Final Design Project: Smart Watering System

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Group S-2
ENGR 111 J-2
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I pledge my honor that I have abided by the Stevens Honor System.

Introduction:
For this project, we essentially were tasked to build a smart watering system that autonomously decides when to water a plant. We were tasked with this challenge because of the huge impact greenhouses were caused when it came to water waste. Our client, IoTSmartFarm, wants a system that can monitor the environment in real time and only water the plant when it actually needs it. That means tracking four things: temperature, humidity, soil moisture, and illumination. After tracking these things we will be sending all that data through MQTT while handling some processing on the device itself. The main problem we're trying to solve is how to deliver the right amount of water at the right time without relying on constant human supervision. Our design has to measure those four physical quantities every ten minutes, automatically log them to the cloud, and supply 20 mL of water daily plus extra when the soil gets too dry every 24 hours. At the same time, we're working under tight constraints like only 8 hours of 3D printing time, size limit restricted to 5x5x10 inches cubed, a five-day deployment test, and a requirement that the whole system be one sturdy, self-contained unit.

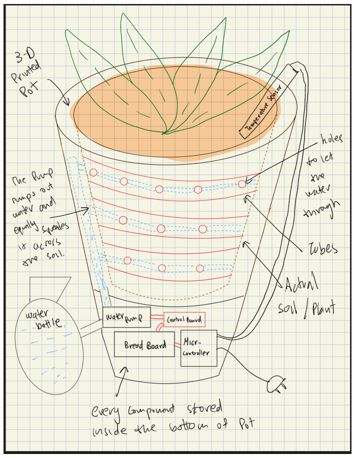
Concept Development (Phases I & II):

Design Objectives Morphological Chart:

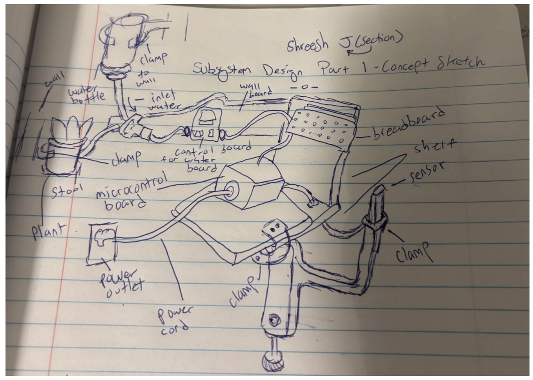
Functions	1	2	3
Power	Batteries	Plug	Solar Power
Placement of Source of Water	Above the Plant	On the bottom side with a pump	Middle
Cable Management	Wire	Plastic twist ties	Zip Ties
Component Management	3D Printed Casing	Plastic Casing	Wood Casing
Where to put the plant	On top of the casing	To the Side of the casing	To the bottom of the casing

Based on the Design Objectives we clarified above, the group decided to create 3 different concept ideas that would implement the objectives above and try to add some different touches to see which one turns out the most unique and meets the criteria.

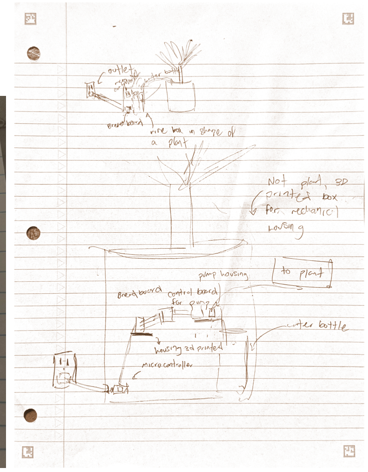
3 Concept Ideas:



Concept #1



Concept #2



Concept #3

To evaluate the concept sketches, we chose to create a concept evaluation matrix that combined the previous objectives and some new ones to better fit the project. Whoever had the lowest score would be crowned the winner and that's the concept sketch we would use.

