Mid-Term Report
Advanced Physical Computing: Countertop Garden System Using Arduino

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BSc (Hons) Applied Computing
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1 Aims and Objectives

The aim of this project is to create an at-home, countertop garden system that is easy to use and to incorporate into your life and home. Many people are switching to a lower/zero waste lifestyle and/or want to include more organic foods into their diets due to the current climate crisis. It is still commonplace in most supermarkets for fruits and vegetables not to be sold loose, instead being packaged in unnecessary plastic packaging. Supermarkets are in the process of removing single-use plastic packaging, but this process is far from completion [1]. The ability to grow your own herbs and vegetables in your own home would help the user reduce their single-use plastic consumption greatly, yet not many can do this as a result of living in a cold country, not having the time or space to tend to crops in their day-to-day lives, or simply not having enough experience to successfully grow these items from seeds in normal conditions.

2 Background

2.1 Market Research

The first area of research conducted was market research - what solutions are already out there? The first product considered was the Aerogarden Harvest (Classic Model) kits [2]. This product contains six small sections in which a user can plant Aerogarden 'Seed Pods'. These pods are then submerged in water inside the product - making it a hydroponic system. With light up reminders on the front to notify the user if the water is running low or the plant is in need of more nutrients, and a button to manually turn the lights on/off. Aerogarden provides a great number of different hydroponic systems but a comparison is being made to this one as it is one of the most reasonably priced systems at $149.95 from their official website [2], or £129.95 on Amazon UK [3]. This product has generally very positive reviews, but it also has some flaws. Several reviewers state that their pods never grew, and some further reviews state that the pods are very rarely in stock. This information supported the decision that the system in this report would be a free-growing space (like a small pot, as opposed to pods), and would not be intended for use with any specific type of seeds. This also influenced the decision that this product would be a garden system and not a hydroponic system.

The second product considered was the Click & Grow Smart Garden 3 [4]. This product is very similar to the Aerogarden product, using 'plant pods' for growing and including an automated lighting system. This system is also associated with an app 'to make you a true plant expert' [4]. Although this system gets overwhelmingly positive reviews, there are several negative points to address. The companion app does not actually link up with this product at all, providing only care tips about a subset of plants. This system also does not allow the user to manually turn on/off the grow lights. This system has a very sleek and minimalistic design but ultimately this led to the decision that a small screen and button on the front of the application in this report would be great additions to the design and user experience.

2.2 Material/Method Research

The next area of research conducted was into which type of plastic to use for 3-D printing the base model. The three most common types of plastic to 3-D print with are ABS, PLA and PETG. Upon research into these, PETG was the obvious choice for printing this product with. It is fully waterproof, slightly flexible (ideal for the moving parts in this system), and produces less odour when printing than ABS. It is also less prone to faults when printing than ABS, which is notoriously difficult to print with. This is due to the need for a heated printer bed of temperatures up from 100°C. If the print is under-heated, this can cause warping and cracking in the model. PETG is much more lenient with this, requiring bed temperatures of 50°C-80°C [5]. PLA was ruled out immediately as it is not water-resistant [6].

Another area of research briefly conducted was into LED use for plant growth. The colour of the light and the benefits of this is mostly what was focussed on. Generally, the spectrum of light plants absorb for photosynthesis is between 400nm and 700nm. However, red and blue wavelengths are particularly important for this. Blue light plays a large part in early growth - ensuring healthy stems and well entrenched roots. Then, the plant will gradually need to absorb more red light. This red light increases leaves and fruits/flowering of plants [7]. Balancing these two wavelengths is essential for plant growth, provides a great environment for high photosynthetic activity [8], and therefore an efficient growing environment. This section of research led to the decision to stray from a monochromatic white light for the grow light in this application.

3 Main Features

The main features of this product include:

- An automated watering system: When the soil moisture sensor determines that the soil is too dry, this will trigger the system to water the plant.
- An automated lighting system: Lights will turn on and off on a timer, using a balance of red and blue light.
- Periodic temperature and humidity sensing using a DHT11 sensor.
- LCD to provide notifications to the user: e.g. If the temperature is too low or the water tank is empty.
- 3D printed main body and internal water tank: printed using PETG to ensure waterproofing.

See Appendix G for Requirements document.

