a 10 years old boy born in 2008; he has a personal smartphone, uses it between 3 and 5 hours a day and likes to play game on it (1-3 hours per day); he likes to grow plants. Before the child started to trial: both the child and the parent liked the general view of the system; the child was willing to play with “Happy Plants” and was thinking that it can be fun and educational; the parent was willing the child to play with “Happy Plants” and improve himself; and the parent thought that it could be beneficial for the child. The aforementioned information are obtained from pre-survey and had showed us that the correct subjects were selected. Use of plant device by the child during the trial is shown in Figure 55.

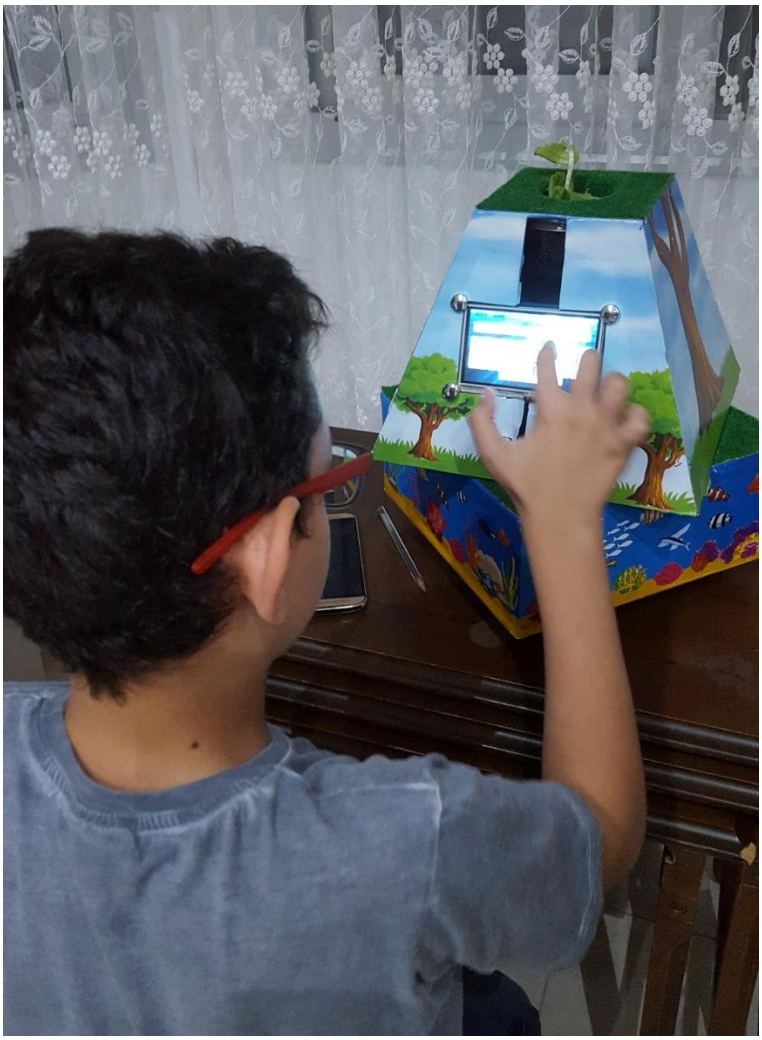


Figure 55: Use of plant device by the child

After the system trial, the child said that he was interested with “Happy Plants” between half an hour and one hour in a day. He stated that he learned and enjoyed with “Happy Plants”. He thinks to recommend this system to his friends. Furthermore, he suggested an additional feature that the system talks to the child user with her/his name. The parent stated that “Happy Plants” was beneficial for the child and is a nice work. In addition, he thinks to recommend the system to others. The child and the parent rated the system as 8 and 7 points out of 10, respectively.

Based on the positive responses in surveys and the observations, it can be said that HSES (“Happy Plants”) could be a successful system.

Chapter 6

CONCLUSION & FUTURE WORK

This system is composed of Android application, Raspberry Pi, Web server, MySQL server and Hydroponics system components. Its aim is to contribute to improvement of children on cognitive, affective and psychomotor domains.

