Fall 12-8-2017

Automated Color Selector

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Executive Summary

Design, build, and sell a safe automated primary color dye mixer to schools for the purpose of teaching children how 12 secondary colors (and shades) on a color wheel can be made via the primary colors. The user will select the desired color and then the machine will automatically deposit the correct amount of each primary color to create the selected color. Either water-based paint or dye will be used in the machine so that if a mess is made, the cleanup is easy. The cup with the colors will then be mixed automatically. From here, the final dye mixture will match the desired color chosen at the beginning.

MEMS 411: Senior Design Project

Group B: Automated Color Selector

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1 Introduction and Background Information

1.1 Initial Project Description

Design, build, and sell a safe automated primary color dye mixer to schools for the purpose of teaching children how 12 secondary colors (and shades) on a color wheel can be made via the primary colors. The user will select the desired color and then the machine will automatically deposit the correct amount of each primary color to create the selected color. Either water-based paint or dye will be used in the machine so that if a mess is made, the cleanup is easy. The cup with the colors will then be mixed automatically. From here, the final dye mixture will match the desired color chosen at the beginning.

1.2 Existing Products

1.2.1 Mixing Mate 10-090 Gallon Size Paint Can Lid: Home Improvement

This product is similar to the Automated Color Selector strictly because this of the automation and because of the mixing capability, something that was an option for the project at the beginning of the semester. The automated portion of this product gave the group ideas about how to make the Automated Color Selector automated.

1.2.2 Automatic water color paint paint mixing machine Y-30A3

This product is similar to the Automated Color Selector strictly because this of the automation and because of the mixing capability, something that was an option for the project at the beginning of the semester. The automated portion of this product gave the group ideas about how to make the Automated Color Selector automated.

1.2.3 Multifunctional computerized color mixing machine for wholesales

This product is similar to the Automated Color Selector because the product is computerized and can be used to mix powdered paint. This product was helpful for the senior design project because the computerized portion is essentially automated and early on in the semester, dry paint powders were an option for the contraption.

1.3 Relevant Patents

1.3.1 Paint Dispensing Apparatus - US 9393536

This patent is for a computer controlled spinning wheel that can control the dispensing of liquids. Equidistant housings hold canisters of base paint while the software / motor rotate the wheel to the desired canister for dispensing. Our design is different mainly in the way that it outputs the entirety of the color instead of just a dye into a base paint and the way that the user inputs colors. In addition, this system is made for selling paint and not for educational purposes.

1.3.2 Paint Agitating System - US 9492799B1

This patent is relevant to our project because for the Automated Color Selector at the beginning of the semester during the designing phase, Group B was contemplating having an automated mixing feature that would mix paint or dyes. From this patent, Group B decided to explore water-based paints or dyes that would mix without needing any mixing.

1.4 Codes & Standards

1.4.1 ASTM F963-17- Standard Consumer Safety Specification for Toy Safety by ASTM International

This standard was used for the Automated Color Selector because the standard applies to children's safety for toys, which is relevant for Group B's project. Considering children could be using this project in conjunction with teachers, the standard was necessary for the project.

1.5 Project Scope

1. Purpose

When it comes to teaching kids the mixing of colors, it would be useful to have a hands-on way to see it in action. A solution to this would be to have a machine that has 3 water reservoirs colored with food coloring, one for each primary color. By turning a dial on a color wheel, the child would be able to select a color and the machine would release the correct amount of each primary color to create the desired mixture.

2. Customer

School teachers (Mainly Kindergarten or Pre-K) would be our primary customers.

3. Value or Benefit to Customer

A tangible, safe, engaging way to teach the concept of color mixing to students.

4. Goals
Make the machine aesthetically pleasing enough to place in a classroom.
Have the device works more than one time.
Automated dispensing.
Do not harm kids.
Meet ASTM F963 standards.
Lightweight enough to transport.

5. Scope
Be able to cover 12 colors.
Container and collector move relative to each other in automated way.
Self contained machine.
Manual option for students to choose color distribution and find resultant mixture.
Time out period between button presses.
Accommodating multiple sizes of cups.

6. Out of Scope
A continuous gradient of colors.
Accommodating all sizes of cups.
Self stirring.
Using paint – possible future work (including paint powder mixer).
Drainage system to get rid of excess liquid.

7. Critical Success Factors
Resusabability.
Color Quality.
Safety.
Non leaking valves.
Solidly coded software.
Visibility of process.