4 Progress Summary

At this stage in the project, the design phase is mostly complete. Requirements have been set for the system based on market research and personas created for the purposes of this project. From this, appropriate user stories along with associated priorities and risk evaluation are in development. Market research was completed in the early stages of the project, but more research is ongoing for areas such as plant care (e.g., scheduling for the light system), and the implementation of the Arduino components involved in the project.

Over Christmastime, a research spike was taken to refresh prior knowledge of Arduino, the components needed for the final product, and basic circuitry.

The next stage of development was testing the individual Arduino components. This has involved reading the documentation for getting started with each component. As a result of these tests, two components have been switched out for new ones. First, a switch in water level sensor components has been made. The original sensor for this was to be partly submerged in water, which would not work for this application due to the size of the water tank. Instead, opting for a non-contact water level sensor that would be attached to the side of the water tank. Second, a switch in Arduino boards has been made. The number of pins needed for the application is larger than anticipated, causing a switch from the Arduino Uno board to the Arduino Mega board to be made.

Alongside the testing of components, a 3-D model is being created to house the Arduino components and create a sophisticated product. This has required more time than anticipated. A lot of research has been conducted into the use of Autodesk Inventor to create the model, as well as into the creation of hinges for the water tank lid, the pipes that move to allow the opening and closing of the lid, and screw holes to allow the removal of the bottom of the product for development purposes. See Appendix A for the model so far and Appendix B for technical diagrams. Time here has also been spent printing test versions of all moving parts - see appendices C, D and E. These are now all in a completed state and ready to be added to the full model for the final print.

5 Personal Reflection

As much as I am very happy with the progress I have made this month, I had expected to be slightly further ahead than I currently am with development. This is due to underestimating how heavy the workload of last semester would be, especially towards the end of last semester, during large deadlines for the other two modules.

The biggest challenges faced throughout the project so far have been relearning circuitry, learning how to program components I have never used before, and learning how to model for 3D printing a product - as this requires exact measurements and I have never tackled moving parts in a model before. Another challenge has been that my 3D printer was inaccessible and broken for a period of time which stinted the modelling process slightly.

However, I am particularly happy with the design of the base model, the model I have produced so far, and with how I have overcome the challenge of modelling the moving parts.

6 Future Plans Summary

For the remaining duration of the project, the following milestones are to be achieved:

- Base model completed and printed by 12th February 2021,
- Components implemented and tested individually by 12th February 2021,
- Full circuit built by 5th March 2021,
- Circuit installed inside model by 12th March 2021,
- User testing completed by 26th March 2021,
- Final report completed by 16th April 2021,
- User/Technical Manual written by 9th April 2021.

See Appendix H for full Gantt Chart schedule.

In terms of risk, there are a few major areas that may occur in the remaining project time. The first of these is that components may break/become faulty. In order to mitigate this, float time has been left to allow for reordering any components. All the components that have been delivered thus far have been delivered within two days. Another way in which this will be mitigated is ensuring the documentation for each component has been followed to ensure proper use.

The second major risk that could occur is that the model does not work as intended. This could mean that leaks occur, components do not fit where they should, or there is not enough space for wires where intended. In order to mitigate this, float time has been allowed for a second print of the base model if necessary. Parts of the model intended to hold water, such as the water tank, will also be thoroughly tested before any installation of circuitry into the model occurs.

References

[1] Greenpeace UK. 2021. *Plastic packaging: which supermarket topped this year's league table?*. [online] Available at: <https://www.greenpeace.org.uk/news/supermarket-plastic-league-table-rankings/>

[2] Aerogarden.com. 2021. *Harvest*. [online] Available at: <https://www.aerogarden.com/harvest-base.html>

[3] Amazon UK. 2021. *AeroGrow Harvest - Black Indoor Garden*. [online] Available at: <https://www.amazon.co.uk/AeroGarden-Black-Indoor-Garden-Harvest/dp/B07WFWP72V/ref=cm_cr_arp_d_pdt_img_top?ie=UTF8>

[4] Click & Grow EU. 2021. *The Smart Garden 3*. [online] Available at: <https://eu.clickandgrow.com/products/the-smart-garden-3>

[5] All3DP. 2019. *PETG vs ABS: The Differences – Simply Explained | All3DP*. [online] Available at: <https://all3dp.com/2/petg-vs-abs-3d-printing-filaments-compared/>

