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MEMS 411 Design Project: Dry Ingredients Dispenser

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Executive Summary

The Dry Ingredient Dispenser is a device for avid home bakers that want to reduce their preparation time when baking. There are four main problems bakers run into during preparation, these problems include: storage containers typically take up a lot of cabinet or counter space, measuring and dispensing dry ingredients creates a mess, and cleaning up spills and used measuring cups takes a long time. The Dry Ingredient Dispenser addresses all of these problems by containing, measuring, and dispensing up to four different dry ingredients such as flour, sugar, baking soda, and salt. With the ability to measure, dispense, and create minimal mess in less than two minutes, this device provides users with an efficient preparation process.

The Dry Ingredient Dispenser was designed with a number of considerations in mind. This report is a collection of these considerations and the steps taken throughout the design process from the conceptual phase to the final prototype. We began the process with interviews of potential customers which placed certain constraints on our design choices. These constraints factored into our concept generation and our final design selection. Initial tests of our prototype were promising, 3 out of the 4 ingredients tested (sugar, baking soda, and salt) were dispensed accurately, quickly and with minimal mess; however flour has proven to be more problematic, as well as the limitations on the manufacturing process and time.
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8.2.2 Was the project more or less difficult than you had expected?

8.2.3 In what ways do you wish your final prototype would have performed better?

8.2.4 Was your group missing any critical information when you evaluated concepts?

8.2.5 Were there additional engineering analyses that could have helped guide your design?

8.2.6 How did you identify your most relevant codes and standards and how they influence revision of the design?

8.2.7 What ethical considerations (from the Engineering Ethics and Design for Environment seminar) are relevant to your device? How could these considerations be addressed?

8.2.8 On which part(s) of the design process should your group have spent more time? Which parts required less time?

8.2.9 Was there a task on your Gantt chart that was much harder than expected? Were there any that were much easier?

8.2.10 Was there a component of your prototype that was significantly easier or harder to make/assemble than you expected?

8.2.11 If your budget were increased to 10x its original amount, would your approach have changed? If so, in what specific ways?

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INTRODUCTION AND BACKGROUND INFORMATION

1.1 INITIAL PROJECT DESCRIPTION
When making baked goods, the consumers have four main problems: dispensing ingredients makes a mess, measuring ingredients accurately is difficult, storing ingredients takes up a lot of space and the whole process wastes a lot of time. The Mechanical Dry Ingredient Storage/Dispenser is a device created to solve all four of these problems. This device has several storage containers with each holding a different ingredient (e.g. flour, sugar, baking powder). The storage containers have internal vibrating mechanisms, sifters, measuring devices, and dispensers. The vibrating mechanism and sifter allow the ingredients to flow smoothly through the dispenser. The measuring device is automated so that the appropriate amount of ingredients are dispensed. All ingredients are dispensed into a larger mixing bowl and the consumer is now provided with all the necessary, premeasured dry ingredients to create whatever they are baking. The device will incorporate three important qualities in unison: contain, measure and dispense.

1.2 EXISTING PRODUCTS

![Figure 1: Server 86690 Dry Product Dispenser](image)

I was unable to follow the link due to the seller website being infested with malware, but this product is like a really poor bare bones version of what we’re interested in designing.
This product is intended to dispense sweeteners for coffee in a hotel lobby type setting, but the idea of a large reservoir to store a dry ingredient to be dispensed in small amounts is consistent with our design goals.

There will need to be a sifting mechanism to ensure no caked/packed pieces of flour or baking powder make it into the batter; an electric system such as the one pictured above would make sense for our design.
Measuring cups and measuring spoons are the most common products used to measure out dry ingredients. These require the dry ingredients themselves to be stored in a different container or their original packaging. When the user is ready to bake/cook the user must pour/scoop the ingredients from the larger reservoirs into these products in the right proportions and then combine them in a larger mixing bowl. These items are generally inexpensive and can be found at any grocery store or dollar store.

The cylinder sugar click dispenser stores a liter of dry ingredients and can dispense them with the click of a button. The device is purely mechanical and with the help of gravity easily dispenses a controlled amount of sugar. The large reservoir ensures that the device will not need to be refilled too frequently. While the device has large reservoirs and a user friendly dispensing mechanism, the device does not allow
for precise measuring of larger volumes of ingredients. The machine dispenses about \( \frac{1}{2} \) to 1 tablespoon per button push. The three containers can be found online for $212.

![Figure 6: Standard Storage Containers](image)

The standard storage containers that already exist are small enough that they are easy to store and easy to handle. However, their size also requires them to be refilled from their original bags more often. The ingredients must be scooped with measuring spoons or poured into measuring cups in order to dispense the proper proportions. A nice looking set can be found in a home goods store or online for 30-70 dollars.
The ingredient dispenser by Hb-Technik is a large scale, automated dispensing machine that weighs different ingredients and dispenses them onto a conveyor belt. This machine is computer aided so different recipes can be picked on the computer and the machine will weigh and dispense out the appropriate amount of ingredients for each specific recipe. All the ingredients are then sent into a mixer. This machine is large scale and would most likely be used in a factory or a place where bulk quantities of baked goods are being made.

Figure 7: Commercial Sized Automatic Ingredient Dispenser

Application:
Fully automatic dosing and weighing of components (ingredients) like salt, sugar, spices, baking-additives and flour. Computer aided recipe-work out.
The PantryChic is an ingredient storage and dispenser system that’s purpose is to make baking preparation easier. There are several different storage containers available, each to store one dry ingredient (like flour or sugar). Each storage container is compatible with an automatic dispensing system. The automatic dispensing system measures how much product comes out of each container, sifts the product, then dispenses it into a bowl. Users must attach and remove each storage container from the automatic dispensing system when they want to use a different ingredient.

The Zevro Smart Space Wall-Mounted Dispenser, Triple Canister is a device that holds dry ingredients in three separate storage containers. Users have to manually turn the knob on each container to dispense ingredients. This device does not measure out each ingredient but dispenses and stores each ingredient.
separately. It is easy to refill the container. The device also is meant to be mounted on the wall, which allows for out of the way storage for consumers.

1.3 RELEVANT PATENTS
The Food Ingredient Dispenser primarily was invented to mix dry powders with liquid drinks. The device uses funnels and blowers to mix the dry ingredients. The invention uses disposable paper cutouts to prevent the vapor from the hot drink from contaminating the dry ingredient container.

Patent Number: US2939614A

Figure 10: Patent #US2939614A; Food Ingredient Dispenser
The automatic dispenser for dry ingredients uses gravity and a series of vibrators to dispense the desired ingredients into a mixing bowl. The device contains a number of different reservoirs each with their own vibrator so the user can select which ingredient they would like to dispense. The device is electrical in nature and has knobs and buttons for a user interface.

Patent Number: US5460209A

1.4 CODES & STANDARDS

Specification 7 is standard 5.28.1 from NSF/ANSI 18-2016: Manual Food and Beverage Dispensing Equipment. The standard states: “Compartments intended for the storage and display of single-service items (e.g., cups, containers, utensils) shall be designed and manufactured so that the items may be added directly from their original packaging without their food contact surfaces being handled.” This specification is necessary and relates to the customer need that the device needs to be easily refillable (need number 5).

