# SOME ASSEMBLY REQUIRED: AUTONOMOUS PLANT NURSERY

# ATTITUDES OF SMART GARDENING IN DEVELOPED AND DEVELOPING COUNTRIES

A Thesis Prospectus
In STS 4500
Presented to
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By
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On my honor as a University student, I have neither given nor received **unauthorized** aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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The action of growing plants in an indoor environment can provide benefits such as improvement in air quality, a reduction in stress, an improved sense of well-being, and support of cognitive health (“Health Benefits of Indoor Plants”, 2022). Furthermore, growing plants in an outdoor environment can provide additional health benefits such as increased exposure to Vitamin D, decreased risk of developing dementia, and mood-boosting benefits including a reduction in recorded stress levels (Hayes, 2022). Despite these benefits, around 40% of houseplants that are grown for consumers die in the supply chain process, while another 30% of houseplants die inside the homes of customers (Narishkin & Tejapaibul, 2022). A survey conducted on 2,000 Americans aged 25 through 29 found that on average, people aged 25-39 have killed a total of seven houseplants, and said the most anxiety-inducing features of growing houseplants include ensuring the plant received enough sunlight (60%), received enough water (56%), and ensuring the plant stays alive (48%) (“Survey: Decorating with houseplants”, 2020). Despite this, plants exposed to extreme environments adopt a generic metabolic processes for plant adaptation to extreme habitats (Dussarrat et al., 2022, p. 1,624). This resilience, developed over generations of plants, gives plants the ability to restore performance after sustaining serious damage by unexpected threats (Pasman et al., 2020).

The technical project and tightly coupled STS research project proposed in this prospectus directly addresses the issues of plant growing in smart gardening and how similar solutions are perceived in different parts of the world. For the technical project, my technical team and I will construct an “autonomous plant nursery” that allows a user to define growing parameters for different plants, and takes care of the plants without actions needed from the user other than basic maintenance. The user will be able to take advantage of integrated push buttons and an LCD screen to view and edit current plant growing regiments in two separate plots define them as desired. The technical work will be completed during the Fall 2022 semester in the class ECE Capstone or ECE 4991. The tightly coupled STS project will analyze similar autonomous plant nursery implementations in both indoor and outdoor environments. Known more commonly as Smart Gardening, various implementations of this field will be analyzed in both developed and developing countries and determine how the technology is viewed “that account for the diversity of both the farmers and their practices,” (Findji & Howland, 2019).

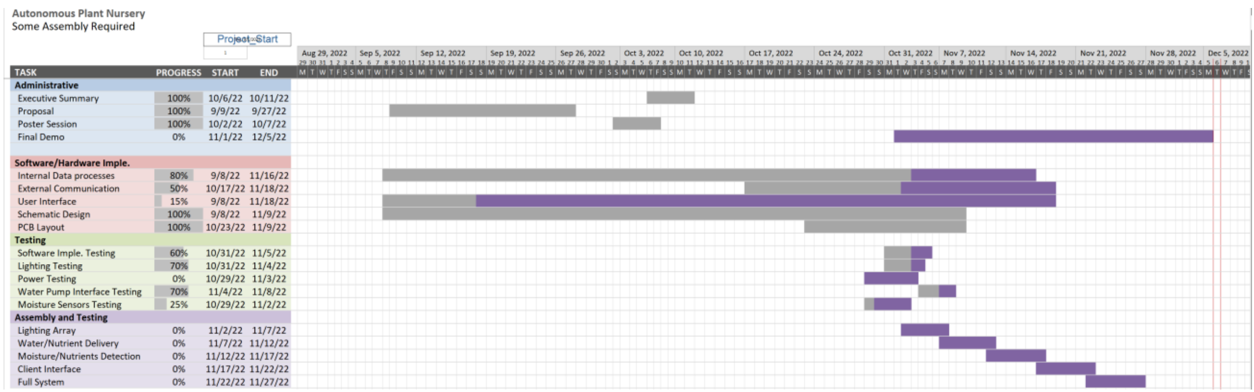


Figure 1: Gantt Chart for Technical Project. This figure presents the major milestones and overall timeline for the Technical Project in a visual format. (Buck 2022).