[6] 3dPrinterGeeks.com. 2019. *Is PLA Water Resistant?*. [online] Available at: <https://3dprintergeeks.com/pla-water-resistant/#:~:text=How%20to%20Make%20PLA%20Waterproof,like%20rice%2C%20potato%20and%20corn.&text=If%20you%20left%20PLA%20printing,water%2C%20methane%20and%20carbon%20dioxide.>

[7] BIOS Lighting. 2020. *Grow Light Spectrum Explained: Ideal LED Spectrum for Plants*. [online] Available at: <https://bioslighting.com/horticulture-lighting/grow-light-spectrum-led-plants/>

[8] Darko, E., Heydarizadeh, P., Schoefs, B. and Sabzalian, M., 2014. Photosynthesis under artificial light: the shift in primary and secondary metabolism. *Philosophical Transactions of the Royal Society B: Biological Sciences*, [online]. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3949401/>

Appendices

Appendix A: Model - Base Model

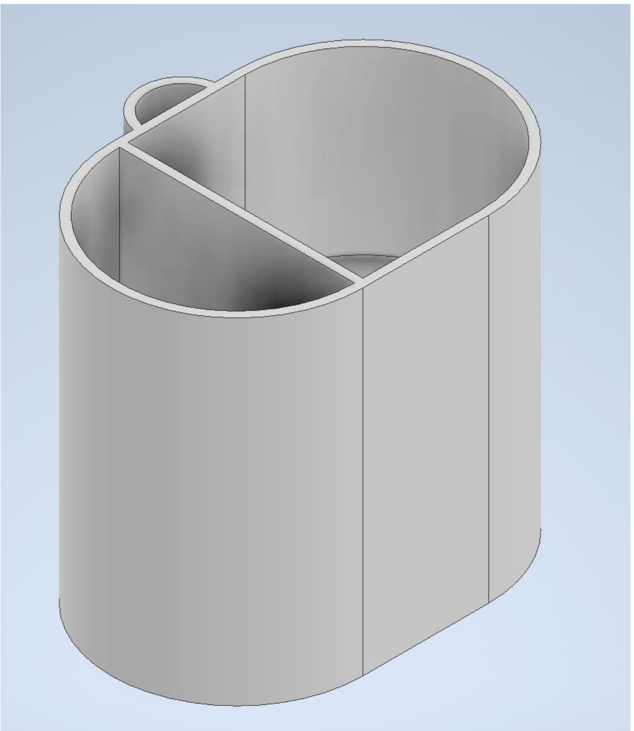


Figure 1 : Top View

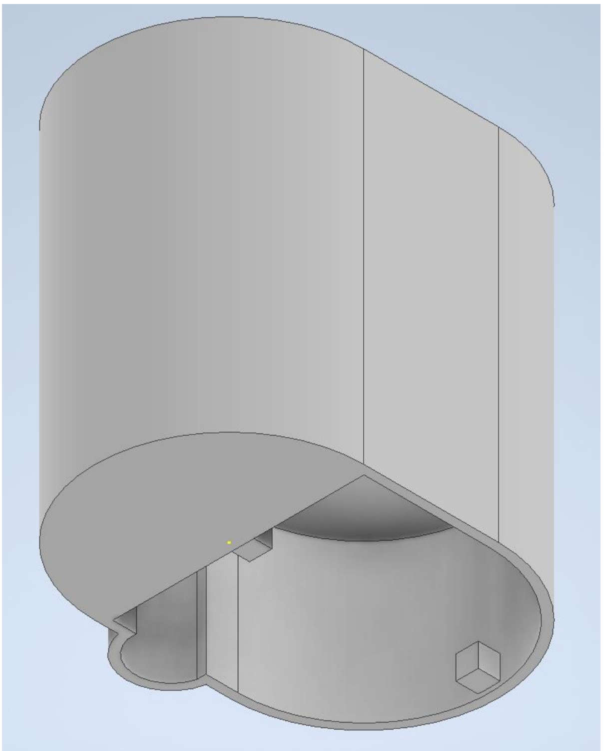
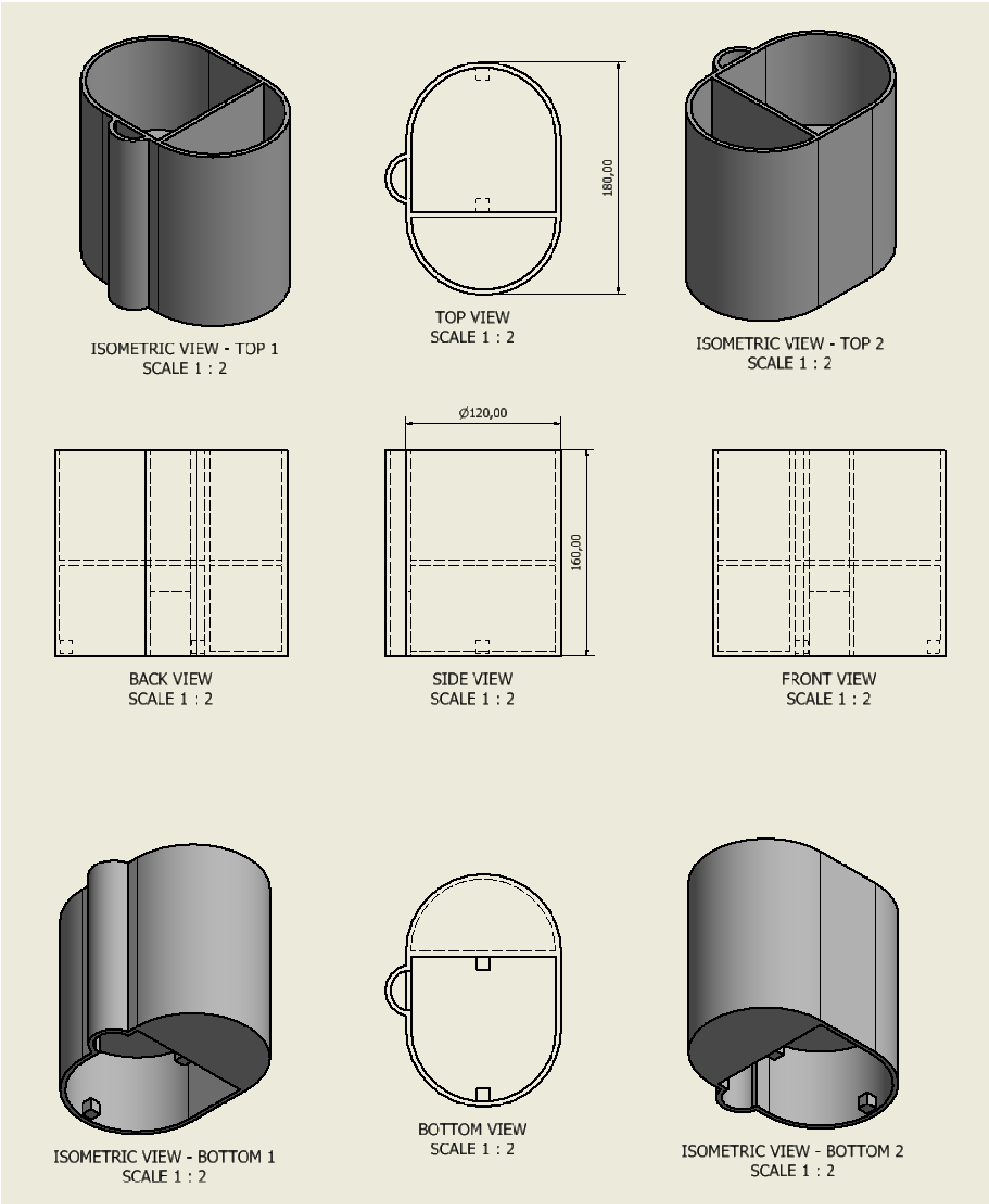