Specifications 2, 3, and 4 is standard 5.16.3 from NSF/ANSI 18-2016: Manual Food and Beverage Dispensing Equipment. The standard states: “Portable equipment shall not weigh more than 80lb (36 kg) and shall not exceed 36in (90 cm) in any plane.” Although our device is intended to be kept on the counter and not often moved, NSF/ANSI 170-2007 defines portable as: “Intended to be manually lifted and moved between periods of operation.” This standard is applicable because although the device is intended to be kept on a user’s counter, some users may prefer to keep it in their pantry. Also, NSF/ANSI
18-2016: Manual Food and Beverage Dispensing Equipment states that “counter-mounted equipment shall be designed and manufactured to be: portable or sealed to the counter or elevated on legs that provide a minimum unobstructed clearance of 4.0in (100mm) beneath the unit or elevated on legs that provide a minimum unobstructed clearance of 3.0in (76mm) beneath the unit provided that no part of the counter top under the footprint of the equipment is more than 16in (41cm) from the point of cleaning access or elevated on legs that provide a minimum unobstructed clearance of 2.0in (50mm) beneath the unit provided that no part of the counter top under the footprint of the equipment is more than 3.0in (76mm) from the point of cleaning access”. Therefore, to adhere to this standard the Dry Ingredient Dispenser will be made as a portable device.

1.5 PROJECT SCOPE

Purpose of the project:
To create a product that can store, measure, and dispense dry ingredients used for baking. Separate containers will hold the following ingredients: flour, granulated sugar, baking powder, baking soda, and powdered sugar. The product will be a stand-up device.

Customer:
The customer would be an at-home, avid baker.

Value or benefits to the customer:
Storage benefits- consolidates several measuring devices into one.
Prevent spilling- the customer will no longer have to use measuring cups therefore eliminating the possibility of spillage
Lifting heavy bags- customer will not have to lift heavy flour or sugar bags to measure out ingredients
Dirty dishes- there will be no dirty measuring cups to clean up
Time saver- customer won’t have to individually measure out each ingredient; the device will measure all ingredients at once, therefore saving time

Project goals:
The goal of this project is to create four storage containers that will hold flour, sugar, baking soda, and baking powder (or other dry baking ingredients). The containers for the flour and sugar will hold approximately two liters and the containers for the baking soda and baking powder will hold approximately 1-2 cups. The mechanism used for measuring the dry ingredients will be easy for the user to read and select appropriate volume measurement.

All containers will be held by one device. Containers should be air tight and easily refillable. Dry ingredients will flow consistently into measuring devices.

What is in scope:
Measuring, dispensing, and storing dry ingredients. Shape and materials of containers. Stand to hold device. Mechanism to dispense ingredients.

What is out of scope:
Any non-dry ingredient, customized measurements, mixing ingredients, baking, brown sugar, metric measurements, automation

**Identify critical success factors:**
The product should dispense the ingredients in appropriate volumes.
The product should store and preserve the dry ingredients.
Adhering to material food handling standards (NSF/ANSI 18-2016)
Order materials early, procure accurate amount of funding

**Identify project assumptions:**
We assume that a majority of people store dry ingredients in separate containers in their pantry and use several different measuring cups when baking. Our product will eliminate storage area taken up by the dry ingredients. The use of measuring cups for dry ingredients will be made obsolete.
This product assumes people will have counter to store the device.

**Identify project constraints:**
Time constraints- 10 weeks to conceptualize, design, and build
No automation
Limited to machine shop at Washington University

**Identify key project deliverables:**
A prototype of the product that is sized to scale with the appropriate materials that abide to the NSF standards (NSF/ANSI 18-2016).
1.7 REALISTIC CONSTRAINTS

1.7.1 Functional
The functional design constraints for our project was the overall geometry, the motion of the parts, and the forces involved. The overall geometry was constrained by the fact that we wanted it to be the size of an average countertop appliance. The slide mechanisms were supposed to make it easy for anyone to use and simple to operate with minimal amounts of force required.

1.7.2 Safety
The biggest safety concern for our device is if someone applies excessive force on one of the slides, there is a potential for the entire device to topple over. We wanted to design the support base so that if someone were to apply excessive force on the slides, the device would not fall over and hurt them.

1.7.3 Quality
To ensure device quality, we want to make sure that the device is compliant with safety standards. The safety standard we will adhere to is: NSF/ANSI 18-2016: Manual Food and Beverage Dispensing Equipment. The reliability of the device is also crucial, as we want the sliding mechanisms to withstand the test of time. We need the sliding tracks to stay clear of dry ingredients that are dispensing.

1.7.4 Manufacturing
We want the manufacturing process to be as streamlined as possible. It is important that the drawings we use to laser cut our acrylic are laid out such that we get the maximum number of parts out of each 12” by 12” sheet of material. The assembly process would also be improved if we redesigned how the containers fit into the support frame. The availability of the 3-D printer is certainly a constraint as it is high demand.
1.7.5 Timing
The allocated time to come up with a completed design is five and a half weeks; from September 8th to October 18th. The allocated time for ordering parts, fabricating, and assembling the prototype is four weeks; from October 18th to November 15th.

1.7.6 Economic
The budget for this project is $230.40. The money will go towards manufacturing costs such as buying and fabricating the parts. Since our budget is strict, we will try to use a majority of free, available parts left over from previous projects in the MEMS Department at Washington University.

1.7.7 Ergonomic
There were several ergonomic considerations in our design process. First and foremost, we needed to ensure that the slide mechanisms were easily manipulated by the user. This required us to redesign the smaller dispensing mechanisms several time, as the initial design didn't leave enough space between the slides for a user to comfortably grip them. Second, we needed to make some adjustments to the way we secured the smaller reservoir (for the salt and baking powder) such that is was removable for cleaning and refilling. At first we were going to simply glue it in, but before we did we realized that there wasn't a good way for the user to refill or clean the reservoir. We decided to mount it on some angled brackets from behind, and secure it from falling forward with a small, removable piece of acrylic. When the user removes the acrylic, the reservoir stays in place but can easily be removed for cleaning or refilling. The last major ergonomic consideration in our design was the frame for the device. We needed to make sure it was tall enough to fit a standard mixing bowl beneath the dispensing mechanisms, but wide and deep enough to provide a stable base considering the high center of gravity.

1.7.8 Ecological
Our prototype is made from wood, steel, acrylic, PLA, hot glue, and an acrylic bonding agent. Should our device be redesigned for serial production, we would want to replace the acrylic parts with injection molded food-safe plastics, and replace the wood frame with aluminum to save weight. Ideally this product would be considered a durable good with a considerable lifetime, but when the end-user decided to replace or get rid of it, the device would likely need to be thrown away. Due to the composite nature of its construction, it would be difficult for the consumer to recycle it, however a motivated individual could certainly take apart the device and recycle the aluminum and some of the plastic parts (depending on their region, the plastic may or may not be recyclable).