## DESIGN OF AUTONOMOUS PLANT NURSERY SYSTEM

The effects of an expansion of the construction sector, a steady rise in the greenhouse effect around Earth, and an increase in disposable income has led to a hypothesized growth of the smart gardening market from “$105,627.0 thousand [$105.627 million] in 2019 …to $176,559 thousand [$175.559 million] by 2027, which registers a CAGR [Compound annual growth rate of 8.4% from 2020 to 2027,” (“Global Smart Indoor Garden Systems Market (202 to 2027) - by Type, Technology, End-user and Region", 2021). Despite such growth, the largest inhibitor to smart gardening implementation is the price of developing a smart gardening device, which ultimately is passed to those who desire to use the technology. The costs of these devices are primarily driven by the number and quality of sensors used to record/measure plant parameters and additional technologies not required for plant care operation, such as Internet-of-Things (IoT) technology which allows for devices containing sensors and processing capabilities to transmit measured data to an IoT-compatible device. The various parameter sensors typically raise the possibility of a sensor failing and increase the total power consumption needed for the system to operate. Additional functionality not needed for core operation of the operation, IoT functionality being one example, further raises the total power needed for a device, and also becomes a detriment to smart gardening implementation when wireless communication is not available or desired.

The objective of this technical project is to develop an autonomous plant nursery device that will be able to define and save settings for water content in the soil, nutrient content in the soil, and lighting times for plants set by the user. The device will determine if water and nutrients are needed by one or both plant plots by reading in complex impedances via a single capacitive soil moisture sensor and will material via electric motors until the threshold specified by the user is met, and will illuminate LED plant grow lights with the duration and time of day of illumination specified by the user. An LCD screen will be displayed on the front of the device to view currently defined plot settings, and pushbuttons. The two plots will run independently of one another, allowing for two different plant species with two different growth specifications to be cultivated at the same time. A first proof-of-concept rendering of the autonomous plant nursery can be seen in page 4 below and a block diagram detailing the Finite State Machines

(FSMs), a model of the logic of the system that can be in only one state at a time, of the water and nutrient delivery systems are detailed in Figure 3 below.