Figure 2 : Underneath View

Appendix B: Model - Base Model Drawing



Appendix C: Model – Hinge

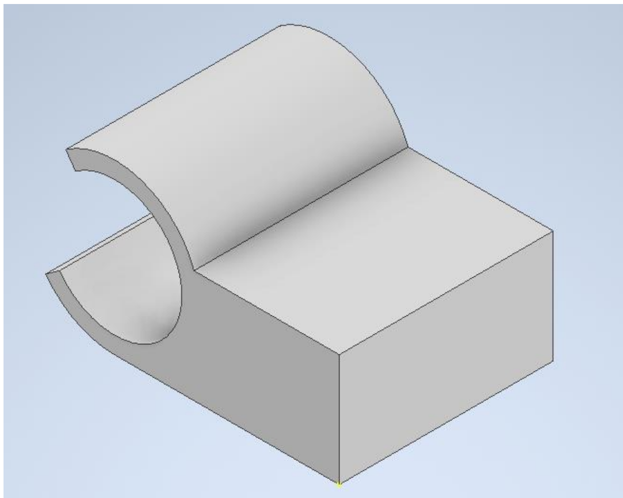


Figure 1: Hinge Part 1

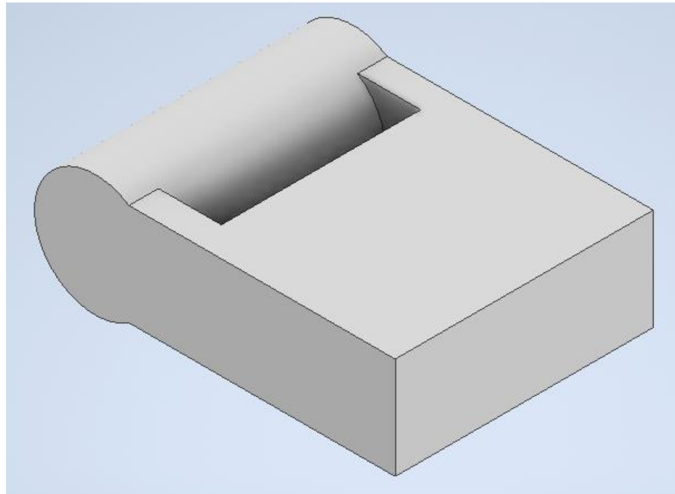


Figure 2: Hinge Part 2

Appendix D: Model – Extender Pipes

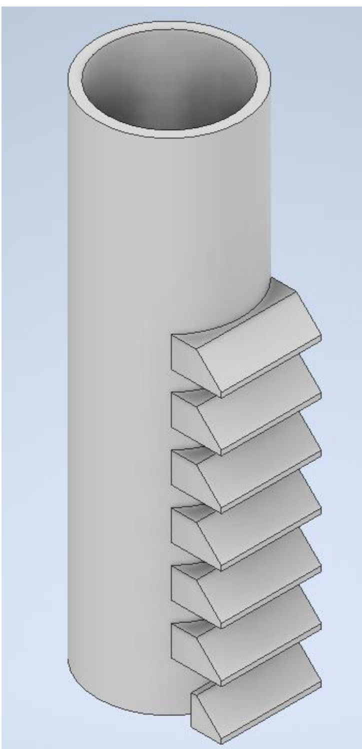


Figure 1: Extender Part 1

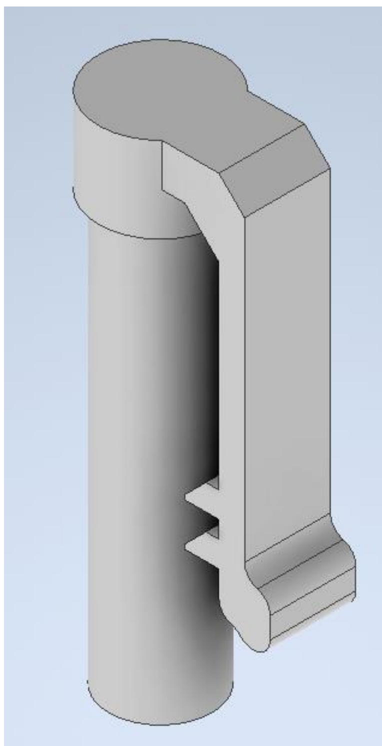
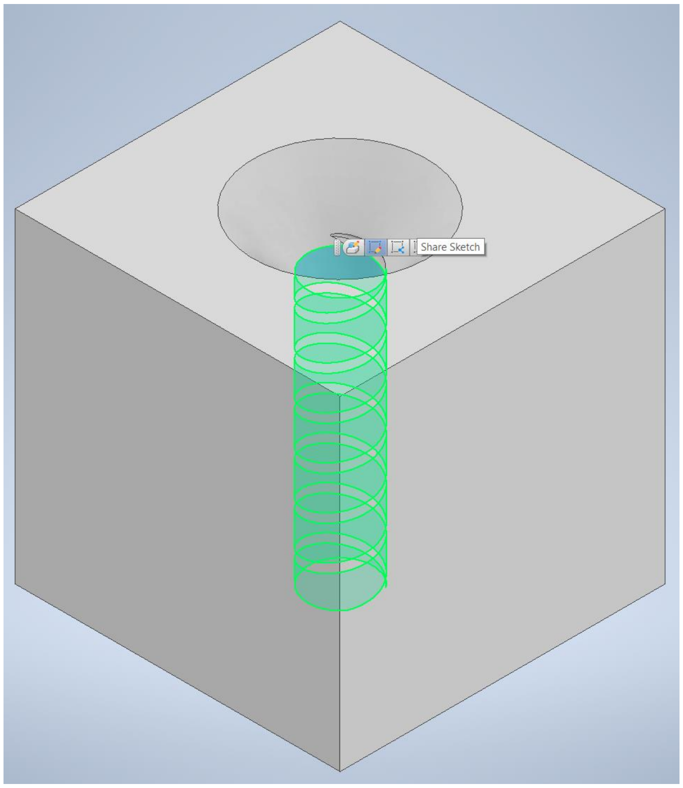


