GNG 1103 – Engineering Design

Faculty of Engineering – University of Ottawa

Final Design Report

Attachment for the Bowie Robot

Group A20

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Abstract

In 2018, Robot Missions sought the help of the class of GNG1103 to create an attachment which will help Bowie the robot excel at its job of cleaning the environment. The document outlines the process that group 20 used in order to achieve their goal of creating said attachment using the process Design Thinking which begins by empathizing with the client, understanding their needs and using design tools to appease said needs.

1. Introduction

In the winter term of 2018, Erin from Robot Missions presented before the class of GNG1103 and explained that the beaches are being continuously polluted and littered by the negligence of mankind. The class was then challenged to develop an autonomous system which can work in conjunction with Bowie the robot to increase Bowie's efficiency at environmental restoration. Pollution is an aspect of life that everyone should worry about because it impacts us all in more ways than one. Not only does it physically hurt animals but also humans, it also damages the environment itself and destroys the future of mankind. The challenge beset upon us allows us to play a vital role in creating a more efficient and more straightforward way of cleaning the environment making the world a better place.

The creation that we plan on creating is an attachment which helps improve upon Bowie. Being that Bowie is an automated robot, our product will also be automated which will help cut down on man hours and render the environmental restoration process easier and more efficient. This automation allows our product to be an aggressive competitor to the current environmental restoration products on the market.

The task to develop our product was accomplished using the five steps of the Design Thinking process. The first and second step is to gain information from the user and create a definition of their needs. The third step is to hatch ideas that may solve the task, and the fourth step is to create the prototypes of said ideas and to improve upon them. Finally, testing the final prototype to ensure its function is the last step. At the end of this process, the team successfully created a functional system that accomplishes the task that was given to us. Our solution involves an automated seed dispenser that allows Bowie to plant various types of seeds as it cleans up litter and debris. This allows Bowie to give back to the ecosystem and recover its overall health.

2. Design Related Work

Before starting work on the product, some research was necessary to help us forge our path and keep to deadlines. Some critical research that was conducted was the benchmarking. This is when we compare already made inventions on the market to collect ideas of what already exists and to compare them to our own product. This also allows us to see what part of the existing products can be improved. These improvements can then be implemented into our final creation. Furthermore, we also made a schedule using a Gantt chart to help us keep our deadlines in check and ensure we do not miss any deadlines. Along with the Gantt chart, we developed a financial plan to ensure that our project remains below our budget of one hundred dollars.

2.1 Benchmarking

Table I. Benchmarking

Specifications / seed dispenser	Importance (weight)	All-in-One Precision Garden Row Seeder Planter	Garden Metal Precision Seeder Vegetable 5 Row Manual Planter	Tow Lawn Spreader Fertilizer Seed Large Universal Hitch Flow Agri-Fab
Cost	3	USD $105	USD $144	USD $250
Weight	5	6.5kg	1.8kg	25kg
Dimensions	4	762x381x1041 mm	120x130x370 mm	965x1096x1041 mm
Seed capacity	5	3.4kg	0.3 x 5 kg	75kg
Automation	3	No	No	No
Coverage area	3	228 m^2	350 m^2	4046 m^2
Maintenance	2	Low	Low	Low
Total		45	50	45

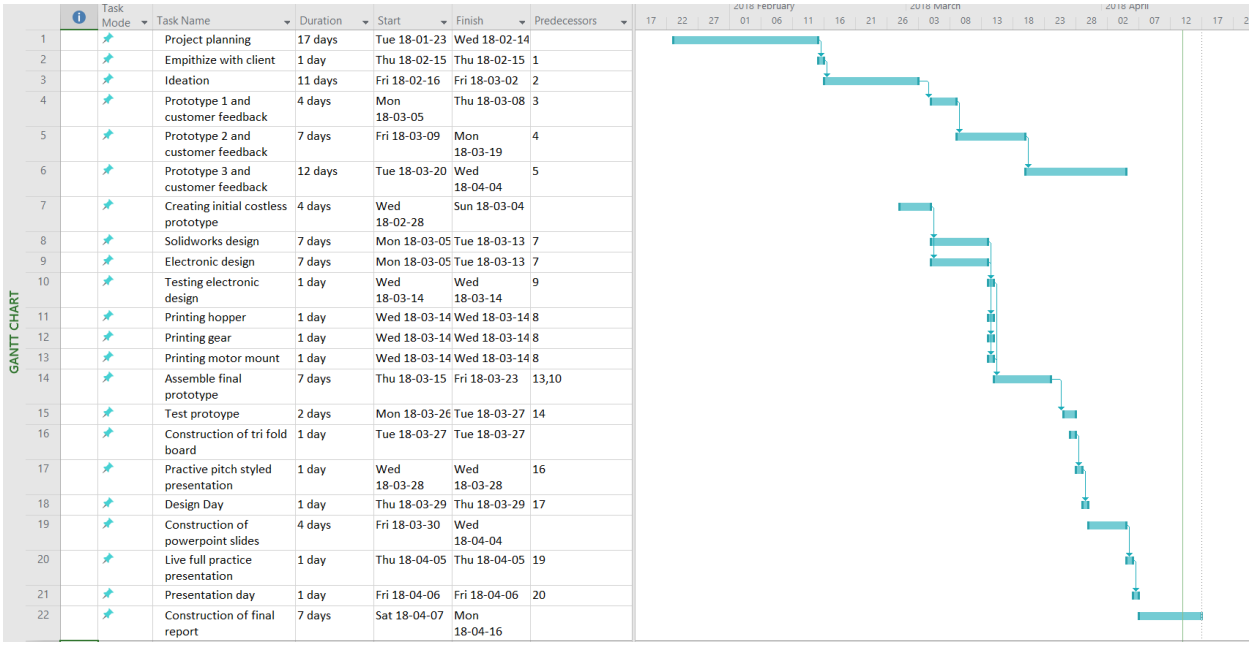
It is to be noted that the importance of each specification (scale from 1-5, 1=useless, 5=very important) is multiplied by the product comparison (scale from 1-3, 1=red, 2=yellow, 3=green) for each specification, later added together to receive a total and compare each product.

