Easy Indoor Composting

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Special thanks to our instructor Brian Rickard.

Acknowledgements

The Easy Indoor Compost project was a very valuable learning experience. We would be remiss if we did not thank the many people and groups that helped us along the way. Our classmates provided the group valuable feedback all along the way which was especially helpful during the brainstorming process when we needed to come up with a good idea to start from. Thanks to Nathan at the Innovation Hub for all his help with the tools we needed to create the prototype. Thanks to Jason, the PLTW affiliate for his help getting supplies and other requests, including lots of Diet Pepsi to help keep us going.

Thanks to Wichita State University for access to their wonderful facilities. The Innovation Hub and GoCreate Lab were not only helpful for completing our prototype but also for ideas on how to setup our classroom to encourage success of our students on their projects.

Thanks to the Travis and Katie from Compost ICT, Rebecca a Master Gardener from Kansas State Extension Office and to Jessica, a Senior Project Manager at Cornerstone Environmental Group, LLC, for their expert feedback on our project. Thanks to Josh for supplying us with the kitty litter pail we re-purposed.

Last, but not least, thanks to our instructor Brian. Your continued support and encouragement made all of this possible. Your high expectations of us made us want to make the best project, portfolio and presentation possible. You constantly checked in on us and helped us through all obstacles.

Abstract

Research shows that composting is really good for the environment for a variety of reasons. A survey we conducted shows that almost all 237 participants know about composting but only 17% own a compost bin. The main reasons they don't compost are smell and time consuming. This proposal covers the research and development of a product that is an easy to use indoor composting solution that doesn't smell.

Research was conducted to see what products exist today, no patents or similar products conflicted with what we had in mind. Once it was determined that we had a viable problem, we created design requirements and began brainstorming potential solutions. These solutions were then narrowed down to our top 4, each of which we built a mock-up of. We then used a solution matrix to determine which idea we should go with, but in the end we combined the best features of all the ideas.

A design was documented and then bill of materials was created. Once all the materials were gathered construction of prototype began. Some issues were troubleshooted during build that are detailed in this proposal. The prototype was tested to all requirements that could be tested in a week and was shown to experts for their constructive feedback. Finally, the proposal ends with a reflection on the whole process and recommendations for future projects.

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Element A | Presentation and Justification of the Problem

Problem Statement

In the United States each person throws away an average of 277 lbs (Maldarelli) of items per year that could be composted instead. However, current composting methods are time-consuming and geared for outdoor use.

Background Statistics

- 25% of our trash is comprised of materials that can be composted (Eureka)
- 37.5% of US greenhouse gasses come from human waste products (Eureka)
- Compostable items don't break down in landfills, but add to greenhouse gasses (Eureka)
- Landfills are the largest source of methane gasses (Eureka)
- Composting traditionally takes time and effort, but can require little investment to start (Day)
- Indoor composting is ideal during winter conditions
- According to the EPA, composting can clean the soil and prevent pollution (Paul)
- Compost can improve the quality of soils by improving soil structure, water required for crops, and increase yield (Paul)
- Recycling or composting saved the emission equivalent of over 38 million passenger cars (EPA)

Justifications

This problem has a variety of justifications, the main ones are:

- Environmental
- Economic
- Health & Safety
- Technical and Legal
- Market Research

Environmental

It is without a doubt that composting can help the environment. A study performed over three years in London showed that home composting has a direct effect on diverting waste to landfills. It was measured that each family was contributing 370 kg of waste each year to home compost bins. This was substantial enough to even be recognized by local and national governments as helping the environment. Moreover, the study showed Biodegradable materials (garden waste, kitchen waste and waste paper/card) represent 55 % of the total quantity of municipal solid waste deposited in landfill in England. It presents potentially a significant environmental problem because anaerobic decomposition of biodegradable organic matter is responsible for the principal pollution risk and greenhouse gas emissions associated with landfill disposal of waste. (Smith)

The study also showed that when compost was used in the production of flowers gardens, that the flower yield increased dramatically. (Smith) It has been noted by many sources that compost is great for overall health of the soil. Compost improves soil structure, soil moisture content, and helps plants be less susceptible to disease and insects. (Paul)

Economic

There are definite economic benefits to composting. According to an academic article from the University of Minnesota at Morris, implementing a composting system on campus would save the university about $5,000 per year. This was calculated by taking into account cost of hauling garbage, of which they would have 24.3 tons less saving $6,114.08 in waste hauling fees and the costs of implementing the compost system. (Beattie) This article shows that this could have an economic effect for larger businesses, organizations or schools that implement compost systems. It doesn't address personal economic savings for implementing an in home compost system.

Some cities do charge for garbage based on the size of the garbage bin you use. By putting less food in the trash you can opt for a smaller garbage bin. "In 2014 alone, more than 38 million tons of food waste was generated, with only 5.1 percent diverted from landfills and incinerators for composting. EPA estimates that more food reaches landfills and incinerators than any other single material in our everyday trash, constituting 21.6 percent of discarded municipal solid waste." (Sustainable) The article is on epa.gov website so the data is very accurate. According to Waste Management a reduction from a 96 gallon to a 64 gallon garbage cart will get you a savings of $28.07 per month or about $337 per year. (Waste Management) The only issue with this data is not everyone in America uses companies that offer variable garbage rates so the data isn't applicable to everyone.

The final aspect for economic justification is the savings on fertilizer. According to Arbororganic Acres, US Composting Council supported organization, a cubic yard of good compost will contain the same amount of nitrogen, phosphorus and potassium as $160 worth of fertilizer. These nutrients are needed to grow fruits, vegetables and flowers. Compost has many other benefits to soil, including holding water better allowing for less water used which is another way to save money from composting. According to Arbororganic Acres a 5% increase in organic material, which composted material adds to the soil, quadruples the soil's water holding capacity.

Health and Safety

The amount of food produced is linked to the quality of soil in which it is grown. The more nutrient-rich the soil, the more biomass produced by plants. One of the most popular ingredients in fertilizer is nitrogen, and because of the creation process, compost is very nitrogen-rich. In a study done in 2018, tomatoes and wheat grown in soil with compost added had significantly more biomass than plants grown without compost (Ngo, 2018). Commercial fertilizers with synthetic nitrogen compounds are contributing to the amount of "fixed" nitrogen in our nitrogen cycle, and this increase in nitrogen can lead to health effects such as respiratory ailments, cardiac disease, and several cancers (Townsend, 2003). Compost uses nitrogen that is already in the nitrogen cycle but makes it more readily available to plants, therefore cutting down on the amount of nitrogen runoff contributing to increased levels in drinking water and meat products.

Technical and Legal

Composting is a time-honored, worldwide practice as an inexpensive, effective means of enriching soil for crops and gardens. Over the past two decades, composting has become an increasingly common method for reducing the volume of organic materials, particularly yard waste sent to landfills. In Europe, the entire organic portion of municipal solid waste is often composted. Up until recently, that approach had been less common in the United States; however, as more states enact tougher landfill laws, diverting a higher percentage of organics found in municipal solid waste is attracting more interest (Tardy and Beck, 1996)

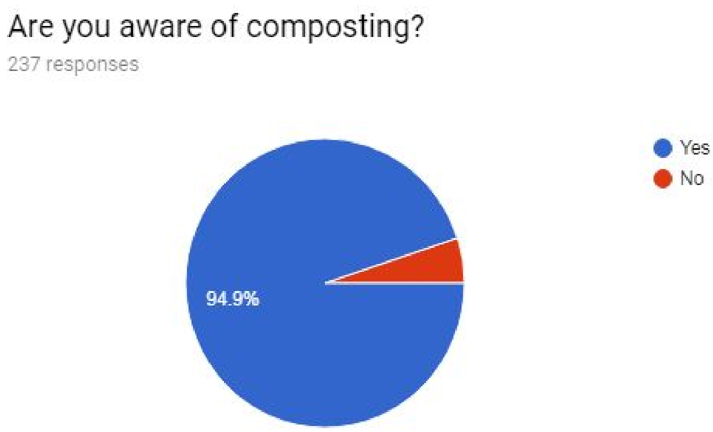
Although composting has been around for centuries, we are continuing to learn more about ways to make composting a more cost-effective alternative to source reduction, methods of controlling odors, and new technologies enabling acceptance of a greater variety of organic materials. In the United States, this knowledge is pursued through the efforts of developers, academia, environmental entities, and municipal governments.

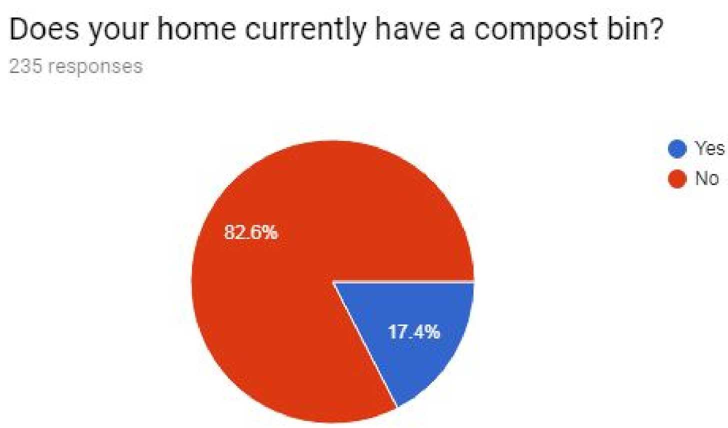
In 2011, the San Francisco Board of Supervisors passed the Mandatory Recycling and Composting Ordinance, where it requires everyone, from residents to tourist, to separate their trash into three bins: recycling, landfill, and compost. The law requiring food waste to be composted is part of San Francisco's aggressive goal to hit zero waste by 2020. The city was the first high-profile US city to adopt such goal with a whopping 80 percent landfill diversion rate (it measures the amount of waste that is redirected from ending up in a landfill) in the country. Phoenix, by comparison, has diversion rate of 20 percent with a goal of hitting 40 percent by 2020. Nationwide, the average is about 35 percent according to the Environmental Protection Agency (EPA). But since the EPA says organic materials such as paper and food are the largest component of municipal solid waste, adding mandatory composting makes a significant difference.

New York City and Los Angeles have pledged to zero waste by 2030. With more than 1 million residents and 60 million visitors, New York will have the largest curbside composting program once it's in full swing. Dallas, San Diego, Seattle, and Minneapolis have jumped on the zero-waste wagon too. In late July of 2017, New Jersey Gov. Chris Christie signed a law establishing a statewide to reduce food waste 50 percent by 2030.

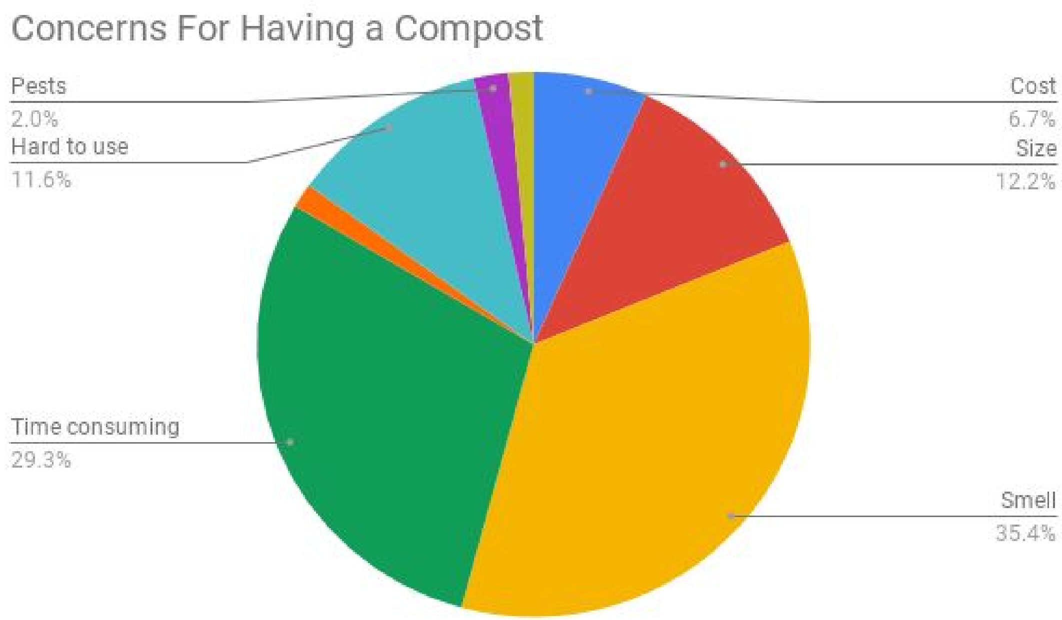
Market Research

While researching composting it was noticed that there was a lack of data on why people do not compost. We conducted a survey via sharing on social media and with friends. This survey went out to a variety of regions in the U.S. due to the varied make-up of our team (members are from Arkansas, Oklahoma, California and New Jersey). We closed the survey after receiving 237 responses. The important information gathered is that 95% of those surveyed are aware of composting but only 17% own a compost bin. See pie charts below.





A question on the survey asked participants "What are your biggest concerns with having a compost bin (choose all that apply)?" There was an option to write in a response if it wasn't available in the current list. The answers were synthesized into appropriate categories to simplify the results. As seen in the below pie chart the main concerns are smell and time consuming. This validates our problem statement that current composting methods are time-consuming and geared for outdoor use.

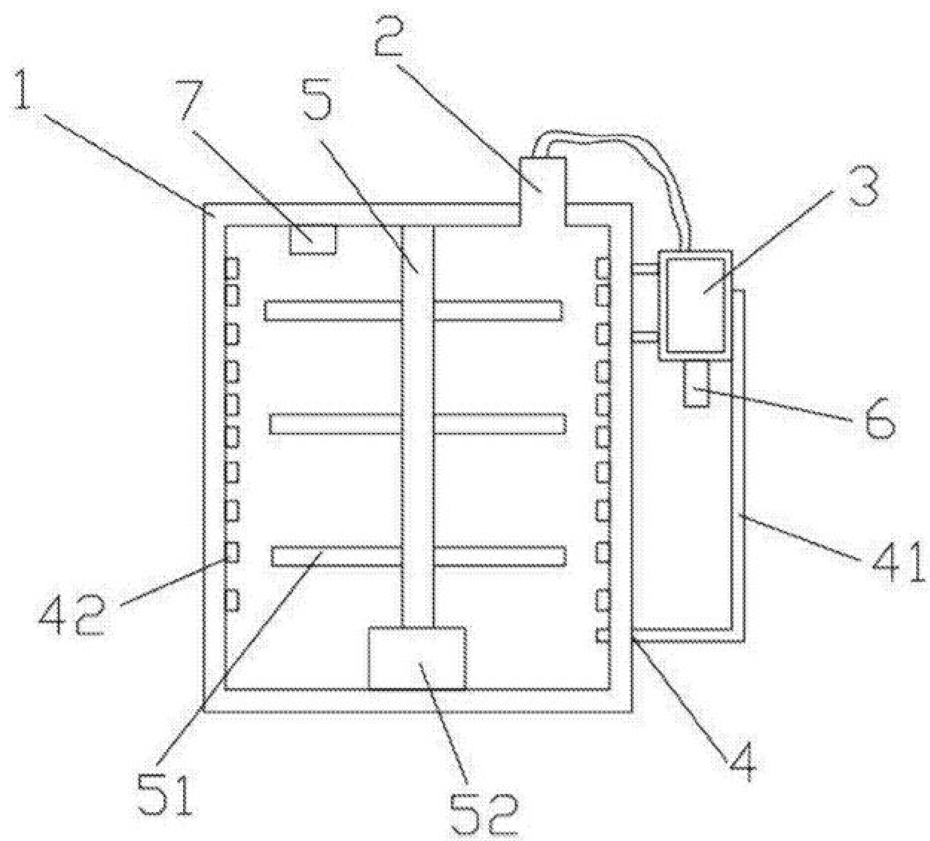


Element B | Documentation and Analysis of Prior Solution Attempts

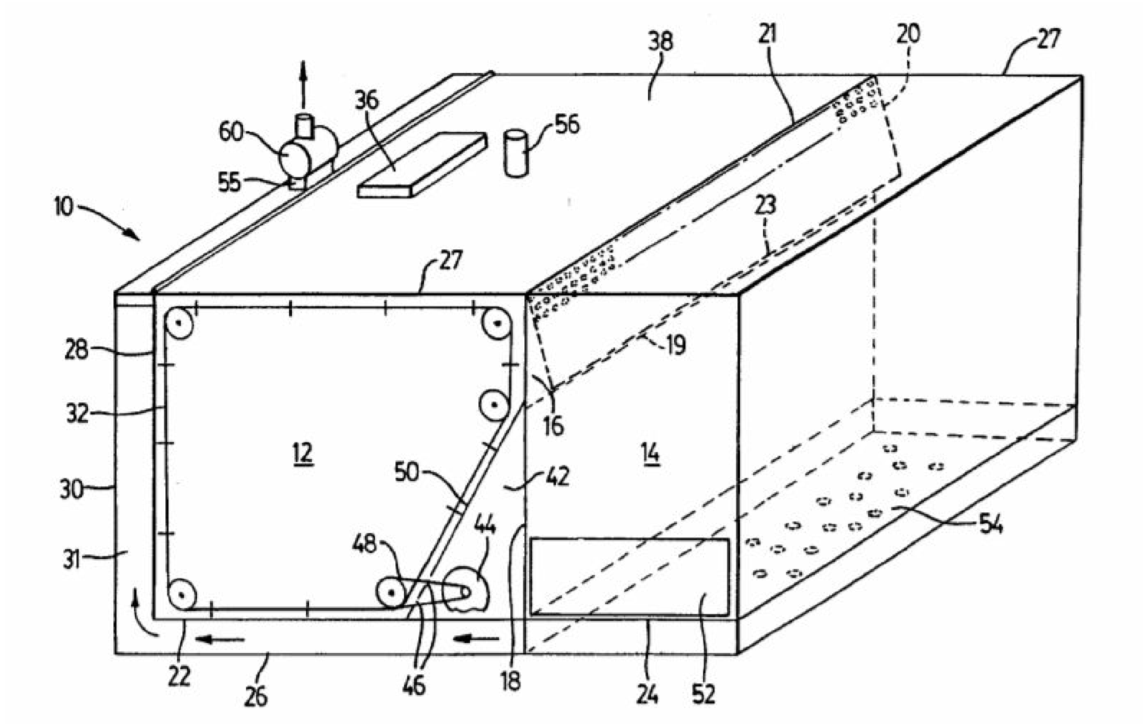
Category 1: Indoor Electric Composter

Citation:
Food Cycler Indoor Kitchen Compost Container - Easy to Use and Environmentally Friendly Food Composter with No Water, Chemicals, Venting or Draining Required (n.d.). Retrieved July 11th, 2018, from http://a.co/jkPrY19
Product Summary:
This indoor electric composter takes kitchen scraps and quickly (4 hours) turns it into a soil amendment. It can fit on a kitchen countertop at 17" x 17" x 15". The basket is dishwasher safe and claims to be easy to use and maintain, odorless, energy efficient and environmentally friendly.
Product Critique:
This product does meet the requirements of being easy to use and small for indoor use. However it doesn't make proper compost, it makes a soil amendment which can not be used in place of soil or in small indoor plants without smelling as mentioned by one Amazon reviewer Rayna J. Many reviewers also complained about the high price of filter replacements ($25) coupled with the large shipping fee of $10. Finally, another reviewer on Amazon, Voracious Reader, returned two due to the clutch plates that govern the grinder wearing out.
Images:

Citation:
Automatic compost machine (2018, February 2). Retrieved July 11th, 2018, from https://patents.google.com/patent/CN107651992A/en?q=automatic&q=compost&oq=automatic+compost
Patent Number: CN107651992A
Product Summary:
This automatic composter uses heat distribution via a combustion chamber to get compost to ferment evenly instead of rotation of material. There are a lot of details on how this is achieved but no specifications on size or wattage required.
Product Critique:
We could not find evidence that this product was produced and tested. In theory heat distribution should work as well as turning.
Images:
The accompanying drawing is a schematic of the present invention; FIG items are: a fermentation chamber, the gas collecting port 2, combustion chamber 3, water circulation passage 4, pipe 41, the distributor 42, the heat pipe 5, the manifold 51 , gear motor 52, the exhaust gas treatment apparatus 6, the temperature sensor 7.



Citation:
Small Scale Automated Composter (September 4th, 2001) Retrieved July 11th, 2018 from https://patentimages.storage.googleapis.com/74/bf/7e/3aeccb6f3e713f/US6284528.pdf
Patent Number: US 6,284,528 B1
Product Summary:
A domestic or Small Scale composter has an air tight housing with an inlet for compostable material such as garbage. The inlet leads to a mixing chamber having mixing means to mix the compostable material and to direct it into a composting chamber for further processing. An overflow dam wall is provided between the mixing chamber and the composting chamber . Airflow is preferably provided downwardly through the composting chamber.
Product Critique:
While this machine is automated and air tight it has not been introduced into the marketplace.
Product Image:



Category 2: Outdoor Composters

Citation:
Yimby Tumbler Composter, Retrieved from amazon July 11th, 2018.
https://www.amazon.com/Yimby-Tumbler-Composter-Color-Black/dp/B009378AG2/ref=cm_cr_arp_d_product_top?ie=UTF8

Product Summary:
This product is a dual bin compost tumbler that is supposed to give consumers the ability to make composting easy. This is due to its ability to turn easy and not take up too much space. It is meant to be set outside on a porch or balcony. It is 36 x 31 x 28 inches in total size. It requires the owner to turn the bin 5 or 6 times 2 or 3 times a week. With the dual bins the owner can add daily waste to one side while the other side is being turned into compost.

Product Critique:
This product is fairly simple to use, is BPA free, and only costs $79. However, this product is made with poor quality parts, is extremely hard to assemble, and when it rains it fills with rain water. Thus, indoor use would not be advised due the fact it would produce a smell. Also, loading and unloading this mechanism is cumbersome due to the small size of the opening. Plus, when unloading it takes a lot of time to get the sludgy material to come out of the bin.

Images:

Citation:
Miracle Gro Dual Chamber Compost Tumbler, Retrieved from Amazon July 11th 2018
https://www.amazon.com/Miracle-Dual-Chamber-Compost-Tumbler/dp/B0785HCXB5/ref=sr_1_7?s=lawn-garden&ie=UTF8&qid=1531321344&sr=1-7&keywords=composter

Product Summary:
This outdoor composter has a dual chamber composter and rotates separately. Each bin can hold up to 19 gal of compost materials. The way this product works is while you're curing the compost in one chamber, you add more scraps to the other for a steady supply of ready-to-use compost. There's also a built-in handle to give a few turns every few days. The internal mixing bars creates an efficient aeration system to speed up the composting process. The product is made from recycled polypropylene, BPA free, and UV protected which is good for outdoor especially under intense sunlight. The galvanized steel frame is corrosion-resistant, and can withstand to any weather.