1.7.9 Aesthetic
Our prototype is not particularly aesthetically pleasing. If we were to commercially produce this device, we would remake the mismatched colors of the PLA with a clear plastic more similar to the material used in the large reservoirs. The wooden frame would be replaced with brushed aluminum to provide a two-tone (transparent plastic and brushed aluminum) device that would fit nicely into most modern kitchen decors. Replacing some of the sharp corners with radius corners would also improve the aesthetics of the device, as well as increasing the manufacturability of the device.

1.7.10 Life Cycle
As indicated above, this product is intended to be a durable device, used for a long period of time before failure or replacement. Due to its plastic and metal construction, it would be reasonable to expect a typical
lifetime of between 1 and 3 years, but it is possible excessive use could shorten that lifespan and proper care could increase it.

1.7.11 Legal
We are not aware of any patents that our prototype infringes upon, despite fairly exhaustive research. We were able to find some industry standards that likely would apply to our device, specifically the NSF/ANSI 18 - 2016 Manual Food & Beverage Dispensing Equipment (link: https://global.ihs.com/doc_detail.cfm?&rid=IHS&item_s_key=00266240&item_key_date=830623 &input_doc_number=NSF%2018-2016&input_doc_title). Our current prototype does not meet these specifications, however it would not be impossible to make some design changes to accommodate the relevant aspects of these standards.

1.8 REVISED PROJECT DESCRIPTION
The Dry Ingredient Dispenser is a device created to make baking easier. This device has four storage containers to hold flour, sugar, baking soda, and salt. The storage containers have attached measuring devices and dispensers. The ingredients flow through a funnel and then into the mixing bowl, thus providing the consumer with pre-measured dry ingredients for baking. The device will incorporate three important qualities in unison: contain, measure, and dispense.

2 CUSTOMER NEEDS & PRODUCT SPECIFICATIONS

2.1 CUSTOMER INTERVIEWS

Customer Needs Interview

Table 1: Customer Needs Interview

<table>
<thead>
<tr>
<th>Question</th>
<th>Customer Statement</th>
<th>Interpreted Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>How long does it usually take you to measure out dry ingredients for baking? How long to clean up?</td>
<td>Clean up takes around 5-10 minutes Taking out/ measuring dry ingredients takes about 5-10 minutes</td>
<td>Device measures and dispenses dry ingredients in less than 5 minutes Device creates minimal mess; cleanup takes less than 5 minutes</td>
<td>4</td>
</tr>
<tr>
<td>How are your dry ingredients stored? Are they easy to access?</td>
<td>Take up a lot of room in the cupboard, plastic containers hold the dry ingredients but ar</td>
<td>Device is easily stored and accessible</td>
<td>5</td>
</tr>
<tr>
<td>Question</td>
<td>Response</td>
<td>Rating</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>What is your biggest inconvenience when working with dry ingredients?</td>
<td>Mostly the mess that the dry ingredients make.</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Taking out all the different containers is difficult; the device should store large volume of ingredients</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>How do you ensure accurate measurements?</td>
<td>Pour and shake/hit the side of the measuring cup, scrape the top off with a knife, if there’s a little extra it won’t totally ruin the baked good item because it makes more a mess to scrape the top off so accuracy isn’t extremely important</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>What dry ingredients do you use the most?</td>
<td>Flour, sugar, baking soda, powdered sugar (on occasion brown sugar)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>What size items do you typically keep on your counter?</td>
<td>Larger size is fine like a kitchen aid mixing item because you won’t need to have large containers on your counter that contain flour, sugar, etc. It shouldn’t be larger than 18” in any dimension.</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>It also shouldn’t be too much of an eyesore if it’s going to be left out on the counter.</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>It shouldn’t weigh a lot. If I need to move it, it should be easy to do so.</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Any other capabilities you would like the dispenser to have?</td>
<td>An option to mount it on the wall would be nice because it would give more storage, a way to collect the mess if the bowl is not in the correct place (like the Keurig has)</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Device is airtight
Device is easy to refill
Device does not make a mess of dry ingredients
Device doesn’t require lifting or manhandling of heavy parts.
Device stores large volume of ingredients
Device accurately measures dry ingredients
Device will properly store and dispense flour, sugar, baking soda, and powdered sugar
Device is approximately 15” tall and 15” deep; no larger than 18” in any dimension
Device will look simple and aesthetically pleasing
Device will weigh less than 20 pounds
Device can be mounted on the wall for better storage
Device has a collection area for dry ingredients
I would love to have ingredients at the push of a button.

Device has a simple user interface.

<table>
<thead>
<tr>
<th>What measurements do you usually use?</th>
<th>Device measures flour and sugar in cup increments</th>
</tr>
</thead>
<tbody>
<tr>
<td>For flour and sugar- cups and half cups</td>
<td>Device measures baking soda in teaspoons and tablespoons increments</td>
</tr>
<tr>
<td>For baking soda- teaspoons and tablespoons</td>
<td></td>
</tr>
</tbody>
</table>

**2.2 CUSTOMER NEEDS**

Interpreted Customer Needs

Table 2: Interpreted Customer Needs:

<table>
<thead>
<tr>
<th>Need Number</th>
<th>Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Device measures and dispenses dry ingredients in less than 5 minutes</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Device creates minimal mess; cleanup takes less than 5 minutes</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Device is easily stored and accessible</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Device is airtight</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Device is easy to refill</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>Device does not make a mess of dry ingredients</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>Device doesn’t require lifting or manhandling of heavy parts</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Device stores large volumes of dry ingredients</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Device accurately measures dry ingredients</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>Device will properly store and dispense flour, sugar, baking soda, and powdered sugar</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>Device is approximately 15” tall and 15” deep; no larger than 18” in any dimension</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>Device will look simple and aesthetically pleasing</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>Device will weigh less than 20 pounds</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>Device can be mounted on the wall for better storage</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Device has a collection area for dry ingredients that may fall out/spill during measuring and dispensing</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>Device has a simple user interface</td>
<td>4</td>
</tr>
<tr>
<td>17</td>
<td>Device measures flour and sugar in cup increments</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>Device measures baking soda in teaspoons and tablespoons increments</td>
<td>5</td>
</tr>
</tbody>
</table>
2.3 TARGET SPECIFICATIONS

Target Specifications

Table 2: Target Specifications

<table>
<thead>
<tr>
<th>Metric Number</th>
<th>Associated Needs</th>
<th>Metric</th>
<th>Units</th>
<th>Acceptable</th>
<th>Ideal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,2</td>
<td>Time</td>
<td>Minutes</td>
<td>&lt;5</td>
<td>&lt;2</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>Height</td>
<td>Inches</td>
<td>&lt;36</td>
<td>&lt;18</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>Depth</td>
<td>Inches</td>
<td>&lt;36</td>
<td>&lt;18</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>Weight (empty)</td>
<td>Pounds</td>
<td>&lt;80</td>
<td>&lt;10</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>Volume (flour/sugar)</td>
<td>Cups</td>
<td>&gt;10</td>
<td>&gt;20</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>Volume (baking soda, baking powder, etc.)</td>
<td>Tablespoons</td>
<td>&gt;10</td>
<td>&gt;20</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>Perimeter</td>
<td>Inches</td>
<td>&gt;16</td>
<td>&gt;30</td>
</tr>
</tbody>
</table>
3 CONCEPT GENERATION