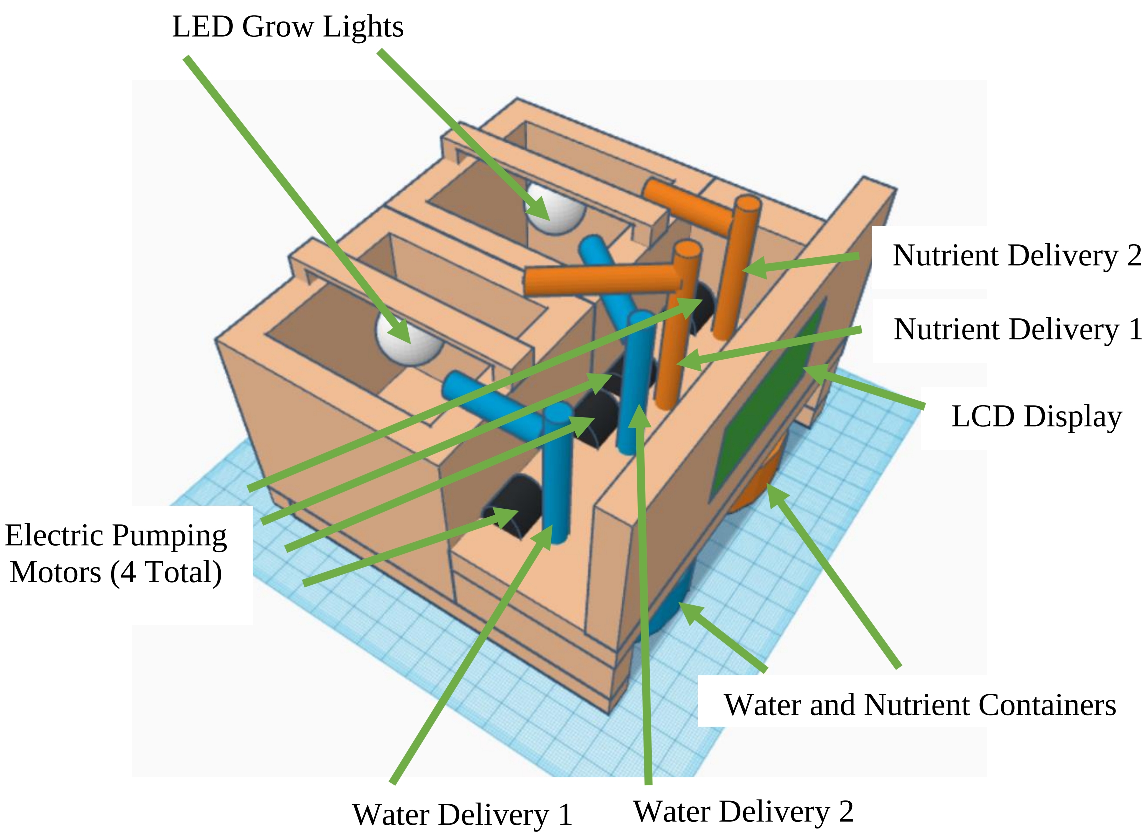


Figure 2: Virtual Proof-of-Concept Rendering of Autonomous Plant Nursery. This initial design presents the most critical components of the design as well as an initial chassis design which places the components near where the components will be in a finalized device (Buck 2022).

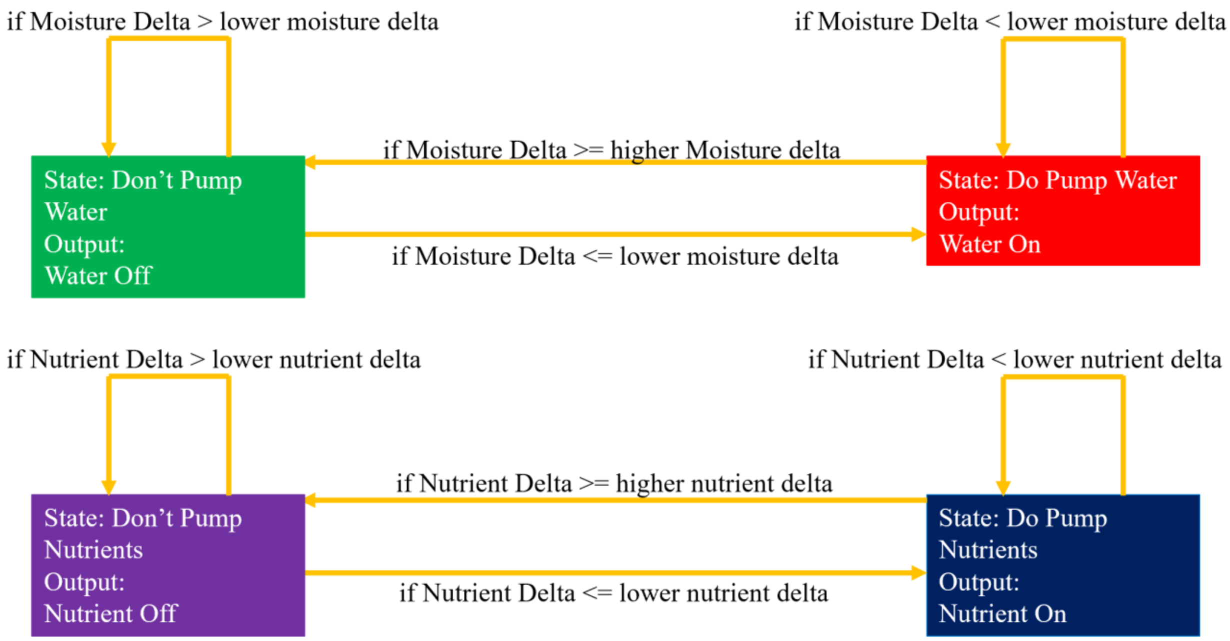


Figure 3: Finite State Machines (FSMs) of Water and Nutrient Delivery Systems. The two independent FSMs check if water or nutrient is above a user-defined threshold, and provides the appropriate resource until the threshold is met. (Adapted by Buck (2022) from Garrison, 2022).

The autonomous plant nursery device will be designed, fabricated, and tested for completeness during the ECE 4991, known as electrical and Computing Engineering (ECE) Capstone, course under Harry C. Powell Jr., an Associate Professor of Electrical and Computer Engineering in the Charles L. Brown Department of Electrical and Computer Engineering at the University of Virginia. Components devoted to the completion of the autonomous plant nursery are the National Instruments Engineering Discovery Laboratory, an MSP430 microcontroller to connect all various subsystems and provide appropriate signals, and Code Composer Studio (CCS) software to create FSM and interrupt logic. This technical project's members are myself Joshua Garrison, Boluwatife Raufu, Joseph Sam, and Mckayla Thomas. Each member of the group is an undergraduate student in the Department of Electrical and Computer Engineering at the University of Virginia. I study Electrical Engineering (EE) in particular, and Joshua Garrison, Boluwatife Raufu, Joseph Sam, and Mckayla Thomas study Computer Engineering (CPE). The final project of the project is a plant nursery capable of maintaining plants for extended periods of time without input from the user, and will be cataloged in a technical report.