Concept Evaluation Matrix:

	Concept #1(Aryan)	Concept #2(Shreesh)	Concept #3(Zayd)
Ease of Use	1	3	1
Durability	2	1	3
Design	1	3	2
Easy to make	2	3	1
Safety	2	1	3
Total Score (Lowest Wins)	8	11	10

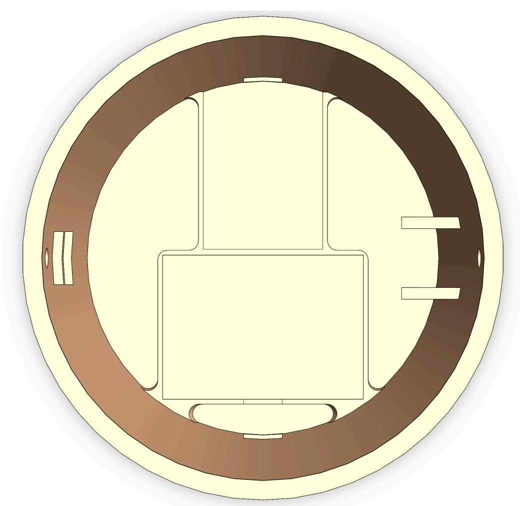
After using the concept matrix, we found out that the most functional and unique concept was concept #1 due to the criteria listed above. The final concept we chose meets the design objectives of the project by giving us an aesthetic and pleasing look at design. Since the design is shaped and modeled like a plant, it blends in with the other plants much better and doesn't stick out. The box near the top of the flower lid is used to hold the water bottle in place, keeping every component of the prototype in one singular place. It fits the criteria of being less than 5 x 5 x 10 inches cubed as well. Inside the pot, we have outlined areas where the different components will be placed, providing a nice and organized build.

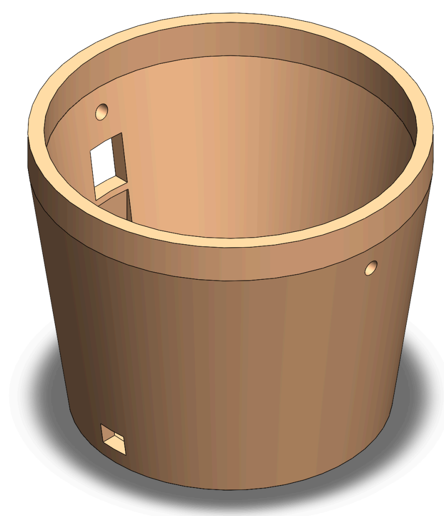
Design Overview (Phase III):

Design Description - Mechanical: (Sliced Product presented in the Assembly & Prototyping)

After our group selected Aryan's design (Concept #1) for the prototype. We decided to create a solidworks rendition of the concept. After carefully looking through the project criteria, we found out that extruding outlines for each circuit part will make sure that it is secured in the base. Because of this change we had to change some parts of the concept, and for it to be one singular piece, we had to compromise and put the water bottle on top of the base (pot), making it secured to the whole prototype as well. For aesthetics and trying to stay true to our concept design, we decided to still include a small plant (flower) on top of the plant, even though it would not add any functionality to the prototype.

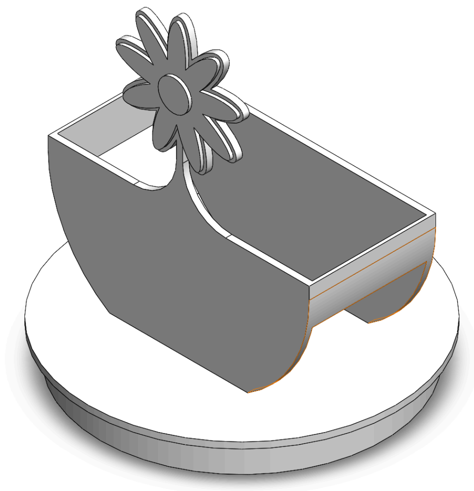
Solidworks Model of Base:





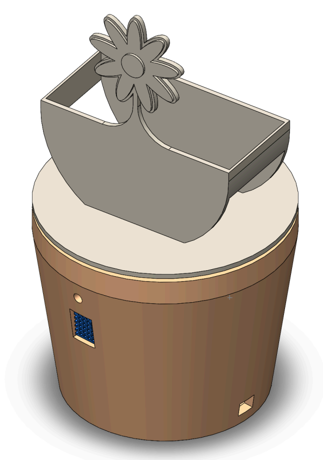
For the base, like we mentioned before, we chose to create extruded outlines at the bottom that would help secure the breadboard and the arduino board. The rectangular hole cut out near the top is for the DHT sensor to rest on since it needs to be exposed to outside air. One of the bottom two rectangular holes were cut out to let the solid humidity sensor wires through the pot and also for the light sensor to poke out. The other hole was cut out for the wire that goes in the arduino board to be easily accessible and easy to remove. There were also two circular holes cut out on top. Those holes are for the tubes that carry the water through the pump to enter and exit from. Through all of this we are not given a well thought out design that would show no exposed wires except for the soil humidity sensor and give a sleek and seamless design.