3.1 FUNCTIONAL DECOMPOSITION

Device accurately measures and dispenses dry ingredients

Lid seals

Position of vibrating sifter

On/off switch for vibrating sifter

Activation to dispense

Interface with kitchen counter

Allows different measurements to be selected

Figure 13: Function Tree for Dry Ingredient Dispenser
### 3.2 MORPHOLOGICAL CHART

**Morphological Chart for Dry Ingredient Dispenser**

Table 3: Morphological Chart for Dry Ingredient Dispenser

<table>
<thead>
<tr>
<th><strong>Lid seals</strong></th>
<th><img src="image1" alt="Images of different lid types" /></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activation to dispense</strong></td>
<td><img src="image2" alt="Images of activation methods" /></td>
</tr>
<tr>
<td><strong>On/off switch for vibrating sifter</strong></td>
<td><img src="image3" alt="Images of on/off switches" /></td>
</tr>
<tr>
<td><strong>Interface with kitchen counter</strong></td>
<td><img src="image4" alt="Images of interface designs" /></td>
</tr>
<tr>
<td><strong>Position of vibrating sifter</strong></td>
<td><img src="image5" alt="Images of sifter positions" /></td>
</tr>
</tbody>
</table>
3.3 CONCEPT #1 – “DRY INGREDIENT STORAGE DEVICE WITH INTERNAL MEASURING MECHANISM”

This device is split into four different containers for four different ingredients. Each container has its own fitted lid. Dry ingredients flow into the measuring area, which is positioned at an angle for easy flow. The ingredients are then dispensed into a vibrating sifter that is controlled by an on/off switch. The ingredients flow through the vibrating sifter then into a funnel which go into a bowl. The device is supported by four legs that interface with the kitchen counter.

Figure 14: Dry Ingredient Storage Device with Internal Measuring Mechanism
3.4 **CONCEPT #2 – “CYLINDRICAL STORAGE DEVICE WITH RETRACTABLE OPENING”**

![Diagram of Cylindrical Storage Device with Retractable Opening]

**Figure 15: Cylindrical Storage Device with Retractable Opening**

This cylindrical device is split into four different containers for four different ingredients. Each container has its own fitted lid that is almost as large as the container area for easy cleaning and easiness to refill. The ingredients are measured then dispensed into a vibrating sifter. A handle operates both the retractable opening and the vibrating sifter. The ingredients flow through the vibrating sifter then into a funnel which go into a bowl. The device is supported by four legs that interface with the kitchen counter.
3.5 CONCEPT #3 – “CALIBRATED SPRING SCALE MEASURING DEVICE”

This device uses spring scales calibrated to each ingredients density to measure out the desired volume. A twist valve is then used to dispense all ingredients into a vibrating sifter that sits above a bowl. The vibrating sifter is turned on using an on/off switch located on the side of the device. Each container is closed with a fitted lid. There are five containers (each holding a different ingredient) that are housed in the same unit.

Figure 16: Calibrated Spring Scale Measuring Device
3.6 CONCEPT #4 – “SLIDING MEASURING AND DISPENSING DEVICE”

This device uses sliding doors to select different measurements and dispense ingredients. The user will pull out the slides that correspond to their desired measurement. There is a slide at the bottom of the measuring cups which the user will remove to dispense ingredients. The ingredients then flow into a vibrating sifter which is operated by an on/off switch. A flat bottom supports the device. Each container has its own fitted lid at the top of the device.
3.7 CONCEPT #5 – "CYLINDRICAL MEASURE AND DISPENS-O-MATIC 2000"

The Cylindrical Measure and Dispense-O-Matic 2000 is a device that uses a plunger-like mechanism to measure out the dry ingredients. The storage container has measuring marks on the side so users manually move the plunger to how much of an ingredient they need. There is a vibrating mechanism inside of the dispenser to prevent clumping of the ingredients. There is a fitted lid on the top and a stand to support the device.

Figure 18: Cylindrical Measure and Dispens-O-Matic 2000
3.8 CONCEPT #6 – “CYLINDRICAL DRY INGREDIENT DISPENSER WITH VARIABLE FLOW RATES”

The cylindrical dry ingredient dispenser with variable flow rates uses pinhole alignments to dispense the dry ingredients at variable speeds. The vibrating mechanism sits inside of the storage container to prevent clumping of ingredients and is turned on/off with a flip switch. The container is made airtight using an overhang lid with elastic plastic. The device is used with a measuring cup.

Figure 19: Cylindrical Dry Ingredient Dispenser with Variable Flow Rates
4 CONCEPT SELECTION

4.1 CONCEPT SCORING MATRIX

Table 4: Analytical Hierarchy Process

<table>
<thead>
<tr>
<th>Safety</th>
<th>Simple user interface</th>
<th>Accurately measures ingredients</th>
<th>Easy to clean</th>
<th>Stores multiple ingredients</th>
<th>Manufacturing ability</th>
<th>Cost of materials</th>
<th>Aesthetically pleasing</th>
<th>Measuring/dispensing time</th>
<th>New Total</th>
<th>Weight Value</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.00</td>
<td>0.80</td>
<td>0.33</td>
<td>0.11</td>
<td>1.00</td>
<td>0.54</td>
<td>0.50</td>
<td>0.50</td>
<td>1.00</td>
<td>9.81</td>
<td>0.03</td>
<td>3.10%</td>
</tr>
</tbody>
</table>

Table 5: Weighted Scoring Matrix

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Weight (%)</th>
<th>Rating</th>
<th>Weighted</th>
<th>Rating</th>
<th>Weighted</th>
<th>Rating</th>
<th>Weighted</th>
<th>Rating</th>
<th>Weighted</th>
<th>Rating</th>
<th>Weighted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>0.22</td>
<td>4</td>
<td>0.80</td>
<td>4</td>
<td>0.80</td>
<td>4</td>
<td>0.80</td>
<td>4</td>
<td>0.80</td>
<td>4</td>
<td>0.80</td>
</tr>
<tr>
<td>Simple user interface</td>
<td>0.11</td>
<td>3</td>
<td>0.33</td>
<td>3</td>
<td>0.33</td>
<td>3</td>
<td>0.33</td>
<td>3</td>
<td>0.33</td>
<td>3</td>
<td>0.33</td>
</tr>
<tr>
<td>Accurately measures ingredients</td>
<td>0.22</td>
<td>3</td>
<td>0.66</td>
<td>3</td>
<td>0.66</td>
<td>3</td>
<td>0.66</td>
<td>3</td>
<td>0.66</td>
<td>3</td>
<td>0.66</td>
</tr>
<tr>
<td>Easy to clean</td>
<td>0.54</td>
<td>5</td>
<td>2.70</td>
<td>5</td>
<td>2.70</td>
<td>5</td>
<td>2.70</td>
<td>5</td>
<td>2.70</td>
<td>5</td>
<td>2.70</td>
</tr>
<tr>
<td>Stores multiple ingredients</td>
<td>0.30</td>
<td>4</td>
<td>1.20</td>
<td>4</td>
<td>1.20</td>
<td>4</td>
<td>1.20</td>
<td>4</td>
<td>1.20</td>
<td>4</td>
<td>1.20</td>
</tr>
<tr>
<td>Manufacturing ability</td>
<td>0.50</td>
<td>2</td>
<td>1.00</td>
<td>2</td>
<td>1.00</td>
<td>2</td>
<td>1.00</td>
<td>2</td>
<td>1.00</td>
<td>2</td>
<td>1.00</td>
</tr>
<tr>
<td>Cost of materials</td>
<td>0.30</td>
<td>3</td>
<td>0.90</td>
<td>3</td>
<td>0.90</td>
<td>3</td>
<td>0.90</td>
<td>3</td>
<td>0.90</td>
<td>3</td>
<td>0.90</td>
</tr>
<tr>
<td>Aesthetically pleasing</td>
<td>0.30</td>
<td>3</td>
<td>0.90</td>
<td>3</td>
<td>0.90</td>
<td>3</td>
<td>0.90</td>
<td>3</td>
<td>0.90</td>
<td>3</td>
<td>0.90</td>
</tr>
<tr>
<td>Measuring/dispensing time</td>
<td>0.30</td>
<td>4</td>
<td>1.20</td>
<td>4</td>
<td>1.20</td>
<td>4</td>
<td>1.20</td>
<td>4</td>
<td>1.20</td>
<td>4</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Total score: 3.265
Rank: 3