After reviewing the complete results, the *Garden Metal Precision Seeder Vegetable 5 Row Manual Planter* has more points than the two other competitors. This is due to our importance of specification scale, which implicitly says that weight, dimensions and seed capacity are the most crucial factors which determine the best seed dispenser for our project, since we are trying to maximize seed distribution with the constraint that our seed dispenser must be mounted on Bowie the robot.

This benchmarking table has helped us ideate our prototypes while following certain important constraints, to fulfil our objective in an appropriate manner.

2.2 Schedule

Figure 1. *Project Plan created using Microsoft Project (Gantt chart)*



	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Project planning	17 days	Tue 18-01-23	Wed 18-02-14	
2		Empithize with client	1 day	Thu 18-02-15	Thu 18-02-15	1
3		Ideation	11 days	Fri 18-02-16	Fri 18-03-02	2
4		Prototype 1 and customer feedback	4 days	Mon 18-03-05	Thu 18-03-08	3
5		Prototype 2 and customer feedback	7 days	Fri 18-03-09	Mon 18-03-19	4
6		Prototype 3 and customer feedback	12 days	Tue 18-03-20	Wed 18-04-04	5
7		Creating initial costless prototype	4 days	Wed 18-02-28	Sun 18-03-04	
8		Solidworks design	7 days	Mon 18-03-05	Tue 18-03-13	7
9		Electronic design	7 days	Mon 18-03-05	Tue 18-03-13	7
10		Testing electronic design	1 day	Wed 18-03-14	Wed 18-03-14	9
11		Printing hopper	1 day	Wed 18-03-14	Wed 18-03-14	8
12		Printing gear	1 day	Wed 18-03-14	Wed 18-03-14	8
13		Printing motor mount	1 day	Wed 18-03-14	Wed 18-03-14	8
14		Assemble final prototype	7 days	Thu 18-03-15	Fri 18-03-23	13,10
15		Test protoype	2 days	Mon 18-03-26	Tue 18-03-27	14
16		Construction of tri fold board	1 day	Tue 18-03-27	Tue 18-03-27	
17		Practive pitch styled presentation	1 day	Wed 18-03-28	Wed 18-03-28	16
18		Design Day	1 day	Thu 18-03-29	Thu 18-03-29	17
19		Construction of powerpoint slides	4 days	Fri 18-03-30	Wed 18-04-04	
20		Live full practice presentation	1 day	Thu 18-04-05	Thu 18-04-05	19
21		Presentation day	1 day	Fri 18-04-06	Fri 18-04-06	20
22		Construction of final report	7 days	Sat 18-04-07	Mon 18-04-16	

This Gantt chart allowed us to build an effective system, assuring we will not miss any deadlines and allowed us to plan ahead of time when inconveniences were to occur. This chart has enabled us to work in an organized manner throughout the whole semester.

2.3 Financial Plan

Table II. Used materials and their estimated cost of final prototype

Material	Cost
Cardboard	n/a
Tape	n/a
Arduino	$25
Electric motor	$20
Wires + Resistors + Protoboard	n/a
Plastic (PLA)	n/a
Total	$45

After evaluating the cost of each individual material used to achieve our final prototype, our total cost of the attachment was $45, which means we were able to build our attachment while not getting near our $100 budget, which proves that our seed planter is very cost effective.

3. Need Identification and Problem Statement

3.1 Need Identification

The first step in the design thinking process is empathy. This step is all about getting to know the client and putting ourselves in their shoes. This allows us to have a better understand of the client's needs and how they will use the product that we will create. In order to accomplish this, we asked the client open ended questions to get a deeper understanding of their needs. The needs of the client are what guides the rest of the process to ensure that the final product is in fact the correct product and the one that fulfills the needs of the client. After speaking with the client, we were able to gather the raw data and after processing this data and interpreting it, we were able to produce a priority table of the client's needs.