With temperature task, the child would consider finding a solution to compensate the environment temperature and would apply the method(s) s/he has found. So, this task could contribute to the child's improvement on cognitive, affective, and psychomotor domains. NW task regarding to level in the water tank and game task that the child would play with fun and improve himself could also contribute to the child's improvement on all three domains. General knowledge task, which is included with the logic of every-day-new-information, could contribute to the child's improvement on cognitive and affective domains. Draw attention function is added to the system in order to attract the child's attention and, hence, motivate him to use HSES. It could contribute to the child's improvement on affective domain.

With this system's diverse features, contribution to improvement of children on cognitive, affective and psychomotor domains could be done, as it is also perceived from the observations and the results of surveys in the test.

New games, brightness control, multi-way voice communication and talking to the child with her/his name will be included into our system. Separate plant device designs could be done for girls and boys. It is thought that our system is for 9+ years old children; however, a formal action is needed and will be done for finding out the definite minimum age limit. For the test, more trials will be done with more detailed versions of surveys.

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APPENDICES

Appendix A: Use Case Diagram of Android Application Component

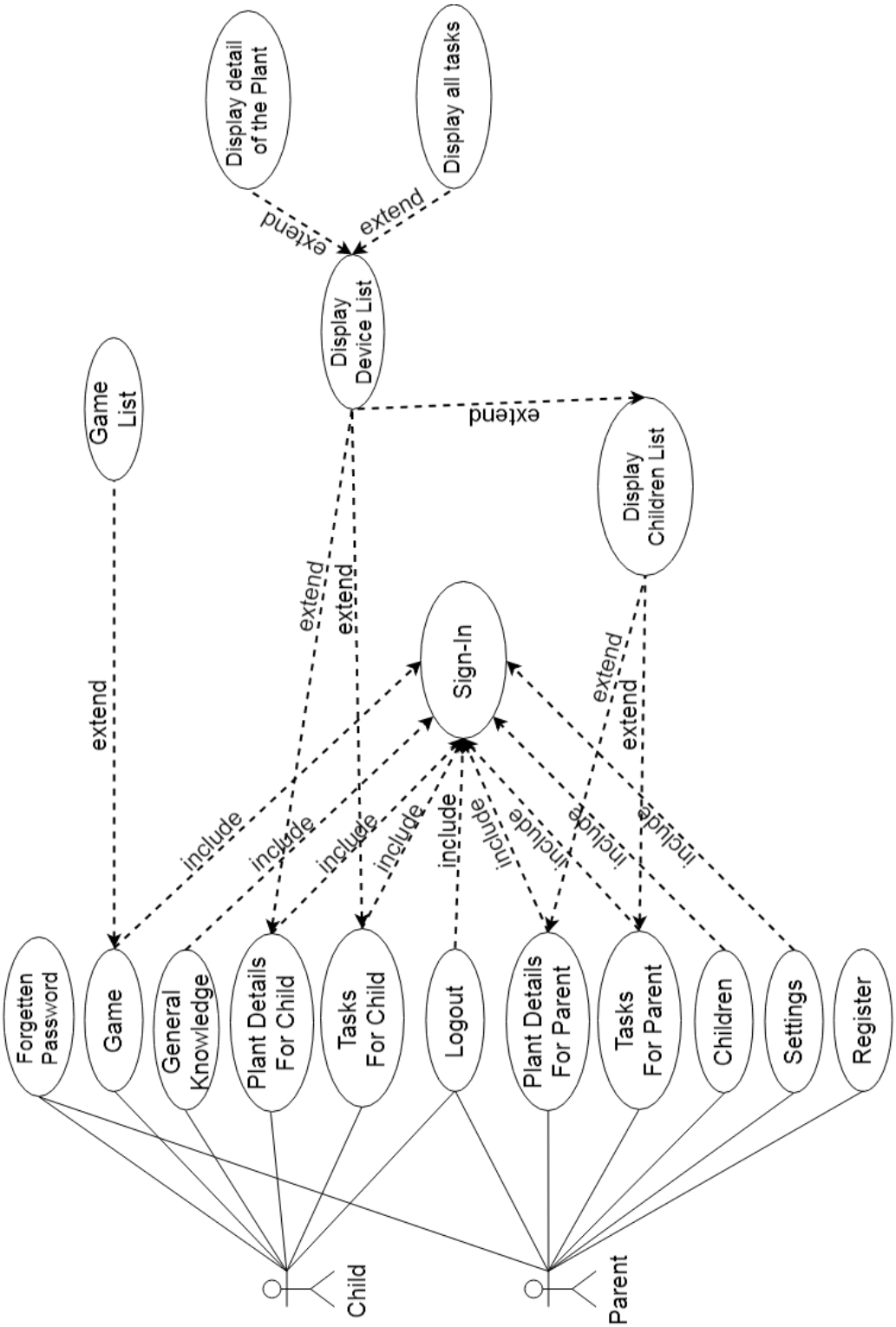

Figure 56: Use case diagram of Android application component

Appendix B: Pre-Study for the Plants