4.2 EXPLANATION OF WINNING CONCEPT SCORES

The first-place concept design that was selected is concept #4, a rectangular shaped container that uses a sliding mechanism to select different measurement and dispense dry ingredients. This concept scored better than the reference concept for its manufacturing ability, simple user interface, and aesthetics but it did not score better than the reference concept for portability. This concept measures the ingredients more accurately than the reference because the users are physically opening the device to what measurement they want. The reference device has users press a button that then changes the measurement; this can be problematic if there are any mechanical issues with the device and could lead to improper measurements. The user interface is also more simple and clear because users can see everything that is being done (the
process of measuring, dispensing, and sifting). This device is also more aesthetically pleasing than the reference device because the measuring cups are directly below the containers making the device have a smaller volume than the reference and giving a sleeker appearance. Although this concept scored lower on portability than the reference, the shape of the device can be changed so that it has a lower center of gravity or other such things that will make moving it easier. Lastly, as a group we thought this concept was also the most feasible to design and create a prototype of.

4.3 EXPLANATION OF SECOND-PLACE CONCEPT SCORES

The second-place concept design that was selected uses spring scales that are calibrated to each ingredients density to measure out the desired volume of a dry ingredient. This concept scored better than the reference in its ability to accurately measure ingredients and its aesthetics but scored lower in its user interface, cost of materials and portability. Making sure the device accurately measured the ingredients was weighted heavier than cost of materials and portability combined and is the reason why this concept came in second place. Although using spring scales calibrated to each ingredient’s density would provide extremely accurate measurements it would not have a simple user interface and springs would have to be calibrated every time the user wants to change ingredients in the container. Also, the spring scale would measure out ingredients in grams which is not a typical measurement used by bakers; this could be problematic and cause users to do extra work when converting cups or teaspoons to grams.

4.4 EXPLANATION OF THIRD-PLACE CONCEPT SCORES

The third-place concept design that was selected uses internal measuring devices that are activated by external buttons. This concept was the reference concept, so it makes sense that it scored in the middle. This concept was the most basic design that had mostly 3s for every criteria and a couple 4s. This design is most like concept #4 (the first-place design) but less aesthetically pleasing and didn’t measure out ingredients as accurate. The wideness and bulkiness of this device makes it less aesthetically pleasing and would take up more room on a user’s counter than the winning concept. This design is also not as easily manufactured because the measuring cups are internal instead of external.

4.5 SUMMARY OF EVALUATION RESULTS

The criteria we deemed most important for the dry ingredient dispenser device were that it accurately measured ingredients and that it had minimal measuring and dispensing time. Our second most important criteria were that the device would store multiple ingredients and have a simple user interface. Our least important criteria were easiness to clean and for users to be able to refill the device without making a mess. Though these criteria are important to the final, overall concept/idea of the device, they are not important in making sure the device does what we intended it to do (measure and dispense). Overall, it seems that the evaluation results align with our desired functionality of the device. The first and second place concepts had the highest scores in their ability to accurately measure the dry ingredients. The first, second, third, and fourth place concept scored the highest and all the same for measuring and dispensing time, which again agrees with the main functionality of the device. The fifth and sixth place concepts scored the highest in easiness to clean, which as stated above, was weighted lowest in comparison to the
rest of the criteria. Thus, from these criteria we made a well-informed decision for the concept we selected for the dry ingredient dispenser (which was the winning concept).

Overall, the

5 EMBODIMENT & FABRICATION PLAN

5.1 ISOMETRIC DRAWING WITH BILL OF MATERIALS

Figure 20: Isometric View and Bill of Materials for Dry Ingredient Dispenser
5.2 EXPLODED VIEW

Figure 21: Exploded View of Dry Ingredient Dispenser
5.3 ADDITIONAL VIEWS

![Diagram of the device](image)

Figure 22: Front, top, and side view of device

6 ENGINEERING ANALYSIS

6.1 ENGINEERING ANALYSIS RESULTS

6.1.1 Motivation

The engineering analysis was done on the center of gravity of the entire device. This was important because the users will need to pull multiple slides out of the device to measure and dispense the ingredients and there is a possibility that these slides could get stuck and users would have to use extra force to pull the slide out. To ensure that the device wouldn’t topple over when users pull out the slides, an analysis was done to find the center of gravity of the device and the force required to topple it over.
From this analysis, we expect to understand if the current design is acceptable or if the frame of the device needs to be changed to have more stability.

6.1.2 Summary Statement of the Analysis

SolidWorks was used to determine the mass and the location of the center of mass (CoM) when the device was filled with ingredients. Due to the complex geometry and different material used for the device, it would be difficult to determine the location of the CoM without SolidWorks. Previous physics knowledge was used and applied to determine the minimum forces to slide and topple the device over.

Below is a simple schematic of the forces that will be acting on the device when it is in use.

![Force-body diagram](image)

**Figure 23: Force-body diagram**

6.1.3 Methodology

The engineering analysis could have been conducted experimentally using a simple tension scale to test at what force the devices started to slide and at what force the device began to topple. This test was not conducted, but certainly should have been. The experiment could then be compared to the theoretical values obtained below.

We first tested how much force would be necessary to slide the device if it was pulled at its center of mass. Using the density of flour, sugar, salt, and baking soda and the volume of each container, the mass of the container while full of ingredients was found; the mass of the container full is 14.632kg. The force of the pull is assumed to be applied at the CoM, but it does not really matter for the basic sliding model for overcoming static friction. The coefficient of friction was estimated for wood on wood. Below is a calculation summing the forces on the entire container to find the minimum amount of force necessary to slide the device.