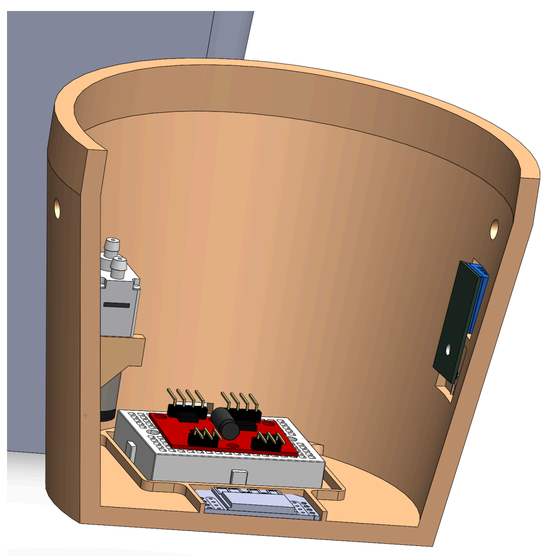
Solidworks Model of Lid:



For the lid, we chose to add a thin layer that would surround the clear water bottle, with some cutouts on the side to show the water level as the model continues to expel water. The lid is also the right measurement so that it would snugly fit on top of the base so it gives a cohesive look. For aesthetics we also added a small flower design that would help signify the plant-like shape that we were trying to go for.

Full Assembly:

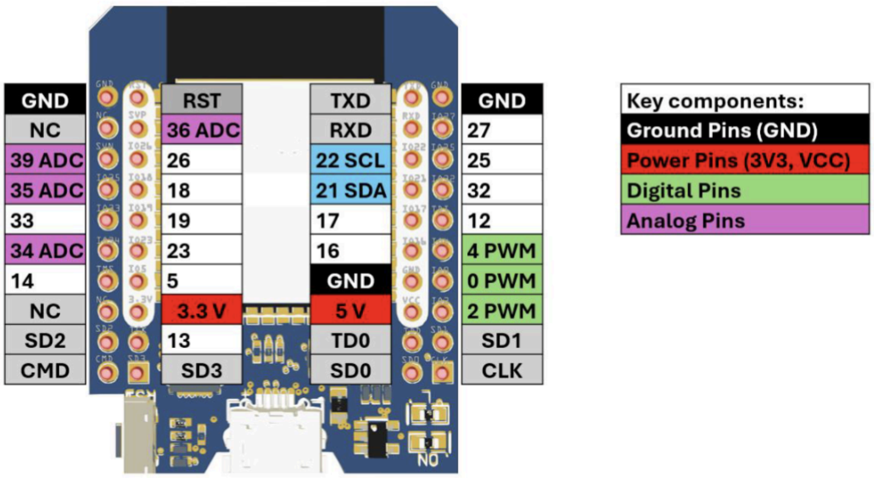


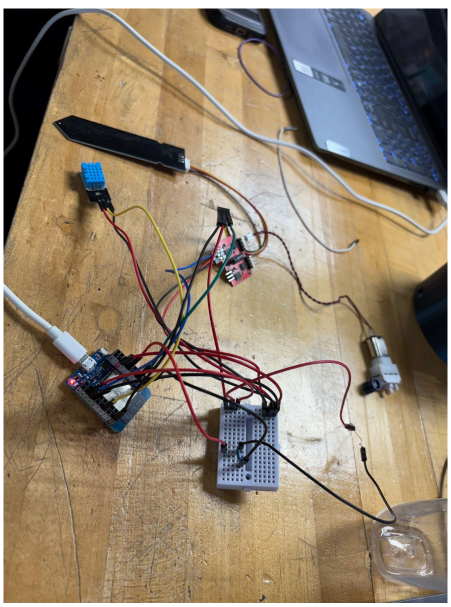


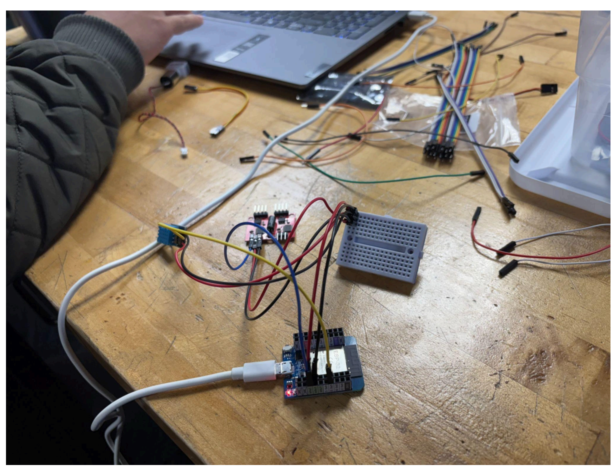
For the assembly, we just used simple fastened mates to connect everything together. Through the assembly we finally found out what a completed prototype would look like if we followed it exactly the same way as the solidworks. This gave us a lot of clarity when building the actual product.

