A Relationship with Nature: Systems and Methods for Better Integrating Greenery into Our Lives

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Abstract

Despite that centers of urban continue to grow and their populations increase more and more, most people surprisingly spend more of their time indoors, isolated from the natural environment. Recently, this trend has remarkably intensified by the prolonged COVID-19 outbreak and excessive air pollution. This unusual moment has resulted in urban dwellers began to seriously seek to improve their indoor environments. For instance, they have been purchasing and attempting to care for potted plants, which often ended with varying levels of success since certain plants have certain needs, understanding and accommodating these needs can quickly become confusing and lead to frustration.

For this reason, this study aims to simplify the methodologies to cultivate nature indoors and design a system where both plants and humans can thrive in today's context. The authors bring their own experiences, problems encountered, and knowledge gathering from a wide variety of online blogs, forums, social media groups, instructional videos from both amateur and professional YouTubers, printed articles and books, as well as direct discussions with fellow enthusiasts and experienced professionals to design the plant care system that consisted of 3 parts; 1) Plant care cards that simplify complex knowledge for easier understanding, 2) Plant pots for caring four groups of plants; plants that need moderate moisture, plants that need more moisture, plants that need less moisture, and plants that can be grown in a semi-hydro, and 3) An application that provides plant care information and reminders for watering, fertilizing, changing soil, and assessing plant health. The result is that the urban dwellers can grow and care for indoor plants in an easier way. The plant pots have the potential to help the plants thrive in urban residences. The system can support the determination and desire of the urban dwellers by connecting them with nature and enjoying their daily life by integrating greenery into their life.

Keywords**:** *Growing Indoor Plants, System to take care of the indoor plant*

1. Introduction

More and more people live in urban areas than rural areas, with 55% of the world's population living in urban areas in 2018 and by 2050 it is estimated that 68% of the world's population will be in cities (World Health Organization, 2014). Most people spend 90% of their time indoors and almost 70% are at home (Klepeis et al., 2001), as shown in Figure 1. During the recent quarantine period of the COVID-19 outbreak, people were stressed and anxious to constantly check news about the situation and were forced to spend most of their time at home. The surrounding environment also affects people's well-being and their daily life (Brown, Barton, & Gladwell, 2013). Maintaining Our Lives in Good Health is the most obvious example of a development focusing on biophilic design that seeks to blend nature into indoor spaces. Also, the biological and naturalist hypothesis of Edward O. Wilson pointed out that "Humans have an innate tendency to seek connections with nature and other forms of life" to reduce anxiety and stress, improving our overall health (Pieranunzi, 2020).

Since ancient times, humans have had the prime desire to surround themselves with nature and bring plants into their homes. Even though humanity has now become urbanized, the impulse has never disappeared. Plants became a symbol of status in the early model era for the elite to show off their wealth and use the collection of their exotic plants in greenhouses as a projection of their worth in much the same way that they would art and architecture. With the advent of the industrial revolution, mass production, and advanced shipping, the masses could also afford to have plants at home, and they began to fill them with exotic plants bought from far-off lands.

In the present times, we see new trends on social media. Various websites suggest growing plants and provide very detailed instructions on choosing appropriate plants and suggestions on how to grow and

care for the plants. We can find many pictures of the plants decorated inside homes in countless Instagram and Pinterest feeds, which have become tools for connecting with others interested in indoor plants and can reach millions of people sharing their stories and leading to new relationships (Gareth, 2020).

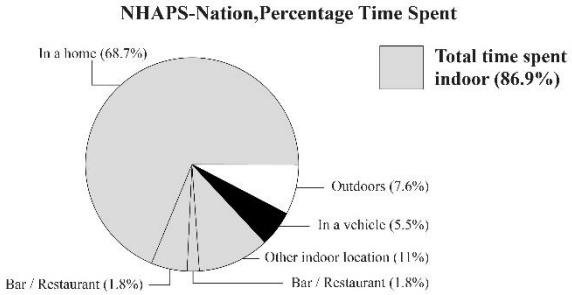

Figure 1 Pie showing the percentage of the NHAPS respondents spent in six different locations on the diary day **(**NHAPS − Nation, Percentage Time Spent)

Other information that encourages more and more people to pay attention to plant and tree planting activities comes from a project led by the National Aeronautics and Space Administration (NASA) in collaboration with the Associated Landscape Contractor of America (ALCA) to research ways to clean the air in confines space like the space station and manage the carbon dioxide and oxygen released through photosynthesis. Some indoor plants can naturally remove volatile organic pollutants (Cruz, Christensen, Thomsen, & Müller, 2014)

Connecting with nature isn't always easy as it depends on where one lives. For example, if someone lives in a city not close to a park, going outside might not be much different from being indoors (Smith, 2020). Although planting plants is the easiest way to approach nature, it is not easy to cultivate indoor plants if they lack knowledge and understanding of growing individual plants' different care needs. Because most of the plants we grow indoors are outdoor plants from warm countries that originate in rain forests, deserts, or mountain areas. They have different likes and dislikes in terms of light, warmth, humidity, and water. As a result of growing a plant in unsuitable conditions, the plant is stressed when adjusting to the new environment and eventually dies (Raworth & Bradley, 1988). The problem with growing indoor plants for urban gardeners is the lack of understanding about the plants. Proper planting and care, there is a wealth of information about plants and plant care available on the Internet and horticultural books, but they are not specific to indoor plant care.

As the details and problems above, the authors have had the idea to design systems and kits that will help us connect with nature and integrate it into our lives. Systematic planting would relieve plant care concerns with recommendations on the appropriate indoor plants being grown. The authors have studied various types of popular plants for indoor cultivation, classified the needs and relevant factors for each plant, and then used all this information to establish a primary care system to integrate greenery into our lives, with the hope to make people closer to nature.