Table III. Interpreted Needs and Priority Rank

Rank (1 to 3) 1 = Low 3 = High	Customer Statement	Interpreted Need
2	The product is intuitive	The device is easy to use and can be used by anyone.
3	Open-source	The device is open-source so that anyone around the world can replicate it and print it.
2	Portable	The device is small enough to be easy and quickly printable. It is also lightweight and portable.
2	Expandable	The device is easy and inexpensive to repair and/or replace.
3	Works with Bowie	The device is able to attach to Bowie and can also be powered by Bowie's batteries.
1	Unintrusive	The device is quiet and does not leave a negative footprint.
3	Automation	The device operates automatically.
3	Helps environment	The device has a use that can help the environment.

3	Cost effective	The device is inexpensive.

This table represents the statement gathered from the customer along with its interpreted need followed by its respective rank of importance.

3.2 Problem Statement

Moving forward with the design process, by using the interpreted needs of the client, we constructed a problem statement to further guide us in the proper direction. This statement is stated in a manner such that anyone can read it and understand. This statement highlights the paramount needs of the client, and which of the user's problems are to be solved. Our problem statement is the following: "There is a need to help citizens clean and preserve the environment with a device that works in conjunction with Bowie, is easily printable by any 3D printer, is cost effective and can be operated automatically with the help of said citizens."

4. Design Criteria and Target Specifications

4.1 Design Criteria

Using the interpreted needs of the client and the problem statement, we created a set of design criterias for our seed dispersing attachment. These criterias will permit us to ensure that the needs of the user are implemented in the final product. The criterias fundamentally transforms the interpreted needs of the client into a physical aspect.

Table IV. Design Criteria

#	Need	Design Criteria
1	The device is easy to use and can be used by anyone.	• Simple ON/OFF switch
2	The device is open-source so that anyone around the world can replicate it and print it.	• 3D printable on a standard FDM printer • Blueprints to easily replicate component
3	The device is small enough to be easy and quickly printable. It is also lightweight and portable.	• 3D printable on a standard FDM printer • Print time • Material used • Size • Weight

4	The device is easy and inexpensive to repair and/or replace.	• Polyethylene costs roughly $0.05 / lb • HDPE costs roughly US$ 0.685 / lb • Reliability • Cost
5	The device is able to attach to Bowie and can also be powered by Bowie's batteries.	• Detachable • Can be battery powered
6	The device is quiet and does not leave a negative footprint.	• Sound level • Can be battery powered
7	The device operates automatically.	• Automation
8	The device has a use that can help the environment.	• Tree/Shrubbery seed disperser (in forests) • Edible low-salt nuts for birds (on beaches) • Disperses Uniola paniculata (on beaches) • Disperses Salt during the winter • Volume of Seeds

4.2 Target Specifications

Expanding upon our design criteria, we are able to create target specifications to gauge our success on once we have finalized our design. These specifications can be separated into three categories, functional and non-functional specifications and constraints.

4.2.1 Functional Specifications

Functional specifications are specifications that determine whether or not the product itself will fully function and do what is required of it. We constructed a table to help us organize the functional specifications of our product.

Table V. Functional Design Specifications

#	Functional Design Specification	Relation (=, < or >)	Value	Units	Verification Method
1	3D Printable	=	yes	N/A	Test
2	Detachable	=	yes	N/A	Test
3	Automation	=	yes	N/A	Test
4	Disperses Seeds	=	yes	N/A	Test

4.2.2 Non Functional Specifications

Unlike functional specifications, non-functional ones do not necessarily determine the function of the product. Instead, they focus on the other aspects of the product all while remaining important the usability of the final product.

Table VI. Non Functional Design Specifications

#	Non Functional Design Specification	Relation (=, < or >)	Value	Units	Verification Method
1	Aesthetics	=	True	N/A	Survey
2	Safety	=	True	N/A	Assess
3	Reliability	=	True	N/A	Test
4	Ease of Control	>	True	N/A	Test
5	ON/OFF Switch	=	True	N/A	Test
6	Can be battery powered	=	True	N/A	Design
7	Product Life	>	5	Years	Test

4.2.3 Constraints

Constraints are measurable metrics which will allow us to judge the success of our final product. These constraints were constructed based on some of the limitations surrounding the project and others are based on the benchmarking that we did.

Table VII. Constraints of The Final Product

#	Design Specification	Relation (=, < or >)	Value	Units	Verification Method
1	Volume of Seeds	>	300	cm^3	Measure
2	Print Time	<	4	hours	Time it
3	Size	<	120x120x120	mm	Measure
4	Cost	<	100	$	Final Result
5	Weight	<	0.3	kg	Measure
6	Operating Temperature	=	-5 to 30	ºC	Test