Product Critique:
The product is easy to assemble and lightweight but sturdy at the bottom, only 22 pounds when assembled. The 10" doors are a little on the poorly designed side as they slide in and out, and sometimes can be jammed. This composter is perfect for small space household.

Image:

Category 3: Bokashi Buckets

Citation: The easy and clean way to compost your food waste! NO foul smell. NO mess. NO pests. (n.d.). Retrieved from http://thebokashibucket.com/

Product Summary:
A bokashi bucket uses anaerobic microorganisms to ferment food. The consumer empties kitchen scraps directly into the bucket and then smashes the layer down to get rid of as much air as possible. "Bokashi Bran" is then sprinkled over the top layer and the lid is closed. Liquid will collect in the bottom of the bucket and the spigot is used to drain the liquid.

Product Critique:
This product is more inclusive than other composting products because you can add meat, bone, and dairy scraps to the bucket. Most other compost methods do not allow these types of materials to be added. This system is also much smaller and can be done in a 5-gallon bucket. The major downside to this product is that it creates a type of pre-compost that must be transferred into soil not used for growing and allowed to cure before being added to a garden or other growing medium. Another downside is that the bokashi bran must be made or purchased and can be expensive and time consuming.

Images:

Similar Solution Matrix

As you can see in the below solution matrix the current solutions available scored between a 15 and a 27. A solution that met all design requirements would have a score of 40 which further justifies the need for the Easy Indoor Compost.

Similar Solution Matrix
Easy Indoor Compost

Scoring		Weighting	
Meets Requirements	2	Required	300%
Partially Meets Requirements/ Yes	1	Desired	200%
Does Not Meet Requirements/ No	0	Optional	100%

Requirement	Level of Importance	Food Cycler		Patent 1 (Automated Machine)		Patent 2 (Small Scale Automated)		Yimby Tumbler		Bokashi Bucket		Miracle Gro Dual Tumber	
		Score	Total	Score	Total	Score	Total	Score	Total	Score	Total	Score	Total
Intuitive	2	2	4	1	2	1	2	1	2	2	4	1	2
Low Touch Time	3	2	6	2	6	2	6	1	3	1	3	1	3
Ease of Disposal	2	1	2	0	0	0	0	0	0	0	0	1	1
No Smell	3	2	6	1	3	2	6	0	0	1	3	1	3
Small Size	3	2	6	1	3	1	3	1	3	2	6	1	3
Composts	3	0	0	2	6	2	6	1	3	0	0	2	6
Durable	2	1	2	1	2	1	2	0	0	2	4	1	2
Uninterrupted input	1	1	1	1	1	2	2	2	2	2	2	2	2
No Electricity	1	0	0	0	0	0	0	2	2	2	2	2	2
			27		**23**		**27**		**15**		**24**		**24**

Element C | Presentation and Justification of Solution Design Requirements

Based upon our research of the market, similar existing products and filed patents, and discussions with experts in the industry we have determined the following are the design specifications that should drive the creation of our product. The design specifications are listed in order priority from most important to least for our stakeholders.
Our primary stakeholders for this problem have been identified as families living in apartments or housing that doesn't provide much space for outdoor compost bins. Thus, these stakeholders are people that would like to compost but do not have a quality product to suit their needs. Other stakeholders will be people that could use the compost in gardens to produce quality higher yielding plants, as well as municipalities that will be experiencing a measurably lower amount of waste distributed into landfills.

Below are the solution product specifications in order of decreasing priority.

1. The unit should have little to no smell at all times. This can be measured by testing whether 50% of a population can distinguish between the odorous sample and an odor free blank as described by Spengler in his book *Indoor Air Quality Handbook.*

   Spengler, John D.; McCarthy, John F; Samet, Jonathan M. (2000). *Indoor Air Quality Handbook*. New York, NY, USA: McGraw-Hill Professional Publishing. ISBN 978-0-07-445549-4.

2. The unit needs to have a small footprint within a living quarters. The average 15 gallon trash can that is commonly found under cabinets in kitchens measures 15 x 13 x 25 inches. This about 3500 cubic inches. Our design would need to be no larger than this to easily fit in most areas of a typical kitchen.
   Amazon.com: Step-On 13-Gallon Trash Can Color Black Dimensions …
   https://www.amazon.com/Step-13-Gallon-Trash-Dimensions-Inches/dp/B01IJ1OCQE

3. The solution should break down organic materials to a soil replacement. The compost material should heat up to 40-50 degrees Celsius in two or three days. Decomposition should occur rapidly within 3 weeks while reducing it's particle size should be to increase the rate of microbial activity on the surface area.

4. The user should spend less than 10 minutes per week interacting with the product solution. Based on our market research 101 out of 237 people surveyed were concerned that composting would be too time-consuming.

5. The product solution should be intuitive which will be measured by customer feedback. According to a 2009 study titled *It Matters a Hole Lot*, by studying the effect of specialized lids on people's recycling efforts they found that "although most people

intend to recycle, they fail to do so because of limited cognitive processing during the act of disposing of waste."
Duffy, S. and Verges, M. (2009). It Matters a Hole Lot. *Environment and Behavior, Volume 41*(5), 741-749.

6. Ease of Disposal - There are many factors that can play into the easy of disposal. The first factor would be the overall weight of the compost bin. This could be a factor if the bin is being carried to a dumping location. Secondly would be the size of the opening that allows the compost to be unloaded out of the bin. If the flap is too small compared to the size of the bin, the compost could have a hard time releasing from the inner wall and coming out of the bin. Also, if a shovel is needed to unload the bin, the flap will need to large enough for easy shovel access. A shovel measures around 11 inches wide.
Wonkee Donkee Tools
https://www.wonkeedonkeetools.co.uk/shovels/what-is-a-west-country-shovel/

7. The product is durable and able to exist for a long time without a significant visible deterioration in quality or value. The metal parts of the unit should be free from any corrosion, and the plastic parts (polypropylene) should have a tensile strength of no less than 40 MPa (http://www.matweb.com/reference/tensilestrength.aspx). The plastic parts should not warp or deform due to natural heat produced during the composting cycle. The product can carry out its function with no damage in at least 5 years or so.

8. Uninterrupted Input - The product is good source of steady supply of ready to use compost of up to 15 gal. The unit should be able to accommodate fresh materials for composing even on a daily basis without any downtime.

9. No Electricity - The unit operates without any electricity or external energy (battery, fuel, gas, etc) that can be carried out in wired or wireless connection, and it is self automated.

Element D | Design Concept Generation, Analysis, and Selection

Problem

In the United States each person throws away an average of 277 lbs (Maldarelli) of items per year that could be composted instead. However, current composting methods are time-consuming and geared for outdoor use.

Brainstorming

To start the brainstorming process, we sat with a panel of stakeholders and four team members that are experts in the problem to gain possible design ideas. We reiterated the problem with the group. Then, the following list of design specifications was given in order of priority, with the most important listed first.

1. No odor
2. Small in size
3. Composts
4. Low touch time
5. Intuitive
6. Ease of disposal
7. Durable
8. Uninterrupted Input
9. No Electricity

The following sketches are the result of the session. Each of the ideas generated were evaluated by our team and we decided to take four of the ideas to pursue further for product development. The ideas that were chosen are indicated.

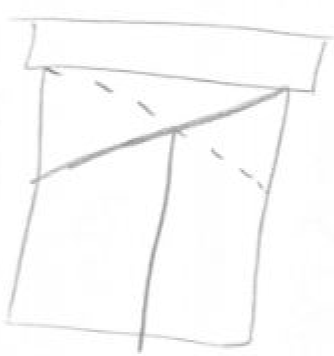
Brainstorming Generated Concepts

Chosen: Dual Bin Composter

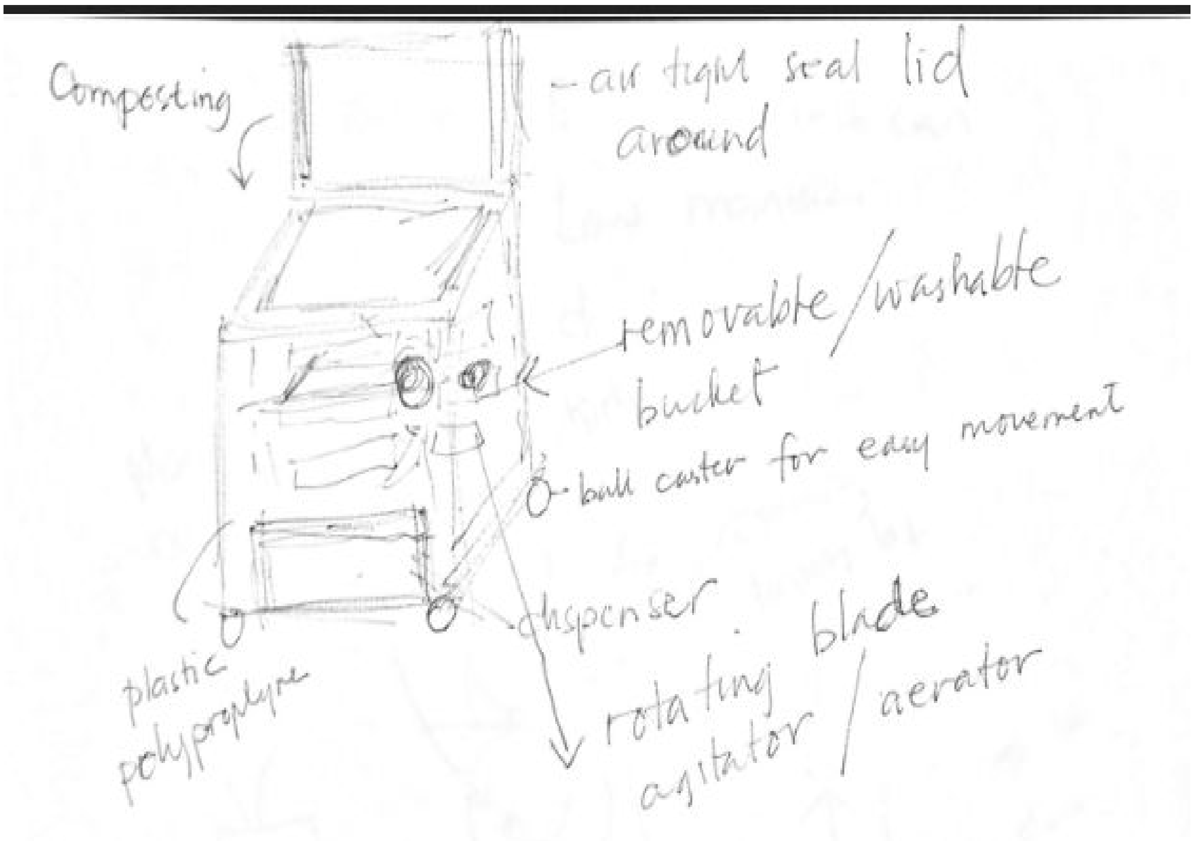
Concept Description: This idea meets design requirements because it is small, has holes to prevent smell, has uninterrupted flow because it is dual bin, is easy to unload because it has a small bucket at the bottom, and it does not require electricity.

Scraps are fed into an intake that shuttles it to one of two places. When spot 1 is 75% full, ~~it sw~~ the composer starts shuttling scraps to spot 2. When spot 2 is 75% full, it goes back to spot 1, repeat. Once spot 1 + 2 are full, light goes on to dispose of compost.

- need air
- need to balance composition



Chosen: Movable Compost Bin
Concept Description: This idea meets the design requirement because it is small, has an airtight seal to prevent odor, has an easy bucket to pull out for ease of disposal, in on wheels for easy movement, and is non electric.



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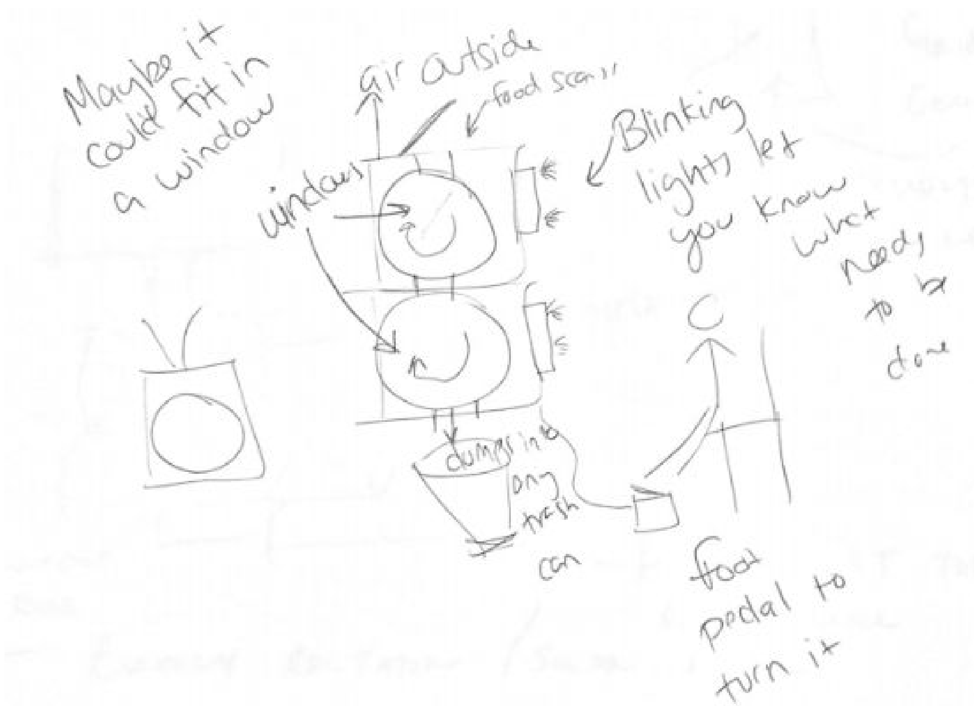
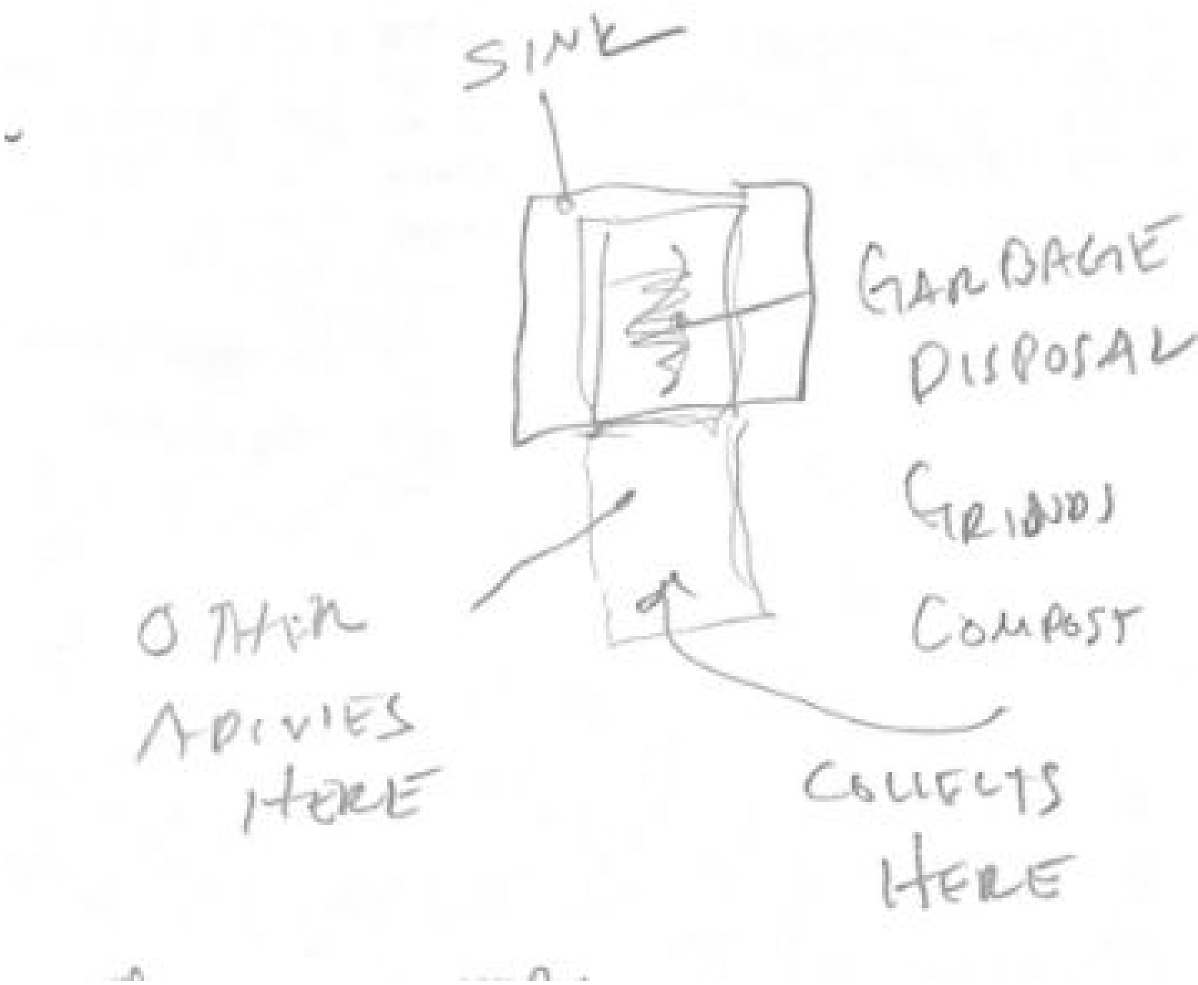
Chosen: Wall Mount Compost Bin With Visible Composting

Concept Description: This concept idea was to mount a compost bin on the wall, put compost in the top, the compost would then move in a cycle from the first round bin to the second round bin, and then dumped out of the bottom of the second bin when ready to dispose. Interesting features to this idea is that it has an air vent to the outside and a solar panel mounted on the air vent to power the device for movement. This design meets the requirement by being small, the smell is vented to the outside, there is uninterrupted flow of compost with the two bins, it is easy to use, and low maintenance since it powers itself.



Chosen Concept: Compost Bin Attached to Garbage Disposal

Concept Description: This concept idea attaches a collection bin underneath a sink just past the garbage disposal. This concept meets the design specifications by being small, odor free, and it should have a low touch time and easy to dispose. It doesn't require electricity, but would require a technician to install.



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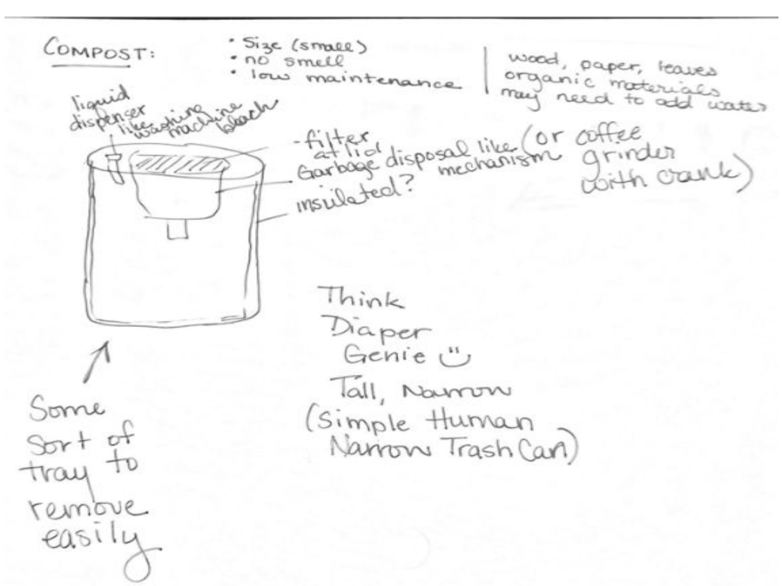

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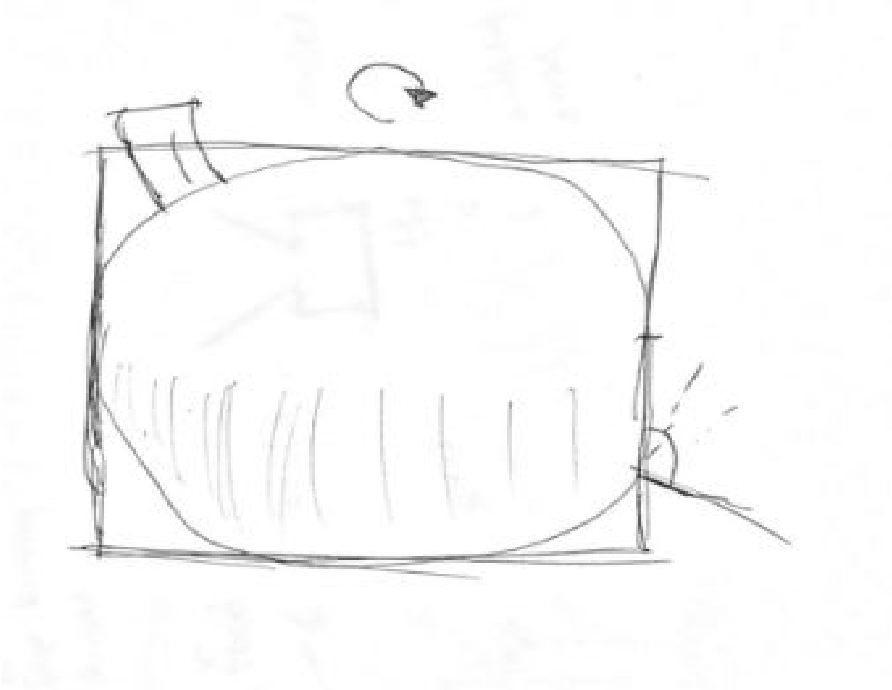

