Big nature archive document

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1. Short description of your challenge/problem (500 words)

As of today (januari 26 2020) pretty much all agriculture is done on the countryside. Since there's a lot of space necessary for growing crops and, at least in common agriculture, crops can't be stacked, a lot of space is lost in agriculture. Currently about 54 percent of the ground surface of the Netherlands is used for agriculture[*1]. This on its own wouldn't be a problem if it weren't for the growth of cities. In 2035 Amsterdam is expected to have grown 20 percent in citizens[*2]. All these people need housing and space to live. This means there's something else that needs to be cut back on to create space. If agriculture could be implemented in urban areas this would greatly reduce the surface area which is needed to grow crops, thus leaving more space for urban expansion while at the same time creating greener cities.

Luckily there's already a lot of products which help with urban agriculture, specifically designed for the consumers. See for example the 'Click & Grow Smart Garden'[*3]. This smart plant pot automates the care process of a plant. Obviously this helps with urban agriculture, consumers don't have to think about their plant anymore since it just grows on its own in ideal conditions. But this doesn't focus on the core of the problem. Most people are able water a plant on a daily basis if necessary and pretty much all houses have windows where a plant can get its necessary sunlight. The problem is that most people don't know how to take care of their plants. Only when most people learn to take care of plants can urban agriculture by consumers really grow. Self sustaining smart plant pots do help with this problem but they are expensive, the click & grow smart garden 3 costs €99,95 [*3]. This price tag means many people cannot afford to grow a significant amount of crops at home in these kind of smart plant pots, whereas a well educated person in the field of agriculture can have as many plants as they desire.

This is where the plant-pot-hub comes in to play. The plant-pot-hub on its own looks a lot like a normal plant pot but inside the pot are a lot of sensors which detect the water and light levels of this specific pot. This data is wirelessly sent to a central hub which analyses the data. The computer in the hub compares the data to a database and to the other smart-plant-pots connected to the hub. With the data from these comparisons certain levels are displayed. It is left to the consumer what to do with this information since the device doesn't give any direct advice on how to improve these levels when they aren't perfect. The only thing the smart-plant-hub gives is whether or not some values are imperfect and if so, how far they are from the ideal situation. If the consumer chooses to do so he or she can read a small piece about the specific plant summarizing some crucial information about the plant, like whether or not it likes direct sunlight and how much water it needs. This information is accompanied by some general information on how to improve these levels, like how you can decrease the moisture level relatively quick. This method of facilitating all necessary information without direct instructions is called Inquiry-based learning. The user itself needs to be motivated to read and learn the information about the plant and they need to actively look for this information themselves. The fact that the user needs to

look actively for information instead of it being directly delivered helps with the effectiveness of the learning process.
The goal of this product is to increase awareness on the needs of a plant and the process of growing a plant and perhaps even inspire consumers to grow a sizeable part of their own food.