2. Objectives

To design a system for planting indoor plants that takes into account the problems aroused among the indoor plants

3. Materials and Methods

1. Study popular indoor plants to identify needs and care factors to design a suitable care system for the selected plants

2. Experiment by planting the selected plants according to the instructions and gather the care methods for plants from online sellers and plant nurseries

3. Design a system for indoor planting.

4. Create a prototype of the pot kit made from transparency acrylic sheet and online handouts by trying out the planting process

4. Results and Discussion

4.1 Cultural requirements care of indoor plants

A first suggestion for the growers is that the plants in the shady area are indoor plants since they need low or indirect light whereas those at the front, which is directly exposed to the sunlight, are outdoor plants. Figure 2 shows an example of a plant nursery that applies to indoor cultivation under shading areas and the outdoors plant can be found in the area of direct light.

Figure 2 A nursery where trees are arranged according to the planting types

The authors selected 25 plants as in Table 1 that can be planted in a room defined as a shaded area. Based on recommendations from various social media articles, the abbreviation and code numbers of the guidelines for care treatment (Pennisi, 2020) are detailed below;

L = Light
1. Sunny light areas: At least 4 hours of direct sun
2. High-light areas: Over 200 ft-c, but not direct sun
3. Medium-light areas: 75 ft-c to 200 ft-c
4. Low-light areas: 25 ft-c to 75 ft-c

T = Temperature
1. Cool: 10°C at night and 18.3°C during the day
2. Average: 18.3°C at night and 24°C during the day
3. Warm: 21°C at night and 29.4°C during the day

H = Relative Humidity
1. High: 50% or higher
2. Average: 25% to 49%
3. Low: 5% to 24%

W = Watering

1. Keep the soil mix moist
2. Surface of the soil mix should dry before re-watering
3. The soil mix can become moderately dry before re-watering

S = Suggested Soil Mix for specific ingredients, refer to the various growing mixes in "Soil/Growing Medium." The soil mixes are keyed as follows:

1. Flowering house plants
2. Foliage plants
3. Succulents and cacti

Table 1 List of Indoor plants and their cultural requirements

Botanical Name	Common name	Cultural Care				
		L	T	H	W	S
Epipremnum aureum	Golden Pothos	3	3	2	2	2
	Neon Pothos	3	3	2	2	2
	Manjula Pothos	3	3	2	2	2
	N-Joy Pothos	3	3	2	2	2
Philodendron	Philodendron Micans	4	3	2	2	2
	Philodendron Hastatum	3	3	2	2	2
Scindapsus pictus	Exotica	3	3	2	2	2
	Argyraeus	3	3	2	2	2
	Silver Lady	3	3	2	2	2
	Unknown	3	3	2	2	2
Syngonium	Mini Allusion	3	2	1	2	2
	Erythrophyllum	3	3	1	2	2
Piper or Pepper vines	Piper ornatum	3	3	1	2	1
	Piper Sylvaticum	3	3	1	2	1
Begonia	Maculata	2	2	1	2	3
	Fremental	2	2	1	2	3
	Snowcap	2	2	1	2	3
Aglaonema	Dud Unyamanee	2	3	2	2	2
	Dud Rapgoenrapthong	2	3	2	2	2
	Siam Aurora	2	3	2	2	2
Calathea	Calathea makoyana	2	3	2	2	2
Alocasia	Amazonica	3	3	2	2	2
	Bambino Arrow	3	3	2	2	2
Monstera	Monstera sp. 'Karstenianum'	2	3	2	2	2
Stephania	Stephania 'Erecta'	1	3	2	2	3

4.2 Experimental results

4.2.1 Survive condition of plants

In the experiment, three groups of indoor plants were classified with respect to the cultural requirements of the plants that survive them.

1) Group of Epipremnum aureum, Scindapsus pictus, and Philodendron, well known in the planting and care group close to the pothos, can adapt and grow well within the room.

2) Group of Alocasia can be grown indoors but must be controlled with careful humidity and watering, and the leaf will burn if exposed to direct sunlight.

3) Syngonium got yellow leaves and died due to over-watering and improper humidity in the room.

4) The Aglaonema, Calathea, Begonia group grew well on the balcony as they prefer the bright light and airy. If planted in the room, their leaves would be yellow and falling, respectively.

5) Cactus & succulent plants were planted in a room with low light so the stems stretched for light. They were transplanted to a well-lit balcony to allow the plants to grow.

Regarding preliminary plant changes over 2 months, the authors found problems such as root rot due to over-watering and the container does not drain, yellowing of leaves due to insufficient lighting and soil too wet, and withered and not growing leaves pale, yellow, and fall due to improper mix of planting materials.

Based on the above cultural requirements, the authors researched additional care information, inquired an expert on planting or observing plants both indoors and outdoors, as well as gathered information from a variety of sources such as research articles, books, and YouTube videos to fully understand the indoor plants' care and solutions and to organize a new care regimen for each plant. One of the most important factors for planting is sunlight, therefore, it is crucial to understand the position of lighting requirements for indoor plants. A different type of plant requires a different lighting density. A suggestion of the density of light is shown in Figure 3 illustrating zones of the bright, medium, and low light in a room. It is important to determine what kind of light the plants need to ensure that they expose to a balanced amount of light. The plants can be "conditioned" to different light levels, but care must be taken when adjusting their position by observing for the first few weeks because a sudden change in light levels can cause the plants to shock and wither (Léon & George, 2019).