Before the started to use lettuce for our system, we researched how to grow lettuce. We searched answer to what we need, what should we do, how lettuce is growing in hydroponics system vs. questions. In general, water values for lettuce should be between 800 and 1200 for electrical conductivity (eC) and between 6 and 7 for power of hydrogen (pH) and environment temperature should be between 5 and 25 degrees. Generally, water values for pepper should be between 1800 and 2200 for eC and between 6.5 and 7 for pH and environment temperature should be between 12 and 30 degrees.

Based on 1050 eC and 6.5 pH values lettuce-nutrient-solution bought from Turkey is adjusted with acid (HCL) or base (NaOH) and our NW is obtained.

Lettuce sucks water and nutrients continuously from NW. During the first 11 days, RW was added as much as the amount of NW had been sucked. At the end of 11th day, NW values decreased to about 850 eC. So, we changed NW with new NW. Because, we had no possibility to check which nutrient decreased in NW. Our new mixture was adjusted 875 eC and 6.5 pH values. This values should have been closed to the poured NW values because plant should not be stressed. After this day, we added NW with 1050 eC and 6.5 pH, when missing. On 22nd day, NW values increased to about 1050 eC; so, we changed NW with new NW again. New NW was adjusted to 1050 eC and 6.5 pH in order to avoid to stress the plant. After 22 days, RW was added as much as the amount of NW that had been sucked. At the end of 33rd days, we found that lettuce could be eaten-level. Note that if it is observed that there is not enough growth at the end of 33rd day, a few more days could be waited.

RW/NW add point and pour point are shown in Figure 57. In Figure 58, 59 and 40, before planting of lettuce, the growth stages of lettuce and after harvest of lettuce are shown.

For pepper, we have decided to use the time ranges as 8 days and pepper-nutrient-solution with 2000 eC and 6.8 pH values based on our aim and experiences.

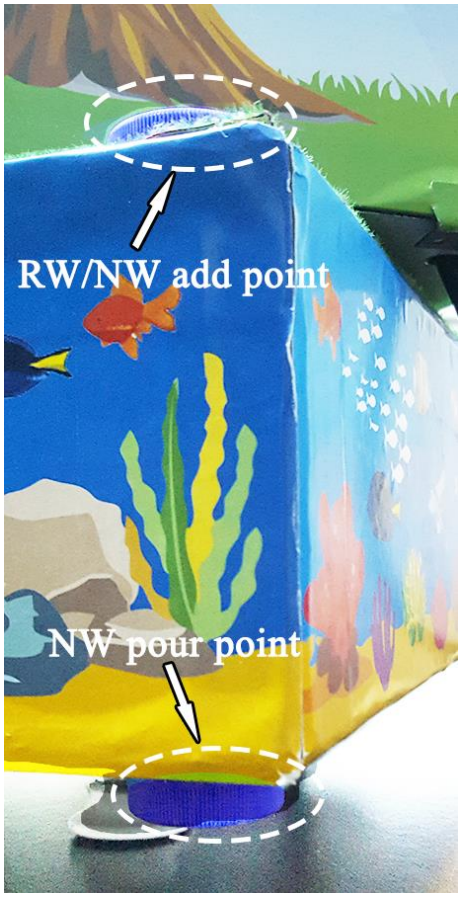

Figure 57: RW/NW add and NW pour points

Before planting

First day after planting

7th day after planting

Figure 58: Growth stages of lettuce (1 of 3)