Design Description - Electrical:

Wiring and Pin Configuration Summary - Yes, our report includes pictures of both the wiring diagrams and pin configuration table for all the sensors we have used.







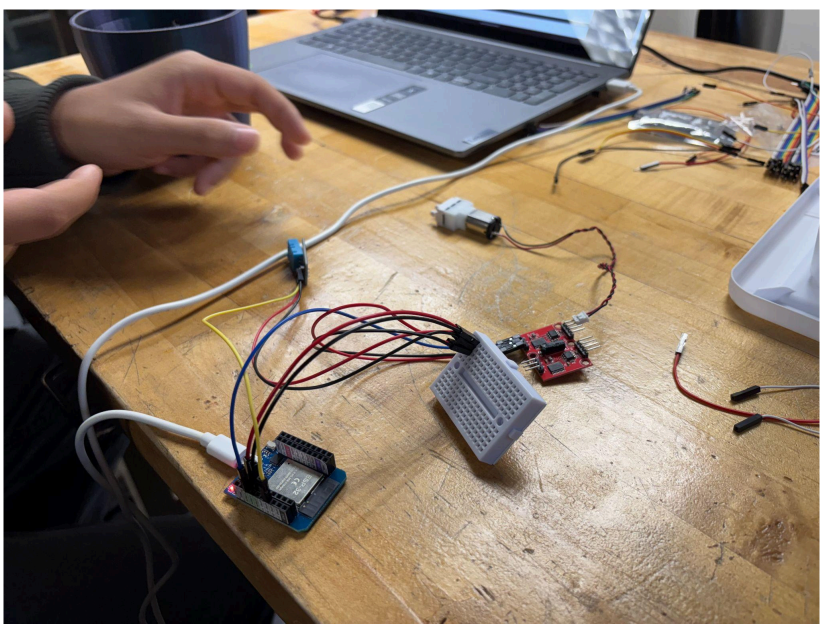
Wiring Color Code - The design does follow the wiring color code depicted on the color pictures given to identify each pin. We used the red wires to indicate the voltage, we used the black wires to indicate ground state, and used an assortment of other colors, yellow and blue for specific pins from specific sensors. For example as shown for the DHT 11 sensor we used a yellow wire to connect it to the pin number we wanted.

Pin Selection for Sensors - For each sensor we assigned the appropriate pins based on their intricate assignments. For example the ADC pins for the analog sensors and the GPIO pins had a very specific sensor number that they had to be imputed in. However for the DHT 11 sensor we had the freedom to use a pin number from a selected few GPIO pins we had.

ADC, PWM, and GPIO Descriptions - Our system uses ADC pins on the ESP32 to read the capacitive soil moisture sensor and the photocell. Both produce analog voltage signals that are converted into numeric values. The DHT11 is connected to a digital GPIO pin because it uses a one-wire digital communication system.