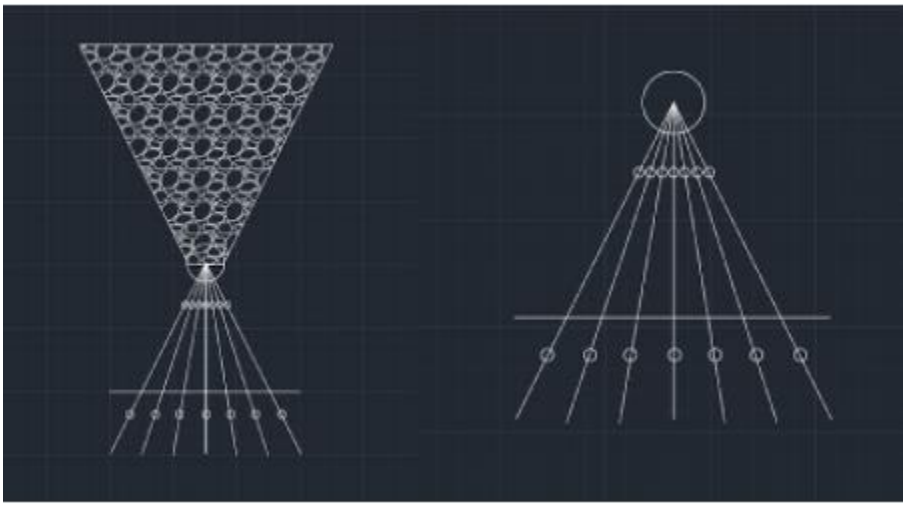
7	Operating Conditions: Snow, Sand, Dirt	=	yes	N/A	Test

5. Conceptual Design

The third part of the design thinking is called Ideation. The goal of this step is to formulate many concepts based on our team's problem statement, benchmarking and our list of prioritized design criteria. Our principal goal with this step is to analyze as a team the concepts we created in order to filter the less appealing ideas and focus on the more desirable ones for further development. This step focuses on the quantity of ideas made rather than the quality of the sketches.

5.1 First Design

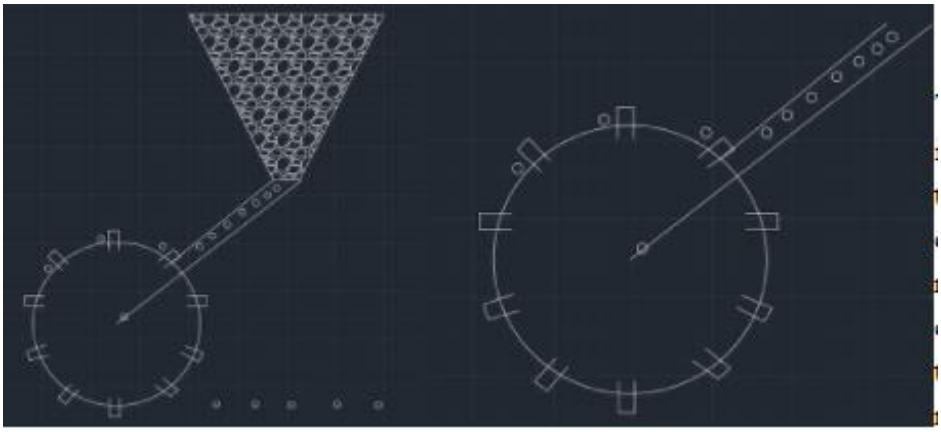
Figure 2. CAD Sketch of First Design



The sketch above illustrates the front view of this concept. This concept functions similarly like a rake and will be placed on Bowie's rear end and will be dragged along the soil creating lines in the ground. These lines will then be filled with the seeds to allow to grow. This concept features a cone shaped container containing all the seeds and while Bowie is in motion, the seeds will be dropped via cylinder tubs connected to the bottom of the container. This mechanism is able to encompass a much broader area since it has multiple drop point, allowing quick and efficient planting. This concept fits our design criterias and constraints such as being be easily 3D printed, automatically operated, easily attachable to Bowie and is very cost efficient.