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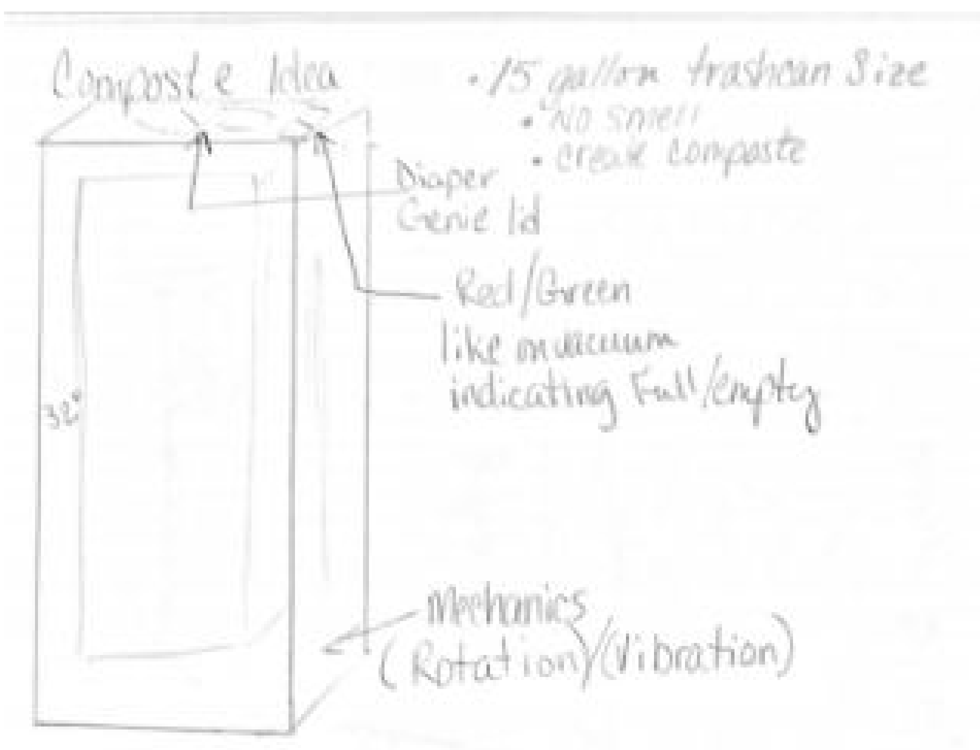

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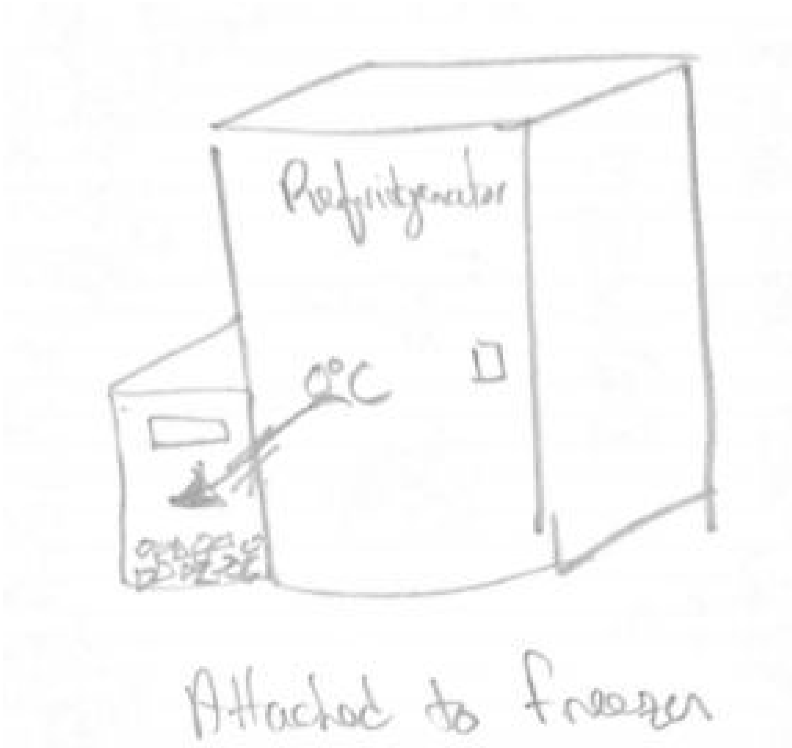
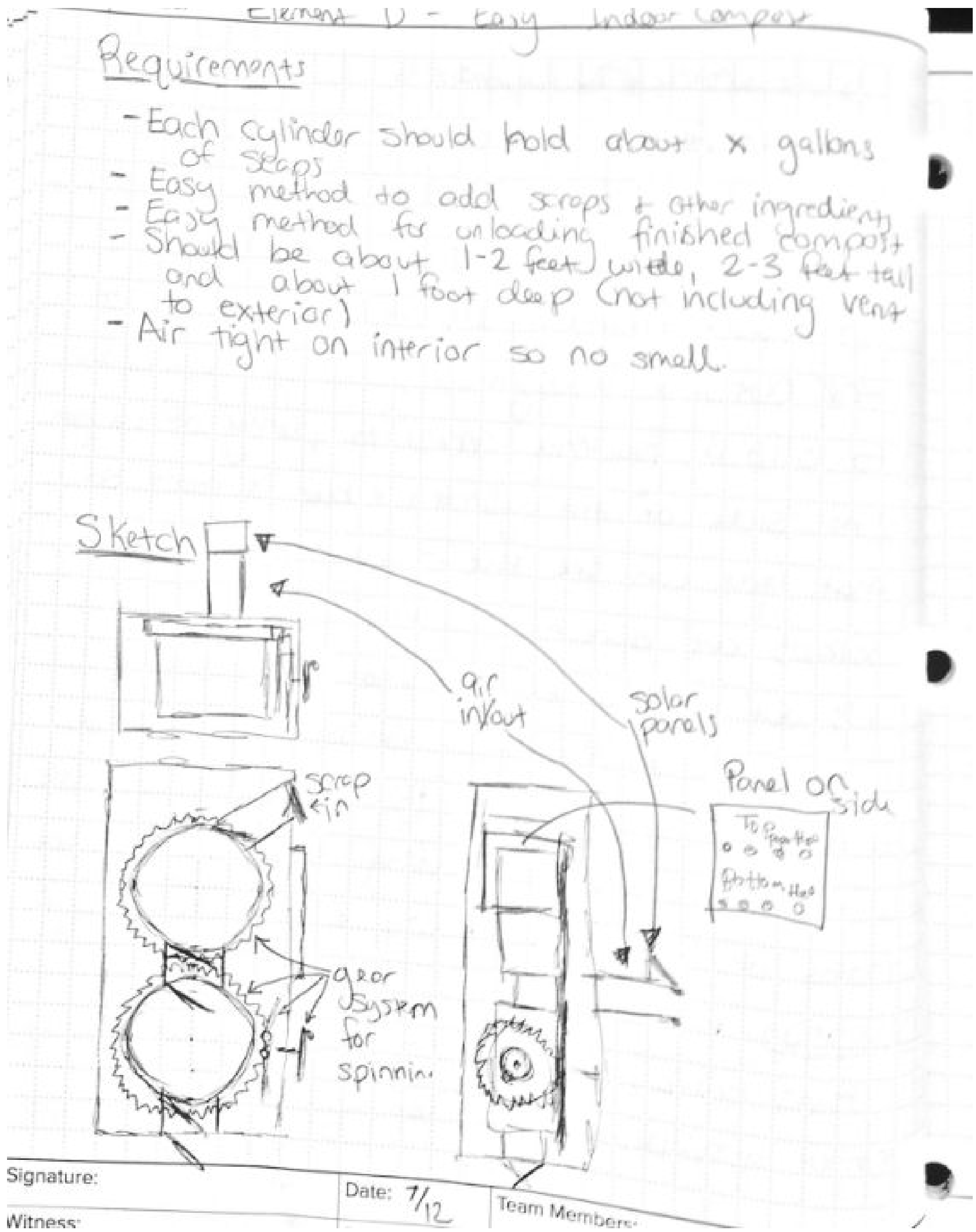


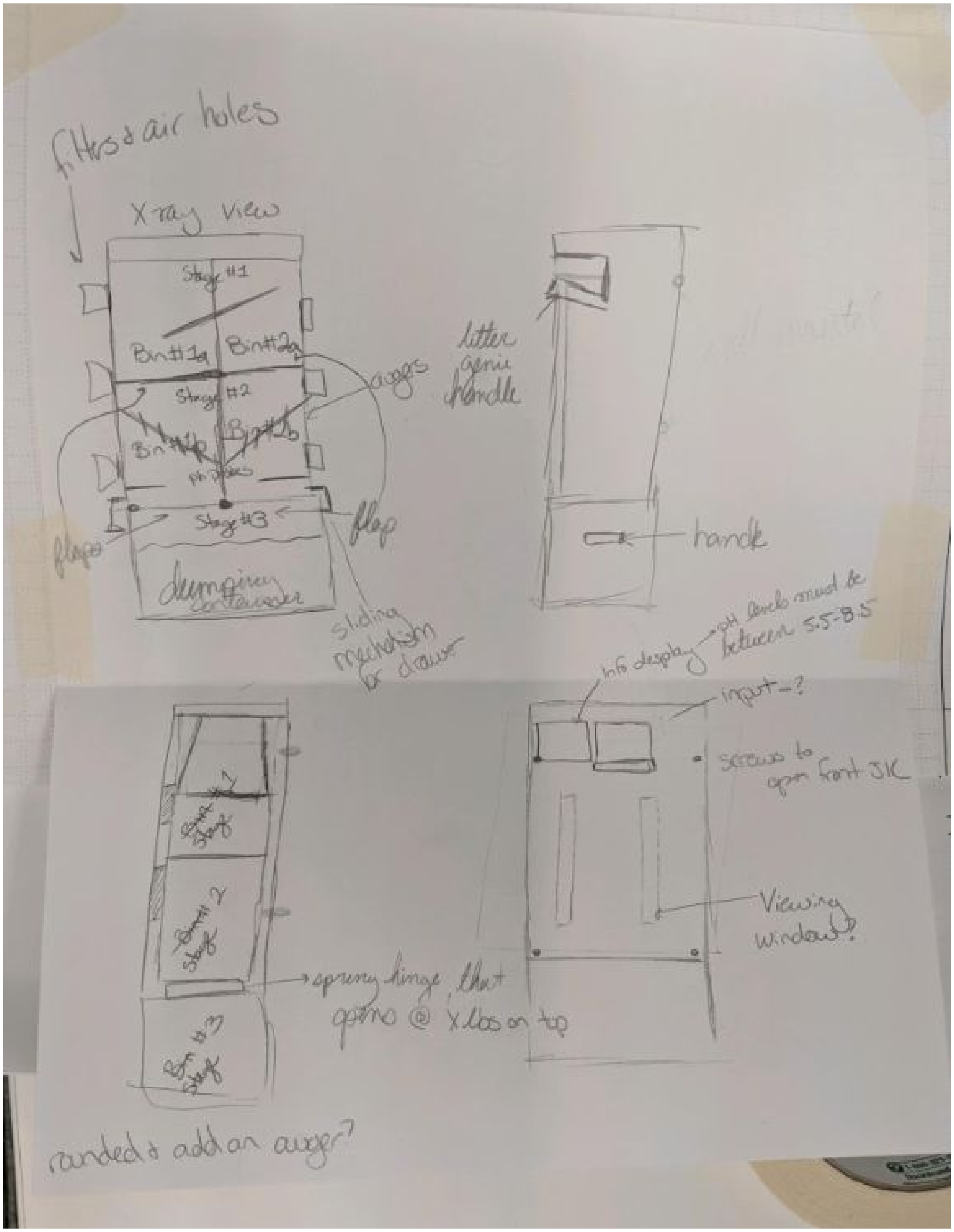
Developed Concepts

At this point our group chose four of the brainstorming ideas to investigate further to determine how well each of them would truly meet the design requirements. The following are our notebook sketches and description of how the idea will perform.

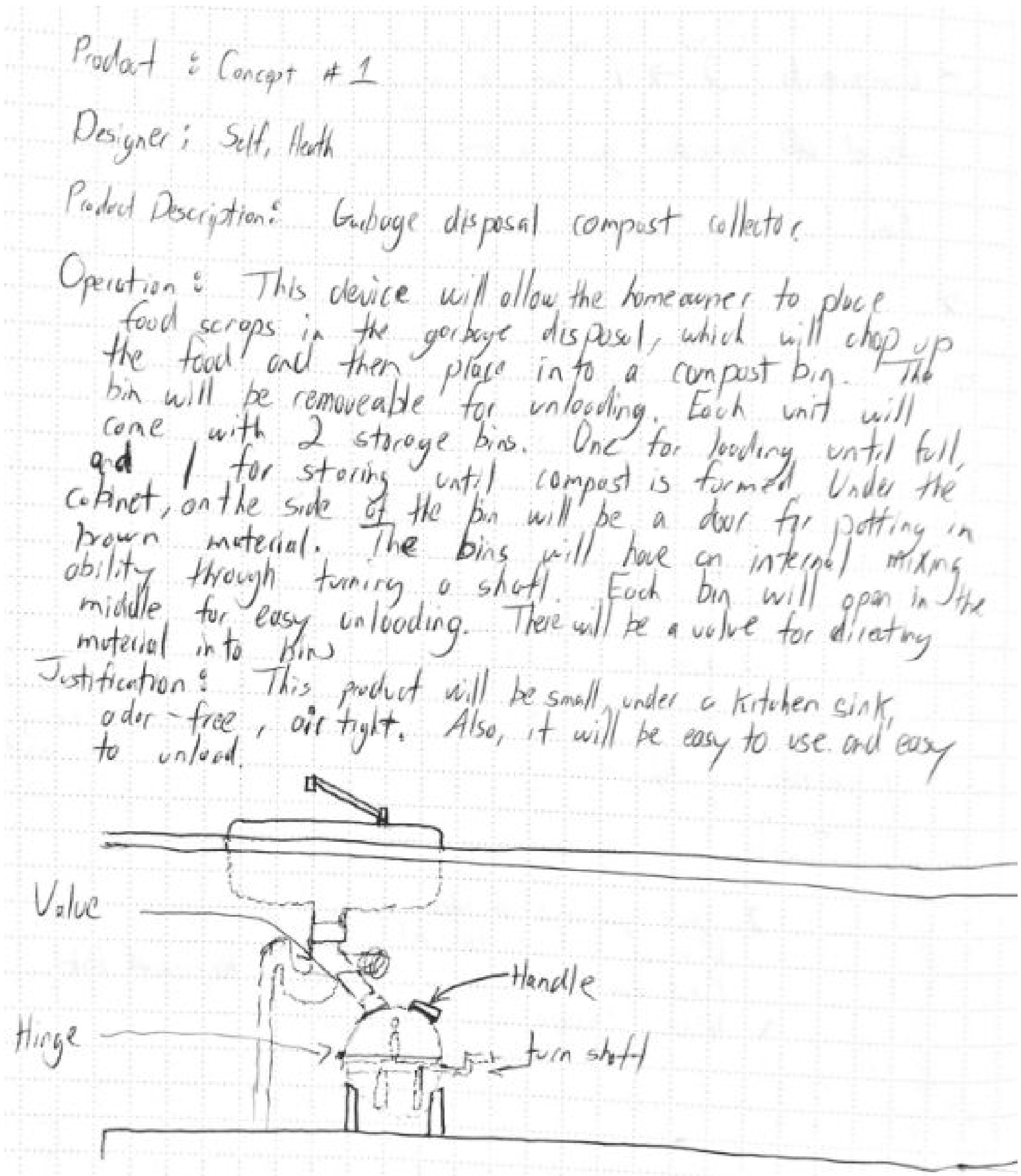
Concept: Wall Mount Compost Bin With Visible Composting



Concept: Dual Bin Composter



Concept: Compost Bin Attached to Garbage Disposal



Product: Concept #1

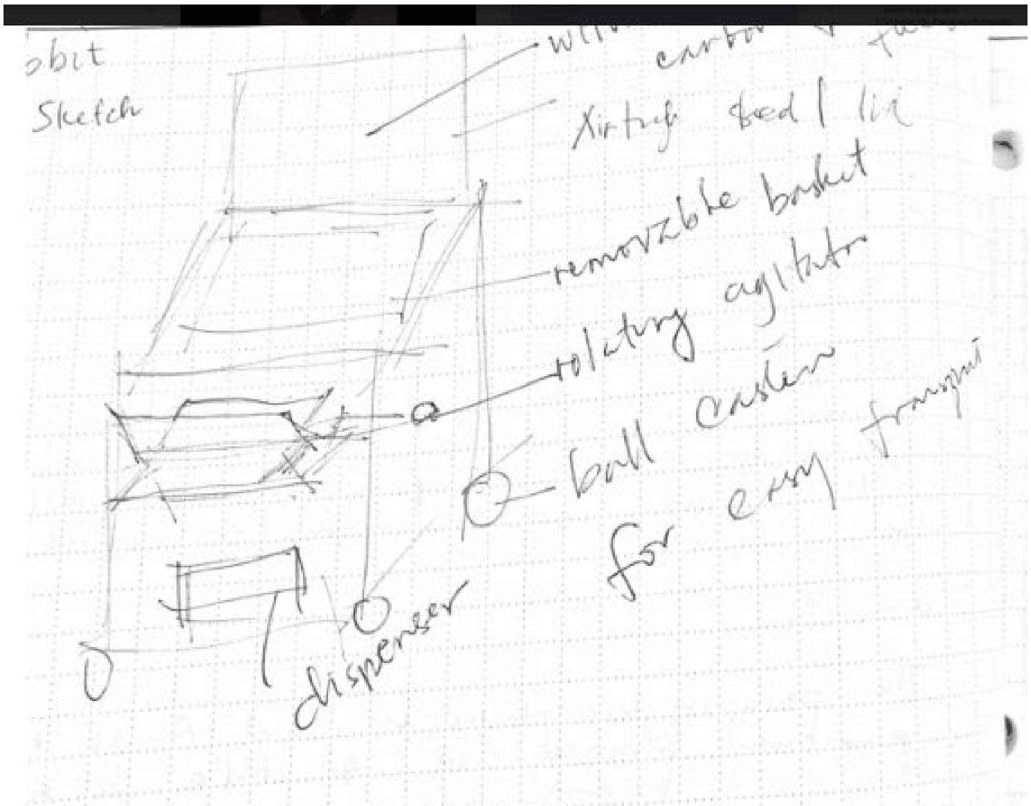
Designer: Self, Heath

Product Description: Garbage disposal compost collector

Operation: This device will allow the homeowner to place food scraps in the garbage disposal, which will chop up the food and then place into a compost bin. The bin will be removeable for unloading. Each unit will come with 2 storage bins. One for loading until full, and 1 for storing until compost is formed. Under the cabinet, on the side of the bin will be a door for putting in brown material. The bins will have an internal mixing ability through turning a shaft. Each bin will open in the middle for easy unloading. There will be a valve for directing material into bins

Justification: This product will be small, under a kitchen sink, odor-free, air tight. Also, it will be easy to use and easy to unload.

Concept: Movable Compost Bin



Concept Comparison:

At this point our group compared each concept that we developed, determined how well each concept met design requirements, and used the results of our decision matrix to determine which concept to build a prototype with.

Product Solution Decision Matrix

New Solution Matrix
Easy Indoor Compost

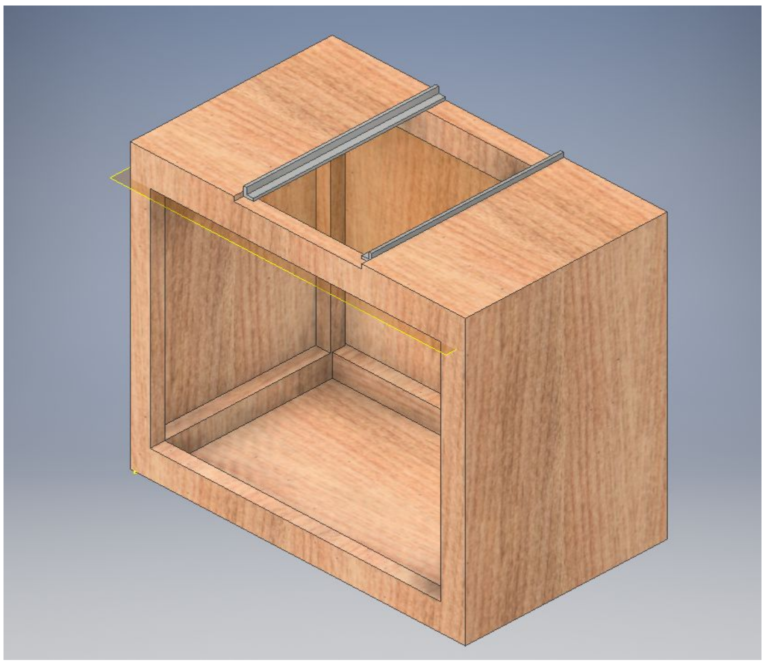
Scoring		Weighting	
Meets Requirements	2	Required	300%
Partially Meets Requirements/ Yes	1	Desired	200%
Does Not Meet Requirements/ No	0	Optional	100%

Requirement	Level of Importance	Ashley		Heath		Allison		Marlon	
		Score	Total	Score	Total	Score	Total	Score	Total
No Smell	9	2	18	2	18	2	18	2	18
Small Size	8	2	16	2	16	2	16	2	16
Composts	7	2	14	2	14	2	14	2	14
Low Touch Time	6	1	6	1	6	1	6	1	6
Intuitive	5	1	5	0	0	2	10	2	10
Ease of Disposal	4	2	8	1	4	2	8	1	4
Durable	3	2	6	2	6	2	6	2	6
Uninterrupted Input	2	2	4	2	4	2	4	1	2
No Electricity	1	1	1	1	1	0	0	2	2
			78		**69**		**82**		**78**

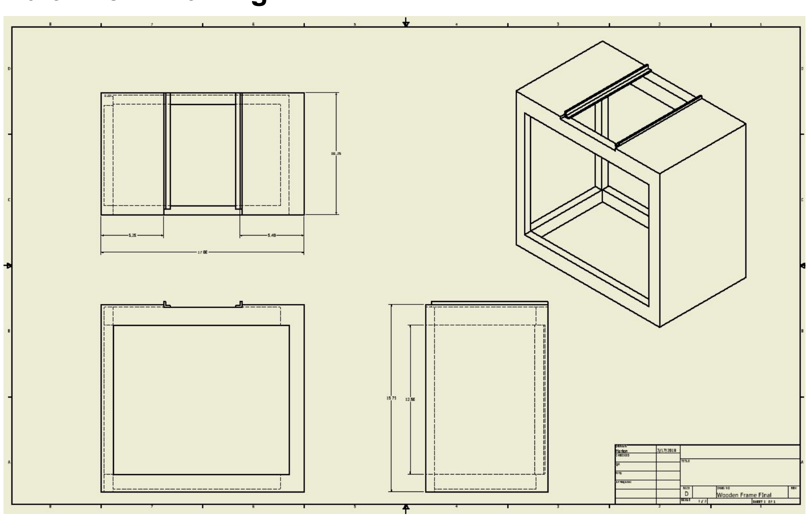
Concept Conclusion:
After our group compared the different concepts we chose to formulate a hybrid version that used features of the dual bin composter and the wall mount composter. Our design will have a single bin on top to collect compostable material, and a rotatable bucket on bottom with a window to watch the composting process. It will be small, have non-interrupted flow, non electric, and vented to produce compost without smell. The following technical drawing show the individual systems within our idea.