8. Project Assumptions
Food coloring mixes to non murky colors.
People would actually buy this.
Not needing a mixer for dye.
We have the ability to machine or buy the necessary parts.
We have enough knowledge / budget to make the device self contained.

9. Identify Project Constraints
Budget
Skills with machining and software
Time
Safety standard

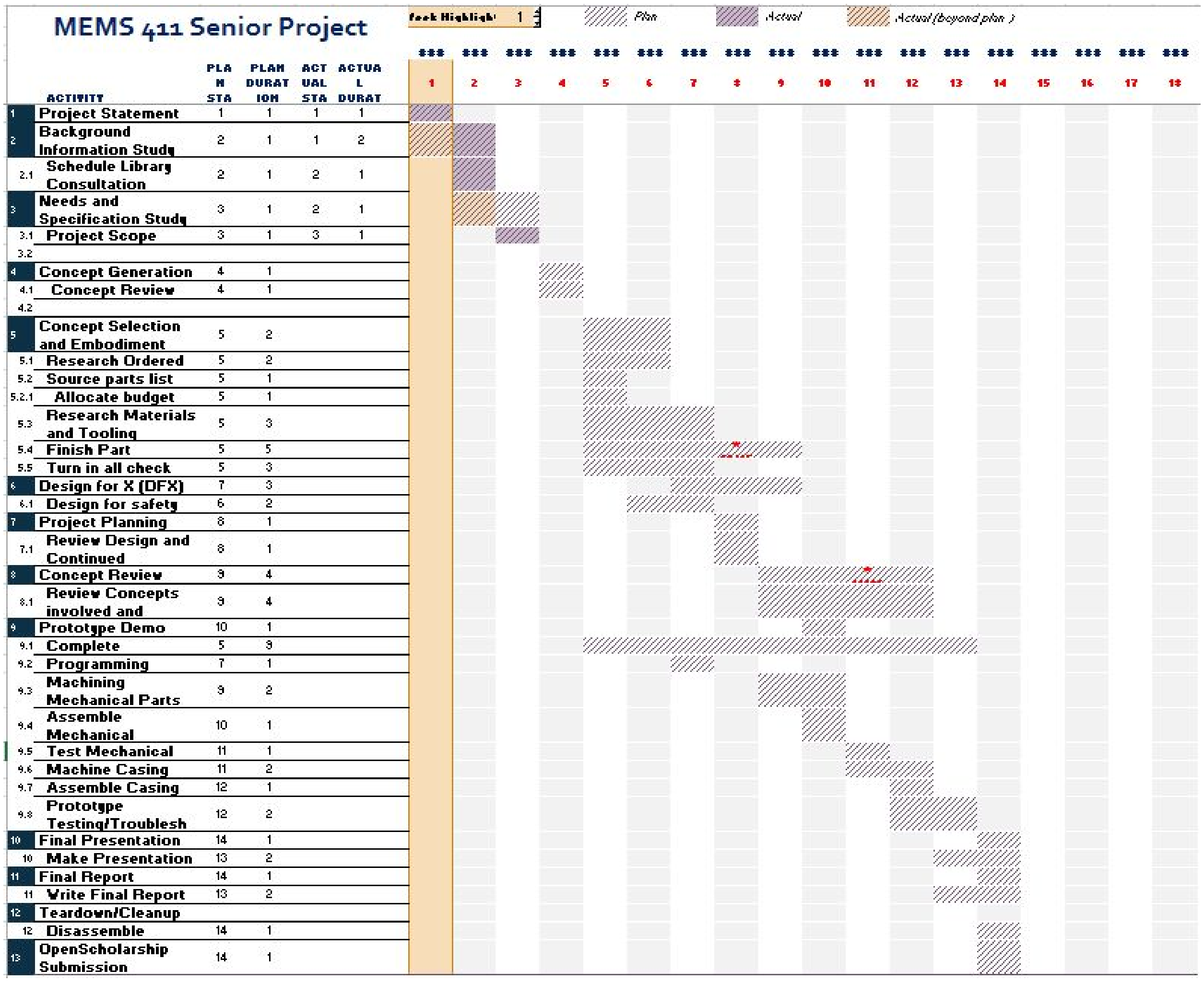
10. Key Deliverables

The final product

All 12 colors working (more than once each)

1.6 Project Planning

Table 1: Gant chart illustrating the proposed progres of the project.