## ATTITUDES OF SMART GARDENING IN DEVELOPED AND DEVELOPING COUNTRIES

As the smart gardening industry continues to grow in both effectiveness and prevalence, there has become a desire for smart gardening devices to be implemented in places around the world where the threat of food insecurity is either already present or could be present in the future due to factors such as an increase in global population and climate change, among others. For example, the Organization for Economic Co-operation and Development (OECD) estimated for around 251 million people in least developed countries (LDCs) are severely food insecure due to factors such as the inability to meet domestic food demand and subsequent reliability on international trade, changing circumstances of countries with large agricultural exports such as war, and other countries' locally imposed export bans leading to a shortage in growing materials (Vickers et al., 2022). Despite the apparent opportunity to increase smart gardening implementation, the vast majority of food production in these countries continue to be traditional manual home gardens that are "an integral part of local food systems and the agricultural landscape of developing countries all over the world," (Galhena et al., 2013, p. 1).

Smart gardening technology also has struggled to become a technology used by a large number of people in developed countries, which actively promote the use of local gardens including smart gardens for various societal initiatives and overall health. An example of this would be the United States of America's "People's Garden" initiative designed to promote "grow fresh healthy food and resilient, local food systems; teach people how to garden using conservation practices; nurture habitat for pollinators and wildlife and create greenspace for neighbors," ("USDA opens people's garden initiative to gardens nationwide", 2022). For example, the number of commercially available plant watering sensors that actively measure the moisture content of the soil decreased due to loss in consumer demand, limited functionality of the device, high number of devices needed to actively measure all desired climates, and high price point of the device given its functionality (Gebhart, 2018). This stagnation, and even contraction of the smart gardening industry, stands in contrast to the growth of a similar industry, the smart home industry, which is expected to become a $537.01 billion dollar market globally in 2030 from $79.17 billion dollars in 2022, with North America registered the highest revenue share of over 41.0% in 2021 ("Smart home market share & size analysis report, 2022 - 2030", n.d.). It is clear Smart Gardening needs to undergo changes in terms of user functionality and standardization in order for the technology to become as technologically and economically mature as smart home technologies.

## SMART GARDENING INTEGRATION AROUND THE WORLD

While there have been discussions on the lack of smart gardening implementation, there has also been discussions on how to improve the ease of access of smart gardening to make operation of a device easier to the user. In general, individual factors that influence whether someone considers, and eventually adopts, a specific innovation or technology include training, managerial support, incentive, perceived usefulness, personal innovativeness, image, prior experience, enjoyment with innovation, peers and social network variables (Taluker, 2012). These factors can be seen in a social experiment conducted and recorded by the Wall Street Journal. The WSJ asked gardening expert Timothy Hammond to use a Rise Gardens Smart Garden, a product advertised for small footprint, modular construction, and Wi-Fi connectivity, to grow alongside traditional outdoor gardening to compare the yield from both methods (Hammond & WSJ, 2021, 1:54). Hammond at the end of the test found the Rise Gardens Smart Garden device grew plants well, was simple to use, and the included app to monitor the device was convenient. He loved what the device was able to accomplish, but found the device lacked customization, the water reservoir was difficult to clean and empty, and it was too expensive compared to the cost of growing plants naturally (Hammond & WSJ, 2021, 5:46). In this instance, the device provided a compelling alternative to traditional growing methods, but was unable to overcome shortcomings such as price. This factor, among others, which would be an inhibitor to smart gardening implementation in developed and developing countries, making the technology inconvenient for developed countries and unaffordable for developing nations.

The differing expectations of smart gardening devices in developed and developing countries demands an investigation into the various socioeconomic factors underlying the perceptions of the technology in both locations. All smart gardening devices must provide the same basic functionality. They must monitor various parameters, in order to meet the agreed upon expectations of the technology, but also be readily adaptable to the specific environment it is placed in, otherwise the technology will be ignored for more traditional plant growing methods. Despite the study of implementation and effectiveness of smart gardening technology in both developed and developing countries, the two sets of countries have not been analyzed in tandem such that the underlying desires for implementation, and the specific styles of implementation, are put into context with each other and compared for similarities and differences. By recognizing the desires and capabilities of prospective smart gardening implementation from the beginning, smart gardening will be able to evolve into a more robust field that can more readily supply different smart gardening implementations. This will eventually allow smart gardening to approach specific needs and desires while maintaining a base set of capabilities, and allow people in both sets of countries to be become more agriculturally educated and self-sufficient.