Technical Drawings

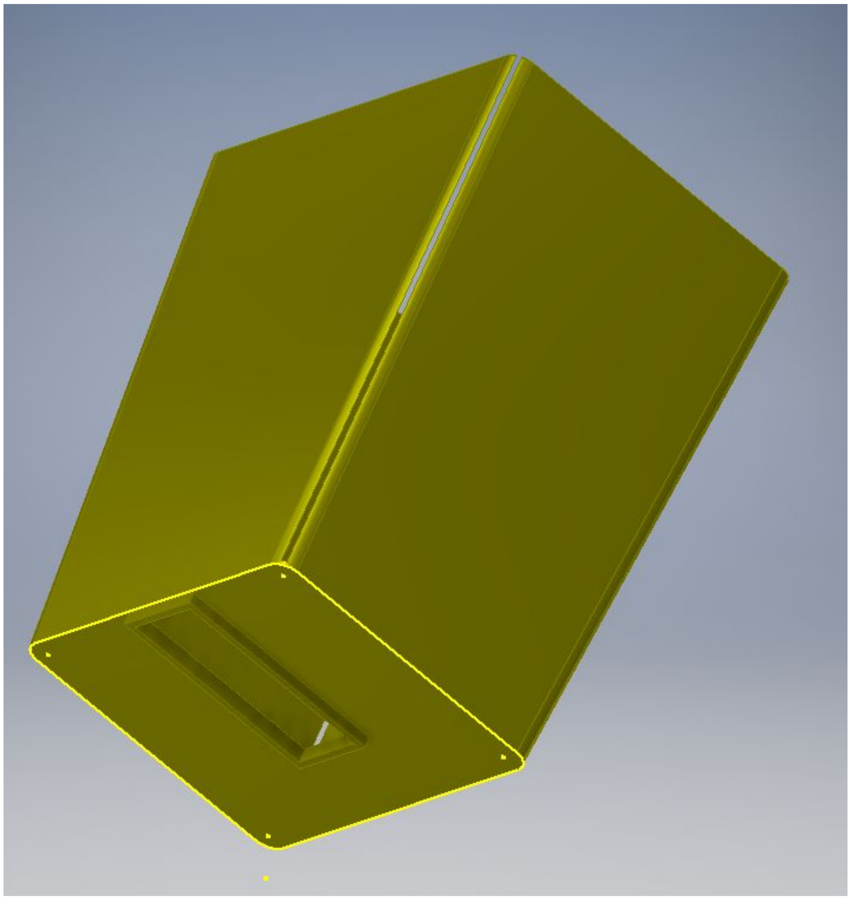
Wooden Frame



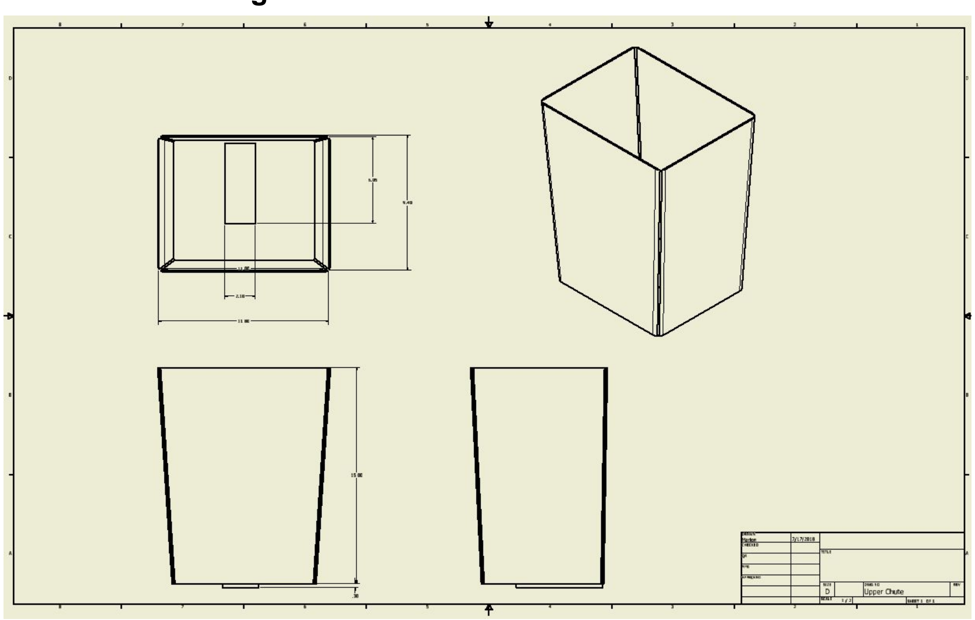
Multi-View Drawing



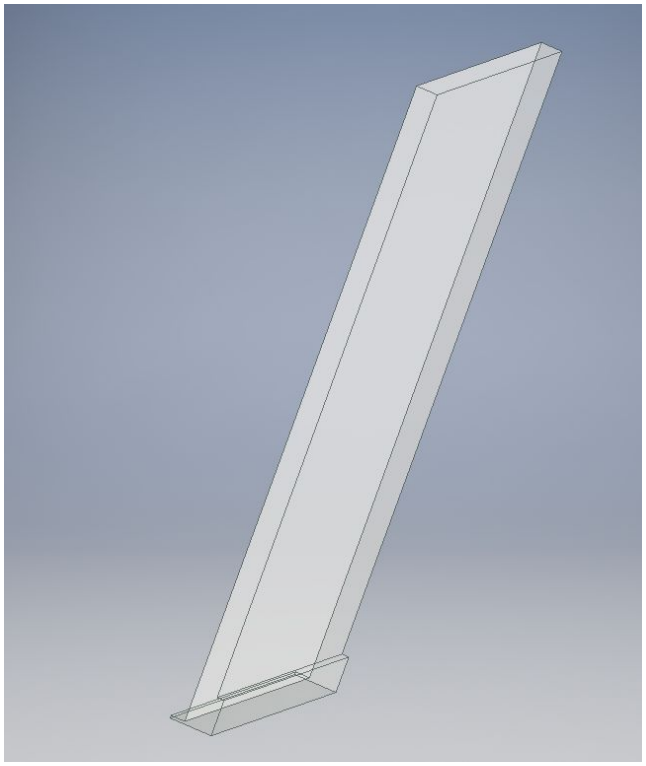
Bin:



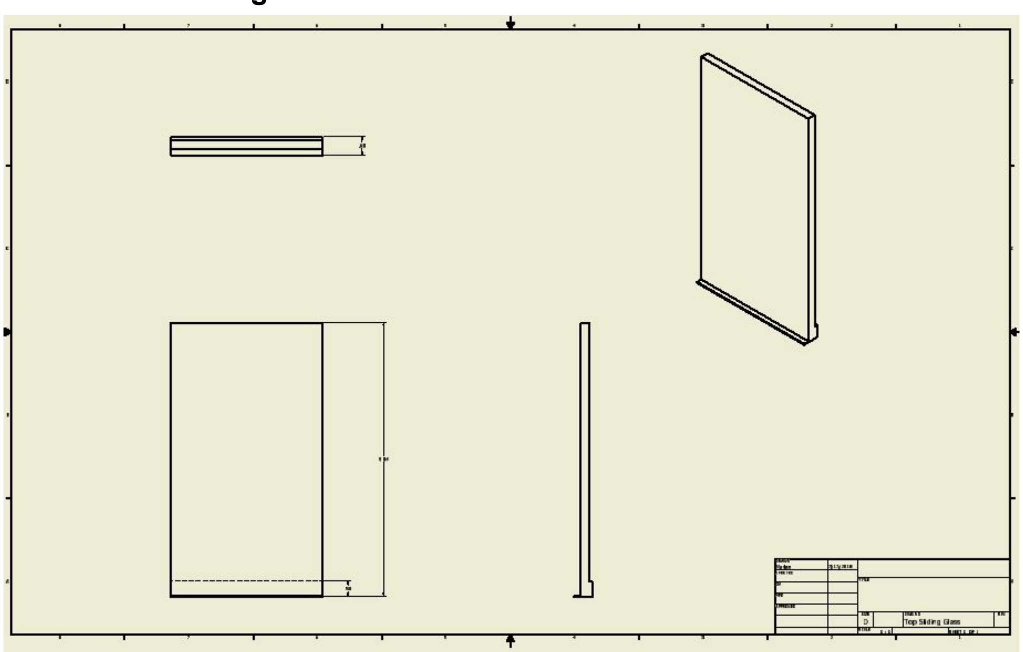
Multi-View Drawing



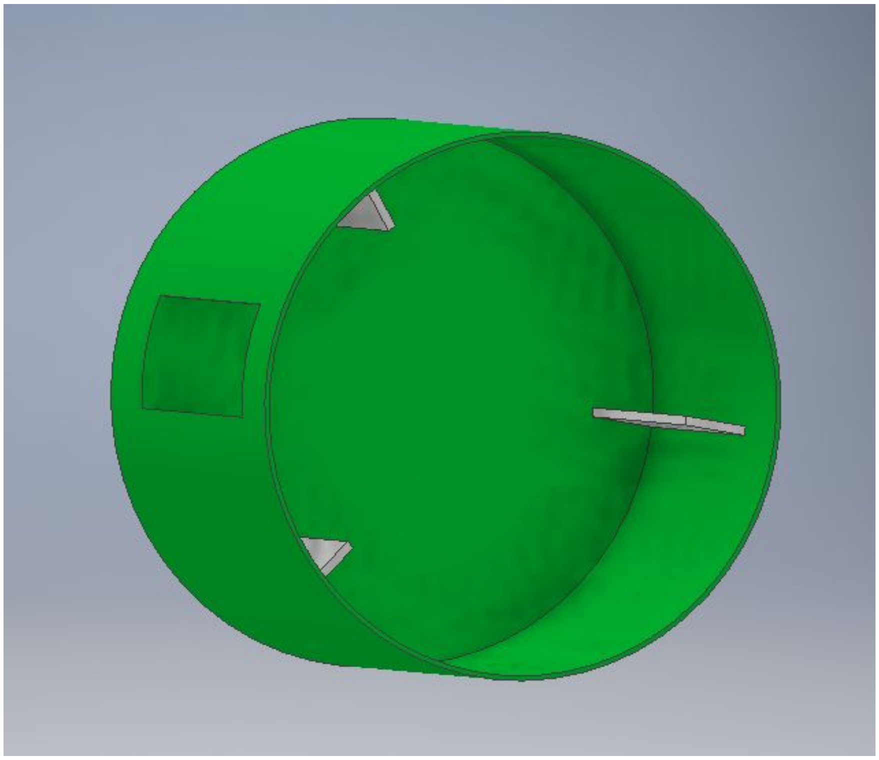
Sliding Glass Cover for Bin:



Multi-View Drawing



Compost Barrel



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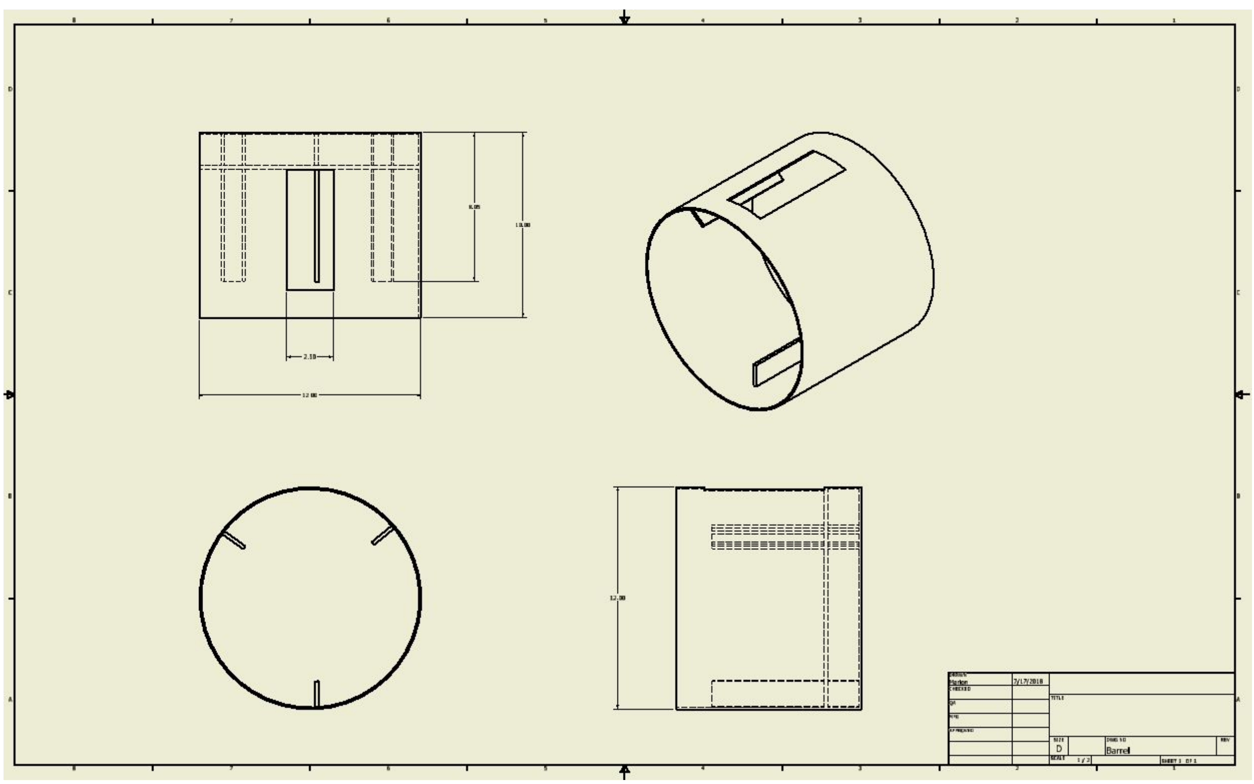
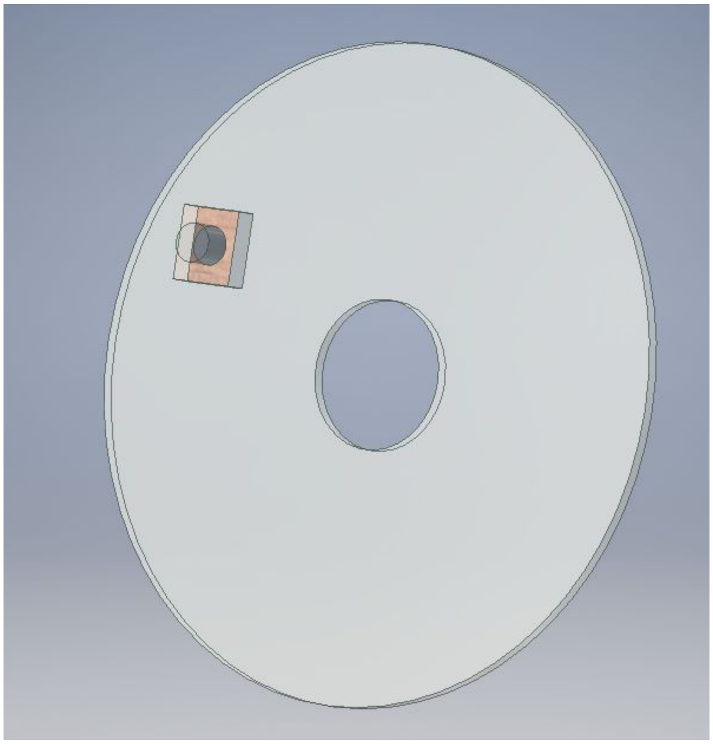
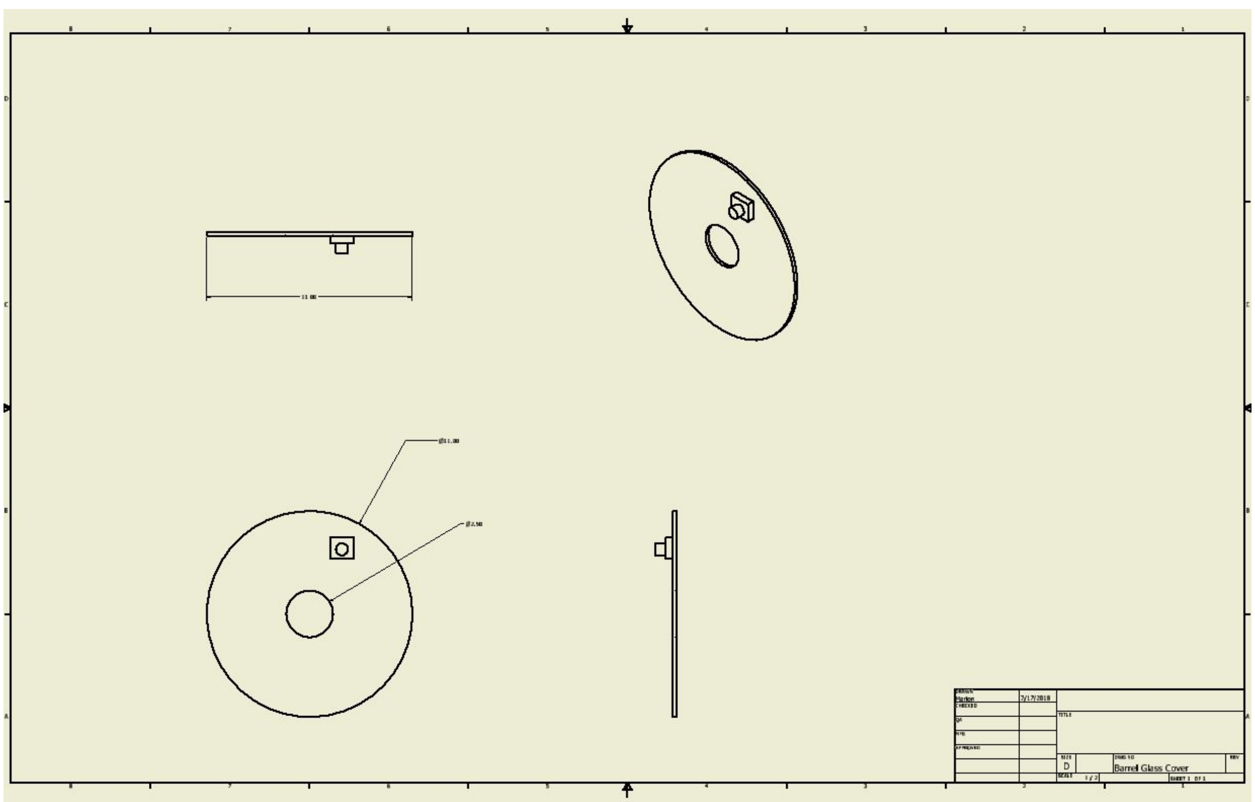


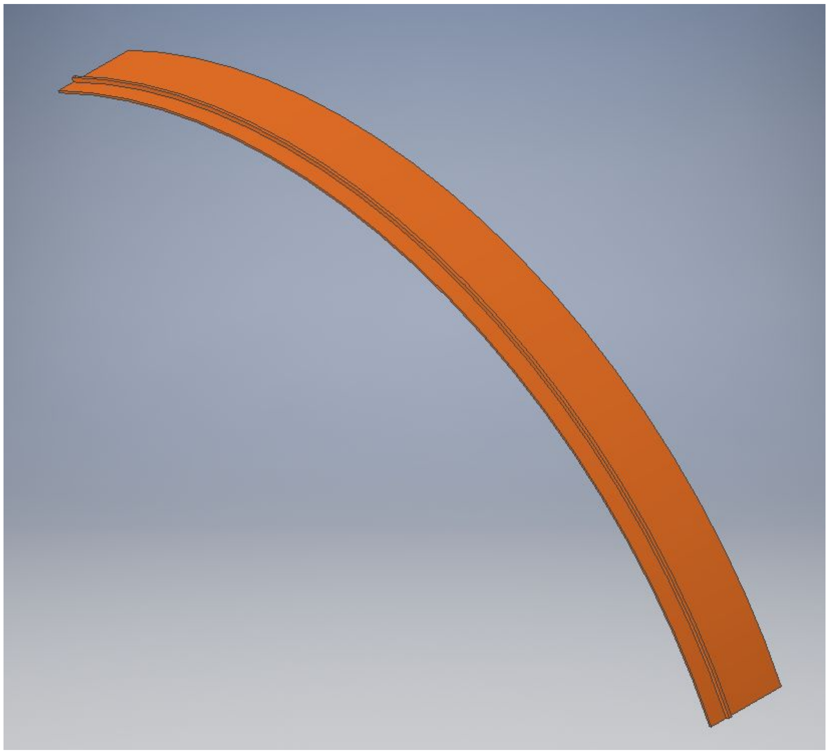
Barrel Glass Cover:



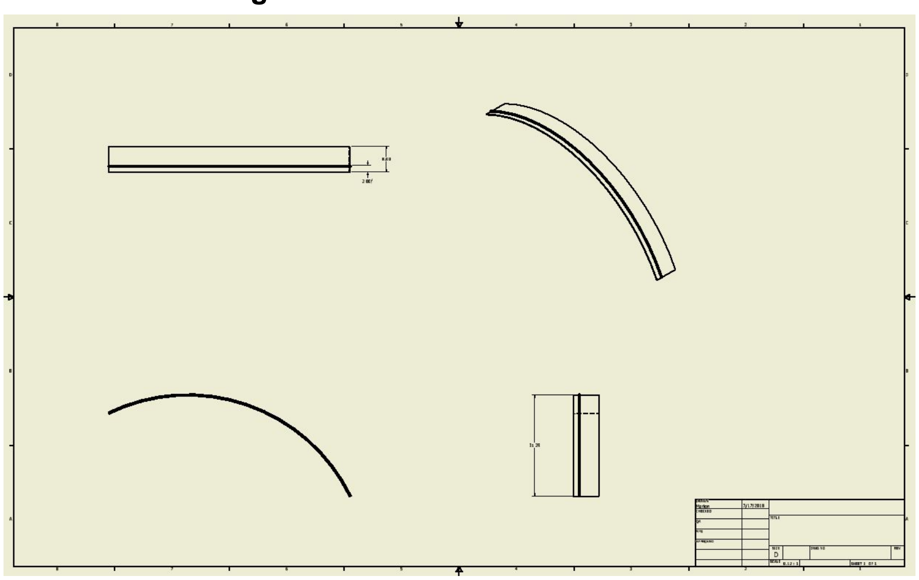
Multi-View Drawing



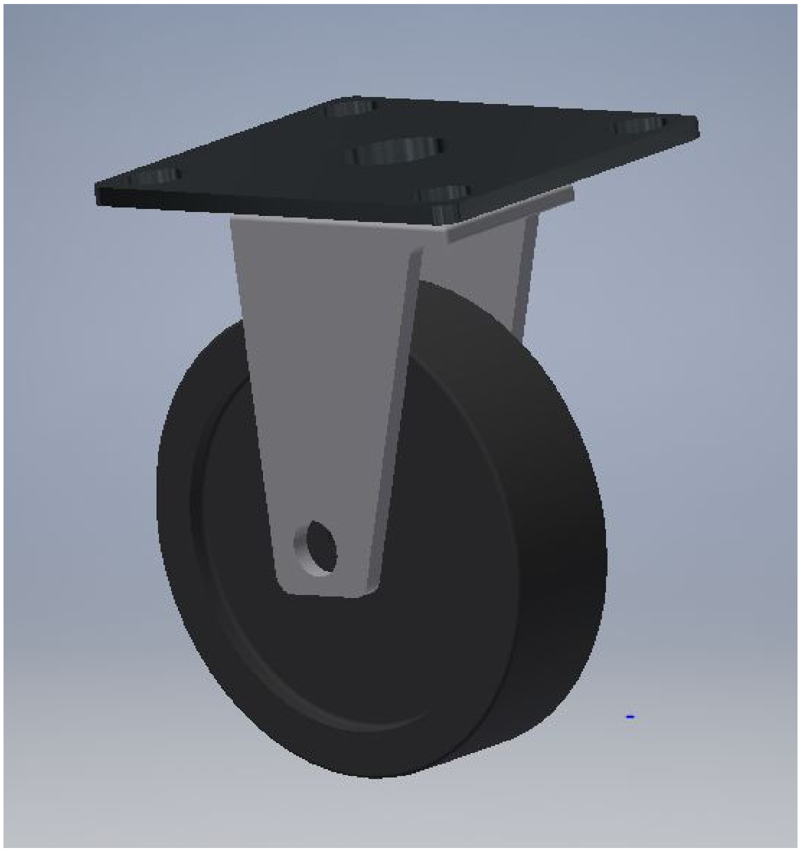
Sliding Cover for Barrel:



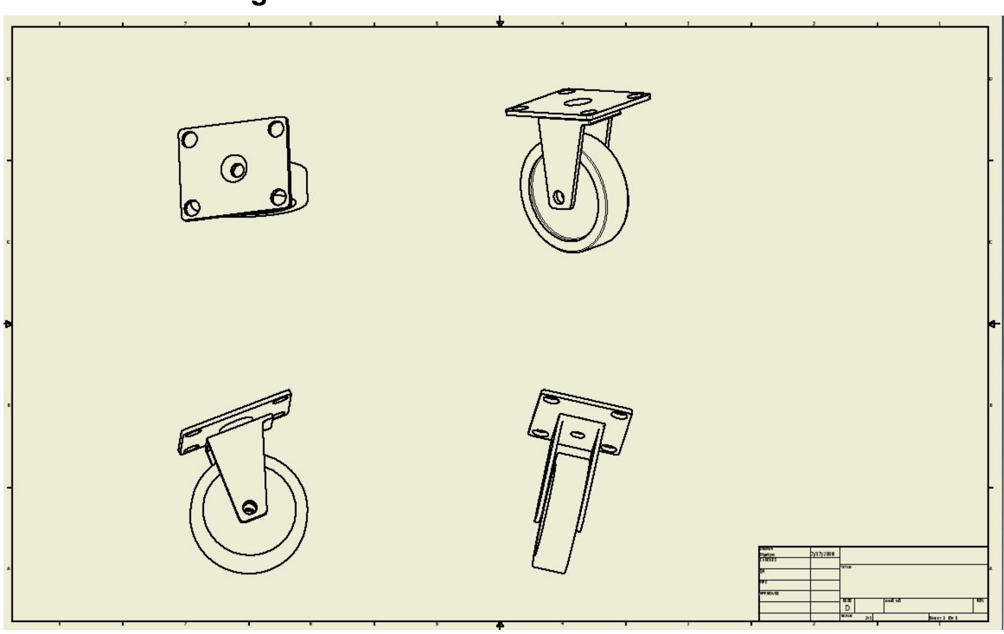
Multi-View Drawing:



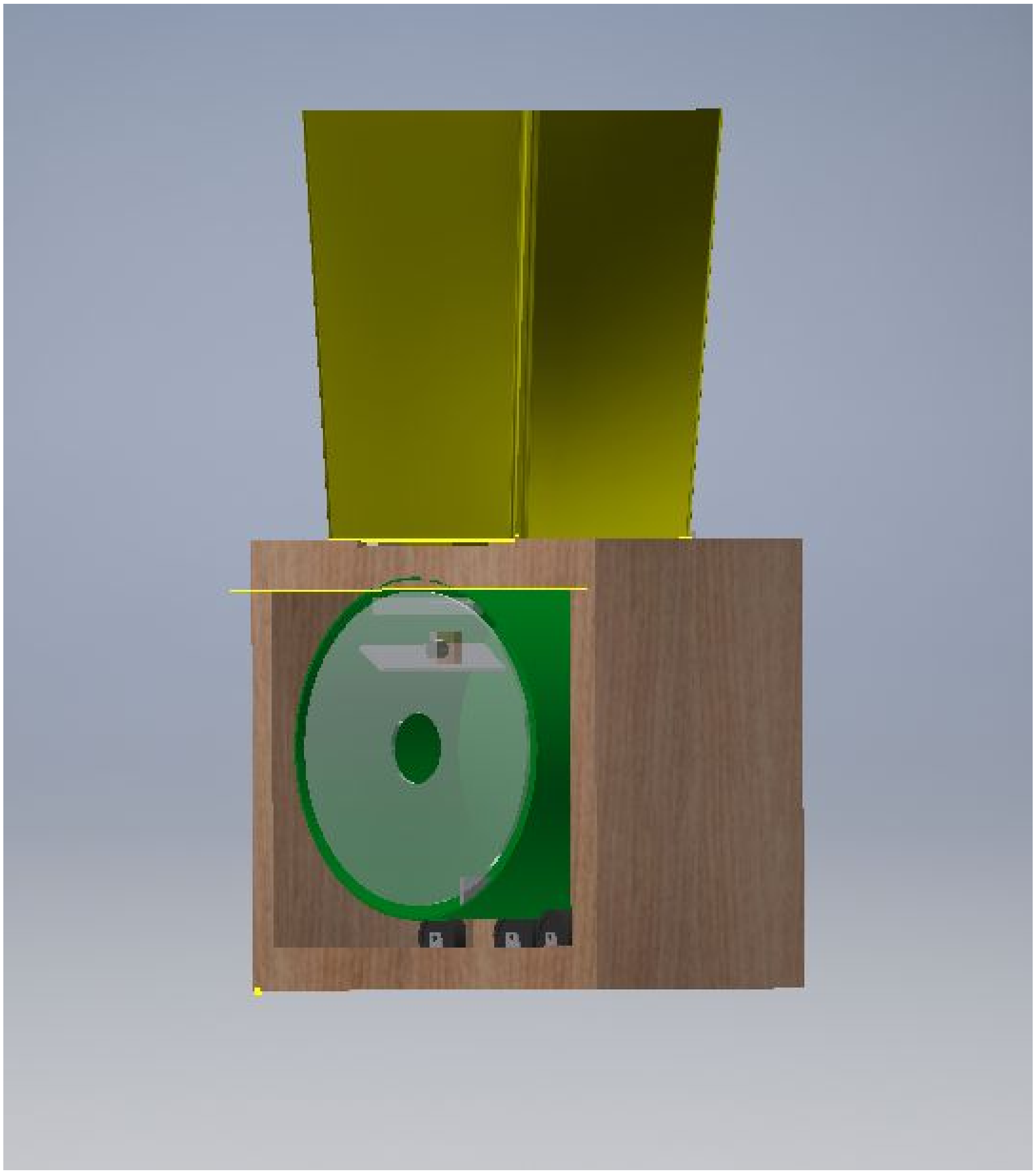
Wheel Caster Assembly



Multi-View Drawing



Indoor Composter Assembly



Element E | Application of STEM Principles and Practice

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Title:

STEM Principles:

① Size

a) The size of the whole thing has to be equal to or less than the volume of a 13 gallon trashcan in order to be able to fit in an average apartment.

Trashcan	Dimensions	Volume
Hefty touch-lid 13.3 gal	15.95 x 12.95 x 29.83	6,161.46 in^3
Hefty Step-on 13gal	15.50 x 13.20 x 24.9	5,094.54 in^3
Hefty Swing Lid 13.5gal	17.38 x 12.82 x 29.02	6,466 in^3
Rubbermaid Step-on 13gal	18.19 x 15.56 x 42.38	11,995.08 in^3

Our design is 33" x 14" x 10", so our volume is 4,620 in^3 which is smaller than a traditional 13gal trash can

b) Size of the bucket:

diameter: 13"
radius: 6.5"
height: cut to 9"

volume: $\pi r^2 h$

$\pi(6.5)^2(9) = \underline{1,194.6}\ in^3$

Signature: | Date: | Team Members:

Witness: | Date:

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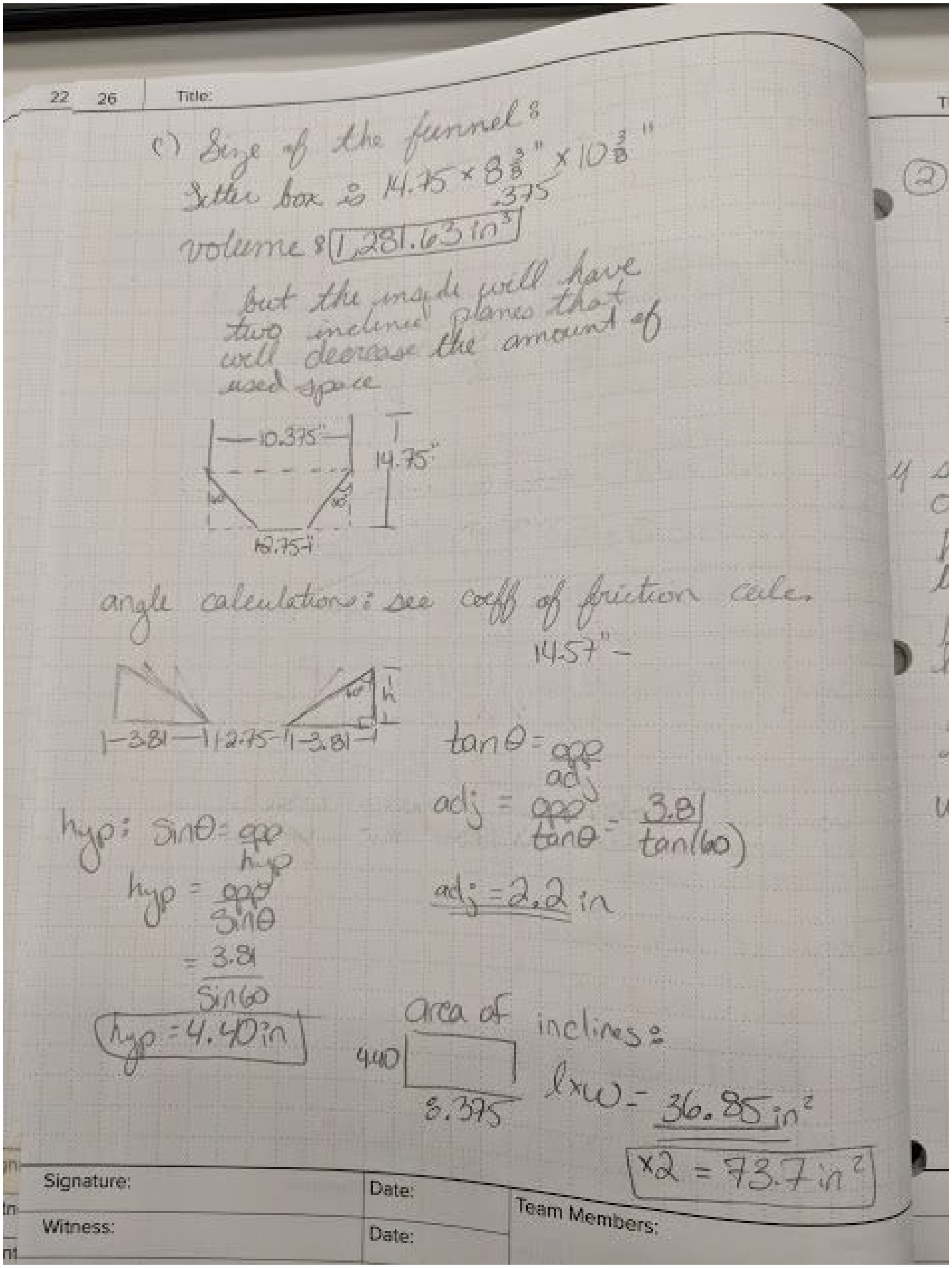
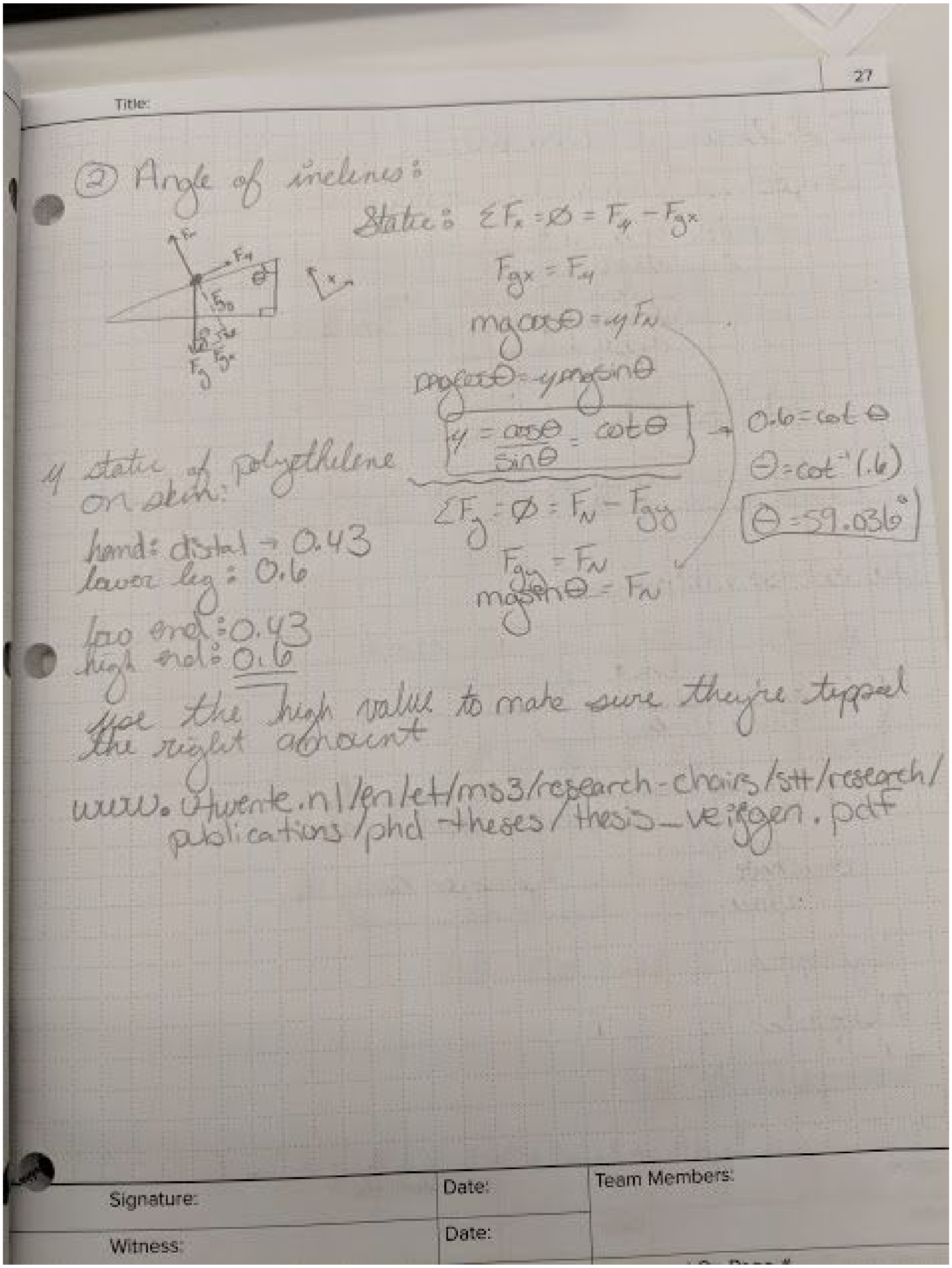

22 26 Title:
c) Size of the funnel:
litter box is 14.75 × 8 3/8" × 10 3/8"
.375
volume: 1,281.63 in³
but the inside will have two incline planes that will decrease the amount of used space
10.375"
14.75"
60
60
2.75"
angle calculation: see coeff of friction calc.
14.57"
h
3.81
2.75
3.81
tanθ = opp/adj
adj = opp/tanθ = 3.81/tan(60)
adj = 2.2 in
hyp: sinθ = opp/hyp
hyp = opp/sinθ
= 3.81/sin60
hyp = 4.40 in
area of inclines:
4.40
8.375
l×w = 36.85 in²
x2 = 73.7 in²
Signature:
Date:
Witness:
Date:
Team Members:


27
Title:
② Angle of incline:
Static: ΣFx = Ø = Fμ − Fgx
Fgx = Fμ
mg cosθ = μFN
mg cosθ = μ mg sinθ
μ = cosθ / sinθ = cotθ
0.6 = cot θ
θ = cot⁻¹(.6)
θ = 59.036°
ΣFy = Ø = FN − Fgy
Fgy = FN
mg sinθ = FN
μ static of polyethylene on skin:
hand: distal → 0.43
lower leg: 0.6
low end: 0.43
high end: 0.6
Use the high value to make sure they're tipped the right amount
www.utwente.nl/en/et/ms3/research-chairs/stt/research/publications/phd-theses/thesis_veijgen.pdf
Signature:
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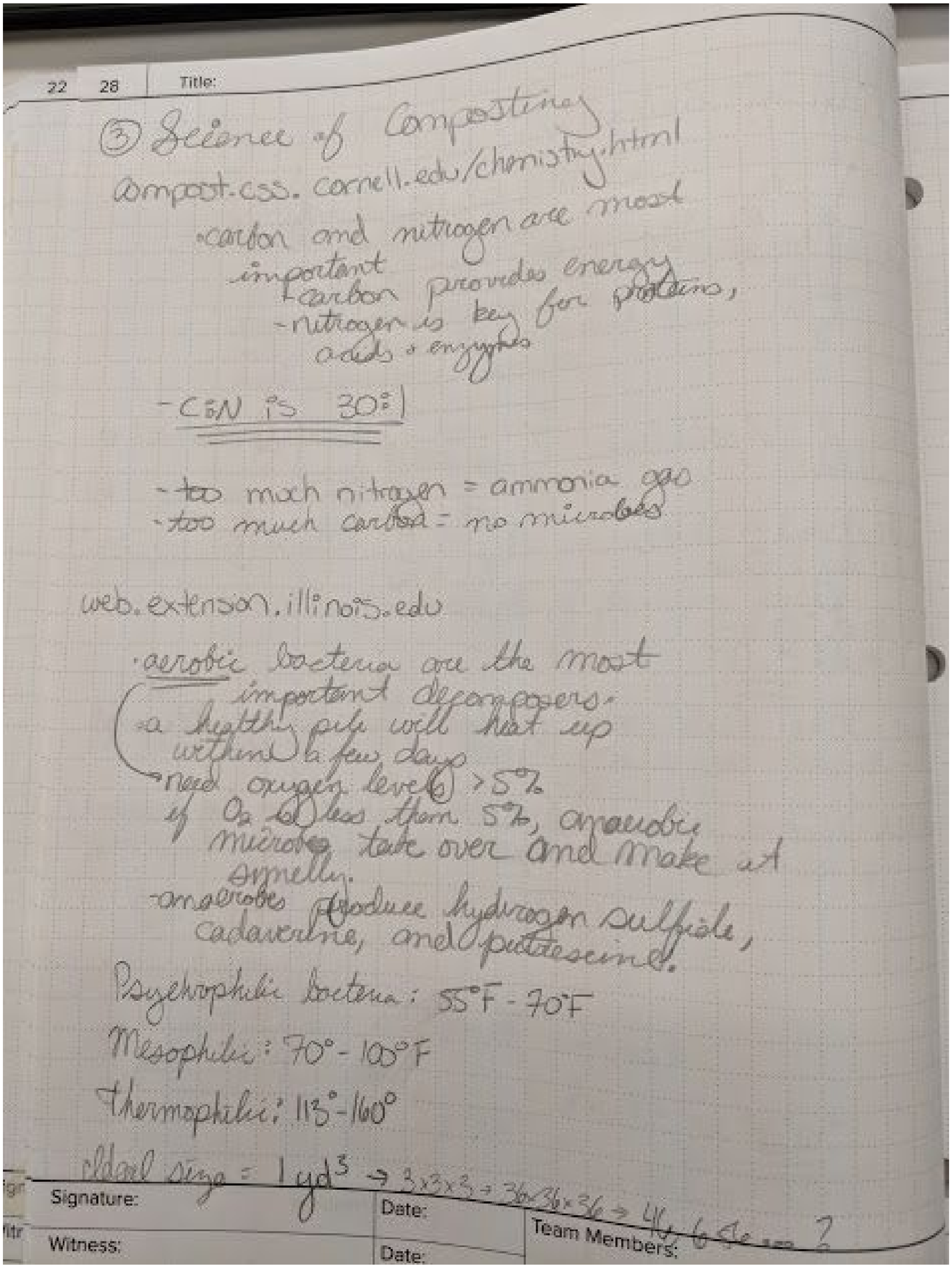
Team Members:
Witness:
Date:



22 28 Title:

③ Science of Composting

compost.css.cornell.edu/chemistry.html

- carbon and nitrogen are most important
  - carbon provides energy
  - nitrogen is key for proteins, acids + enzymes

- C:N is 30:1

- too much nitrogen = ammonia gas
- too much carbon = no microbes

web.extension.illinois.edu

- aerobic bacteria are the most important decomposers.
- a healthy pile will heat up within a few days
- need oxygen levels > 5%

if O_2 is less than 5%, anaerobic microbes take over and make it smelly.

- anaerobes produce hydrogen sulfide, cadaverine, and putrescine.