	ACTIVITY	PLAN STA	PLAN DURATION	ACTUAL STA	ACTUAL DURAT
1	Project Statement	1	1	1	1
2	Background Information Study	2	1	1	2
2.1	Schedule Library Consultation	2	1	2	1
3	Needs and Specification Study	3	1	2	1
3.1	Project Scope	3	1	3	1
3.2					
4	Concept Generation	4	1		
4.1	Concept Review	4	1		
4.2					
5	Concept Selection and Embodiment	5	2		
5.1	Research Ordered	5	2		
5.2	Source parts list	5	1		
5.2.1	Allocate budget	5	1		
5.3	Research Materials and Tooling	5	3		
5.4	Finish Part	5	5		
5.5	Turn in all check	5	3		
6	Design for X (DFX)	7	3		
6.1	Design for safety	6	2		
7	Project Planning	8	1		
7.1	Review Design and Continued	8	1		
8	Concept Review	9	4		
8.1	Review Concepts involved and	9	4		
9	Prototype Demo	10	1		
9.1	Complete	5	9		
9.2	Programming	7	1		
9.3	Machining Mechanical Parts	9	2		
9.4	Assemble Mechanical	10	1		
9.5	Test Mechanical	11	1		
9.6	Machine Casing	11	2		
9.7	Assemble Casing	12	1		
9.8	Prototype Testing/Troublesh	12	2		
10	Final Presentation	14	1		
10	Make Presentation	13	2		
11	Final Report	14	1		
11	Write Final Report	13	2		
12	Teardown/Cleanup				
12	Disassemble	14	1		
13	OpenScholarship Submission	14	1		

1.7 Realistic Constraints

The goal of designing products is to design the best and most functional design to meet the customer needs and specifications. However, typically the best design is not attainable as their are many real world constraints. These can range from many things including, cost, time, safety, repeatability, etc. so when designing one must do the best they can under these circumstances. In our project specifically, time, money, and safety are our main constraints; however, there are many other peripheral constraints that we had to consider in the designing of the paint mixer.

1.7.1 Functional

One of our main functional constraints is that this device be portable so that it can be moved between classrooms inside a single school building. To achieve this we designed a product which is not awkward to carry nor is it too heavy. Additionally, we had some energy constraints as we needed enough energy to run the motor to turn the assembly as well as enough energy to power our arduino. We chose to use acrylic materials as we needed something cheap and could be seen through so the children could observe the process.

1.7.2 Safety

The safety of this machine is imperative as any dangerous portions of the machine would make it not usable for children. We are keeping all of our moving parts outside where a hand would need to go to operate the machinery. Additionally, we have a guard that can be pulled down to prevent people from having their hand's in the machine while it is operating. Moreover, we rounded all of the exterior edges and corners to prevent children from getting hurt by hitting or running into our machine. Lastly, we used a food coloring to make sure that no toxic materials were used in the output of our machine.

1.7.3 Quality

To assure quality we consulted with ASTM F963 to make sure that our product was quality enough for children. Additionally, we placed a label on the machine reminding people to lower the guard before operating. We ran multiple tests to make sure that our project could make 20 runs continuously to make sure that we created a reliable machine for our final project. We did multiple color runs for each color to ensure that we got consistent colors out of the machine each time we ran it.

1.7.4 Manufacturing

In terms of manufacturing constraints, we are limited by the quality, reliability, and inspection of all pre purchased parts. We did not create any of them, and we do not have the time to test every individual component, so we are constrained to the tests ran by the manufacturer. In terms of assembly and production of the casing we are constrained by our knowledge of machining operations and the schools equipment to machine parts. For example, welding would be used in the final product, but we are not using it for the prototype due to shop limitations.

1.7.5 Timing

This is a major constraint for us as we are limited to this whole semester to design and build the product. We are constrained additionally by the structure of the course, we had to adhere to the course timeline so we did not order any parts until late October. This constrained us to only having a couple weeks to build our assembly since we had a prototype demonstration in mid-November, and the prototype final was due in early December so we need to have it ready for this deadline.

1.7.6 Economic

The economic constraints are very important for our project. We are constrained by the budget that our group received for funding by the school. We also have a constraint by the amount that the market is willing to pay for this product. Teacher's typically do not have a lot of money nor do they have large budgets, so we cannot market our product too expensive. Our materials and motors need to be purchased with our budget in mind so instead of ordering the best products we had to buy products.