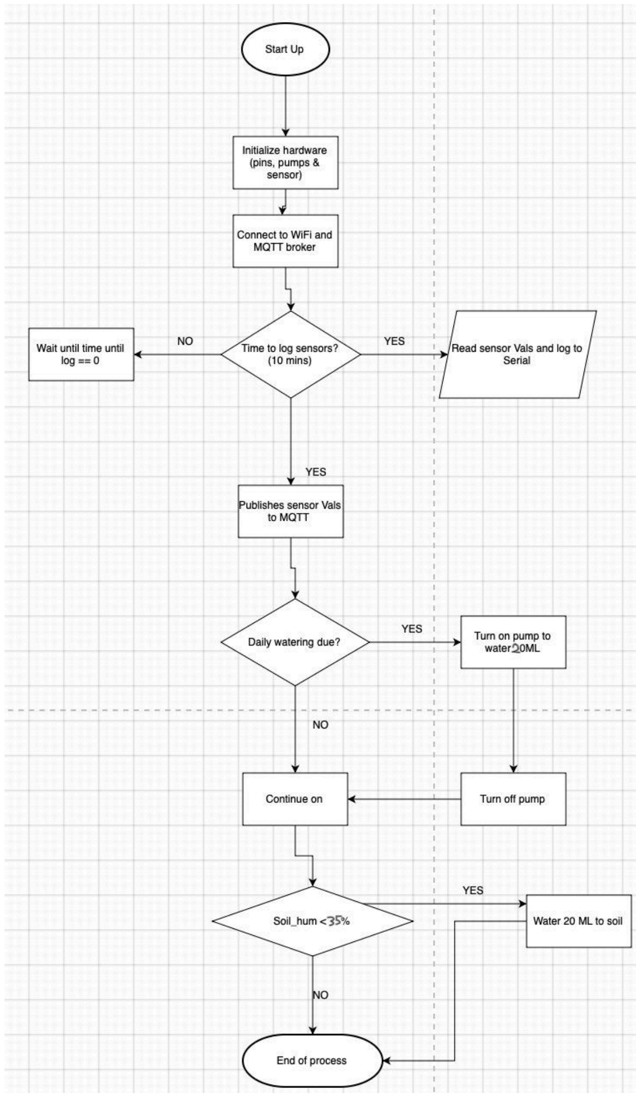
We used PWM-capable GPIO pins for controlling the mini water pump through the motor controller board. This accepts a signal to switch the pump on and off when needed. The rest of the sensors and systems were assigned to standard GPIO pins based on the best arrangement of the wiring.

Most importantly, we would like to emphasize on our arrangement of the wiring in this area that helped with the electrical system. Since our prototype stored the wiring inside of it, having too many wirings and the amalgamation of different systems connected makes it difficult if our placement on the breadboard was cramped. To fix this problem we assembled all the voltage wires together and the ground wires in one place and organized them in lines to ensure right compactness and easy arrangment.



Design Description - Software:

Software Flowchart:



This flowchart represents the exact logic that went into our code and how it is supposed to perform when fully built. Look at it in order to gain a full understanding of the structure that is being implemented.

Lux Conversion:

In our code, the light sensor doesn't directly give us lux, so we had to convert the raw analog reading into something meaningful. We kept it simple: after testing the photocell, we used a basic formula where we divided the analog value by 15.2 and then multiplied by 100 to get a rough percentage that matched what we were seeing in the room. It's not perfect, but the goal wasn't scientific accuracy, just a consistent way to track brightness changes over time.

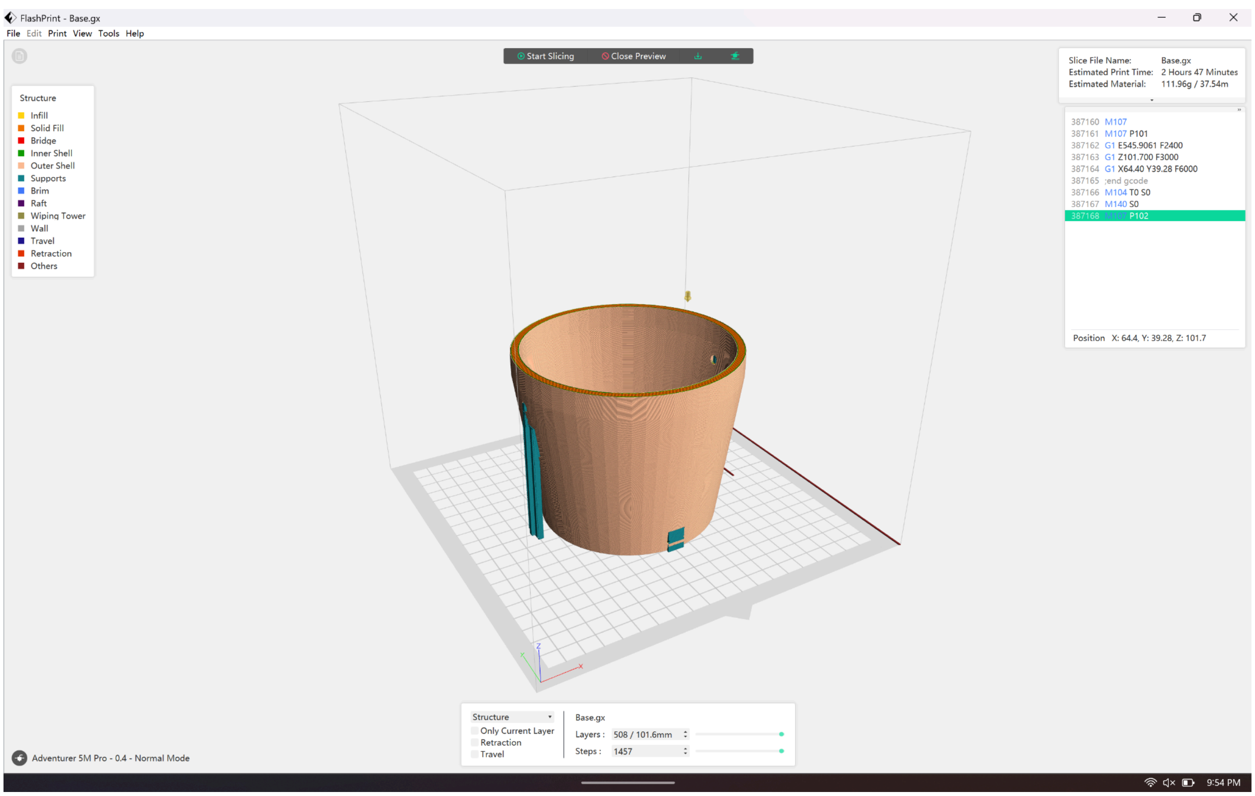
IoT sensor network:

To connect to the network we connected the ESP32 to Stevens-IoT WiFi and then set up an MQTT client using the HiveMQ cloud server and the certificate stored in SystemLogic.h. Every sensor value can then be formatted as a string and published to its own topic following the required naming structure, like 2025/ENGR111/J/S2/soil_hum. The ESP32 keeps a secure connection open using TLS, and the mqtt_loop() function just maintains that link and reconnects if it drops. All four sensors publish once every ten minutes, since our sampling interval is set to 600,000 ms. The whole process is basically: read the sensor then convert it if needed then format it, publish it, and finally wait for the next cycle.

Assembly & Prototyping:

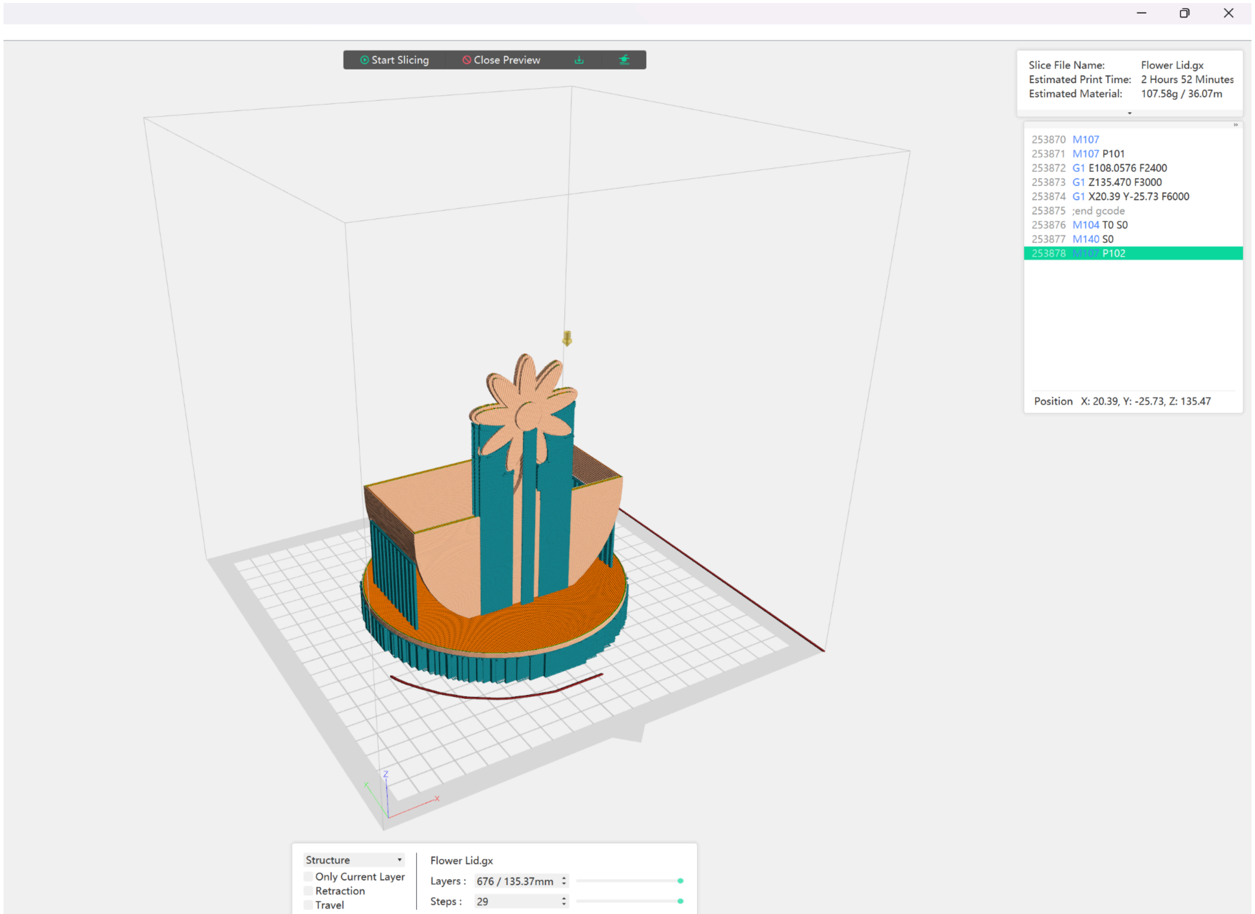
(Presented the sliced version here and the Solidworks in mechanical section as per the instructions on the *2025F_ENGR111_FinalProject.pdf*)