2. Short description of your solution (500 words)

The solution we chose to elaborate on is the smart-plant-hub idea. This concept was chosen because it differs from the standard 'smart plant pot' idea. Namely, our idea focuses primarily on the educational aspect, specifically Inquiry-based learning. With Inquiry-based learning, users aren't given direct instructions to, for example, give a plant fertilizer, instead they are informed about the mineral levels of the plant soil, if the user then decides to use plant fertilizers, they can read about which fertilizers have which specific minerals. Users themselves then need to think about what fertilizer would be best for their plant. The goal of such an approach is that after a couple of times, the user will no longer need to read the information provided in order to know which fertilizer the plant needs since they have learned it over time.
The idea of the smart-plant-hub is that it is a plant pot filled with sensors and an arduino. The sensors with which the plant pot is equipped are two light dependent resistors attached to the sides of the plant pot and a hygrometer laying in the soil in which the plant is growing. These measure respectively the light levels of the plant and the moisture levels of the plant. The collected data is being sent via a bluetooth module connected to an arduino uno. The data is received by another arduino uno connected to a laptop or a pc. Here the data is compared to a database with ideal plant conditions for this specific plant. When the data has been compared to the database the results are shown to the user. When the results are lower than ideal it is displayed via a red bar beneath the corresponding level type. When the values are too high compared to the database a blue bar is shown beneath the corresponding level type. Depending on these levels some tips and tricks are shown on how to improve these levels. Without giving explicit instructions of course.
The plant pot is divided into two compartments. The top compartment is for growing the plant and collecting the data. Here lays all the soil and in and around this soil are the sensors. In the compartment beneath the waterproof layer are the other electronics. Here is the arduino uno and the bluetooth module. The cables from the light dependent resistors and the hygrometer are pulled through the waterproof layer and later again made waterproof.
Another advantage of the plant-pot-hub is the possibility of intercommunication between multiple smart plant pots. When two or more smart plant pots with the same plant are connected to one hub, data could be communicated between the two. When, for example, plant A is growing a lot faster than plant B, the smart plant-pot-hub could and analyse the data from these two pots. If plant A has gotten a lot more sunlight than plant B, the user could be informed about this and the hub could advice the user to give the plant more direct sunlight.

3. Short description of method and tools used (software, hardware) (1,000 words)

The following is the methodology of building the smart-plant-hub. These are the most important equipment and data needed for the smart-plant-pot to properly function.

Methodology

Equipment

The product consists of at least two parts: the hub and at least one smart plant pot.

The plant pot needs an arduino with bluetooth shield to send information, whereas the hub needs a computer for data analysis and a screen for displaying the data. The input for the arduino in the plant pot is provided by sensors. The chosen minimum requirements for the pots are a light sensor (ldr) and a humidity sensor (hygrometer).

Prior data collection

The plant-pot-hub needs some data before it can properly function. To know what levels of the collected data is healthy for the plant, the hub needs to know what situation is ideal. This means that a selection of which plants, which are compatible with the system, is made. For each of the selected plants the ideal water, light, Ph and salinity levels are researched.

Operative data collection

When the system is operative, there is constantly data that needs to be collected and analysed. The plant pots collect data about the plant's moisture level and light level. Moisture and light are then compared to the ideal levels in the database, this comparison is displayed to the user, along with potential advice on how to improve these values. The data of the different pots can be compared and then the differences in light of moisture level can be seen. Perhaps one plant gets a lot more light and gets way too dry while the other has a perfect balance between light and moisture, so the client will know that the dry plant may need to be placed somewhere else.

Design process

There were different components of our plan- pot-hub which needed to be designed, namely the pot(hardware) and the interface(software) of the hub through which users interact with the system.

Software

The interface was the most difficult to design since multiple values needed to be visualised while still keeping the interface uncluttered and clear for the user. The various aspects that needed to be displayed were: the scientific and common names of the plants, the amount of sunlight it currently gets, the amount of water it is getting and an educational aspect such as a 'Tip of the day'.
The interface consists of multiple pages: homepage, add a plant, education corner, water levels over time and sun levels over time. Each of these pages introduced their own design challenges which we overcame with trial and error. A few of the pages and their design process are shown below.

As for the homepage, we wanted to give the user a quick look into the state of each plant. In order to keep the clutter to a minimum, we opted to show the water and sun levels using circles that filled up as the plant got more sun or water. The perfect amount is represented when the circle is exactly half filled, this makes it possible to visualise too much water or sunlight and watering and too little water and sunlight watering. On top of the circular indications, we added small smileys next to the plant images to give the user instant information on how their plants are doing, the smileys work as such:
Green and happy: both the water and sun levels are ideal
Yellow and neutral: either the water or sun level is not ideal, the other is ideal
Red and unhappy: both the water and sun levels are not ideal
At last, we had to incorporate the educational aspect of our project in the home page, this was done by dedicating the right side of the screen to fun facts and 'tips n tricks' about plants and notifications that informed the user on what to do with certain plants that were not doing very well.