5.2 Second Design

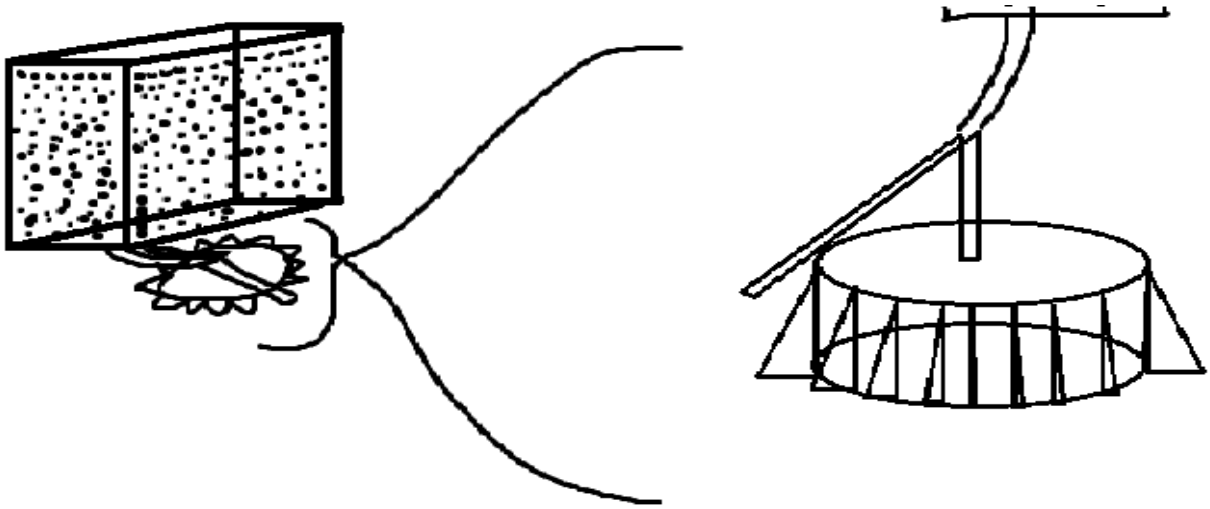
Figure 3. CAD Sketch of Second Design



This sketch constitutes the side view of the concept. Similar to the first design, this also features a cone shaped hopper to hold the seeds. This concept uses a vertical disc with grooves that act as containers for individual seeds. As the disc rotates, the grooves collect a seed through the tube that is attached to the hopper and when the groove reaches a particular point, the seed will simply fall out and onto the ground. This concept allows a linear type of planting where all the seeds are planted in a straight line similar to crop fields and farms. The disc will be spun using an electric motor which will allow the disc to rotate with the rotation of Bowie's wheels. This means that when Bowie is stationary, the disc will not rotate and thus no seeds will be dropped which minimizes the amount of seed dropped on the same spot rendering the seed dispersal ineffective.

5.3 Third Design

Figure 4. Sketch of Third Design



This concept focuses on a wide radius of seed dispersal. Unlike the other designs, this one features a cubic hopper for the seeds. From the hopper the seeds travel through a tube which leads to a horizontal gear type disc. The disc uses gears that are attached to Bowie's wheels to rotate on a horizontal axis. The seeds travel through the tube and are dropped on top of a slide as seen in the Figure 3. As the disc rotates, so does the slide which allows the seeds to be dropped in a 360-degree radius.

5.4 Final Design

After inspecting all our concepts and analyzing their advantages and disadvantages, we have decided to go further with the second concept. Some modifications were applied to the design to refine it such as employing a more cubic hopper instead of a conic one to be able to store as many seeds as possible. We felt that the use of the rotating disk (gear) to dispense the seeds and limit the amount being dropped is one of the best methods there is. It is efficient and not impossible to implement. This also goes with the advantage of being able to mirror Bowie's speed. This means that as Bowie speeds up so will the dispensary of seeds. When Bowie comes to a halt, the seeds will also stop being dropped.

6. Prototyping

The fourth step in the design thinking process is the prototyping part. This part revolves around pursuing the final design chosen in the ideation process and to transform it into a tangible product. In this project, three prototypes were created during this process. Each prototype built upon the previous one. After a series of discussions and tests had been done on the prototype, we determined what aspects of the prototype needed to be improved or scrapped completely.

6.1 Prototype 1

The primary goal of the first prototype of our design was to grasp a basic idea of how the final product will be. It is a proof of concept of our design. As such, we used only basic materials to construct the product. We focused on the idea of the prototype rather than its build quality.

Figure 5. Prototype 1

Figure 6. Prototype 1

In these figures, the basic idea of our design is evident. A hopper containing the seeds would connect to a tube which leads to the disc which spreads the seeds. With this first prototype we found that our initial plan of using a gear and motor to carry the seed from the hopper to the ground would be a feasible idea. An aspect that proved to be difficult to implement into our next prototypes was how we would attach all of the systems together to make the product self-contained. Realizing this, we brainstormed ideas as a team in order to figure out the most adequate solution to our newly encountered problem. Our essential idea was to use a set of arms that connect the disk to the hopper. As we moved further with our prototyping, it became evident that some modifications were necessary to ensure that the final product comes out as expected.

The types of results we expect from our prototypes are: “Good”, “To be Improved” and “Bad.” The good results are ones that are fine and work as intended and can remain the same. The “To be Improved” results are ones that can be made better utilizing our knowledge and skills so that they may work as intended. The bad results are ones that cannot be fixed or improved and must be scrapped and remade so that they may work as intended.

These results will permit us to recognize what aspects of the prototype must be improved so that the prototype can be functional and which aspects must be completely re-worked because they are impossible to improve. Overall these will allow us to make sure that our final prototype can be as functional as possible.

6.2 Prototype 2

Our second physical prototype for a seed dispenser was made with the intention of clearly communicating how the seeds will be dispersed under Bowie. Of all the aspects of our seed disperser, the only controversial topic was *how* we were going to get the seeds to get from the

hopper to the ground at a controlled rate. This is done with the use of an Arduino. With this second prototype, we will clearly plot out how our team has and will continue to analyze our prototypes for the seed dispenser attachment.