Psychrophilic bacteria: 55°F - 70°F

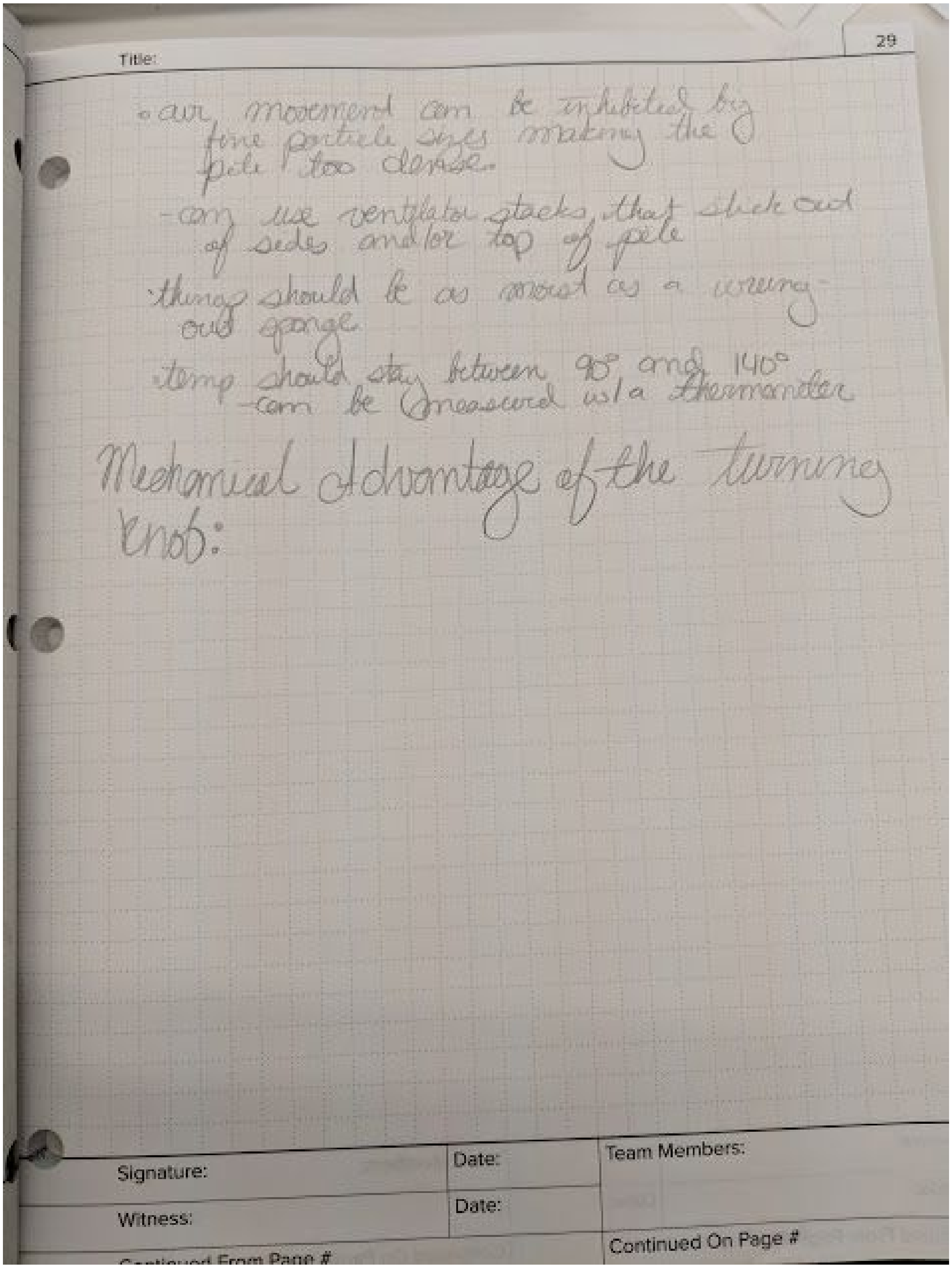
Mesophilic: 70° - 100°F

Thermophilic: 113°-160°

Ideal size = 1 yd³ → 3x3x3 → 36x36x36 → 4ft, 6 ft ?

Signature: Date:

Witness: Date: Team Members:



29

Title:

- air movement can be inhibited by fine particle sizes making the pile too dense.
  - can use ventilator stacks that stick out of sides and/or top of pile
- things should be as moist as a wrung-out sponge
- temp should stay between 90° and 140°
  - can be measured w/a thermometer

Mechanical Advantage of the turning knob:

Signature: | Date: | Team Members:

Witness: | Date:

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Element F | Design Viability

Design Viability

Problem Solving

The first design consideration is does it satisfy the requirement of being an indoor solution to composting people will want to use. While presenting our initial solution our Master PLTW teacher, Brian Rickard, he mentioned he would be interested in buying something like this. We interviewed him once we had finalized our design further as a stakeholder that is both a gardener and potential consumer of our product. After going over it Brian said “I think I would utilize something like that.” He further mentioned that he would want it to look nice so that he could put it somewhere everyone could see it. It’s less cumbersome than the current method he uses outdoors so he is more likely to use it.

Manufacturability

While determining how to build a prototype there were many readily products that we were able to re-purpose for our first iteration. A simple kitty litter container and a 5 gallon bucket made up the majority of the components. They were supplemented with some wood and screws for framing and some mechanisms for needed flaps. By working on the prototype it is evident this will be able to be easily manufactured.

Simplicity

The planned overall function of the design will make it easy and straightforward for people to turn their food scraps into compost from the comfort of their home. The easy flap load allows the user to add food quickly The compost tub can be easily removed to distribute compost in appropriate location seamlessly. The food scrap holder will have a slide out bottom allowing it to drop to the compost tub seamlessly.

Environmentally Friendly

The design will save 250 pounds per house per year of trash that would normally be destined for the landfill. Instead it will provide valuable compost that is great for potted plants, gardens or even lawns. The appealing design of this allows for it to be prominently displayed as a conversation piece which will encourage others to compost food scraps also.

Laws and Regulations

Some cities and states are implementing laws to prevent food and yard waste from making its way into landfills. Two cities in particular, Seattle, WA and San Francisco, CA, have been at the forefront of this and have enacted residential requirements that food waste must make it in to the yard waste bin, not the garbage. The local garbage company then ensures that food and yard waste is turned into compost.

List of Obstacles

The following obstacles have been identified as needing to be tackled in order to have a marketable prototype. They have been prioritized in the order that we plan to tackle them.

1. Design needs to remain within 5100 cubic inches.
2. Compost cylinder should easily rotate in a way that properly aerates material.
3. Flaps should function that allows easy flow from entrance as scraps exit as compost.
4. All openings should fully seal when closed to prevent leakage.
5. Walls need to be slick to ensure food glides down properly.
6. Will need a way to remove or add moisture as needed to the compost bin.
7. Design should make it obvious to user if proper carbon/nitrogen level is reached and if not a method for fixing.
8. The system needs to have no smell even when considering some misuse.
9. All fasteners and materials used must be protected to prevent fungal and bacterial growth.
10. Instructions for proper mounting to ensure it won’t tip or fall.

Element G | Construction of a Testable Prototype

Bill of Materials

- Plastic or similar to make slopes
- L brackets
- Wheels or rollers
- 2 5 gallon buckets with lid
- Weather stripping
- Agitator materials (metal T bracket)
- Door hinges, spring mechanisms and locks
- Plexiglass
- Kitchen Cabinet knob
- Carbon filters
- Wood
- Duct Tape
- Hot Glue
- Resin

General Building Process

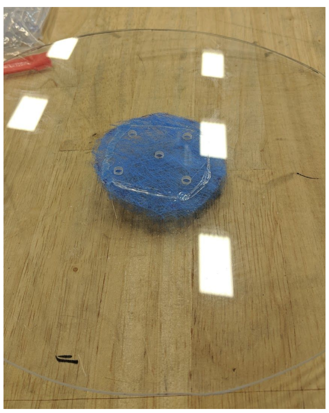
1) Compost Bucket

a) Remove handle from bucket
b) Cut the bottom of the bucket off 9” from the top (where the lid would go)

c) Cut a rectangular hole in the bucket that is 2.5” wide and 6.25” long. This hole should start 1.5” below the top of the bucket.

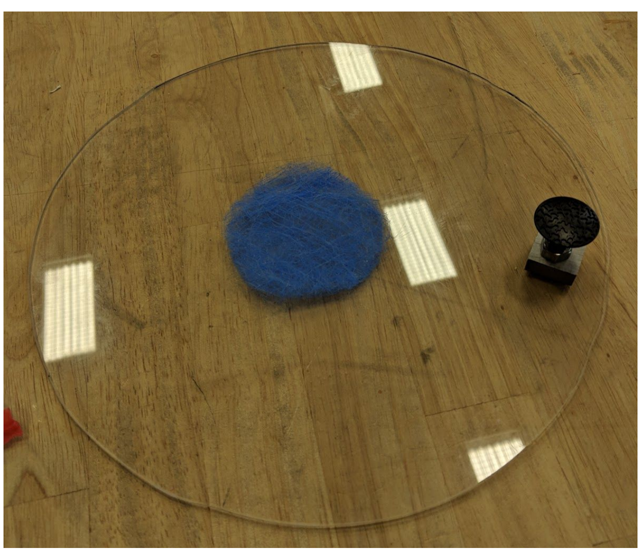
d) Cut out a circular piece of plexiglass with the same diameter as the now-cut bottom of the bucket.

e) Drill at least five holes in the center of the plexiglass and one hole 4.75” away from the center.



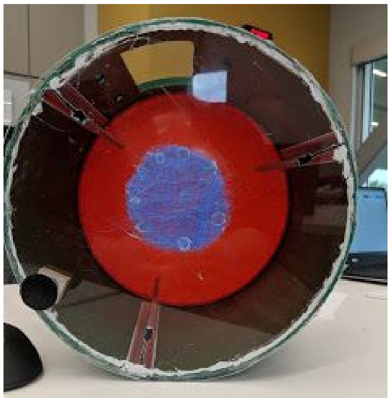
f) Glue three small plastic L-brackets in a U shape around the holes to create a slide-in pocket for a carbon filter.

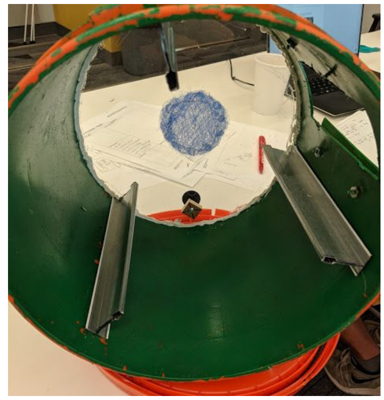
g) Assemble the kitchen cabinet knob in the hole 4.75” away from the center.



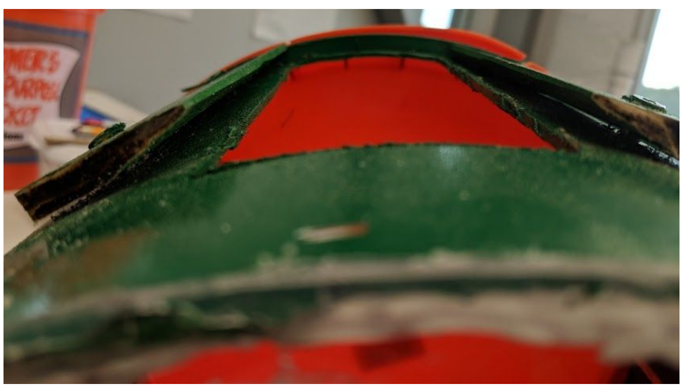
h) Attach the plexiglass circle to the now-open base of the cut bucket with caulk and allow to set.

i) Cut a strip of aluminum t-bracket into 3 nine-inch strips. Use epoxy to attach these t-brackets in even increments around the inside of the barrel to act as agitators.



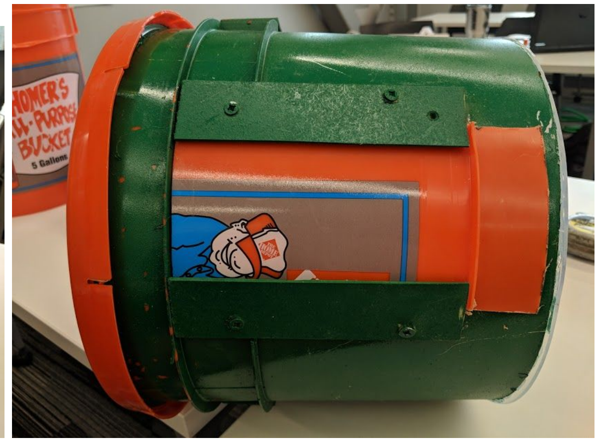


j) Cut two 6.25”x3” pieces of fiberboard and bevel one side of each. Err on the side of keeping a slope that is too low as opposed to a steep slope. Use wood screws to attach these pieces on either side of the rectangular hole in the bucket, lining them up at the end closest to the lid of the bucket. Make sure the beveled edges are facing the bucket and create a slot for another piece of plastic.



k) From a separate bucket, cut a 8”x4” section of the bucket that includes a ridge. The 8” should be measured down the side of the bucket (top to bottom) and the 4” should be measured as part of the circumference. This way the curvature of this new slider matches the curvature of the rectangular hole in the bucket with the plexiglass.

l) Slide this new section of plastic into the beveled edges of the fiberboard and make sure it fits tightly.It should be able to slide in and out with a bit of resistance.

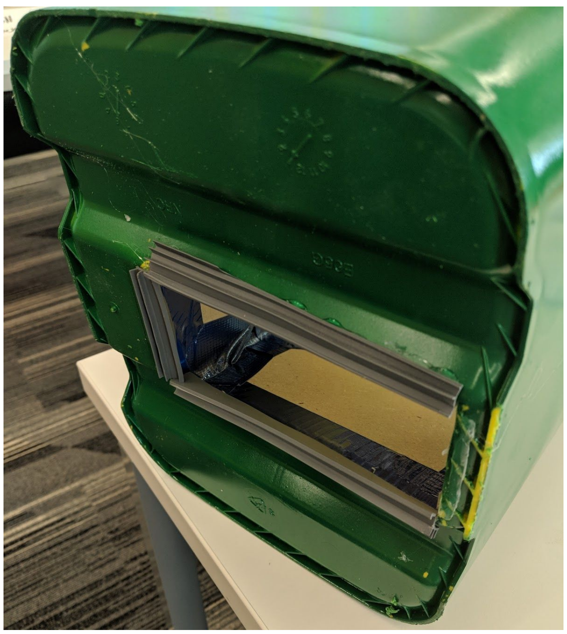



2) Scraps Bucket

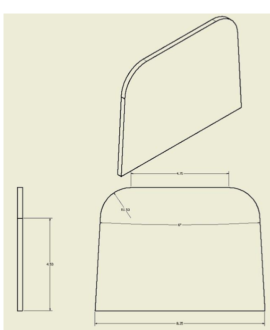
a) Start with a kitty litter container that is 11.5” deep, 14.5” high and 9.5” wide.
b) Remove handle.
c) Cut hole on the bottom of the container along middle depression, centered but 0.5” from front. Hole should be 2.5” wide and 5.5” deep.

d) Spray paint green.

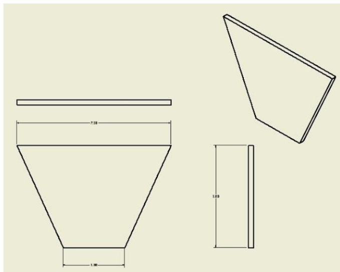
e) Add weather stripping to all four sides of hole. Take “XXX” weather stripping and hot glue onto ledges so stripping faces out. See below image for view of cut hole with weather stripping..



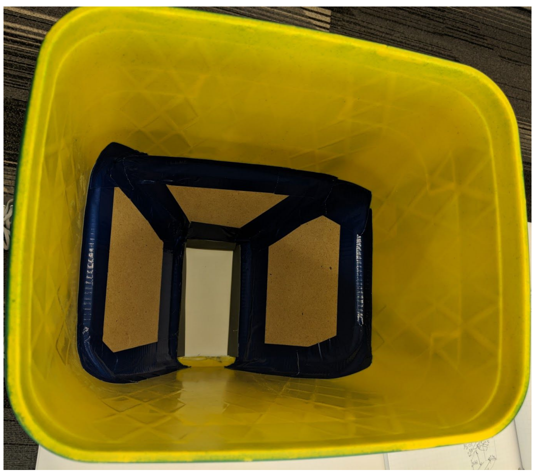
f) Cut 2 of the below template out of ¼ inch fiber board or similar to ensure proper sloping from sides towards the hole. The bottom should be along the slit and the top should rest on the side of the container. Duct tape was used to adhere to the bucket.



g) Cut 1 of the below template out of ¼ inch fiber board or similar to ensure proper sloping from back towards the hole. This should be sandwiched between the above side slopes. The bottom should be along the slit and the top should rest on the back of the container. Duct tape was used to adhere to the bucket.



h) Once all slopes are installed it should look as shown below. The dark blue is the duct tape holding the slopes in place.



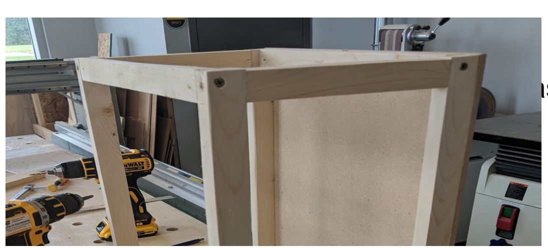
i) In the absence of resin or other coating material that maintains low friction, duct tape was used to cover the wood.

j) Add holes to the bucket in 2 rows, 1.5” and 4.5” from the top using a drill to ensure air flow.

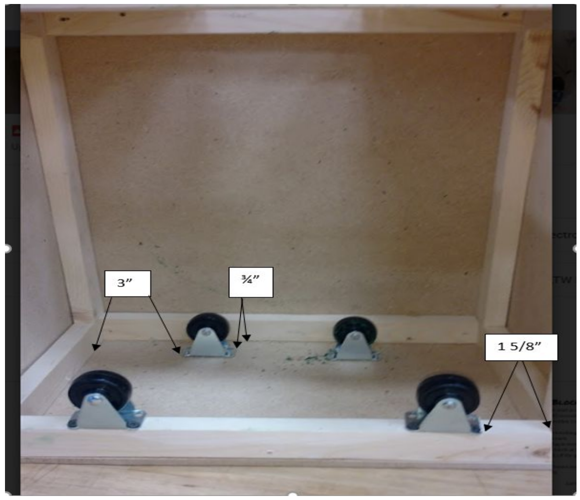
k) Add a sign to the front of the bucket with the instructions shown in picture below.

3) Compost Bucket Frame

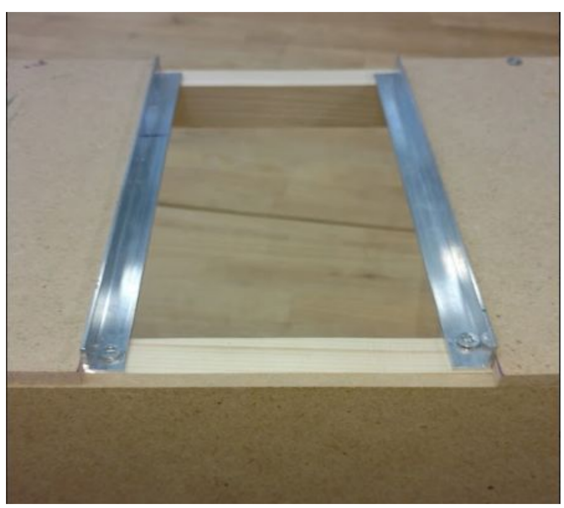
a) Cut wood frame pieces
   i) 15” x 4, 13.25” x 4, 7.25” x 4
b) Cut wood for sides of sides, bottom, and top of frame
   i) 15” x 15” back, 15” x 10” x 3 sides and bottom, 10” x 5” x 2 top pieces,
c) Screw wood frame pieces together. (see figure 1)
d) Screw wood sides onto frame. (see figure 1)
   i) Figure 1



e) Screw two rollers on the bottom, front frame piece 1 ⅝” away from the side frame piece. (see figure 2)
f) Screw two rollers on the bottom, side piece of wood ¾” from the back and 3” from the side. (see figure 2)
   i) Figure 2

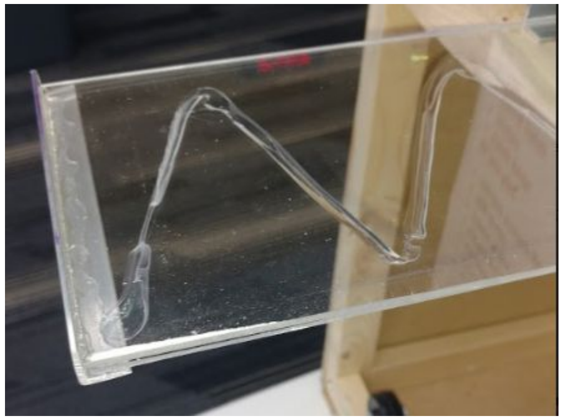


g) Cut two pieces of L channel 9” long, and 1 piece of L channel 5 “ long. (see figure 3)
h) Drill holes near the end of the two 9” pieces of L channel. (see figure 3)
i) Screw the 9” pieces of L channel to either side of 5” opening on the top of the frame, and glue the front of the L channels down to the wood. (see figure 3)
   i) Figure 3

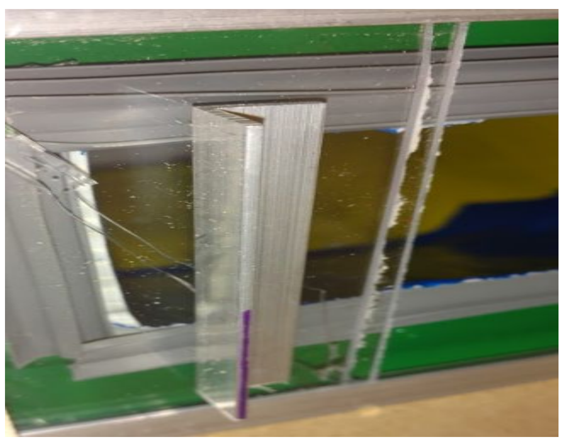


j) Cut two pieces of fiberglass 4 ¾” wide and 9” long. (see figure 4)
k) Glue the two pieces of fiberglass directly on top of one another. (see figure 4)

l) Glue the 5” piece of L channel to the front edge of the two glued pieces of fiberglass. (see figure 4)
m) Slide the fiberglass into the open slot on top of the frame (see figure 4)
    i) Figure 4



n) Cut a 3” piece of L channel and glue it the bottom of the fiberglass slide. Position it 1” from the back edge. (see figure 5)
    i) Figure 5



o) Bevel a rounded edge on the top, front frame piece 5” long and ½” tall. This allows the bucket to move in and out of the frame easier. (see figure 6)
    i) Figure 6

Design Element Challenges and Solutions

1) Compost Bucket

a) We spent a lot of time trying to figure out how to get scraps into the compost bucket without the compost coming out of the container when the container was rotated. Our first thought was to have a self-closing latch that was kept closed using a spring. The user would then push down on part of the flap to allow scraps to fall through from the top container. The problem we faced was that the hinge that we were going to use from Home Depot had much too high of a spring constant and would have deformed the bucket before opening the hatch. You can see the strain in the third knuckle

We then decided that another sliding mechanism like we were using with the scraps bucket would be appropriate. This is where Heath came up with the beveled fiberboard and slider from another bucket.

b) The second issue we had with the compost bucket was how to keep it aerated. If not enough oxygen is getting into the bucket, anaerobic bacteria takes over and things start to smell. Our solution for this prototype was to add some holes and a "carbon" filter to the front of the bucket, but in further iterations we would like to get even more airflow by using a material that allows air through but keeps liquid in the bucket. One thing we could use is the lining from a rain jacket. This liner allows air to move from the inside to the outside, but does not allow moisture in. We would attach this backwards with the water-resistant lining inwards and the air permeable layers facing outwards.