Next, we needed a way to not only show the current state of the plant, but its state over time. This was visualised using dedicated water and sun pages that visualised the sensor data into a graph through which the user could see the amount of sun and water their plants got over the course of a certain specified time span.

In order to give the user the opportunity to learn more about their plants and agriculture as a whole, we decided to incorporate an education page in our interface. On this page, users can watch videos and read articles about the plants they currently have but also about other plants and agriculture related topics.

At last, we needed to give the user the possibility to add new plants to the interface in order to track them too. This is done by going to the home page and pressing the + in the bottom left corner, this gives the user a few options of plants they could add. Once the user has chosen, information on how to take care of the plant is shown, in order to give them a head start when taking care of their new plant.

Hardware

For the pot design it was clear that a simple and pretty big pot was needed, the color was preferably grey or white and several plants and electronics should be able to fit in it.
The pot that was selected for the prototype is about 30 cm and white, with a secret compartment in the bottom to fit the electronics. In the prototype, which was designed to fit ample room for electronics and house seedlings with small root clusters, the compartment wall is situated about 10 cm from the top of the pot and attached with glue. To reach the electronics a hole was made in the original bottom of the pot with a cap which can be replaced so you can close the pot again and increase its aesthetics.
To add the sensors there are very tiny holes in the top of the pot on two sides so that a light sensor can be added on all two sides so the light can be caught well.
The electronics that are inside the pot are an arduino uno with a bluetooth shield, those are connected to the humidity sensor which is in the soil inside the pot, and with the two ldr sensors which are attached to the side of the pot.
The bluetooth module is connected to the interface and so the arduino sends the data of the pots and the interface will show this data to the client.

4. Short description of results/observations/data gathered/graphs (1,000 words and/or 3-4 figures/graphs).

Ideal situations

The data received from the plant pot needs to be compared to a database. The data shown below are the ideal situations for garden cress and lettuce plants to which the sensors are calibrated.

Lettuce

Light level

Lettuce needs a maximum of 12 hours a day of direct sunlight[*4]. This statistic does not regard the temperature of the environment: When temperatures rise above 21 degrees celsius growth will stagger as well[*5].

Moisture level

Lettuce prefers frequent light watering for optimal growth[*5].

Garden cress

Light level

The light level which the garden cress prevers is full sun, though it tolerates some shade[*6].
On average there is a little over 4 hours of sunlight a day in the Netherlands[*7]. This would mean the garden cress would need 4 hours of direct sunlight at minimum, but preferably more.

Moisture level

Above average water needs. Cress prefers a consistently moist soil. Thrives in hydroponics[*6].

Additional ideal situations

These are the ideal situations[*4] for a selection of some popular plants which are not currently implemented in the system.

Fatsia japonica

Sufficient light, no intense light.
Watered twice a week.
vegetable mould.

Aspidistra

Needs a lot of light but should not stand in the intense sunlight, during the summer it is also possible to put this plant outside in the shadow.
Needs water two or three times a week.
Loam with organic fertilizer.

Maranta

Warm and moist, not too much light, never in the intense sunlight, better to not move the plant.
Frequently water the plant because the bottom should be moist and soaked.
Nutritious and moist mixture of sand, soil,peat and compost.

Cocos nucifera

Needs a lot of light, no intense sunlight.
Water frequently, loam needs to be moist(too dry makes the leaves die and too moist will make the whole plant die).
Humus leaves.

Monstera deliciosa

Moist, enough light, not place it close to hot surfaces like heaters.
Frequently water the plant.
Nutritious loam (too dry loam will lead to very small and nasty leaves).

Philodendron

Sufficient light, no intense sunlight.
Water at least twice a week.
Airy, pretty nutritious soil.