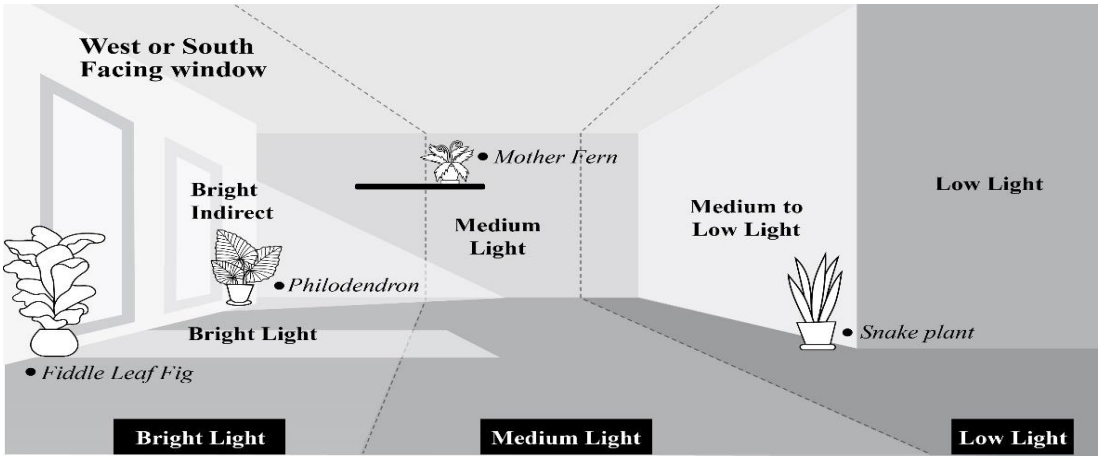

Figure 3 Position of lighting requirement for indoor plants

4.2.2 Potting mixture

A suitable soil mixture for indoor plants is of interest. The compositions of the mixture for potting are explored and listed below.

Water: The medium must retain the right amount of moisture to nourish the plant during watering.

Air: There must be sufficient gas exchange for the roots to breathe.

Fertility: The plant must be able to extract enough nutrients from the soil to survive and grow.

Anchoring: The soil must be sufficiently structured for supporting the root growth.

Moreover, the soil must compose three factors; soil builders, aeration and drainage, and nutrients in which the ingredients of each factor are summarized and shown in Table 2. It should be mentioned here that the growers can choose suitable ingredients that support the required factors. A suggestion for suitable ingredients that fit each plant will be summarized in the final section of this study.

4.2.3 Watering

The Evaluating the Efficiency of Wicking Bed Irrigation Systems for Small-Scale Urban Agriculture by Semananda, Ward and Myers in 2016 was applied as a concept and findings for the design of the watering system in the pots to help control the water content and optimal moisture retention from the underground and to reduce root rot from over-watering. The wick bed systems are shown in Figure 4 illustrating the concept ideas of the storage compartment of humidity.

Table 2 Potting soil Ingredients (Courtney, n.d.)

Soil builders	Aeration & Drainage	Nutrients
Sphagnum moss	Perlite	Worm casting
Peat moss	Pumice	Cow manure
Coco coir	Vermiculite	Leaf composes
Loam soil	Sand	
	coco chips	
	Bark	
	Charcoal	
	Clay balls	

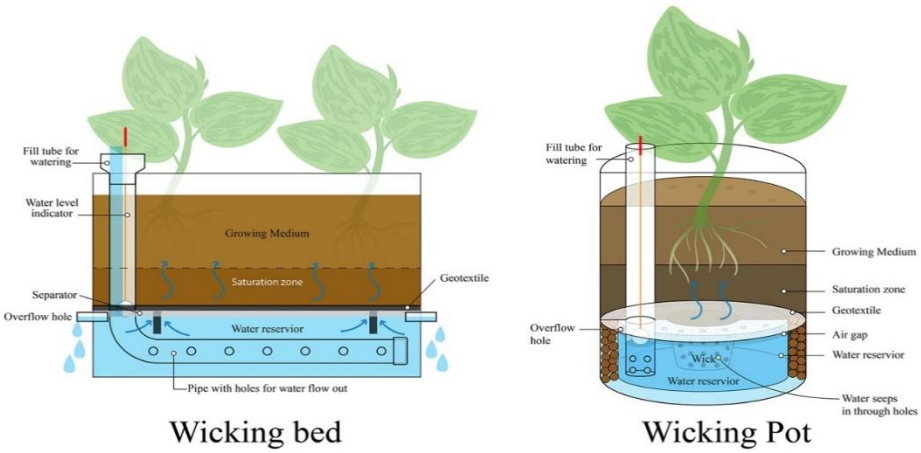

Figure 4 Wick bed system (left) and wick pot system (right)

The authors developed the wick bed system aiming to maintain the moisture in the pot. A compartment for moisture keeper was assembled at the back of the pot as shown in Figure 5. It was designed based on the divided sections of an aquarium tank. The moisture keeper will be filled with sphagnum moss, which can absorb and maintain the moisture for the soil.

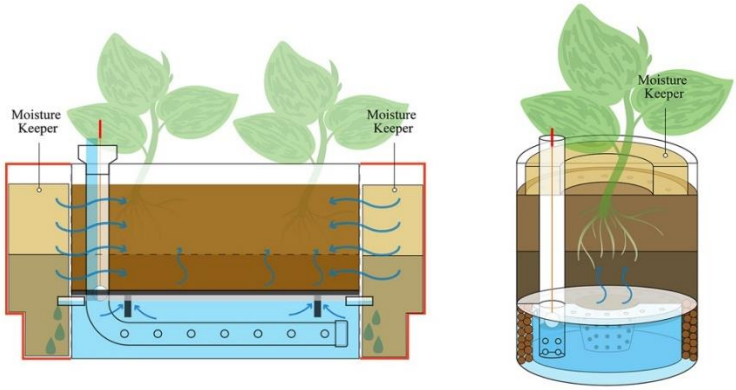

Figure 5 The idea of moisture keeper in the pot

The plants were categorized into groups based on their origin, humidity, light, watering, and soil mix for developing the plant pots following the needs of the plants as shown in Table 3.