Figure 2: Extender Part 2

Appendix E: Model – Screw Hole



Appendix F: Personas

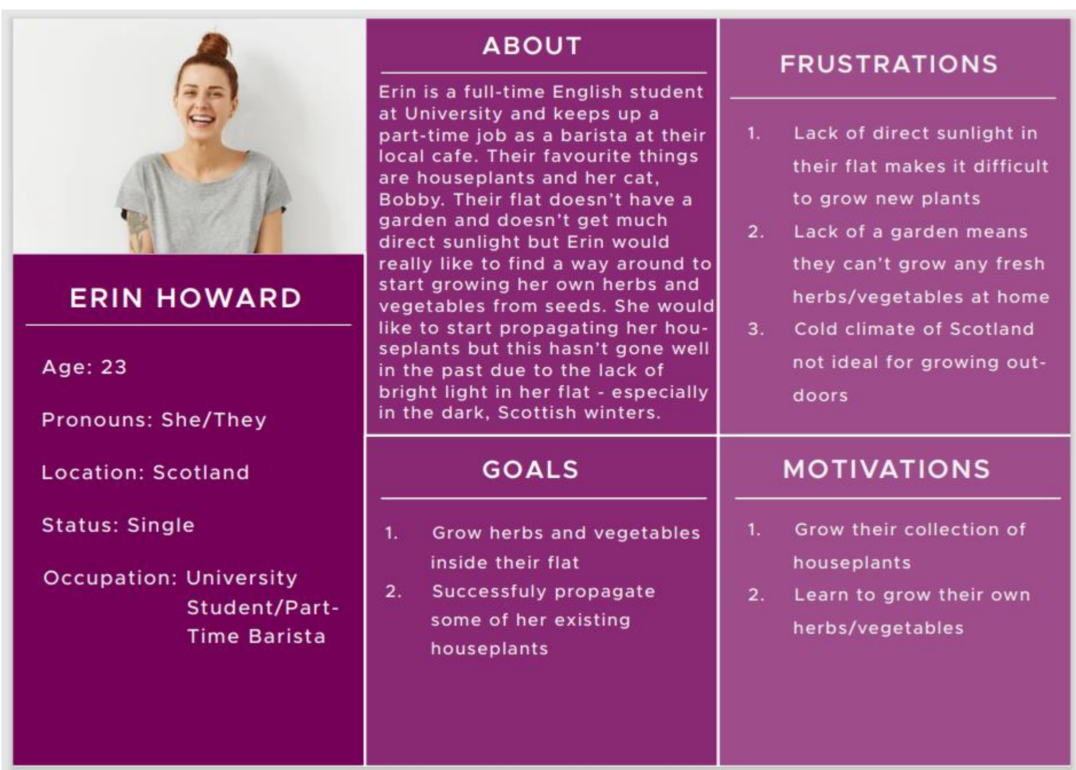


Figure 1 : Erin Howard persona

Figure 2: Andrew Hudson persona

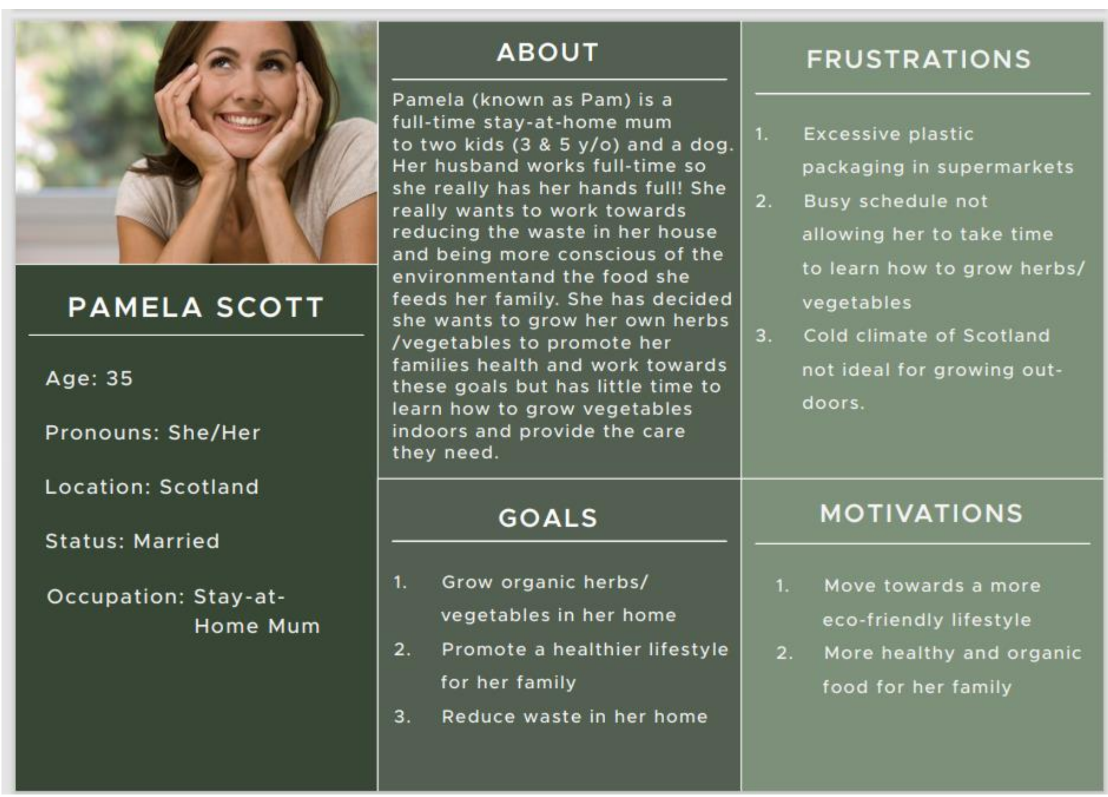


Figure 3: Pamela Scott persona

Appendix G: Requirements

REQUIREMENTS

	DESCRIPTION	RATIONALE	RISK	PRIORITY
1	The system shall have an automated watering system		4	10
2	The system shall have an automated LED grow-light system		3	10
3	The system shall periodically measure the temperature of it's surroundings		2	7
4	The system shall notify the user if the temperature is too low		2	7
5	The system shall periodically measure the humidity of it's surroundings		2	7
6	The system shall notify the user if the humidity is too low		2	7
7	The system shall periodically measure the water level inside the water tank		7	9
8	The system shall notify the user when the water tank is too low		2	10
9	The system shall be waterproof	The main body of the system will be printed using PETG plastic	8	10
10	The system shall have an LCD interface		1	7
11	The LCD shall display notifications to the user		2	5

Appendix H: Schedule – Gantt Chart

Figure 1: Key

WEEKS	
1	Jan 25th 2021
2	Feb 1st 2021
3	Feb 8th 2021
4	Feb 15th 2021
5	Feb 22nd 2021
6	Mar 1st 2021
7	Mar 8th 2021
8	Mar 15th 2021
9	Mar 22nd 2021
10	Mar 29th 2021
11	Apr 5th 2021
12	Apr 12th 2021
13	Apr 19th 2021
14	Apr 26th 2021

Figure 2: Timeline

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Implementation					
Components individually implemented	1	2	1		20%
Components implemented in full circuit	3	4			0%
Components installed into base model	7	1			
Testing					
User testing	8	2			0%
Report					
Introduction	1	3	1		50%
Background	1	3	1		50%
Specification	3	3			0%
Design	4	3			0%
Implementation and testing	8	2			0%
Evaluation	10	1			0%

WEEKS 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Figure 3: Gantt Chart Part 1

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Evaluation	10	1			0%
Description of final product	9	1			0%
Appraisal	11	1			0%
Summary and conclusions	12	1			0%
Recommendations for future work	12	1			0%
Other					
Create user/technical manual	10	2			0%
Deadlines					
Degree show website content submission					
Final report + appendices submission					
Presentation/Demo					

WEEKS 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Figure 4: Gantt Chart Part 2