11th day after planting

17th day after planting

22nd day after planting

27th day after planting

Figure 59: Growth stages of lettuce (2 of 3)

33rd day after planting

After harvest

Figure 60: Growth stages of lettuce (3 of 3)

Appendix C: Surveys for Testing

"Happy Plants" – Child Pre-Survey

1. **Date of birth**

2. **Gender**

   ◯ Boy
   ◯ Girl

3. **Do you have a smartphone?**

   ◯ Yes
   ◯ No

   If your answer is No, you can pass to question 5.

4. **How many hours do you use it in a day?**

0	1-3	3-5	5+
◯	◯	◯	◯

5. **Do you like to play games on phone?**

   ◯ Yes
   ◯ No

   If your answer is No, you can pass to question 7.

6. **How many hours do you spend for playing games on phone?**

0	1-3	3-5	5+
◯	◯	◯	◯

7. **Do you like to grow plants? (including vegetables and fruits)**

   ◯ Yes
   ◯ No

8. Did you like the general view of “Happy Plants”?

◯ Yes

◯ No

9. Would you like to play with “Happy Plants”?

◯ Yes

◯ No

10. Would you like to say something additional about “Happy Plants”?

“Happy Plants” – Child Post-Survey

1. How many hours did you spare for “Happy Plants”?

0 ◯ 0 – 0.5 ◯ 0.5 - 1 ◯ 1 - 2 ◯

2. Did you enjoy with “Happy Plants”?

◯ Yes
◯ No

3. Did you learn with “Happy Plants”?

◯ Yes
◯ No

4. How many points do you give to “Happy Plants”?

1 ◯ 2 ◯ 3 ◯ 4 ◯ 5 ◯ 6 ◯ 7 ◯ 8 ◯ 9 ◯ 10 ◯

5. Do you think to recommend “Happy Plants” to your friends?

◯ Yes
◯ No

If your answer is No, can you explain it in a few sentences?

6. Would you like to say something additional about “Happy Plants”? (Are there any different features you want to see in “Happy Plants”?)

“Happy Plants” – Parent Pre-Survey

Please read the description before starting our survey.

HSES (“Happy Plants”) is a novel smart system based on hydroponics. It is aimed to educate children by contributing to their improvement on cognitive domain, affective domain and psychomotor domain. This hydroponics-based smart education system is giving a different tasks to the child, does not interfere children’s daily life and includes instant child control that you can control your child.

1. **Did you like the general view of “Happy Plants”?**

   ◯ Yes

   ◯ No

2. **Do you want your child to play with “Happy Plants”?**

   ◯ Yes

   ◯ No

3. **Do you want your child to improve himself with “Happy Plants”?**

   ◯ Yes

   ◯ No

4. **Do you think “Happy Plants” could be beneficial for your child?**

   Yes ◯ No ◯ Undecided ◯

5. **Would you like to say something additional about “Happy Plants”**

“Happy Plants” – Parent Post-Survey

1. **Do you think “Happy Plants” was beneficial for your child?**

   ◯ Yes
   ◯ No

2. **How many points do you give to “Happy Plants”?**

   1 2 3 4 5 6 7 8 9 10
   ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯ ◯

3. **Do you think to recommend “Happy Plants” to others??**

   ◯ Yes
   ◯ No

   If your answer is No, can you explain it in a few sentences?

4. **Would you like to say something additional about “Happy Plants”? (Are there any different features you want to see in “Happy Plants”?)**