Education

Education is one of the purposes of this product. Through literature research it was concluded that one of four methods for education would be used. The four categories are: direct instructions, inquiry-based learning, learning through games and cooperative learning. These four categories are further defined and explained below.[*8*9]

Direct instructions
This category relies mostly on the authority and expertise of the instructing party. The teaching party directly conveys instructions to the user, instructing for example when to water the plants in this scenario. The user relies heavily on the device for instructions, resulting in lowered efficiency when it comes to the educational aspect.
Example: When the plants are lacking in one aspect of their needs, the device will take the initiative on the matter, telling the user to add for example a specific fertiliser. The user can still learn to recognise the telltale signs of certain issues, but learning potential is limited.

Inquiry-based learning
In this model, the user will turn to the device for advice, instead of instructions. The device facilitates the option of learning, but it is up to the user to make use of it.
Example: The device might show statistics on the soil quality relative to the needs of the crops contained in the system. It is then up to the user to explore the options for resolving this: The system will not instruct the user on how to solve the issue, but the user can select any one soil quality to find more information on its importance and ways to increase or decrease the level of nutrients in the soil. This forces the user to actively look into the needs of the plants and provides increased learning.

Learning through games
Learning through games means adding game elements with the sole purpose of encouraging learning - the game elements are supposed to make the educational aspects of the product more interesting.
Exploratory learning
In this method, the user learns by exploring on their own, driven only by their curiosity. This, in essence, is always used to a certain extent, but can be encouraged - however, the methods of encouraging this also fall under inquiry-based learning, and as such will not be further explored for this project.

Cooperative learning
Cooperative learning involves multiple users learning by working together. For this product, it could mean bringing different users together to achieve some form of learning - This could be explored, but seems beyond the scope of the current project.

To educate the user about plant care some tips and tricks were developed. In the table beneath are all the collected tips and tricks about growing a lettuce plant[*5]

Condition	Message
Low moisture	“Lettuce prefers frequent light watering”
High moisture	“To much watering will slow the growth of a plant and can even cause the

	roots to rot" "Placing a plant above a radiator will cause the water to evaporate quicker" "Placing a plant in a dry room will cause the water to evaporate quicker"
Low sunlight	"Lettuce needs a maximum of 12 hours of direct sunlight a day" "When a plant has enough sunlight, it will grow faster and when fully grown might even taste better"
High sunlight	"More than 12 hours of sunlight will stagger the growth of lettuce" "Lettuce is a cool weather crop. When above 21 degrees celsius, growth will stagger"
Ideal conditions	"Giving a plant enough of the correct fertilizer improves the taste of a plant!"

Final result

General explanation of the plant-pot hub

The final prototype is the plant pot based around an Arduino Uno with a hygrometer and two LDRs. The hygrometer lays within the soil of the plant and measures the humidity of the soil. The two LDRs are placed on either side of plant pot in the outer ledge and measure the duration and intensity of the light. Both the moisture level and the light levels are sent via bluetooth to a computer which in this prototype will act as the central hub. This central hub evaluates the data and compares the values to a plant specific database with ideal moisture and light levels. Once this comparison is made the results are displayed in the interface and it's shown which levels are off and how by how much they should be corrected.