Minimum force to slide container while full:

\[
F_{\text{gravity}} = (14.632\text{kg}) \left(9.81 \frac{m}{s^2}\right) = 143.5N
\]

\[
\sum F_y = 0
\]
\[ F_{\text{gravity}} = N \]
\[ \sum F_x = 0 \]
\[ F_{\text{min,\,slide}} = F_f = \mu N = (0.6)(143.5N) = 86.1N \]
\[ F_{\text{min,\,slide}} = 86.1N = 20lb\,f \]

Second, we tested how much force would be necessary to topple the device over when the user is pulling the dispensing slides out. The height of the slide, \( d \), from the bottom of the device was 31.04 cm. The distance of the CoG from the point of rotation, \( b \), was 17.54 cm. Below is a calculation summing the moments about the bottom corner of the device to find the minimum amount of force necessary to topple the container over.

Minimum force to topple container while full:
\[ \sum M = 0 \]
\[ (F_{\text{min}} \times d) - (F_g \times b) = 0 \]
\[ F_{\text{min}} = \frac{F_gb}{d} \]
\[ F_{\text{min}} = \frac{(143.5N)(8.77\,\text{cm})}{(31.04\,\text{cm})} = 40.54N \]
\[ F_{\text{min\,topple}} = 40.54N = 9lb\,f \]

6.1.4 Results
The results of the analysis stated that the minimum force to slide the container while full, if pushed at its center of gravity is around 86.1N. The minimum force to topple the container if forced at the height of the dispensing slide is around 40.54N. These results make sense as the device is top heavy due to the fact that there needed to be enough room below the containers and dispensers to fit a typical sized mixing bowl.

6.1.5 Significance
The results of the analysis lead us to three different possible changes to our prototype. The first change would be to increase the overall mass of the device so that the force required to topple it over would also need to increase. The second change would be to change the location or design of the dispenser so that the measuring and dispensing slides were closer to the base of the device. The last change was to increase the width of the base. Because we want the device to be portable to allow users to transfer it from their countertops to their cabinets with ease, increases the overall mass of the device wasn’t an ideal choice. Likewise, changing the location of the dispenser was also not an ideal choice because there needed to be an adequate amount of room underneath the dispenser so that a standard size mixing bowl could fit. Therefore, the most logical change to the device was to change the width of the frame. In the original frame design the width of it was only as long as the width of the containers, but after the engineering analysis, the width of the frame has been extended past the width of the containers.

6.2 PRODUCT RISK ASSESSMENT

6.2.1 Risk Identification
1. Risk Name: Toppling over
   Description: The taller the device, the more likely it is to topple over when force is applied.
   Impact: #3. If the entire device was forced excessively there is a possibility that the entire device could topple over. If this were to happen, the impact is significant because the user could get
injured if the device were to fall on them. Also, depending on how the device falls, it could break and become unusable.

**Likelihood:** #1. The likelihood of the device toppling over is low. This is due to the design of the device and its stable base.

2. **Risk Name:** Dispensing of all ingredients  
   **Description:** There are two separate slides that keep the ingredients from flowing out of the device. The first slide allows ingredients to flow from the container into the dispensing unit. The second slide allows ingredients to flow from the dispensing unit into a bowl outside of the device. Users are instructed to only have one slide pulled out at a time. But if a user were to accidentally pull out both slides at one time, it would result in all ingredients in the storage container being dispensed.  
   **Impact:** #2. The only impact this risk would have is that it would create a large mess for the user to clean up. Other than that, it would have no effect on the device; the device would still be able to function normally if this were to happen.  
   **Likelihood:** #2. The likelihood that this would happen is low. To use the device, users will need to pull out one slide at a time. There is not a need to ever pull out two slides at the same time. The only way that this would happen is if the user doesn’t comply with the given instructions.

3. **Risk Name:** Nuts are a choking hazard  
   **Description:** The separate parts of the device are held together with several nuts and bolts. If taken apart, the nuts pose a serious choking hazard for children as they are small and can be easily swallowed.  
   **Impact:** #5. If a small child were to find one of the loose nuts and put it in their mouth, the end results could be very catastrophic. There is the possibility of choking which could lead to serious injury or death.  
   **Likelihood:** #1. It is very unlikely that the nuts would just unscrew or fall off without the aid of a person unscrewing them. The nuts are secured tightly onto the screw so that a wrench would be needed to take them off.

4. **Risk Name:** Steel slide sharpness  
   **Description:** The steel slides that are used to measure and dispense the dry ingredients must be sharp to break through the built-up flour, sugar, baking powder, and baking sugar.  
   **Impact:** #3. If someone were to take out the steel slides they could possibly cause physical damage if they were to hit or try to cut someone with them.  
   **Likelihood:** #2. This device is for a mature consumer, that will appropriately use the device. Therefore, the likelihood of this happening is low.

5. **Risk Name:** Electrocution from battery  
   **Description:** If the battery and motor are removed from the device and/or misused, this could lead to minor electrocution.  
   **Impact:** #4. The impact of this occurring is significant because electrocution could lead to injury, most commonly, burns.  
   **Likelihood:** #2. The likelihood of this occurring is low-medium. The battery and motor used for the device are relatively small and are hidden behind the containers so they are hard to access.

6. **Risk Name:** Bolt security  
   **Description:** If the bolts and nuts that hold the device together are not secure to one another, they could fall into the dry ingredients leading to the user to possibly use it in baking without knowing
Impact: #4. The impact of this occurring is significant because if a user unknowingly baked with a nut or bolt in the ingredients this could lead to chemically contaminating the food, someone could injure a tooth if they bit into a nut or bolt, or someone could possibly choke.

Likelihood: #1. The likelihood of this occurring is low because the device comes assembled with the nuts and bolts securely tightened to one another; there is no need for the user to take apart the device or adjust the nuts and bolts.

6.2.2 Risk Heat Map

![Risk Assessment Heat Map](image)

Figure 24: Risk Heat Map

6.2.3 Risk Prioritization

Using a Risk Calculation tool provided by the MEMS 411, the six risks were able to be prioritized. Below is a table with each risk score.

Table 6: Risk Scores

<table>
<thead>
<tr>
<th>Risk</th>
<th>Impact</th>
<th>Likelihood</th>
<th>Risk Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toppling over</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
Dispensing of all ingredients | 2 | 2 | 4
Nuts are a choking hazard | 5 | 1 | 5
Steel slide sharpness | 3 | 2 | 6
Electrocution from battery | 4 | 2 | 8
Bolt security | 4 | 2 | 4

It can be seen that the greatest to least risks are as follows: electrocution from batter, steel slide sharpness, nuts as a choking hazard, bolt security/dispensing of all ingredients, and toppling over.

7 DESIGN DOCUMENTATION

7.1 PERFORMANCE GOALS

The performance goals for The Dry Ingredient Dispenser is as follows:
1. Empty device weighs less than 20 pounds
2. Dimensions of device are as follows: 20” wide, 15” deep, 20” tall
3. Measuring and dispensing all four ingredients will take less than two minutes
4. Device will measure the dry ingredients with an error of less than ten grams per cup and less than five grams per teaspoon
5. After dispensing all four ingredients, there will be less than 10 grams of mess/ cleanup

7.2 WORKING PROTOTYPE DEMONSTRATION

7.2.1 Performance Evaluation

Our prototype was able to successfully dispense 3 out of 4 ingredients as-designed. We found, however, that additional demonstrations caused some of the ingredients, especially the sugar, to become stuck in the channels that hold the slides, blocking their motion. Furthermore, our design did not take into account the compacting effect flour has when stored in a column. We attempted to add a vibrating element to disturb the compacted flour at the bottom of the reservoir to encourage it to flow, but the device we used didn't produce strong enough vibrations to break up the compacted flour. For the 3 ingredients that successfully dispense, the device met our performance goals quite well. The sugar was successfully dispensed in 1/4 cup increments, and the salt and baking powder were successfully dispensed in their 1-tsp increments with less than 10 grams of wasted material. The process took less than 2 minutes, and a standard mixing bowl fit comfortably within the frame of the device. The device weighs less than 20 pounds empty, fulfilling the last stated performance goal.