Figure 7. Circuitry

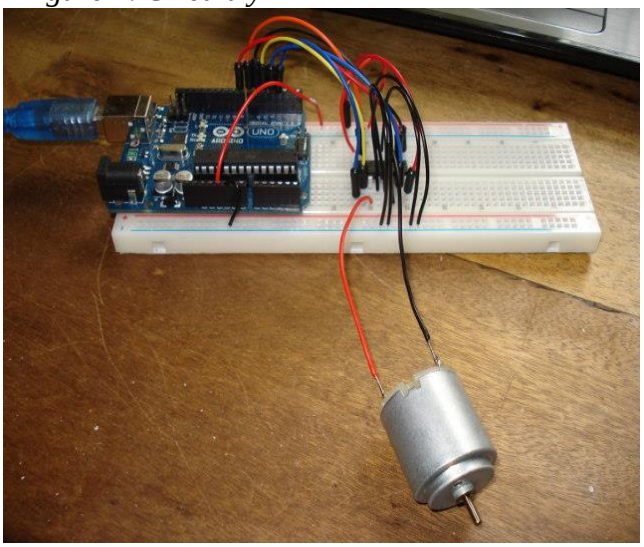


Figure 8. Seed Spreading Disc

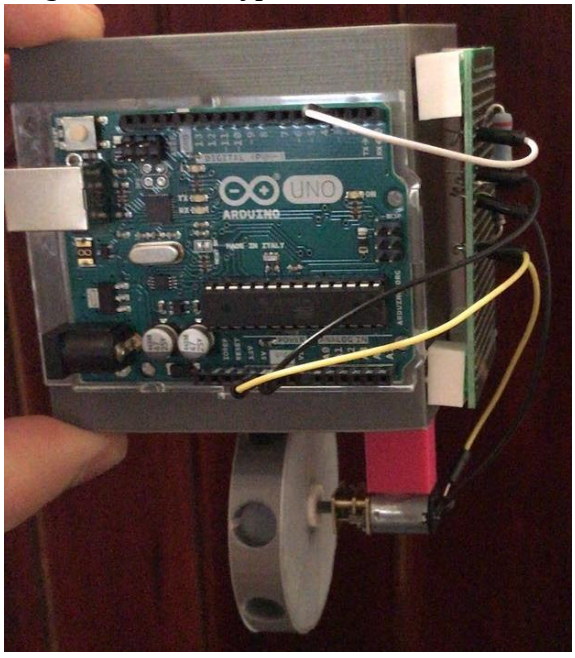
These are our vital components of our prototype 2 that was produced using plastic, an Arduino setup and an electric motor, as shown in the pictures above. The plastic objects have been 3D printed using the Ultimaker 2+ at the MakerLab and includes a seed hopper and the gear to disperse the seeds. The previous prototype has allowed us to eliminate certain components from this prototype such as the tube connecting the seed hopper to the gear. This elimination is due to the gear and the hopper being really close to each other, allowing us to not need the tube anymore. We've respected our $100 allowance, and we are on track to maintain that budget by our last prototype. Our second prototype has cost us a total of $45, leaving us with $55 to spend on any unforeseen expenses for our third prototype. Our test objectives for this prototype were the functionality of the motor and its connection to the disc.

6.3 Prototype 3

The third and final prototype produced for our product had the intention of being a representation of our final product and being the solution to the challenge given to us. We were able to complete this objective along with obtaining feedback from our customer.

Figure 9. Prototype 3

Figure 10. Prototype 3



As seen in the figures, we created a seed hopper along with an arm to connect the motor to the seed hopper using SolidWorks and 3D printing it in the makerspace. We subsequently also had to replace our motor with a smaller one because the old one would not run on the limited voltage of the Arduino. Furthermore, we had to replace the breadboard for a protoboard at the request of our project manager. After we had acquired all the final parts, we attached and arranged everything up to develop our final and functional prototype.

We accomplished our goal by using our materials and objects from our second prototype and further developed the objects we still required. We also used Erin's feedback to help develop our third prototype. As stated, we built a seed hopper along with an arm and replaced the motor (for a functional one) and breadboard. These permitted us to build our final prototype since we had already assembled part of it for the second prototype. With the feedback we collected from Erin, we were able to fix some issues that may have turned up in the final prototype.

7. Conclusion and Future Work

Our final prototype was able to evenly disperse seeds form the Bowie robot to the ground in an even & effective manner. The final prototype follows the design criteria & is an appropriate answer to the given problem statement Erin had told us. We achieved this final model through the engineering design process and applied the very same skills learned in class to develop this solution. The engineering design process particularly came in helpful during the development of our attachment, in the phase in which we began building physical models instead of simple sketches. Employing the skills in class, we were able to effectively work through any issues

amongst our team members, and eventually reach a mutual agreement on what the finished product would eventually look like.

Our attachment for Bowie was fairly simple, but we do have more envisioned for the future if we were able to work on it. The primary improvement we seek to make with our attachment is compatibility with the Bowie controller in order to toggle variables such as dispersal rate and capsule size. These two traits would have looked admirable had we been able to implement them by design day, and could have helped the product feel just that much closer to being complete. Another important trait of our attachment is adding in a modular capsule size. As of right now, the capsule that the seeds fall in to is of a set volume, which does not allow for seeds of all sizes to be dispersed from our attachment. A modular capsule size for our Bowie attachment could place it further ahead of the other seed dispersers seen in class due to it being a unique trait for seed dispersers of similar style.