2) Scraps Bucket

a) Originally we had planned to use plastic as the slopes to funnel food scraps to the hole. While at Home Depot we were unable to find reasonably priced plastic to do this. In the future we could repurpose something that has flat plastic sides to fit this. Since we used wood to do this we covered the wood it in duct tape to prevent rot during prototype testing.

b) We did not account for how to install the slope in the bucket. We used duct tape but in the future we would upgrade to more rigid hardware and some caulking to keep it sealed properly.

c) The weather stripping was adhered with hot glue, would use a more permanent attachment method in the future.

3) Frame

a) The first issue we had was finding the appropriate position for the rollers to allow easy turning of the compost bucket while still holding the bucket in place. We tried several spots for the rollers until we found the current location. However, the front rollers can only be secured by two screws due to the width of the frame at that location. It would be more desirable for the frame to be wide enough in the front to allow for proper securing of the rollers.

b) The second issue we had was the compost bucket did not easily move in and out of the frame. That is why the last step in building the frame is to bevel the top, front frame. Options to resolve this is to keep the beveling step, or add 1” to each of the vertical pieces of the frame, thus, making the frame larger.

Completed Prototype:

Element H | Prototype Testing and Data Collection Plan

Below is a list of the design requirements that apply to the Easy Indoor Compost, in order of importance, and how we plan to test to those requirements if possible.

1. **Design Requirement:** The unit should have little to no smell at all times. This can be measured by testing whether 50% of a population can distinguish between the odorous sample and an odor free blank as described by Spengler in his book Indoor Air Quality Handbook.
   Spengler, John D.; McCarthy, John F; Samet, Jonathan M. (2000). Indoor Air Quality Handbook. New York, NY, USA: McGraw-Hill Professional Publishing. ISBN 978-0-07-445549-4.
   Reason for Not Testing:Due to the length of class we will not be able completely test whether or not our compost bin will produce a smell. This design requirement will need more time to adequately measure. However, we are putting compostable material in the upper bin for the remainder of class, so we will have a small sample data.

2. **Design Requirement:** The unit needs to have a small footprint within a living quarters. The average 13 gallon trash can that is commonly found under cabinets in kitchens measures 15 x 13 x 25 inches. This about 5100 cubic inches. Our design would need to be no larger than this to easily fit in most areas of a typical kitchen.
   Amazon.com: Step-On 13-Gallon Trash Can Color Black Dimensions …
   https://www.amazon.com/Step-13-Gallon-Trash-Dimensions-Inches/dp/B01IJ1OCQE
   Test Plan: Measure the height, depth, and width. Two different calculations will be done based on the position of the lid. The height would first be measured from where the wooden frame touches the table to the top of the lid of the top bucket when the lid is all the way open. The height would then be measured from the bottom to the top when the lid is closed. The depth will be measured from the flat back of the wooden frame to the front of the knob on the compost compartment door. The width will be measured from one side of the wooden frame to the other. Two volumes will then be calculated and compared to the volume of a standard 13-gallon trash can.

3. **Design Requirement:** The solution should break down organic materials to a soil replacement. The compost material should heat up to 40-50 degrees Celsius in two or three days. Decomposition should occur rapidly within 3 weeks while reducing it's particle size should be to increase the rate of microbial activity on the surface area.
   Reason for Not Testing: In order to test compostability you would need at least 2 weeks. Unfortunately the prototype was built with only 3 days left in the training so teasting can not be completed in time.

4. **Design Requirement:** The user should spend less than 10 minutes per week interacting with the product solution. Based on our market research 101 out of 237 people surveyed were concerned that composting would be too time-consuming.
   Test Plan: For this design specification we will allow stakeholders spend time adding compostable material, moving material from the upper bin to the lower bucket, and turning the bucket to agitate the compost. Will will average the time it takes for each stakeholder to perform the following set of events in the same order each time.
   a. Sort compostable items into top bin
   b. Move material from top bin to lower bucket
   c. Turn the lower bucket 3 times
   d. Repeat step b
   e. Take the compost bucket out and put it back in.

   At the end of the test we will multiply the time from step “a” times 7, divide the material moving by two since it will only need to be performed once every two weeks, add the average of steps b and c, and divide the time from step “e” by two since it will only need to be performed once every two weeks. The total should be less that 10 minutes.

5. **Design Requirement:** The product solution should be intuitive.
   Test Plan: A survey has been developed for users to provide feedback. The user will provide their name and profession. The feedback will be on a likert scale for easiness, with 1 being Very Easy and 5 being Very Difficult. The questions being asked on this scale are:
   a. How difficult was it to add food to the compost bin?
   b. How difficult was it to turn the lower bin?

   There will also be a space at the end for users to add in comments.

6. **Design Requirement:** The compost will be able to be easily relocated.
   Test Plan: The first factor would be the overall weight of the compost bin. According the the North Dakota state agency Workforce Safety & Insurance, light work is anything under 20 pounds for 0-3 hours. To test this we will load the bottom bin about one third with soil and weigh it.
   https://www.workforcesafety.com/employers/return-to-work/preferred-worker-program/physical-demand-information
   The second test would verify the ease of removing all compost from the bin. To test this we will fill the bin about one third with soil. Then we will have 3 different people attempt to empty the bin. If each person is able to have 95% or more of the soil removed without the use of tools it will be a successful test.

7. **Design Requirement:** The product is durable and able to exist for a long time without a significant visible deterioration in quality or value. The metal parts of the unit should be free from any corrosion, and the plastic parts (polypropylene) should have a tensile strength of no less than 40 (http://www.matweb.com/reference/tensilestrength.aspx).
   Test Plan: Parts of the compost bin have been tested for safety factor and displacement using the Inventor Program. Generally speaking, all objects have a stress limit

depending on the material used, which are presented as material yield or ultimate strengths. Let say that X material has a yield limit of 10,000 psi, any stresses above this limit will result in some form of permanent deformation or may result into damage. While the displacement, it shows the deformed shape of the model after the force is applied. It also displays the magnitude of deformation from the original shape, and it also indicated in different colors.

8. **Design Requirement:** Uninterrupted Input - The product is good source of steady supply of ready to use compost of up to 15 gal. The unit should be able to accommodate fresh materials for composing even on a daily basis without any downtime.
   Test Plan: Materials will be added to the top container to make sure nothing is spilling out into the bottom container. If nothing spills out, that means that material can be added to the top container without disturbing the processes occurring in the bottom bucket. If there is leakage, then we'll have to make adjustments so that the bottom bucket is self-contained. We can then further test this (if we had time) by timing how long it takes the compost to cure in the bottom barrel and making sure the top bucket isn't overflowing with scraps at that point.

9. **Design Requirement:** No Electricity - The unit operates without any electricity or external energy (battery, fuel, gas, etc) that can be carried out in wired or wireless connection, and it is self automated.
   Test Plan: This will be a qualitative test, either yes it operates without electricity, or no it does not.

Element I | Prototype Testing and Data Collection Results

Below is a list of the design requirements that apply to the Easy Indoor Compost, in order of importance, and the outcome of the tests to those requirements if possible.

1. **Design Requirement:** The unit should have little to no smell at all times.
   No Results Gathered: Due to the length of class we will not be able completely test whether or not our compost bin will produce a smell. This design requirement will need more time to adequately measure. However, we are putting compostable material in the upper bin for the remainder of class, so we will have a small sample data.

2. **Design Requirement:** The unit needs to have a small footprint within a living quarters. The average 13 gallon trash can that is commonly found under cabinets in kitchens measures 15 x 13 x 25 inches. This about 5100 cubic inches. Our design would need to be no larger than this to easily fit in most areas of a typical kitchen.
   Results: Below pictures demonstrate how


Height	Depth	Width	Volume	Percentage of average trash can
38” (lid open) 30.5” (lid closed)	13”	15”	Lid Open = 7410 in^3 Lid Closed = 5947.5 in^3	145% 117%

In conclusion the indoor compostor did not meet the design requirement of having it be smaller, by volume, than a 13 gallon trash can. The footprint of the Easy Indoor Compost is the same as a trash can, it is just taller which makes it larger by volume. At future iterations the overall height could be reduced by having less room between the buckets and wider but shorter top bucket. To have the same volume the overall height would need to be reduced by 5.5”.

3. **Design Requirement:** The solution should break down organic materials to a soil replacement. The compost material should heat up to 40-50 degrees Celsius in two or three days. Decomposition should occur rapidly within 3 weeks while reducing it's particle size should be to increase the rate of microbial activity on the surface area.

   No Results Gathered: In order to test compostability you would need at least 2 weeks. Unfortunately the prototype was built with only 3 days left in the training so teasting can not be completed in time.

4. **Design Requirement:** The user should spend less than 10 minutes per week interacting with the product solution. Based on our market research 101 out of 237 people surveyed were concerned that composting would be too time-consuming.

   Results:

Action	Action Label	Time 1	Time 2	Time 3	Average
Sorting Material into compost bin.	A	4 seconds	5 seconds	3 seconds	4 seconds
Turning bucket 3 times	B	10 seconds	8 seconds	10 seconds	9.3 seconds
Moving material from top to bottom	C	8 seconds	9.5 seconds	9 seconds	8.8 seconds
Dumping materials	D	18 seconds	11 seconds	14 seconds	14.3 seconds

   Total time per week: (A x 7) + (B x 2) + (C+D)/2 = (4 x 7) + (9.3 x 2) + (8.8 + 14.3)/2 = 58.15 seconds.

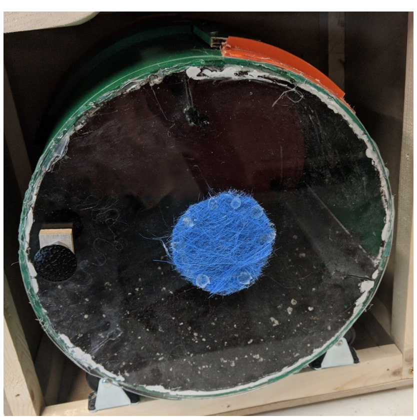
   Conclusion: It takes under a minute to perform many of the functions required to use this compost bin. Understandably some of these numbers can be changed based upon how often compost is moved to a garden or usage facility, and the numbers can change if someone composts more often than others. Even so, this passes the test of have a low touch time, and should be a very user friendly.

5. **Design Requirement:** The product solution should be intuitive.
   Results:

	Difficulty of Adding Food	Difficulty of Turning Bin	Comments
Response 1 (no name, teacher)	2 - Easy	2 - Easy	Not accepting meat is inconvenient
Response 2 (no name)	1 - Very Easy	1 - Very Easy	Needs separation of foods capabilities
Response 3 (Josh PLTW teacher)	1 - Very Easy	1 - Very Easy	
Response 4 (Alex PLTW teacher)	1 - Very Easy	1 - Very Easy	Very cool design
Response 5 (Thomson, student)	2 - Easy	1 - Very Easy	Convenient, could be used for most gardening purposes

   All users thought it was either very easy or easy to use so it passes the test.

6. **Design Requirement:** The compost will be able to be easily repurposed.
   Results: The bin itself weighs 2.6 lbs. After filling the bin one third with soil it then weighs 5.8 lbs. At one-third full, emptying the container would qualify as sedentary work since it is under 10 lbs according to North Dakota state agency Workforce Safety & Insurance.



   If the bin was filled all the way it would weigh about 12.2 lbs. If completely filled, emptying the container would qualify as light work since it is under 20 lbs according to North Dakota state agency Workforce Safety & Insurance.
   https://www.workforcesafety.com/employers/return-to-work/preferred-worker-program/physical-demand-information

The second test would verify the ease of removing all compost from the bin. 3 participants emptied the bin, below are their responses:
Results:

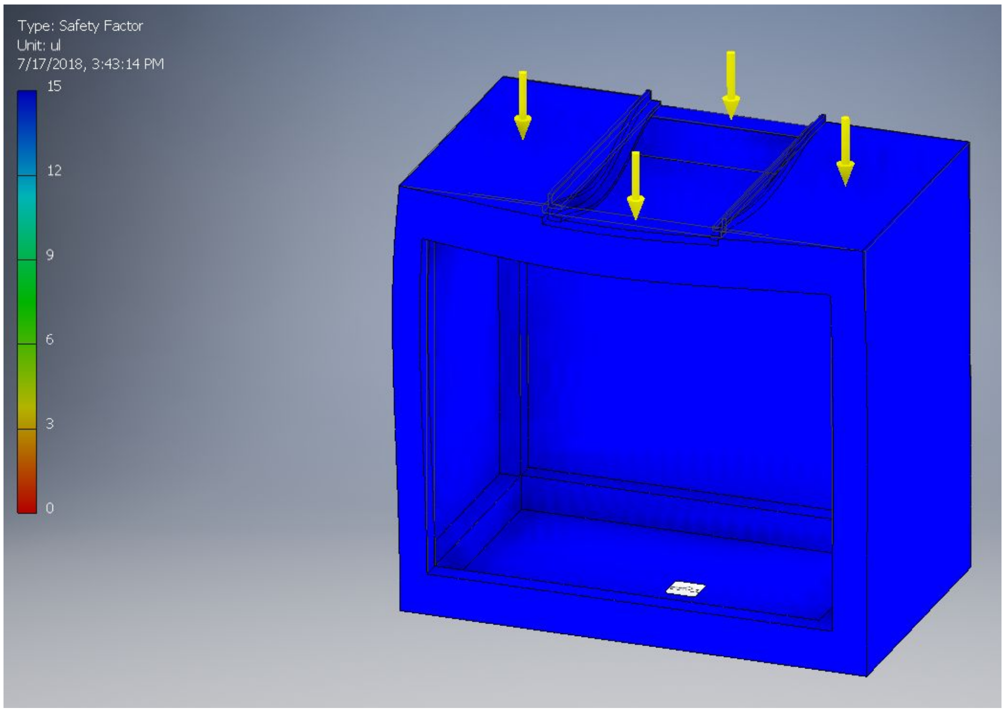
	Difficulty of Removing Compost	Amount of Compost Removed	Comments
Response 1 (Heath, Teacher)	1 - Very Easy	99%	Possibly use easy handle carrier
Response 2 (Marlon, Teacher)	1 - Very Easy	98%	Improve lid to open
Response 3 ()	2 - Easy	99%	Lid requires leverage to open, if no table available you have to bend over.

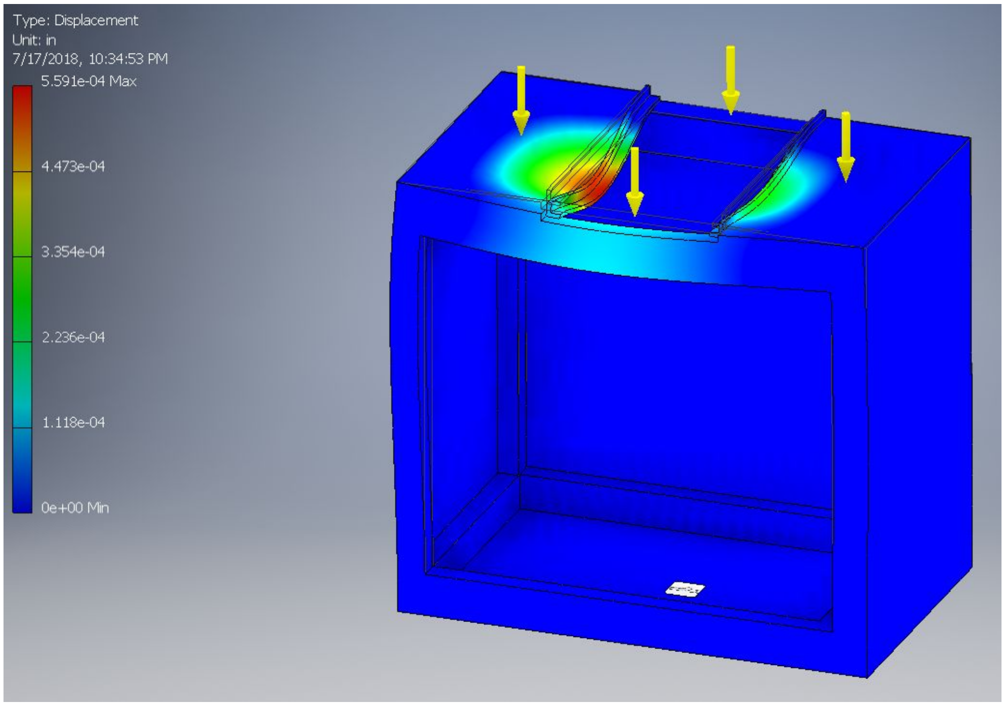
This test passed because each person is able to have 95% or more of the soil removed without the use of tools it will be a successful test.

7. **Design Requirement:** The product is durable and able to exist for a long time without a significant visible deterioration in quality or value. The metal parts of the unit should be free from any corrosion, and the plastic parts (polypropylene) should have a tensile strength of no less than 40 MPa (http://www.matweb.com/reference/tensilestrength.aspx). The plastic parts should not warp or deform due to natural heat produced during the composting cycle. The product can carry out its function with no damage in at least 5 years or so.
Results: With the use of the Inventor Program safety factor and displacement were tested on the different parts of the compost bin. The safety factor can be calculated as the ratio of the maximum allowable stress to the equivalent stress when using the Yield Strength. The only requirement for the design to be acceptably safe is a ratio of at least 1. Any ratio less than 1 means there is some permanent deformation in the design. When using Ultimate Strength, Maximum Principal stress is used to determine the safety factor ratios. The red color in the test shows the highest stress of area and can be considered as the critical. It really doesn't matter whether the value is high or low. Another way to interpret the ratio value of 1 is that the material is essentially at yield, meaning the material can deform elastically but when the stress is removed, it will go back to its original form without any visible damage. The result of the displacement shows the deformed shape of the model after the force is applied. It also Indicates the magnitude of deformation from the original shape. Below is the detailed tests conducted on parts of the compost bin.

Wooden Frame:

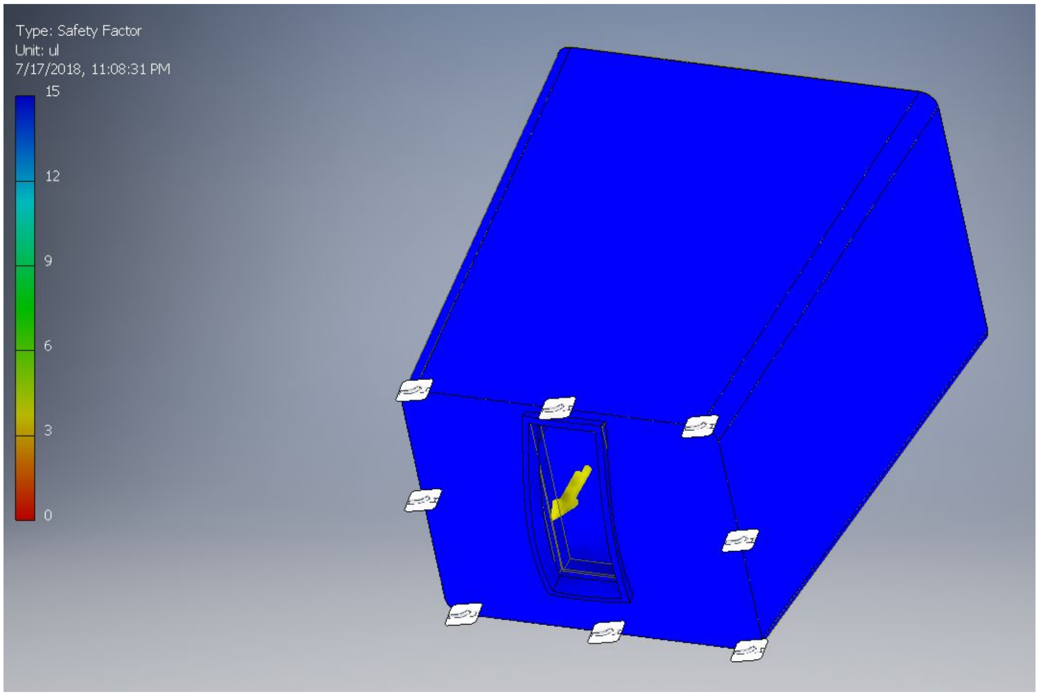
Based on the simulated safety factor test, the wooden frame has a ratio of 15, meaning after applying a load of 15 pounds, there's no visible stress on the upper structure of the frame. Normally, the designer aims for a safety ratio of 2 to 4, but this designed even surpassed the ideal ratio value. While the displacement shows a very minimal almost to nothing on the upper structure except on the left opening edge where the sliding fiberglass is position. This will not be a potential problem in the integrity of the structure simply because the bottom part that is aligned to the grove is slightly elevated, so there's no direct contact between the critical part and the bin.