Table 3 Classification of the plant according to basic needs for proper care

Origin	**Humidity**	**Light**			**Potting mix**
		Type of light	Light level (Foot-candles)	Location	
Tropical: Evergreen Forest plants	Normal 50-60%	Indirect sunlight	75-150	South and east windows and west windows that do not receive direct sun.	Soil drains well
Tropical: Rain Forest plants	High 60-80%	Low to medium	25-75	Northern windows, Center of a room, a hallway or an inside wall.	Keep the soil generally moist
Desert: Cactus & succulents	Low 40-50%	Direct sunlight	150-1000	South-East, West window, Outdoor	Dry soil (Fast draining)

4.3 Design the plant care card

"Plant care card" and "Plant tag" were designed to provide simple plant maintenance information, as shown in Figure 6, by taking into account the necessary and specific information for indoor plants and the simple and complete communication formats. The authors also designed symbols for easier understanding and are more user-friendly. The details on the front of the card include a picture of the plant and its scientific name, common name, origin, brightness level, and similar care plant family names. The back of the card shows the detail about watering, soil used, plant maintenance, and fertilization and a small tag is to remind or provide short information. The seller can attach the plant care card to the plant or the growers can take notes of their plant care by themself. The photos of the plant care card are shown in Figure 7.

4.4 Design the plant pot

4.4.1 System inside the plant pots

The authors selected transparent acrylic to design the pots for easily observing soil changes and root growth. The soil's dryness and the moisture inside the soil can also be checked before watering to properly control the amount of water so the plants will not die from root rot.

To design a plant pot that can provide optimal care for each plant, the authors were inspired by a fish tank with separated parts inside. Therefore, the inside of the pot is divided into parts as follows; a part filled with a fabric wick for the self-watering system at the bottom as shown in Figure 5, a compartment different in size for each model for a planting material that draws a different amount of water from the bottom to the soil, a separated sheet between the reservoir and the planting material, a compartment at the back of the pot for storing moisture keeping materials such as sphagnum moss, a small lid to prevent a quick moisture leak, drill holes between the walls that allow the moisture to flow into the soil, and a pipe for watering from the bottom. The components of the pot and the system inside are shown in Figure 8.

The accessories' sketch ideas such as a wooden box frame, a small terrarium lid, and a vacuum decorative sticker on the pot's body are shown in Figure 9.

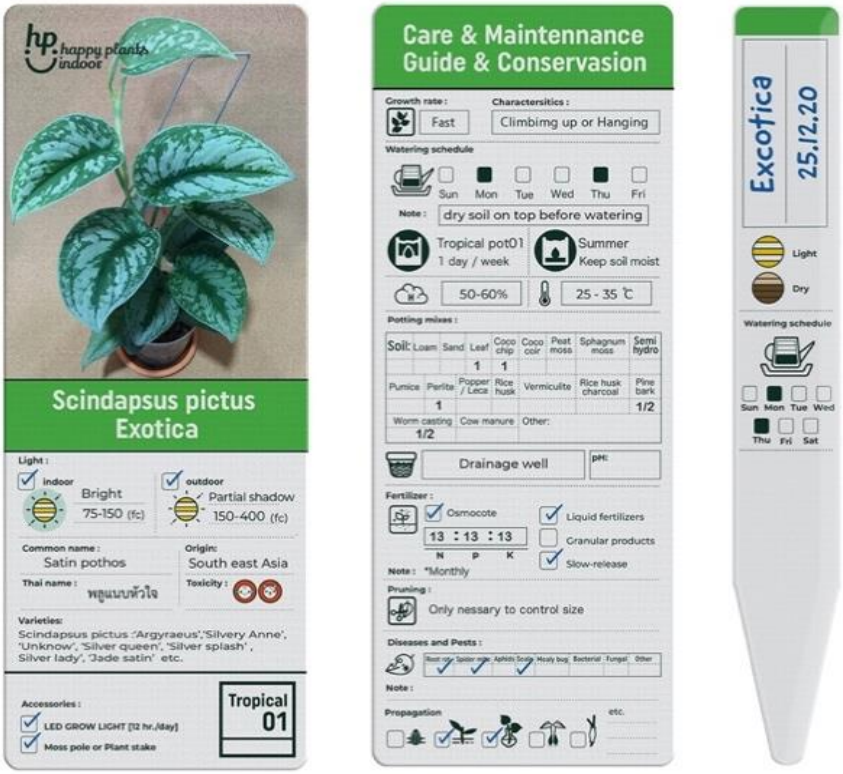

Figure 6 Plant care cards; left is the information in the front, the middle is the information in the back of the card, and the plant tag that provides a shortened version of the information.