Interface

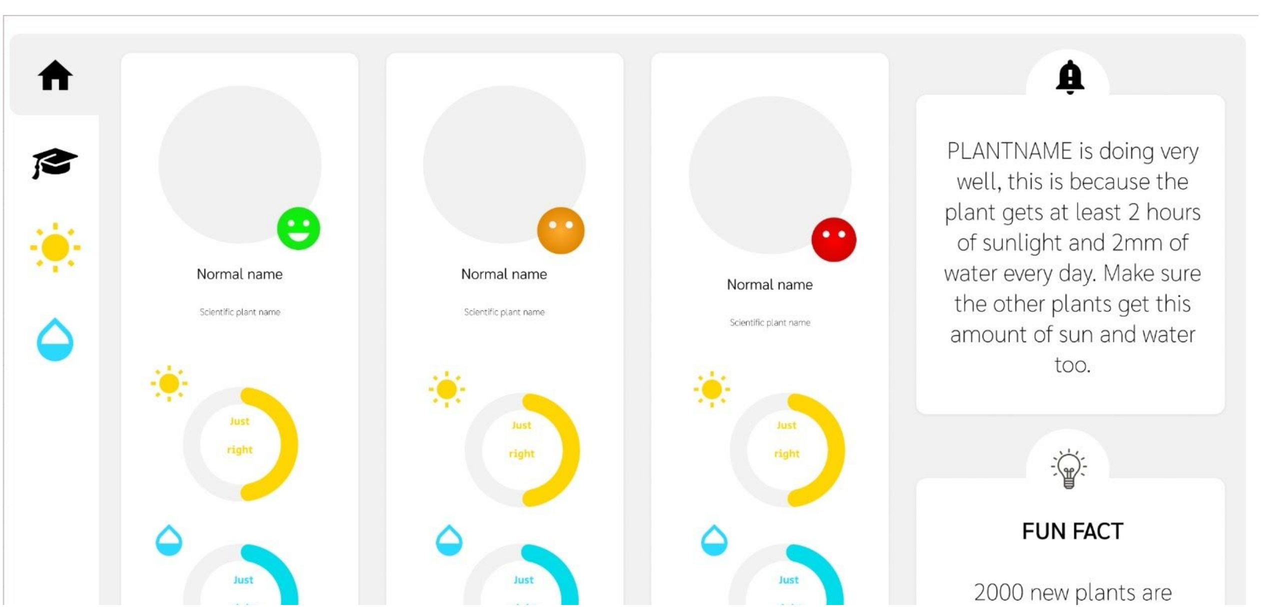
The final result for the interface was made to be as intuitive as possible with smileys and colours representing the condition of the plant and whether or not certain levels are ideal. All of the education and user interaction is done via this interface. When a certain level of the plant is not ideal a useful tip will pop-up giving potential advice to the user on how to improve the conditions of this plant. If the user so desires, they can also look in the education menu. Here they can find additional information about their plant or growing plants in general.

Education

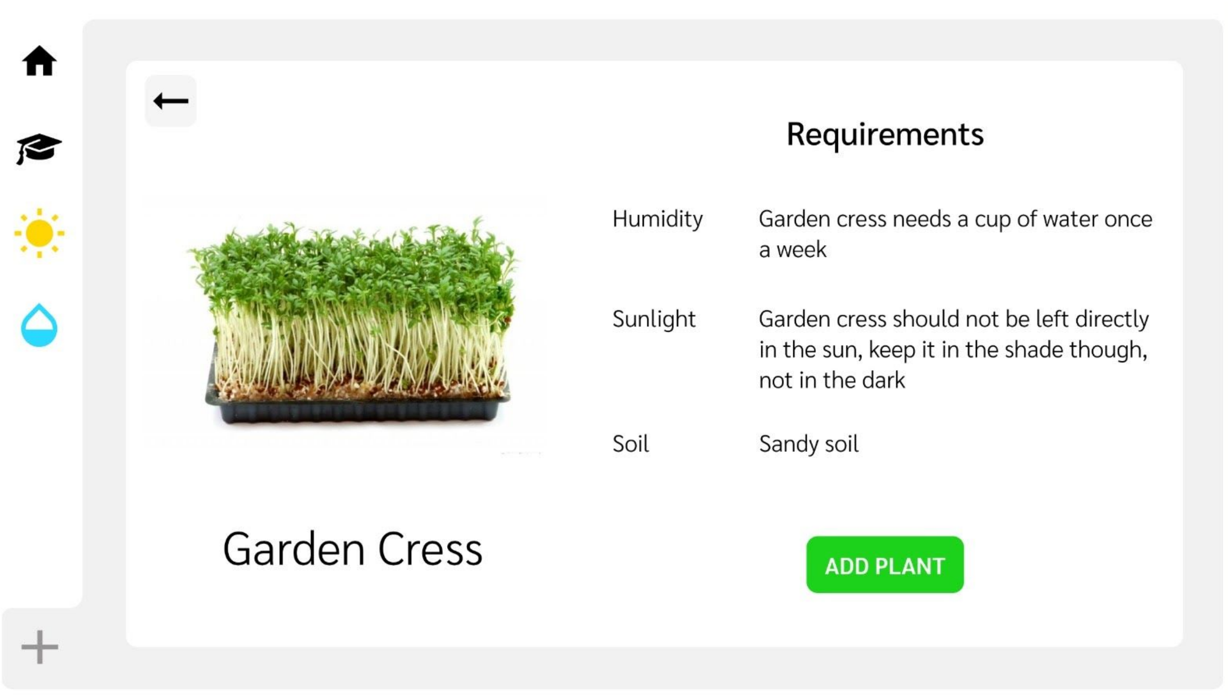
From the different types of learning discussed under the literature header 'inquiry-based learning' was chosen to be the primary focus of the educational aspect. This means there aren't given any direct instructions, merely advice. The inquiry-based learning is done via the pop-ups in the homescreen of the interface. Additional information is given in the education tab found in the side-bar as can be seen in the image below. Here are all of the general tips and tricks, which are given when certain conditions are met, organized and directly made available to the user. There are also links to third-party research papers and educational videos about growing plants or other plant information.