7.2.2 Working Prototype – Video Link

https://www.youtube.com/watch?v=blzS9FsTWfc&t=41s
7.2.3 Working Prototype – Additional Photos

Figure 25: Final working prototype of The Dry Ingredient Dispenser
8 DISCUSSION

8.1 DESIGN FOR MANUFACTURING – PART REDESIGN FOR INJECTION MOLDING

8.1.1 Draft Analysis Results

![Draft Analysis Results](image)

Figure 26: Draft analysis for injection molding

8.1.2 Explanation of Design Changes

First, a selection of pull directions were tested to find the ideal direction that would require the last design changes. Second, changes made to the smaller reservoir include adding draft angles to the side walls to make it possible to use injection molding to manufacture the part. The channel going down the middle of the part was left unchanged as the feature is too small to edit for injection molding while maintaining its shape and function (specifically, to serve as an insertion point for the divider plate to separate the reservoir into 2 sections).

8.2 DESIGN FOR USABILITY – EFFECT OF IMPAIRMENTS ON USABILITY

8.2.1 Vision

The potential problems that may stem from a vision impaired person using the device is that they would not exactly be able to see how much of a dry ingredient they are measuring/ dispensing. The slides used for dispensing flour and sugar are marked in \( \frac{1}{4} \) cup increments so the user knows how far to pull out the slide depending on how much of the ingredient they wish to use. If the user is vision impaired they may not be able to see these marks on the slides and therefore will not know how much ingredients they are dispensing out.
8.2.2 Hearing
The potential problem that may stem from a hearing-impaired person using the device is that they may not be able to hear if the vibrating motor is on or off; leaving the motor on can lead to quickly draining the battery.

8.2.3 Physical
The potential problem that may stem from a physically-impaired person using the device is they may have trouble refilling the device, specifically refilling the flour and sugar containers. The flour and sugar containers sit about 25 inches high, therefore some users may have trouble lifting a five-pound bag of flour or sugar that high to refill the container. To remedy this problem, a user could use a spoon or scooper to transfer ingredients from bag to container.

Another potential problem users may encounter is if they want to transport the device. The device weighs less than 20 pounds but the dimensions of the device may impose difficulty for the user to grip.

8.2.4 Language
The potential problems that may stem from a language impaired person using the device is associated with unit conversions. The device will measure flour and sugar in ¼ cup increments and baking soda and salt in teaspoons. If a person is not familiar with these units or does not know how to convert these units to the units they need, an outside source will be needed.

8.2 OVERALL EXPERIENCE

8.2.1 Does your final project result align with the initial project description?
Overall, our final project aligned very closely with our initial project description. Initially, we intended our project to be a device that held four different dry ingredients used for baking. This device would be able to accurately measure out the appropriate amount of ingredients, then send those ingredients through a vibrating sifter, then through a funnel into a mixing bowl. In the end, we were able to construct four storage containers, each with their own dispensing unit; the large dispensing units measures ingredients in increments of ¼ of a cup and the smaller dispensing units measures ingredients in increments of 1 teaspoon. Three of the four ingredients flowed successfully through the storage container, dispensing units, and funnel but we found trouble dispensing the flour. We initially conducted tests to ensure flour would flow through the appropriate holes but we did not account for the packing of flour when stored in large volumes.

8.2.2 Was the project more or less difficult than you had expected?
The project was more difficult than our group had expected. When we first began brainstorming for the project, we agreed that we wanted to create something that was strictly mechanical as neither of us had experience in electrics or programming. With our project being only mechanical, we assumed that with proper planning and testing, our project would be feasible. In the end, we ran into a lot more problems than we had expected, making the project more difficult than expected.

8.2.3 In what ways do you wish your final prototype would have performed better?
There are a couple ways we wished our final prototype performed better, with the first being that the flour would dispense. In our final prototype the amount of the flour that the storage container held compacted the flour so much that it would not flow out of the container or out of the dispensing mechanism. We tried
to remedy this problem by attaching a vibrating motor in the flour container to help the flow but the original motor was not strong enough; we did not have enough time to buy and test other motors. Additionally, we wished that the slides that measure and dispense the dry ingredients moved in and out of the dispenser easier. Because the dispensers were 3-D printed, the small opening for the slides had some excess plastic because during the 3-D print, the plastic drooped a little; therefore, the slides do not move completely smoothly through the dispensers.

8.2.4 Was your group missing any critical information when you evaluated concepts?
We didn't know about the limitations of the laser cutters when we went through our materials selection process; the sheets of acrylic we purchased were quite literally the maximum thickness the laser cutters are able of processing. One of our parts ended up catching fire and melting mid-cut, which would not have happened if we had selected thinner acrylic sheets. Another issue we ran into was the compacting nature of flour. While our initial flow testing showed that the holes we designed were large enough to allow the flour to flow, we forgot to take into account the fact that when flour is stored in a column, the bottom of the column compacts significantly, which impedes its ability to flow. When we completed our build and tried to dispense flour, we found it wouldn't flow from the reservoir into the dispensing unit. We attempted to fashion a vibrating agitator from an old Xbox controller, but found that the vibrations were not strong enough to break up the compacted flour and allow it to flow.

8.2.5 Were there additional engineering analyses that could have helped guide your design?
Our engineering analysis should have included a particle study of a Solidworks Flow simulation. The simulation would have helped us foresee the difficulty in flowing flour through our device. The study would have informed the geometries of our dispensing unit, especially the size of the opening through which the flour was supposed to flow. Another engineering analysis that would have been useful would have been to think about the amount of friction that would have been introduced in the event that an ingredient got into our sliding track.

8.2.6 How did you identify your most relevant codes and standards and how they influence revision of the design?
We used NSF/ANSI 18-2016 Manual Food and Beverage Dispensing Equipment standard when considering our design. Because our device is designed to only hold dry ingredients and not interact with any wet ingredients or close to where food is being cooked there were not many strict specifications that we had to abide by. Some of the specific standards that we took into consideration was food safe material, standards for dispensing mechanisms, and the standards for mounting equipment. Although the plastic acrylic and PLA we used for the prototype was not food safe, we took into consideration what material we would use if actually creating this device; to determine this material we would adhere to the NSF International Standard for Food Equipment- Food Equipment Material.