1.7.7 Ergonomic

We needed to consider our ergonomic constraints as this device is to be used by humans so there are a lot of man-machine relationship. Part of this was why we placed a safety warning label on the machine near the guard to remind the user to pull the guard down. Also, if we were to market this product in industry it would include a set of instructions to help guide the user. We took human reach and stuff in designing the shape of the machine so that people could comfortably operate the machine as long as the table was around belly button height. In terms of control, the turn knob with the various colors on it is appealing to people as it allows them to visually see what they are going to get as an output rather than just having buttons labelled with the names of the colors.

1.7.8 Ecological

In terms of ecological constraints, we used water as our base liquid for mixing the food coloring in. Water is abundant, natural, and safe for the environment, so our product should not cause any ecological damage. Additionally, we are running on electricity not natural gas or propane so we do not have to worry about any direct environmental impact from our machine. Obviously, there is pollution in creating electricity, but that is not a byproduct of our product. Our materials that we chose are very abundant so there are no issues of us using nonrenewable scarce resources in building our product.

1.7.9 Aesthetic

Aesthetic constraints are a big deal for our product as we need to keep the attention of children who are very aesthetically driven, and we need to make this product appeal to the teachers who would buy it. We designed our knob to feature the 12 colors so that the color wheel would be aesthetically dominating on our device for both the children's attention and to show the teachers how effective our product could be. Also, having our machine see through rather than enclosed by metal makes it look interesting to people as they can see the mechanics of the machine and the colors distilling into the cup as it is occurring.

1.7.10 Life Cycle

The main life-cycle constraint was how many runs could the machine last before it needed to have the liquids refilled. We deemed 20 runs to be sufficient since most classes contain 20 or fewer students at that young age. This would give a teacher enough supplies for one class period so that they should never need to refill during a class. Additionally, we made the refill process pretty easy with the hatch on top of our product to access the bottle so that you could easily refill each bottle without a lot of maintenance. Our product should not need any regular inspections, cleaning, or maintenance. If we were to expand our product to mix paint, this would not be the case as you would need to consider how often it would need to be cleaned out and how to prevent clogging.

1.7.11 Legal

In terms of regulations, we had to make sure that our products would be safe children's products by the CPSC regulations that have been set for children toys. This includes toxicity, sharp edges, and exposure to electricity and other dangerous mechanisms. Ethically, we needed to make sure that we did not design a product that could affect the health and welfare of the users. Whether that is designing the product to guard the mechanical movements from the children or our choice of dies we had to make sure that the users of our machine would not be harmed by this product. We needed to also make sure that there were no patents or other intellectual property infringements that we are limited by. We had to make sure that our mixing process was not in infringement of other agitation processes from mixing liquids.

1.8 Revised Project Description

Design, build, and sell a safe automated primary color dye mixer to schools for the purpose of teaching children how 12 secondary colors (and shades) on a color wheel can be made via the primary colors. The user will select the desired color (on a color wheel) and the machine will automatically deposit the correct amount of each primary color to create the selected color (or shade). The dye will diffuse in the cup, to create the desired color. Dye will be used in the machine so that if a mess is made, the cleanup is easy. However, we will have a sensor to ensure the cup is in place, and we have a drain basin to catch spills. Further work could be expanded to mix children safe paint by dispensing a paint liquid or powder and mixing to the 12 shades of secondary colors or more.

2 Customer Needs & Product Specifications

2.1 Customer Interviews

Table 2 - Results from a customer interview with a preschool teacher and owner.

Customer Data: Automated Color Wheel (ACW)
Customer: Rosalind Griffin, Preschool and Daycare Owner

Address: Olathe, Kansas
Date: 9/12/2017

Question	Customer Statement	Interpreted Need	Importance
How do you currently teach your children the color wheel?	I teach my children the color wheel by showing the primary colors and secondary colors on a chart, and mixing the colors by hand.	ACW is educational for young children. ACW has visible components.	5, 4
What Products do you use?	I use tempera and finger paints so that they are safe around children and do not cause too big of a mess.	ACW is safe for children to use. ACW is simple for teacher use.	5, 3
What do you like about it?	I like that I can show the kids the process of mixing, and they can interact with the process.	ACW has visible components. ACW is interactive learning for children.	4, 4
What do you dislike about it?	I dislike how hard it is to clean up the paint when the kids spill or make a mess. Also, I use a lot of paper, plastic, and cardboard supplies, so there is typically a lot of trash and wasted materials	ACW needs to be easy to clean. ACW needs to have reusable parts.	3, 1
How much do you show the process of color mixing?	Usually, I show them putting the various colors in the mixing cup, show them the mixing, and show them the final product, which they can then use to paint with.	ACW has visible components. ACW is interactive learning for children.	4, 4
What age range do you teach this to?	I usually am teaching children 3-5 years old.	ACW is safe for children to use.	5, 5