Sliced Prototype of Base:



We have decided to keep the print orientation as facing up because this orientation requires the least amount of support and also strengthens the pot by giving it multiple reinforced layering. Due to the pot's size, it will take approximately 2 hours 47 minutes for it to finish printing. It will require ABS filament.

Sliced Prototype of Lid:



We have decided to keep the print orientation facing up on this one as well because this orientation gives the lid the most amount of strength so it can hold up the water bottle. Any other way would have caused it to fail. One flaw of this design however is the fact that it has too many supports, making the printing time much longer. It will take approximately 2 Hours 52 minutes for it to finish printing. It will require ABS filament. One more flaw we found after printing was that the connection holding the flower together was too weak. After taking all the supports out, the connection broke, so we had to resort to gluing the flower on the side of the lid instead.

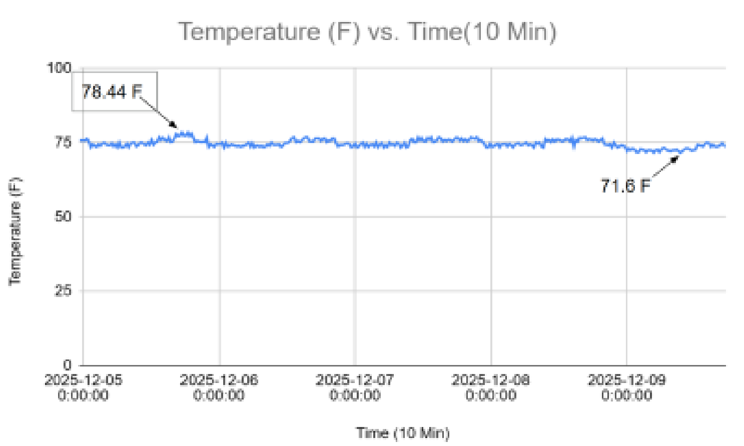
Does it satisfy the requirements and criteria?

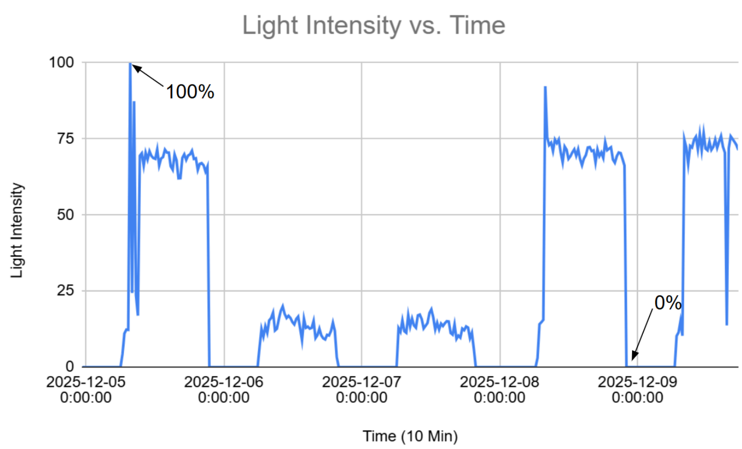
After printing it out and assembling it, it stood at exactly 5 by 5 by 8 inches, which is within the design criteria. It is also a stand alone object and can be moved as a whole. Like we mentioned before, it already fits all the sensors and exposes the ones that need to be exposed. So in conclusion, it does fit the requirements and criteria.