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Appendix

Appendix A

Figure 11. Unused Design 1

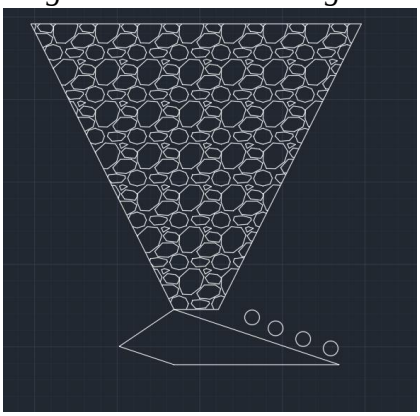


Figure 12. Unused Design 2

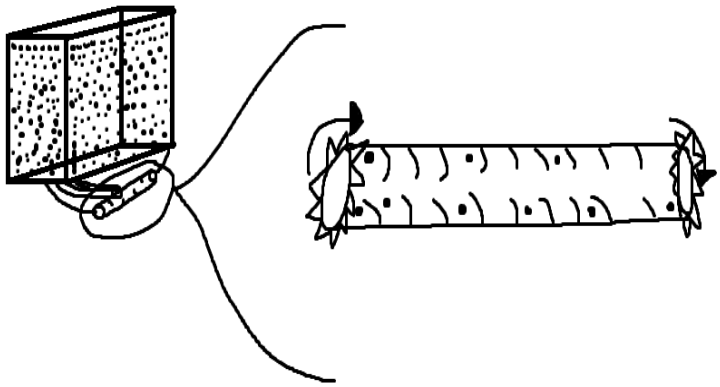


Figure 13. Unused Design 3

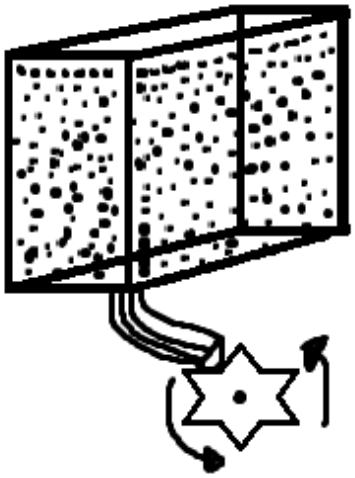
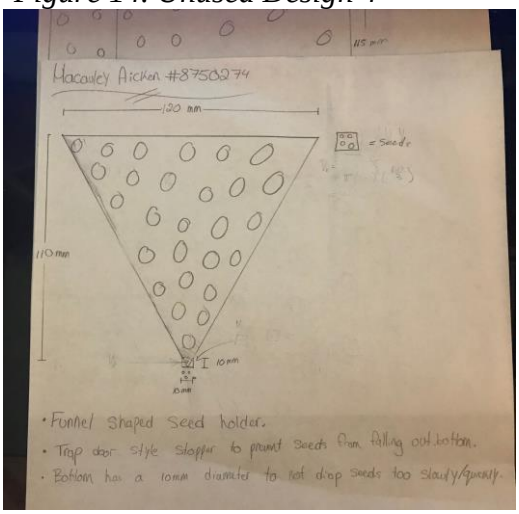


Figure 14. Unused Design 4



These sketches represent concepts that we as a team came up with but decided not to further develop them for various reasons.