Figure 7 Plant care cards and plant tag usage

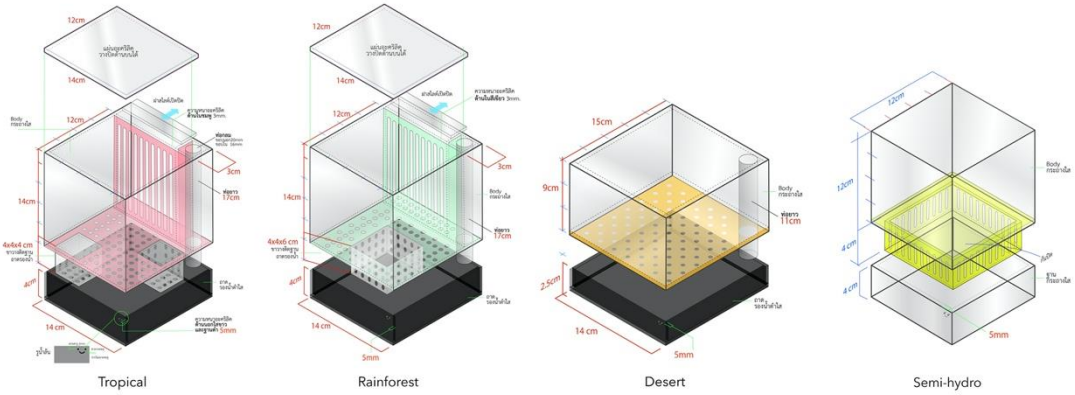

Figure 8 Component of pot and system inside of each plant pot

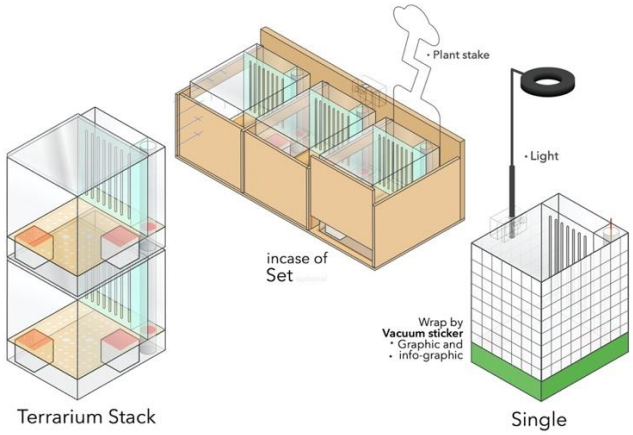

Figure 9 Accessories sketch idea

This section describes the functionality of each type of plant pot in which the exterior shape of the pots is similar but the internal system is different, as detailed in each model below.

1) Tropical-01 model for evergreen plants that prefer normal humidity and require well-drained soil and light to partial shade. This pot model comes with two small fabric wicks to draw water, one in the front and another in the back, and drainage holes to control the water level. This pot model can water only 250 ml from the top of the soil or through the pipe down to the bottom by not over 450 ml. The water is slow drawn up into the soil, so the user does not need to often water, as shown in Figure 10.

2) Tropical-02 model for a tropical rainforest plant. The difference between this pot model and the first one is a bigger fabric wick so more water can be drawn upward, a faster moisture keeper compartment in which moisture material has more holes to draw and release more moisture than the tropical-01 model. This pot model is proper for the moisture-loving plants and the soil mixture includes specifically materials that can keep moisture, as shown in Figure 11.