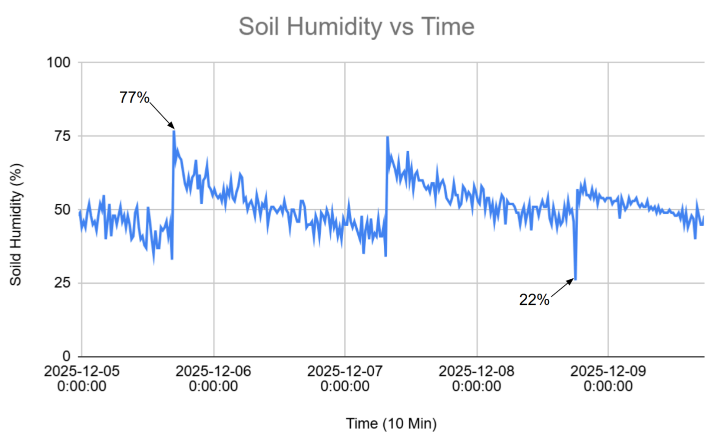
Design Testing and Evaluation:

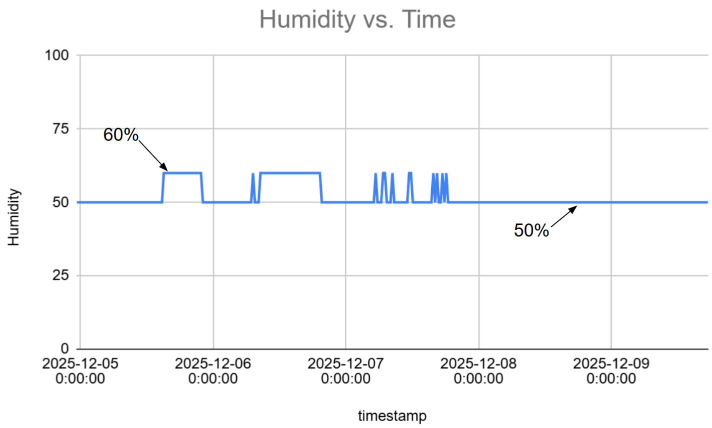
5-day deployment requirement - Our system met the minimum requirement of 3 days of continuous testing and 5 days of testing in total. We started on Thursday Dec 4th, 2025 till Dec 6th, 2025.

Four sensor graphs with appropriate units:









These plots are reliable as they show consistent readings on their relative fields. Possible sources of error can stem from the surrounding temperature of the room affecting humidity readings. Another can be malfunctions with the surrounding light intensity if the power went off during the experiment. As you can see from the light intensity graph it varied a lot due to the surrounding light.

This is a video link for our project demonstration. https://scanned.page/p/mLHy5L

Sampling time conditions:
The sampling time conditions were met as every 10 minutes a ping to the HTTQ server would be made, compiling all of the data onto it. This was done over 3 days.

Project Management:

The work was divided up into different sections, with a person in charge of that section. It didn't necessarily mean they were required to do it all by themselves, but they were responsible for it.

Aryan worked on Solidworks Design and Arduino Programming. He also helped with reports and project submissions.
Shreesh worked on the circuits and electrical part of it, wiring and testing the different sensors out. He also worked on the different reports and project submissions.
Zayd worked on the reports and occasionally helped us with the electrical side of the project.

Overall, the group was able to function as a team and finish the project well on time with some days to spare.

Conclusion:

Our system has been evaluated to confirm it meets the core design requirements. This includes stable operation of the electrical components and reliability during testing. Our performance checks showed that it functions as expected within the intended environment and duty cycle.

A key factor that makes our prototype unique is our thickness and stability as well. Due to the thick pot walls and study lid, there would be no issues of water leaking in to damage the electrical systems. However for future indications and requirements if necessary, weight, and component layout could definitely be optimized. Future improvements include reducing bulk, and refining electrical integration for smoother operation and handling.