		ACW is age appropriate for children.	
How long do you usually block out to teach these classes? How many kids per class?	These are usually 1 hour classes for about 10-15 children.	ACW improves speed of learning.	3
How do you keep the children's attention?	I use visual appeal and interaction to keep them engaged.	ACW has visual appeal for children. ACW is interactive for children.	4, 4

2.2 Interpreted Customer Needs

Table 3: Interpreted customer needs, derived from interview results.

Need Number	Need	Importance
1	ACW is educational for young children	5
2	ACW has visible components	4
3	ACW is safe for children	5
4	ACW needs to be easy to clean	3
5	ACW is interactive for children	4
6	ACW needs to have reusable parts	1
7	ACW is age appropriate for children	5
8	ACW improves speed of learning	3
9	ACW has visual appeal for children	4

2.3 Target Specifications

Table 4: Targeted needs, as taken from meeting with faculty

Metric Number	Associated Needs	Metric	Units	Acceptable	Ideal
1	8	Time of Mixing	Minutes	5	3
2	6, 4	Cups per user	Each	3	1
3	1, 2	Transparent Area of machine	Square Inches	>36	>50
4	3, 7, 9	Flashing Lights	Each	1	6
5	5	Output is useable	Binary	1	1
6	1, 5	Mix ability of paint/die	Scale 1-5	=>3	5
7	3, 7	Output is hazard free ⋆	Binary	1	1