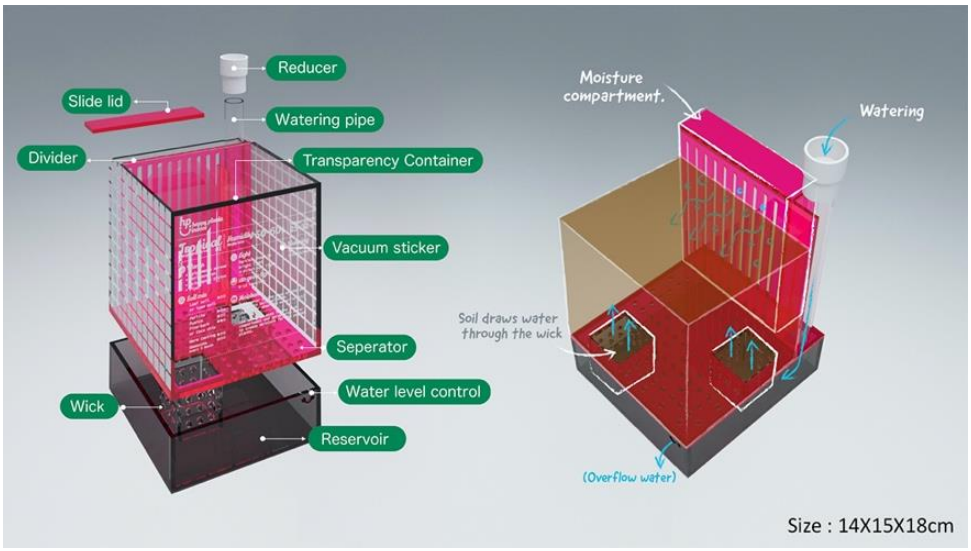

Figure 10 Tropical-01 model for evergreen plants

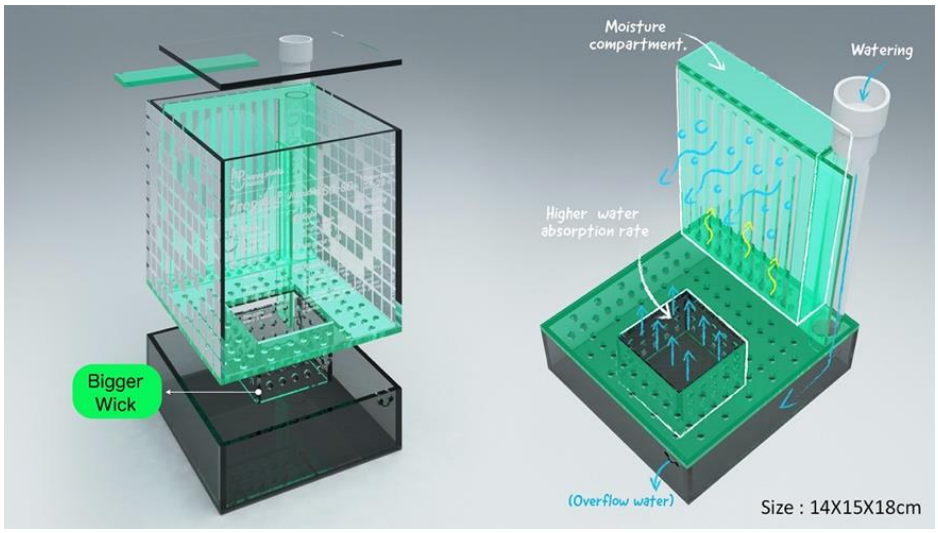

Figure 11 Tropical-02 model for rainforest plants

3) Desert pots are for cactus and succulent plants that do not require moisture in the soil. Some plants do not need soil moisture while some prefer watering from the bottom up. The pot's body is shallow for the ease of moisture control in the soil, as shown in Figure 12. The soil mixture must be specific for cactus and succulent plants only. This pot model was designed for fast water flow to keep only a few moistures, therefore, fabric wick must be used. However, the water must be filled at the bottom when the user will not stay home for a long time.

4) Semi-hydro system pots for growing plants in half water and half dry are for the plants that are transferred from the soil system to the water system. This pot model was designed to solve the plants' root rot in the soil by transferring the plants from the soil to the semi-hydro system to save the plants. This pot model is easy to use and clean since no soil is needed. Clay balls and water are used, with the occasional addition of liquid fertilizer for the plants. The water must be filled not over the edge of the water tray as shown in Figure 13.

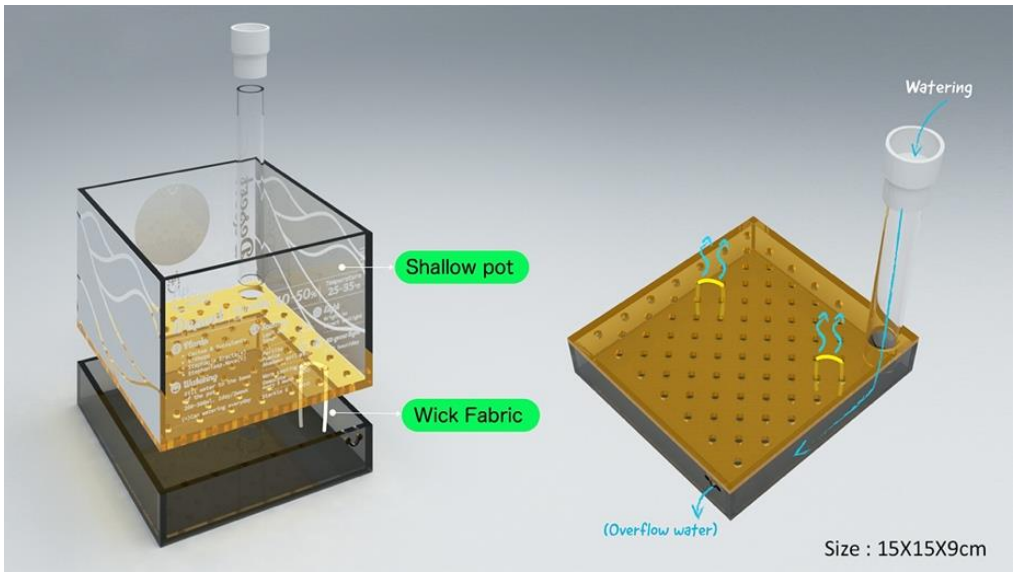

Figure 12 Tropical-02 model for rainforest plants

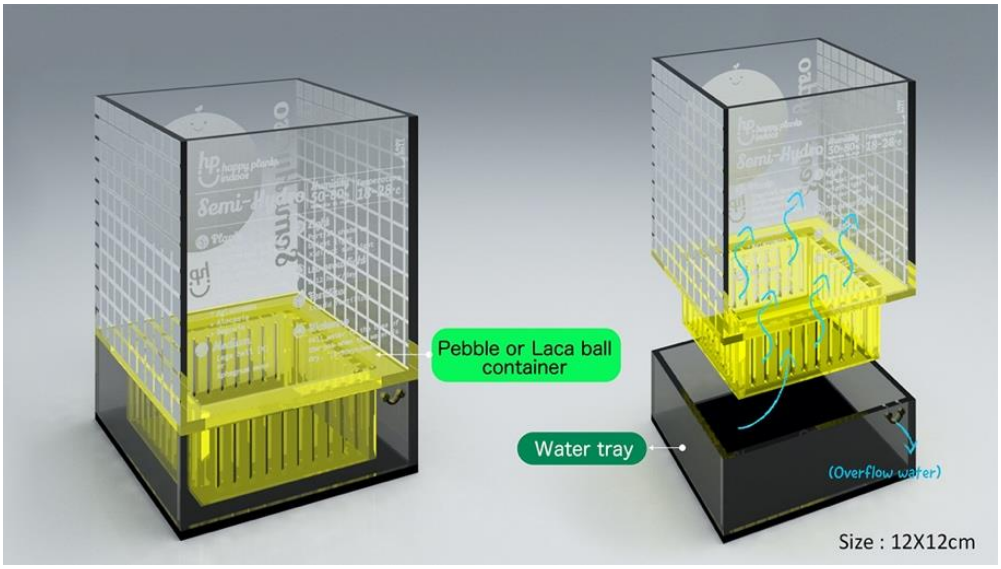

Figure 13 Semi-hydro model

All four types of plant pots have a different moisture retention system and water absorption to suit the needs of each plant group as shown in Figure 14.