Appendix B

Figure 15. Extra Picture of Second Prototype

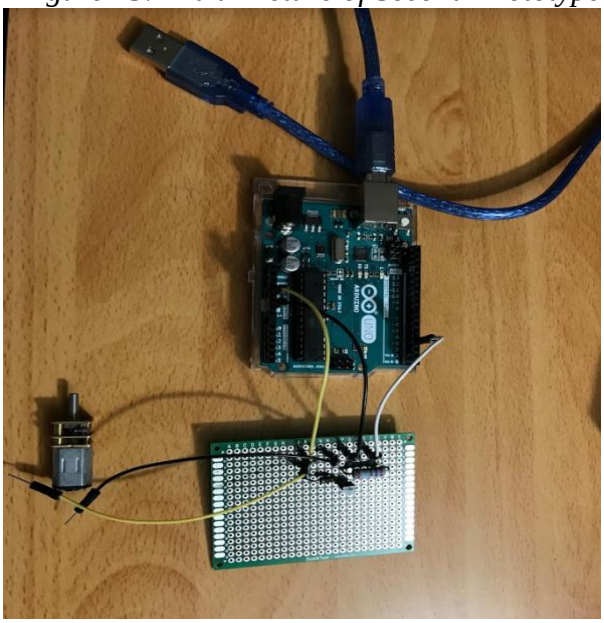


Figure 16. Extra Picture of Second Prototype

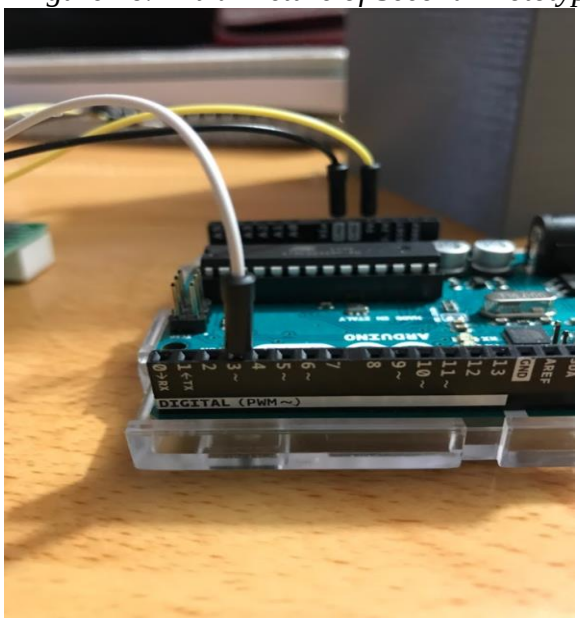
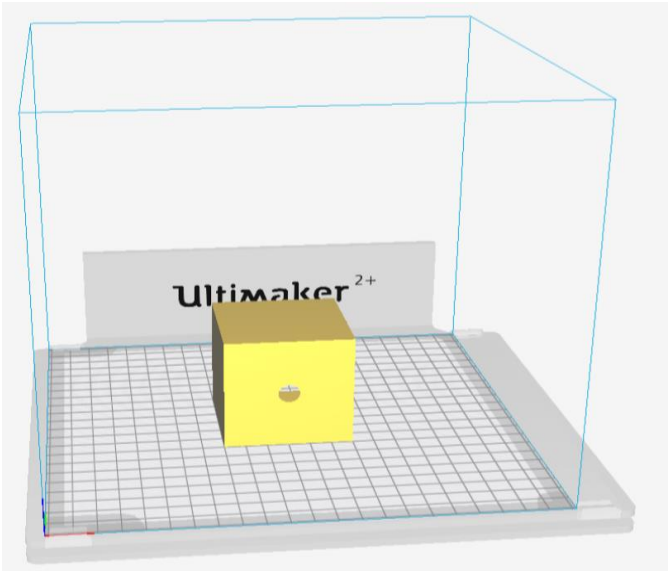


Figure 17. Picture of Seed Hopper to be 3D Printed



These are photographs that were a part of our second prototype.

Appendix C

Figure 18. Extra Picture of Third Prototype

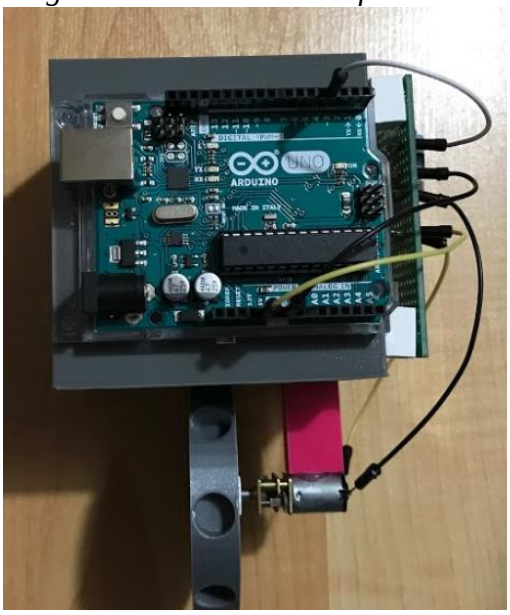
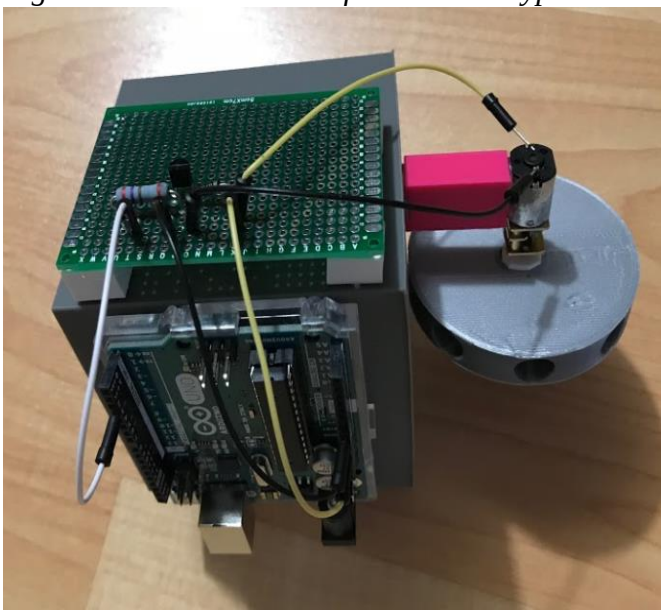


Figure 19. Extra Picture of Third Prototype



These photographs are extra pictures of the third prototype which feature different angles for a more in depth viewing experience.