5. Up to 5 photos of your prototype

The final result of the smart plant pot.



The interface design.



The education tab about Garden Cress.

6. Up to 2-minute video explaining what the prototype does.
Video can be found at
https://drive.google.com/open?id=1bkH8KIOzb3HORnC2ZdC469Uhemqrdbxf

7. Full working code of the project.
Full working code can be found at
https://drive.google.com/open?id=1XmaKM42kE0JxDB4Vpw1SO_k3fUgQqN-6

*1 Centraal Bureau voor de Statistiek. (2016, February 25). Minder landbouw, meer natuur. Retrieved January 27, 2020, from
https://www.cbs.nl/nl-nl/nieuws/2016/08/minder-landbouw-meer-natuur

*2 Centraal Bureau voor de Statistiek. (2019, September 10). Sterke groei in steden en randgemeenten verwacht. Retrieved January 27, 2020, from
https://www.cbs.nl/nl-nl/nieuws/2019/37/sterke-groei-in-steden-en-randgemeenten-verwacht

*3 The Smart Garden 3. (n.d.). Retrieved January 27, 2020, from
https://eu.clickandgrow.com/products/the-smart-garden-3

[*4]Allman, M. (n.d.). Daylight Hours to Grow Lettuce. Retrieved from https://homeguides.sfgate.com/daylight-hours-grow-lettuce-70987.html

[*5]University of Illinois Extension. (n.d.). Lettuce - Vegetable Directory - Watch Your Garden Grow - University of Illinois Extension. Retrieved January 27, 2020, from https://web.extension.illinois.edu/veggies/lettuce.cfm

[*6] How To Grow Garden cress | Herb Gardening Guide. (n.d.). Retrieved January 27, 2020, from http://herbgardening.com/growinggardencress.htm

[*7]Weele, M., & Meirink, J. F. (2017). KNMI - Vier uur zon per dag – op vakantie naar het zuiden of toch in Nederland blijven? Retrieved January 27, 2020, from https://www.knmi.nl/over-het-knmi/nieuws/vier-uur-zon-per-dag-op-vakantie-naar-het-zuiden-of-toch-in-nederland-blijven

[*8]Edelson, D. C., Gordin, D. N., & Pea, R. D. (2011). Addressing the Challenges of Inquiry-Based Learning Through Technology and Curriculum Design. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/10508406.1999.9672075

[*9] Hong Kong Institute of Education. (n.d.). *Cooperative Learning*. Retrieved from https://www.eduhk.hk/aclass/Theories/cooperativelearningcoursewriting_LBH%2024June.pdf