4.5 Prototypes

The plant pots generally look the same and require the growers' skills and understanding in caring for each plant. The authors have designed each pot specifically and properly for each plant to solve the common problems for amateur growers such as root rot or a lack of moisture that makes the plants dead. These designed pots do not require frequent watering, which will be very easy to care for the busy urban growers. In the prototype pot in Figure 15, the authors selected transparent acrylic as a pot's material so that novice growers can observe changes in the plant's roots and soil to learn how to control watering and can observe the proper moisture of the soil. This material is also durable and can be easily cleaned.

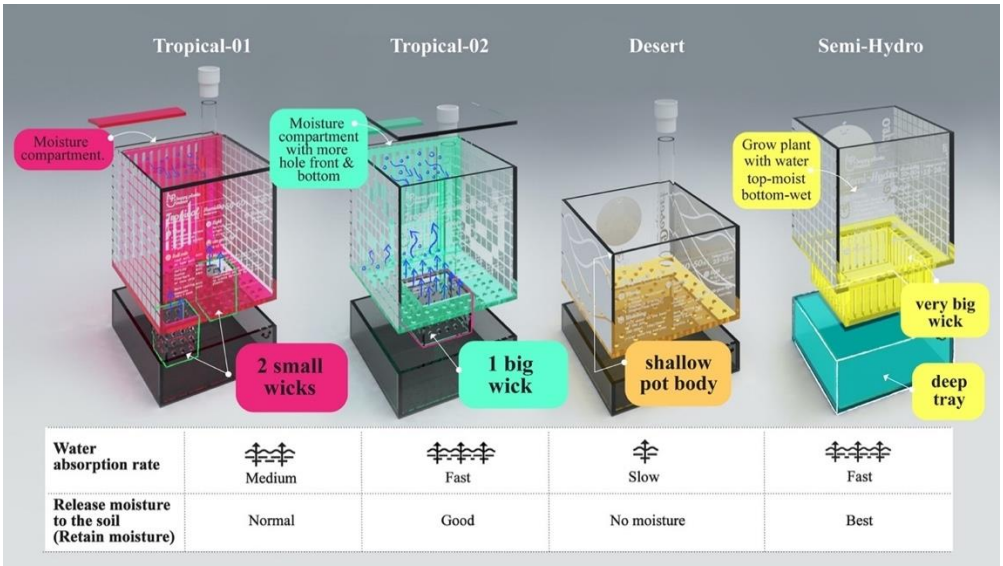

Figure 14 differences of the 4 types of the plant pots

Figure 15 Model Pots Tropical-01, Tropical-02, Desert, and semi-hydro plant pots (from left to right) that were used to grow real plants.

The author also designed the plant pot decorations for the users who want to add graphic patterns to the transparent pots with vacuum stickers to decorate the side of the pot, as shown in Figure 16. The authors selected the vacuum stickers because it is a material that can be attached to plastic without glue, making it easy to peel off and changeable. If the users want to clean the sticker, they can wash it with water or wipe it and put it back in place.

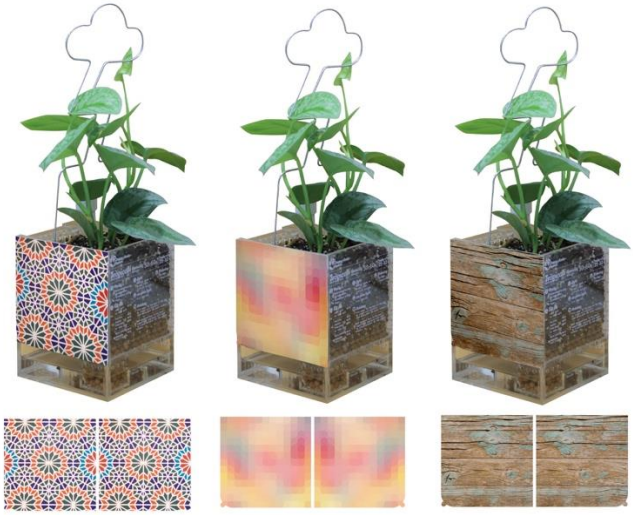

Figure 16 Vacuum stickers on the pot

For the convenience of the growers, if they do not want to mix the soil by themselves, the authors studied and proportioned the planting materials that suit each pot's size and type of plant in the kit. The authors prepared a set of the planting materials according to the type of the plant, such as the planting material to use with the Tropical-01 pots for the plants that prefer normal humidity levels will contain ingredients such as leaf soil, pine bark, perlite, pumice, and worm casting in a proportion of 2:1:1/2:1/2:1/2, slow-release fertilizer Osmocote, clay balls, the airy part to fill the bottom of the plant pot, fabric wick, and sphagnum moss to fill in the moisture keeper compartment. For the semi-hydro pot, the authors prepared clay balls and liquid fertilizers. The planting materials will be adjusted according to the type of the plant and the pot. However, the growers can mix the materials according to the plant care card attached to the pot and plant, which contains detailed planting materials and care information. An example of a set of soils is shown in Figure 17.

Figure 17 Potting materials

Each type of plant pot accommodates a different soil mixture formula according to the plant's needs. For example, some plants need high soil moisture that is not too wet, therefore, the planting material must drain well but can still retain moisture. Using peat moss or coconut coir will hold too much water, so the authors use pine bark or coco chips instead and may add vermiculite, pumice, or perlite to increase the airiness of the soil. Figure 18 shows various plant materials that when mixed, have different drainage and moisture retention properties. The authors created soil mixture formulas as suitable planting materials for use with the plants and the pots.