The perception and adoption of implementations of smart gardening systems will be investigated by studying the socioeconomic factors present in developed and developing countries where the technology is present. This investigation will be performed using the Social Construction of Technology, or SCOT, framework first proposed by Wiebe Bijker and Trevor Pinch in 1984 and later updated by Pinch and Ronald Kline (Bijker & Pinch, 1984; Kline & Pinch, 1996). In this particular framework, relevant groups in relation to a particular technology, in this case smart gardening, provide unique perspectives that inform an engineer's activities and the particular characteristics of the technology. At the same time, the engineer develops and provides the technology that reflects the values, concerns, and interests of each group specified by the various group in exchange for their input. Through this system visualized on page 10, the various expectations, desires, and goals of smart gardening technology can be expressed by the relevant social groups, and the social construction of smart gardening can be incorporated by the engineer to offer as a completed device or devices to each group to satisfy the group's needs. The end goal of the social construction of technology is to "stabilize" the technology, that is to refine the technology until the design is agreed upon by a majority of the social groups.

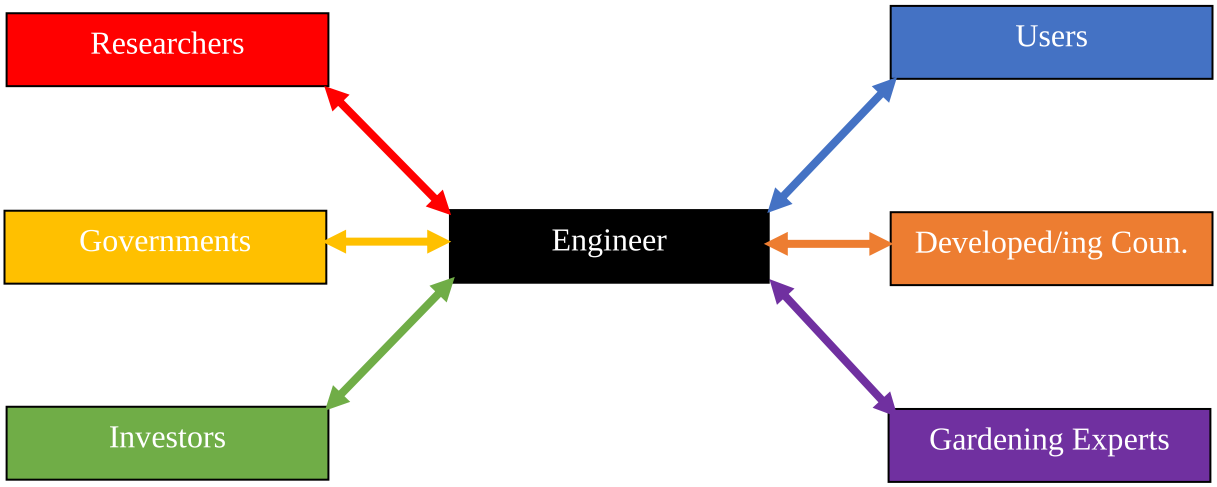

Figure 4: Smart Gardening Implementation SCOT Model. The engineer and relevant social groups negotiate in order for the finalized technology to represent each group's values, concerns, and interests. (Adapted by Buck (2022) from Carlson, 2009).

**SCHOLARLY STUDY OF SOCIOECONOMIC FACTORS IN SMART GARDENING**

This research project will manifest in the form of a scholarly article which will analyze various smart gardening implementations in developed and developing countries. The socioeconomic factors present in the places where smart gardening is implemented will be investigated, and how these factors affect the perception and adoption of implementations of smart gardening systems, to determine what capabilities are expected to be implemented into smart gardening systems. The scholarly article will seek to show what socioeconomic factors in analyzed locations affect the design of the smart gardening implementation. By determining if the main factors that promote or inhibit smart gardening implementations are shared between developed and developing to a significant degree, or if the factors that determine smart gardening implementations are largely independent between developed and developing countries, smart gardening can become more of a robust industry by either offering similar devices across the world or by developed highly specialized devices for specific applications. In addition, the maturing of smart gardening will allow new implementations to be a more technologically and economically viable option for growing local food that could significantly change the status of food insecurity around the world.

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