8.2.7 What ethical considerations (from the Engineering Ethics and Design for Environment seminar) are relevant to your device? How could these considerations be addressed?
The life cycle of our product is something that we need to consider as we move forward into the manufacturing process. The plastics we use should be recyclable and we may want to look into making the device out of recycled plastics. The materials should be sourced or reclaimed from a local company to reduce the carbon footprint of shipping materials. We should improve the design of our product to include more snap fits instead of gluing the parts together. The use of glue makes it harder to reuse and reclaim the plastic parts used in our device at the end of its life cycle.
8.2.8 On which part(s) of the design process should your group have spent more time? Which parts required less time?

Our group should have originally spent more time researching and testing. The testing that we did was minimal and in the end, we realized was completely helpful for our design. We originally tested how flour would flow through different size holes, and while this was helpful, after assembling our prototype we realized that we should have been testing how flour would flow when compacted in a large container. If we would have spent more time researching and testing, this problem may have been discovered before assembling the prototype. Also, if given more time, our group would have spent more time researching different fabrication methods so that some of our parts could be made out of acrylic plastic instead of PLA plastic.

The concept selection and embodiment assignment required less time than assigned. This assignment originally had a duration of two weeks but then got extended twice. As this assignment was extended, our group put more time into re-designing our parts on Solidworks instead of beginning fabrication and testing. In the future, we believe that shorter time for the concept selection and embodiment assignment and more time to begin fabrication and make any necessary changes to the project would result in more complete projects.

8.2.9 Was there a task on your Gantt chart that was much harder than expected? Were there any that were much easier?

One of the tasks that was much harder than expected was the engineering analysis. Originally, we began by analyzing the internal stresses and strains of the storage containers and dispensing devices. After consulting with the MEMS 411 professors, we realized that analyzing the force needed to tip the device over would be much more useful for design considerations. To do this analysis we had to “fill” the containers up with their appropriate dry ingredients; we did this by using each ingredients density. We then had to simulate the tipping over in Solidworks. Figuring out how to first “fill” each container with dry ingredients then simulate the tipping over was harder than expected.

We assumed the part ordering process to be a bit stressful due to the short time between the concept selection and the prototype demo but we ended up using McMaster for a majority of the parts. This made the part ordering process a lot easier as McMaster only took about a day or two to deliver our ordered material.

8.2.10 Was there a component of your prototype that was significantly easier or harder to make/assemble than you expected?

Neither of us had ever worked with acrylic plastic so we assumed that fabricating and putting together the storage containers was going to be difficult due to our inexperience. When we began consulting with MEMS 411 professors, they suggested that we use a laser cutter to cut our acrylic plastic. Because Elijah was familiar with Autocad, he was able to take our Solidworks design and recreate it in Autocad. Once this was done the laser cutting became an easy process. On the opposite end, we found 3-D printing to be harder than we initially anticipated. We all had previous experience with Solidworks and 3-D printing so it was assumed that we could easily 3-D model our parts and print them. While 3-D printing we encountered many problems such a drooping and warping that made this process much more difficult than expected. In the end, contrary to what we initially expected, we found that fabricating the acrylic plastic was one of our easier tasks while 3-D printing was one of our more difficult tasks.
8.2.11 If your budget were increased to 10x its original amount, would your approach have changed? If so, in what specific ways?

If out budget were increased, one of the things we would have done was get some of our parts fabricated by an outside party that is more experienced in fabrication. Many of our small parts had intricate insides and therefore we had to 3-D print them, 3-D printing issues led to some of the problems we encountered while assembling the prototype.

8.2.12 If you were able to take the course again with the same project and group, what would you have done differently the second time around?

If we were able to take this course again, I think we would put more time and effort into research and preliminary testing. Additionally, we would have begun assembling our prototype earlier so that we would have time to address and correct any problems that we ran into.

8.2.13 Were your team member’s skills complementary?

Overall, our team member’s skills were complementary to one another, each person had expertise in a different thing. Elijah was highly skilled in Solidworks and Autocad. David was highly skilled in fabrication and using machine shop tools. Maya was critical to keeping the documentation in order, ordering parts and materials, and keeping track of deadlines.

8.2.14 Was any needed skill missing from the group?

One skill that was missing from our group was someone that was experienced in working with acrylic plastic. We originally intended for most of our parts to be fabricated with acrylic plastic, but found that our lack of experience working with this material prevented us from fabricating the smaller parts of the device from it. If we had someone that was experienced in working with this material, our group may have felt more comfortable using the acrylic plastic for more parts of our device.

8.2.15 Has the project enhanced your design skills?

This project has greatly enhanced our design skills; we are all more familiar with the complete design process one must go through from conceptual design to creating an actual prototype. When this project fist began, we initially had the idea that creating a product from beginning to end involved a lot of actual designing, whether it be in Solidworks or hand sketching and while this was the case a majority of the time, we hadn’t considered many of the important, preliminary steps that needed to be taken and all of the constraints when creating a new product.

8.2.16 Would you now feel more comfortable accepting a design project assignment at a job?

Absolutely. We learned two very important life skills that are useful anywhere, but especially in the design process: managing time and managing resources. One of the trickiest aspects of this project was finding the time to get everything done in one semester. We learned to partition our work into smaller more manageable chunks. The use of Gantt charts and to-do lists made our seemingly nebulous task much more approachable. Further, we learned to manage our resources. We recognized early on that different members of our team had different skill sets. We tried to divide up the work in such a way so that everyone was working on what they were best at. We also identified all of the resources at our disposal such as the laser cutter, the 3-D printer and the reclaimable items in the Jolley basement. By reclaiming materials we managed to come in about $100 under budget. Budgeting is a massive constraint in most design projects, but by taking time to think before we bought we were successful in staying on track.
8.2.17 Are there projects you would attempt now that you would not have attempted before?
This is an odd question to answer, mostly because there weren't projects that we wouldn't have attempted before. We are certainly more confident in our abilities to succeed in a design-and-build project having completed this one, and we've gained valuable skills and experience with new design concepts and manufacturing methods. That being said, we can't think of anything that we wouldn't have at least tried to do before this project.

9 APPENDIX A - PARTS LIST

Table 7: Parts List

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<tr>
<th>Part</th>
<th>Source Link</th>
<th>Supplier Part Number</th>
<th>Color, TPI, other part IDS</th>
<th>Unit price</th>
<th>Tax ($0.00 if tax exemption applied)</th>
<th>Shipping</th>
<th>Quantity</th>
<th>Total Price</th>
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<td>8589K81</td>
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<td>04916-1003</td>
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**APPENDIX C - CAD MODELS**

Figure 27: Part drawing of the flour and sugar storage container

Figure 28: Part drawing of the baking soda and salt storage container
Figure 29: Part drawing of divider for small storage container

Figure 30: Part drawing of the lid for the large storage container
Figure 31: Part drawing of lid for small storage lid

Figure 32: Part drawing of separator for large dispensing device

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Figure 33: Part drawing of large dispensing device

Figure 34: Part drawing of slides for large dispensing unit
Figure 35: Part drawing of small dispensing unit

Figure 36: Part drawing of slides for small dispensing unit

Note:
1. Material: 3D Printed Thermoplastic
2. Material: 1/32" stainless steel sheet metal
Figure 37: Part drawing of tabs used to support small storage device

Figure 38: Part drawing of support frame for entire device