Soil mix formular		Fast drainage				Keep moisture		Semi Hydro	Slow drainage
Ingredients		A	B	C	D	E	F	G	H
Soil	Loam soil	●	○	○	○	●	●	Water	○
	leaf soil	○	●	●	●	●	○		●
	Peat moss	○	○	○	○	○	○		●
	Sand	○	○	○	●	○	○		○
Airy	Perlite	●	●	○	●	●	●	Lega ball ● ○ ○	○
	Pumice	○	●	●	●	○	●	popper ○ ● ○	○
	Vermiculite	○	○	●	●	○	○	Prebble ○ ○ ●	●
Moisture	Pine bark	○	●	●	○	●	○		○
	Coco coil	○	○	○	○	○	●		○
	Coco chip	●	○	●	○	●	○		●
	Coco huck	○	○	○	○	○	○		○
	Rice huck	○	○	○	○	●	○		●
	Brick	○	○	○	○	○	●		○
Nutrition &Fertilizer	Osmocote	●	●	●	●	●	●	Liquid fertilizer	●
	Worm casting	○	●	●	○	●	○	Hyponex	○
	Cow Manure	○	○	○	○	○	○	Earth root	○
	Leaf compost	○	○	○	○	○	○	HB 101	○

Figure 18 A summary of the soil mixture formulas

The authors created a summary for use in the planting set, the soil mixture formulas in Figure 18, and divided the selected plants into three groups: Group A (Tropical evergreen forest); normal moisture-loving plants, Group B (Tropical rainforest); high moisture-loving plants, and Group C (Cacti & Succulents); plants prefer drought. To ease the care for the plants so that they can grow properly, each plant pot was designed specifically to accommodate each group of plants. Figure 19 shows tables that summarized the plant pot properties describing watering quantity, moisture rate, water absorption rate, suitable plant groups for each pot model as well as proper soil mixture and pot size.

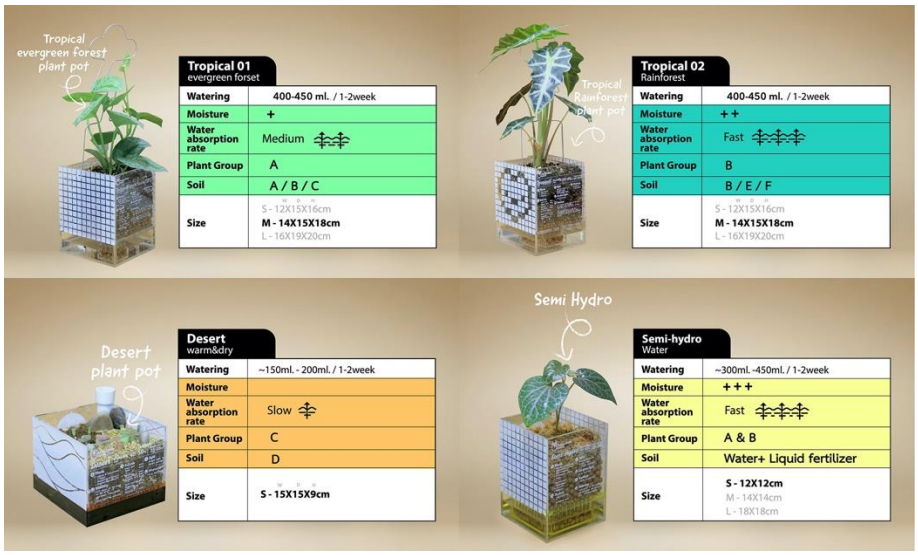

Figure 19 The plant pot properties description

4.6 Application design

The application was designed as an assistant and a reminder to help the users take care of the plants more easily. The steps on how to use the application are as follows:

1. The user must have the whole plant care system before downloading the application. Then, the user must register in the application and scan the QR code on the plant pot. The QR code will lead to the plant selection among the plant groups related to the pots.
2. The user can select and add the plants to the user's gallery.
3. The user can learn more details of the use of the pots from the instruction page and video clips that show the simple process of assembling the pots and the plants.
4. The user can find specific plant care details for each indoor plant by clicking the plus icon.
5. Notification Settings [The default setting of the reminder will be the care of the user's selected plant but the user can modify the schedule and can set a time reminder for watering and fertilizing and for replacing the soil].
6. Notifications
7. After clicking the plus to add the plants to the gallery, the user will find the plants' health status, which is related to the watering and care statistics of the user. The user can also edit the notifications.
8. The user can save pictures to the gallery.
9. Other service concepts are such as plant care service, plant health problems Q&A, and delivery of plant pot set.

An application's screenshot is shown in Figure 20.

Figure 20 An application's screenshot

5. Conclusion

This project aims to design a system and methods for better integrating greenery into people's lives based on the body of knowledge that is confusing and complex for amateur urban gardeners. Several issues that make the plants dead led the authors to design the plant care system specifically for the indoor plants by fabricating the plant care cards, the plant pots, and the application for taking care of each plant properly and systematically—helping the users or growers to perform more convenient cropping activities and increasing the success of indoor plants, which eventually resulted in the plants grow and thrive longer.

The plant pot design with a self-watering "Wick bed" system is suitable for controlling plant-watering and reducing root rot problems. The moisture keeper compartment inside the pot helps save the plant's life in a low humidity condition. The authors used transparent materials in the plant pot design to make it easier for the users to see the soil status and abnormalities of the plant's root system, allowing the users to understand and be able to solve problems arising from faulty plant cares for a higher survival rate.

The plant pots generally look the same and require the growers' skills and understanding in caring for each plant. The authors have designed each pot specifically and properly for each plant to solve the common problems for amateur growers such as root rot or a lack of moisture that makes the plants dead. These designed pots do not require frequent watering, which will be very easy to care for the busy urban growers.

The authors hope that this plant care system will provide the users with a natural corner in their living areas and that their plants grow well. The growers can be close to nature, enjoy planting activities, and upgrade their skills in taking care of more complex plants.

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