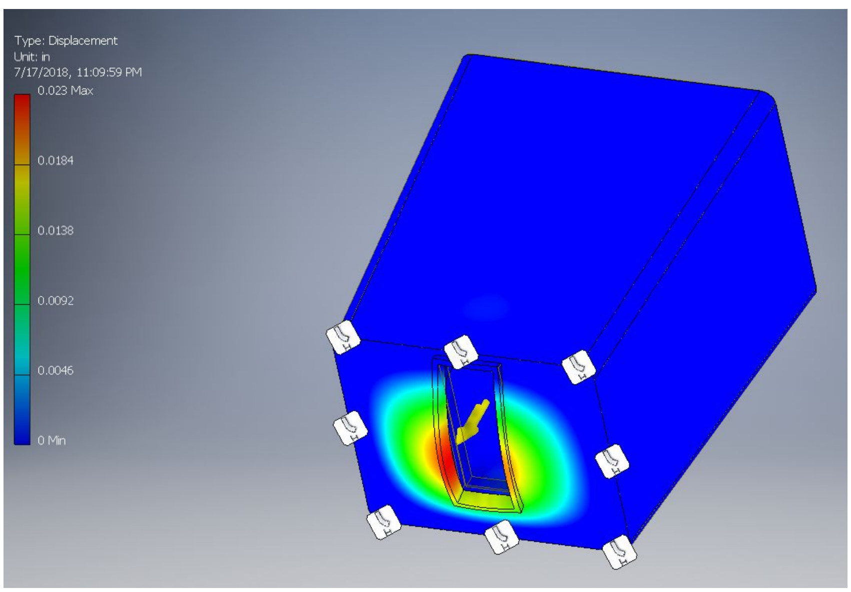




Upper Bin

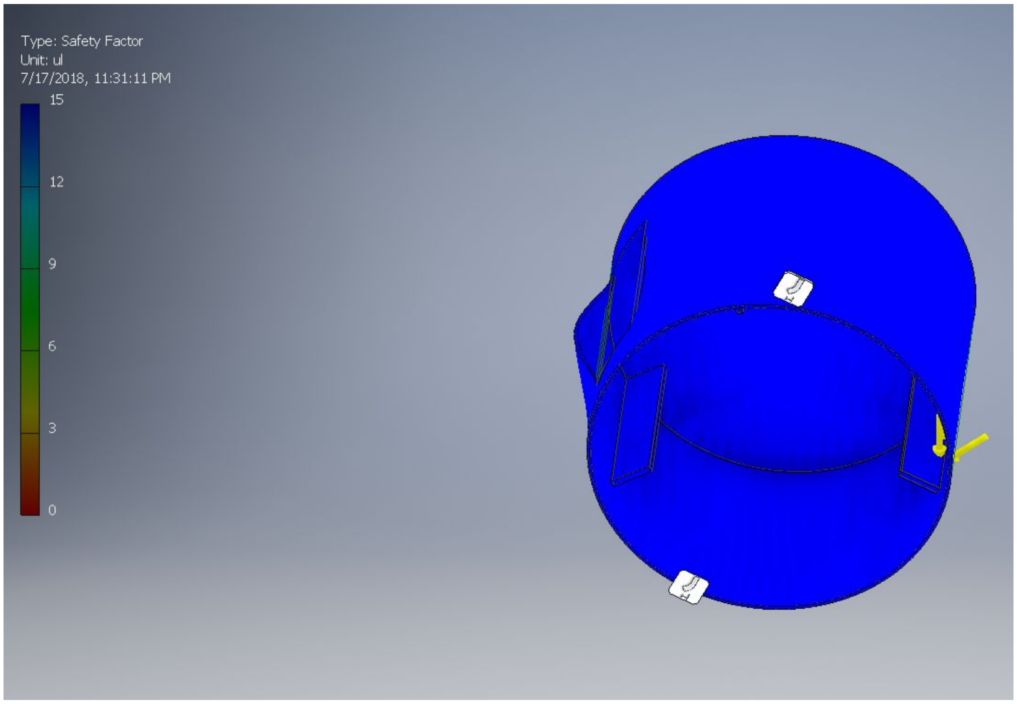
The upper bin also surpassed the safety ratio with a rating of 15. It is also notable that the opening in the bottom was critical when the displacement test was run. There's a possibility that it will warp during the collection of the raw compost material, but in our design there's sliding fiberglass between the frame and the bin that serves as additional support and acts as a counterweight for the downward force.

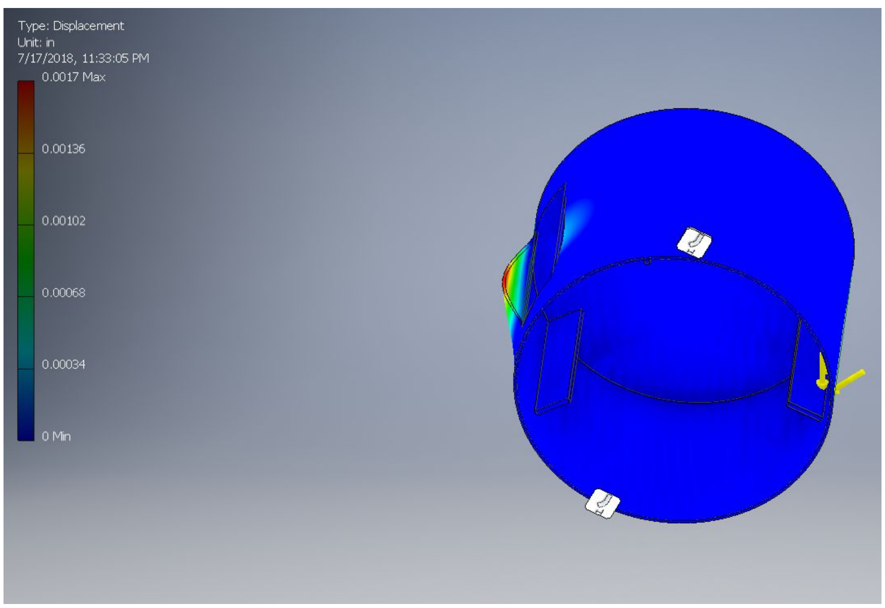




Compost Barrel

The parts in the composting is pretty much consistent in the safety test with a ratio of 15 across the board. Any opening in the design is prone for warping as shown in the displacement test conducted but those critical areas are mitigated with use of the sliding door attached to it.





8. **Design Requirement:** Uninterrupted Input - The product is good source of steady supply of ready to use compost of up to 15 gal. The unit should be able to accommodate fresh materials for composing even on a daily basis without any downtime.
   Results: Scraps were added over two lunch periods, and nothing fell out of the bottom. We could further test this (if we had time) by timing how long it takes the compost to cure in the bottom barrel and making sure the top bucket isn't overflowing with scraps at that point.

9. **Design Requirement:** No Electricity - The unit operates without any electricity or external energy (battery, fuel, gas, etc) that can be carried out in wired or wireless connection, and it is self automated.
   Results: Passed. This prototype contains no parts that need to be powered by electricity.

Element J | Documentation of External Evaluation

Multiple experts from a variety of aspects were consulted to evaluate the prototype.

Large Scale Compost Facility Designer

The first consultations was with Jessica, she is a Sr. Project Engineer at Cornerstone Environmental Group, a Tetra Tech company. She has taken Design of Aerated Static Pile training courses through the US Composting Council and designed several large scale composting facilities. She has also given presentations at several conferences, including the Environmental Research & Education Foundation for aerated static pile facility design.

Jessica informed us that because food waste eats up oxygen faster than landscaping type of materials we should limit the wet food waste to a percentage by mass like 10% at most. We should also provide instructions to break the material down into 3-in sized pieces because large chunks won't break down as well. On future iterations we should make the bottom bin bigger. She also emphasized that the compost needs to get hot, like 130 degrees Fahrenheit to really get going so a larger bin would facilitate this better as well. She suggested getting a temperature gauge somewhere in the box so you can see that it's getting warm. She pointed out that turning for air every few days is perfect for something this size. You may need to be adding moisture if you find that they're adding pretty dry materials. You basically want to be able to take a handful and squeeze it and have it feel moist but no water actually drip out. Finally she shared that the composting process will take at least 3 weeks and if you use the material prior to that, it'll leach nutrients that will be too concentrated for the plants and could do them more harm than good.

Master Gardener Feedback

We took our prototype to Rebecca who is a Master Gardener and horticulture Extension Agent with Kansas State Research and Extension. Her immediate concern was the volume of our prototype. She said that the volume of the top bucket needs to be smaller so that if people fill the top bucket all the way, there will be enough room for all of it in the bottom bucket. As we talked more about the design, she mentioned that keeping it in a kitchen would make it really hard to balance the volume of green material going into the bucket compared to the volume of brown material going into the bucket. She suggested splitting up the sides so there would be a visual comparison of the two, but she told us the “green” side would have to be airtight to prevent smell.

As we explained our design further, she became concerned about the volume of the bottom bucket. She said it would probably be too small to hold enough material to create the conditions necessary for composting. Her last concern was the amount of air making into the bottom bucket. She told us that a lot of backyard piles will have a PVC pipe with holes in it put in the middle of the pile to get air down to the bottom layers. Overall, she assessed that even with multiple modifications, our design might be able to create “decayed organic material,” which is still good for gardens, but probably wouldn’t reach the temperatures necessary to be considered compost.

Home Composting Business

We took our prototype to Travis and Katie, owners and operators of Compost ICT. Their business picks up food scraps from Wichita area homes and composts those scraps in the backyard of their home. They then return the compost to their customers. Without us letting him know what Rebecca told us, Travis had the same concerns as Rebecca did when it came to volume. He agreed that the volume of our lower bucket was too small to create composting conditions. He immediately brought up the idea of composting systems that use worms because they take up much less space than aerobic composting. He also shared Rebecca’s concern about the ratio of brown matter to green matter that comes out of a standard kitchen. Travis also agreed with Rebecca’s assessment that our project would not create actual compost.

Element K | Reflection on the Design Project

Identification and Justification of the Problem

Summary: As a group we each listed around 20 problems that would could think of individually. Then, we did some simple google researching on what we thought were our top 2 or 3 problems. We used this research to determine if any of these were justifiable problems. Each group member then shared what they found through research. At that point we tried to find a problem we wanted to all work on. Through this process we chose the topic of composting. We then looked at different attack paths through which composting in apartments and small homes could defended. Each group member researched different attack paths to learn as much as possible about the problem.
Reflection: The identification and justification of a problem is where a team can find and gain inspiration to really wanting to solve a problem. In this step is where we learned many interesting facts about compost that most of us have never heard. This information brought us together as a group and spearheaded our design efforts. It is very important for any group to spend quality time on this step. It gives a group the foundation to build their whole project on. A poorly justified problem is not a problem at all. The one thing we wish would have utilized more during this step was expert analysis. If we could have had more interviews with experts in the field, it would have given us a clearer picture to the overall problem.

Documentation and Analysis of Prior Solution Attempts

Summary: The team worked together on a Google Document and agreed that once a person found a prior solution attempt they would post a picture in the Google Doc and begin analyzing it. This way nobody was doubling up on design ideas. Heath was able to successfully navigate the Google Patents website and find two prior solutions that had been patented. Neither had been put on the market, and one was too large for our purposes. Ashley found a machine that dried out food scraps and made them into a soil additive, but it wasn't real compost. Allison found a method called the Bokashi method, but it turned out that it was a pre-compost method. She also researched several do-it-yourself methods to get an idea of simple solutions that are already out there. Marlon found prior solutions that were meant to be used outside such as compost tumblers, but they were too large to be used indoors.
Reflection: Splitting up the research this was was incredibly time-effective because we were all working on different prior solutions but had a system so we weren't doubling up on one solution. The research for patents could have been more extensive had we known how specific searches had to be. After meeting with the patent specialist, we knew we had to use a variety of synonyms for keywords instead of just the surface words. Even without this knowledge, Heath

was able to find some really good previous solutions. Because of time constraints, we were not able to go back and further that search.

Presentation and Justification of Solution Requirements

Summary: Our group spent ample time researching the market, similar existing products and filed patents, and had discussions with experts in the industry. Through those we determined what the design specifications that should be. We did place higher priority on certain design specifications, based on what we felt was most important to solve the problem. We then determined how we could measure these design requirements, and how the potential stakeholders could evaluate our solution to the problem.
Reflection: This process allows a group to focus in on the most important features of their solution ideas. If a group was not all focusing on the same priority list of specifications it would be hard to agree upon a quality solution. It is essential to know exactly what is most important, and then move forward. Our group had much discussion as to where some of the design features should fall in the priority list, but overall came to an agreement. The hardest this for us to understand is how the feature of “no smell” could be evaluated. This is because we were not sure how to exactly make a compost bin smell free.

Design Concepts Generation, Analysis, and Selection

Summary: The team generated design concepts by brainstorming ideas with the rest of the class. One team would present their project and the class had two minutes to brainstorm and record their individual ideas. The team then took all of these ideas and analyzed them for viability. Each team member created one mockup of the design that he/she thought would make the best solution and presented it to the team. From here, the team discussed which aspects of the designs were the best fit and began making a build plan.
Reflection: This was one of the most difficult tasks in this process for a number of reasons. The first reason was that this is where we had to be highly creative and synthesize all of the research and ideas we had previously into an actual design. The second reason it was hard is because we discovered that there were some miscommunications about what our design problem was and whether we were building a system to be used indoors or outdoors. We all had different ideas of what our mechanism should do and how much technology should be integrated, so it was hard to compare ideas that were so different. In the end, we narrowed our design down to a combination of two mockups and made a rough plan about how to put it all together. Many of the final design elements were included as we built the prototype and discovered that some ideas weren’t going to work as planned, but we did well working as a team to brainstorm and implement viable solutions.

Application of STEM Principles and Practices

Summary: STEM principles and practices were scattered throughout our other elements, but we pulled them together for this section and quantified anything that we could. Our major STEM principles came down to the categories of size, chemistry of composting, and the design of the interior of our collection bucket. As we began to build, a lot of the measurements changed and we had to re-do our calculations.
Reflection: The biggest issue we had is that the theoretical calculations of the angle of our funnel panels were not feasible in our design build. The angle that was calculated was too low to properly fit in the bucket, so we had to increase the angle by incremental testing instead of theoretical calculations. This part was difficult to separate out from the other sections because the research and calculations were intuitively included in other elements, especially the research about how compost works, because this research was imperative for figuring out our design requirements and our brainstorming ideas.

Consideration of Design Viability

Summary: Our group's primary consideration in the designing the product is its ability to do indoor composting that will take only a small space. We want to consider also the materials that we will use are readily available like the litter cat bucket or any large container that just sitting in your garage, some scrap plywood, and aluminum bar. We also thought that our design should be simple to use, and won't tale so much time.to operrate. Since our design is on composting, it is obviously environmentally friendly as it has a potential to save 250 pounds of trash per year per household that would normally end in landfill. The appealing design can also be a conversation piece which will create awareness and eventually encourage others to compost too. It's also good to mention that there are laws and city ordinance that encourage it's people to recycle and compost whether in their own backyard or a designated place in their community. Our group ran into some obstacles that might be a problem to make our design marketable like the design needs to be within 5100 cubic inches, the compost cylinder must properly aerates material, flaps functions very well, any opening should be sealed to avoid any spillage and the smell which is the primary concern of those who wants to try composting. The design should have a way to add or remove moisture, and proper ventilation for carbon/nitrogen to circulate. The design should also be sturdy and safe to use, meaning there must be some way to prevent fungal and bacterial growth.
Reflection: Our team focused on addressing the major concern of people who might be interested in indoor composting. We designed our product that is compact that will fit in the kitchen corner. The materials that we used were pretty much common and can be found in any households, other than the clear plexiglass that we used as the cover for the barrel. To us it is just aesthetic but has a huge function in determining whether the compost is ready without opening the entire bucket which could potentially dissipate the needed bacteria and other substance in composting cycle.

Construction of a Testable Prototype

Summary: The grouped worked together in constructing the prototype. We cut the bottom part of the circular bucket and glued the circular plexiglass with the same diameter and 4.75 inch hole in the center, then covered it with mesh. We also cut a rectangular slot in the side of the bucket to dump the raw green and brown materials from the upper chute. To cover the rectangular slot in the side, we cut 8”x4” from a different bucket that matches the curvature of the cylinder, and placed two pieces of fiberboard to the cylinder to act as a ridge. For the agitator, 3 nine-inch stip aluminum were glued inside the barrel.
The group used a litter container for the scraps bucket and cut 2.5”x5.5” at the bottom.then put weather stripping to all four sides of the hole, We cut fiberboard material to make a slope from the sides of bucket towards the hole. Duct tape was used to hold the pieces together and to cover the board too. We drilled holes around the top of the scarps bucket to ensure air flow. The compost bucket frame was constructed by cutting wood frames as per design requirement. Screwed plywood on the sides leaving the front and a small portion on the top uncovered. We placed two rollers on the rear and the front at the bottom of the frame to let the barrel roll side to side.
Reflection: When the group started to construct the prototype, we already made a decision that we will use a springed self-closing latch on the compost bucket that the user would just push down the flap to allow the scraps to fall from the top container. The hinge that we got from the store would potentially deform the bucket due to its high spring constant. Heath suggested to use a sliding mechanism that’s similar to the one we placed under the scrap bucket. The group also figured out that drilling a hole in the center of the plexiglass then adding a carbon mesh to cover it will allow airflow and somehow controls the moisture. At first we used hot glue to adhere the plastic parts but weather stripping offers more permanent attachment method, and that’s what we used to glue together the compost cylinder and the plexiglass.

Prototype Testing and Data Collection Plan

Summary: Our groups devised as many testing plans for the time we were allotted in class. For the specification of smell we did not have enough time in the remainder days of class, so we were not able to test. For size, we measured the total volume of the compost bin with the lid open and closed, and compared these dimensions to our target. For composting, again without enough time we could not do this test. It takes at least two weeks to see the composting process. For low touch time, we developed a system of routine events that would occur while using our compost bin. We allowed potential stakeholders to perform these events, and timed how long it would take. We were able to use these numbers to have a quantitative result. For Intuitive, we used a survey that was given to potential stakeholders, and asked them their opinion of our prototype. For durable, we plan to use inventor to design the prototype, and test the structure for stress. For easily relocatable, we simply measured the weight of the bin while loaded to make sure it wasn’t more than 20lbs. Also, we used a qualitative test of whether the

bucket was considered to be easily unloaded or not. For uninterrupted flow, we filled the top bin to see if would leak from the bottom. For nonelectric, it is qualitative as no.
Reflection: This process is difficult for us since we needed more time to truly get accurate data on some of our design specifications. It is extremely important to have the first version of a prototype done early enough. This will allow for adjustments of the design to improve the solution to the problem.

Testing, Data Collection, and Analysis

Summary: For this section we divided and conquered. We only performed tests that were possible with the time given. For size, Allison used the measurements of the prototype find its overall volume. We determined our prototype is actually larger than a 13 gallon trash can, but not enough to discredit this design restraint. For touch time, Allison developed the list of routine activities, and Heath used that to measure the time it took. We had three stakeholders perform the activities to see if the activities would take less than 10 minutes a week. After calculating we learning that it would take only 1 minute a week ot total touch time. For Intuitive, Ashley used the results of the survey to determine that is considered easy to use. For easily repurposed, Ashley weighed the prototype to find out that it weighed only about 5 lbs, which makes it considered easy to transfer. For durable, Marlon performed stress analysis through the use of inventor to find that no part of the prototype is under any damageable stress. For uninterrupted flow, we started using our prototype during lunch. People were throwing compostable items in the bin, and we as a group observed if there were any leaks that would disturb the flow. To have true representation this process would need to be longer. However, we did notice some liquids could pass around the seal at the bottom of the bin.
Reflection: To truly analyze the effectiveness of a prototype it is important to have accurate, genuine, and honest results to all testing and data collection. If any data is not completely true it will give misrepresentation of the prototype. For true solutions to problems, testing must be done accurately. We were honest in our results, but really need more data to complete the improvement of our solution.

Documentation of External Evaluation

Summary: After completing the prototype and testing it for basic functionality we brought it around to experts for their feedback. We met with two experts in person, Rebecca a master gardener from the Kansas State University Agriculture Extension Office and Travis the owner of local company in Wichita that provides a residential food waste pick-up service called Compost ICT. We corresponded via email with Jessica, a senior project manager for Cornerstone Environmental Group, LLC and designer of large scale compost facilities for waste management companies. We learned a lot from each of these people. Our main takeaways with regards to our prototype were that it is too small to compost, hard to add brown materials to, the bottom bin

should be water tight or have a tray and top bin should be air tight and much smaller than bottom bin.
Reflection: We learned a lot from our time with each of these experts. So much so that the information would have been much more beneficial at the mock-up stage. The feedback we got made it clear that we may have conflicting design requirements, it doesn't seem possible to do a proper aerobic compost in a small bin. None of the experts we talked to though were aware if we had a well insulated bottom bin if this would allow composting to occur properly in a small bin. It would have been better to learn this up front when we could have gone with a very different design or changed our design requirements so that we would have started with a better prototype.

Presentation of the Designer's Recommendations

Summary: After talking with experts about our design, we had a multitude of improvements to make and features to test. First, the size of the scrap bucket should match with the volume of the compost bin. The compost bin is not big enough to produce the heat necessary for thermophilic bacteria to thrive and begin composting. The second part that concerned our experts was the size of our intake bin. Because it's bigger than our composting drum, consumers may overfill the top and not have enough room in the composting drum for all of the food scraps. The last part we would need to redesign is a way for consumers to know that they have the right ratio of brown material to green material lest they end up with decomposed sludge.
Reflection: Getting that feedback was kind of tough at this point in the design process, but it showed us that we really need to encourage our students to talk with local experts early in the process so they can avoid this type of disappointment. Our experts had valid and constructive feedback, so it was easy to come up with new features for our prototype, though we may have to change some of our basic design requirements.

Element L | Presentation of the Designers' Recommendation

Testing Compost in Small Volume

One of the major considerations we have learned is being able to reach a high enough temperature, 130 degrees Fahrenheit, in small volume containers. Our interviews with experts gave us the impression that small volume containers have a hard time reaching high temperatures. The spike in temperature needed comes from the bacteria in the mix breaking down the compostable material. If the there is not a large amount of material, then there might not be enough bacteria to create the heat. However, our continued research encourages us to believe that if a composter keeps the correct balance of greens, browns, moisture, and air, composting can occur in a small area. Indeed, keeping the correct balance could be more of a challenge for a novice composter. Thus, we have determined to improve the design of our indoor compost bin there could be these added features. 1) A carbon/nitrogen sensor to make sure the correct balance of browns vs. greens are in the bin. 2) A temperature gauge to ensure the user that the mixture inside is reaching target temp.

Given time, we could test each of these features with varying designs of compost bins until we found a workable solution. Our goal, prove with proper usage that composting in small volumes is possible.

Improve Prototype

Once it is determined that it is possible to compost in a small volume, the current prototype would need to be further tested and updated to get it in a fully functional and marketable product. First step would be to determine how to modify the top bin. It definitely needs to be shortened so that the overall volume is reduced to 5100 cubic inches and so that it is not possible to hold more in the top bin then what would fill two thirds of the bottom bin. Two top bin concepts should be tested, one as air tight and one with an agitator to determine which functions best and is more appealing to potential consumers. The walls of the upper bin should be tested to see if food glides down properly and modified as needed to ensure this.

Both the top and bottom bin need to be made watertight and all openings should fully seal when closed to prevent leakage. The bottom bin needs better air flow which could potentially be achieved by adding PVC pipe that has holes cut into it and extends the depth of the bin. Flap functionality should be improved to allow easy flow from entrance as scraps exit as compost. Incorporate a way to remove or add moisture as needed to the compost bin. Test that the system has no smell even when considering some misuse. All fasteners and materials used must be protected to prevent fungal and bacterial growth and add instructions for proper mounting to ensure it won't tip or fall.

Compare to Vermicomposting

One of the common solutions we found while doing our initial research was the use of worms to compost in small spaces, called vermiculture. We didn’t explore this route because we wanted our design to be able to compost using traditional methods without the use of macroscopic organisms. If given more time, however, comparing small-volume aerobic composting to vermicomposting would be an excellent way to test the viability of our design. WE could create and use a vermiculture bin at the same time that we were testing small-volume aerobic composting and compare the rate of decomposition as well as the smell and space required. According to the University of Nebraska Extension in Lancaster, worm bins need only be between eight and twelve inches high, but they do require macroorganisms, and some people may be uncomfortable inviting worms into their home (Cochran). This would also be an interesting thing to add to the market research to see if stakeholders would be more or less interested in a vermiculture bin. If the market research and our tests show that vermicomposting is more feasible than small-volume aerobic composting, then we would have to take a closer look at our design requirements and our overall goal.

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