8	3,4,5,7	Open Area of Machine ⋆	Square Inches	<60	<40

⋆ Standard: F963 - 17: Standard Consumer Safety Specification for Toy Safety

3 Concept Generation

3.1 Functional Decomposition

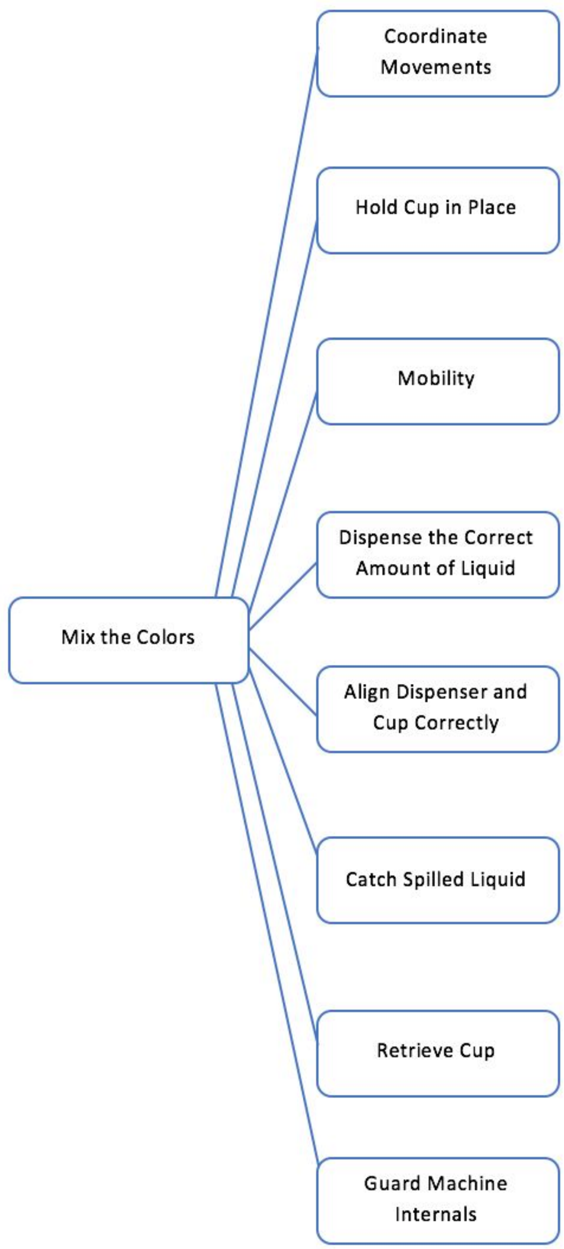


Figure 1: Function tree for automated color selector

3.2 Morphological Chart

Coordinate Movements	Rotate Dispensers	Conveyor Belt	Rotate Cup
Hold Cup in Place	Ridges	Holder	Clamp
Mobility	Wheels on Base	Light Design	Heavy Base with Detachable Machine
Dispense the Correct Amount of Liquid	Time System	Flush Measure	Flowrate Measure
Align Dispenser and Cup Correctly	Program Cylindrically	Program by Distance	Program by Height
Catch Spilled Liquid	Basin with Grate	Suction System	Piping
Retrieve Cup	Manually Grab	Moves Out from Machine	Lower from Machine
Guard Machine Internals	Plate Covering all internals with hole for Liquid to Flow Through	Close a gate	Rotate Cup Away from Opening

Figure 2: Morphological chart for automated color selector

3.3 Concept #1 – "Revolver with color wheel and tray"

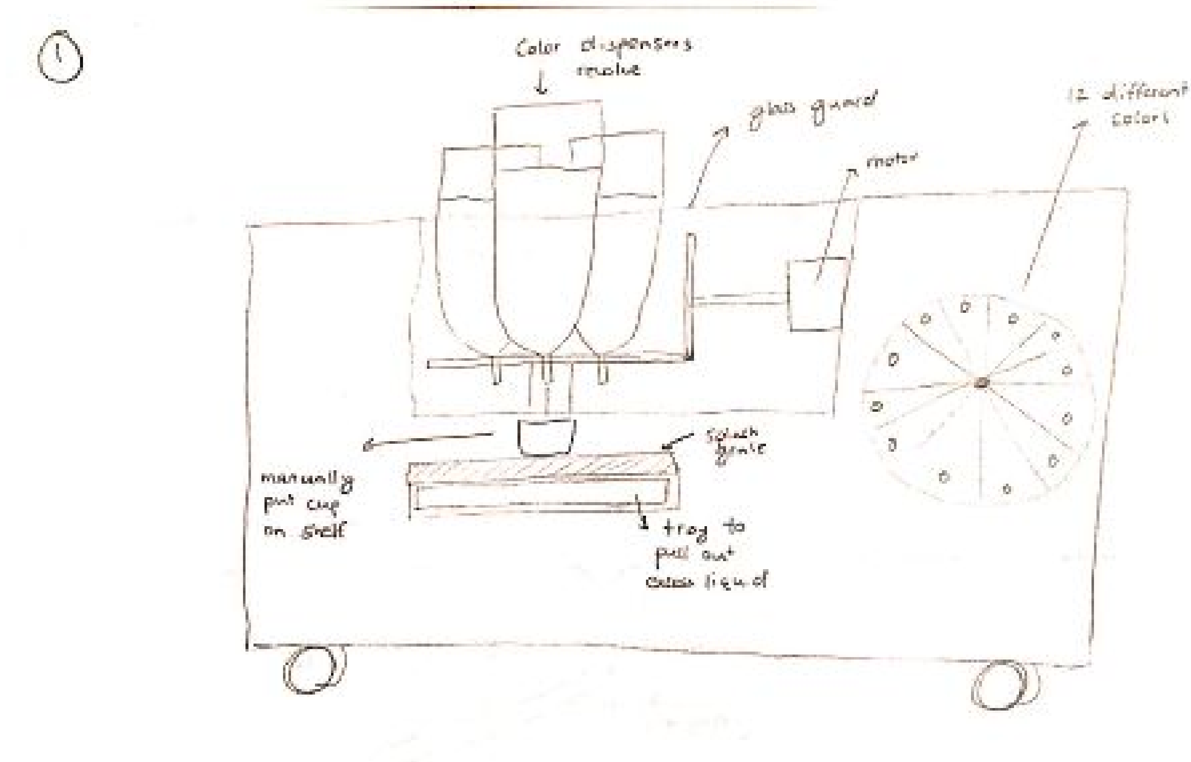


Figure 3: Concept One - "Revolver with Color Wheel and Tray"

Concept name: Revolver with Color Wheel and Tray

Description: The cylinders that hold the primary color dyes revolve around a shaft. The motor turns the gears to rotate the shaft, controlled by an arduino. The arduino is hooked up to a variable selector, used to pick the different colors. The cup is manually put onto the drip tray, a tray that catches all the liquid. A glass guard covers the entire machine to achieve safety standards.

Solutions:

1. Rotate Colors
2. Ridges
3. Wheels on Base
4. Time System
5. Program Cylindrically
6. Basin with Grate
7. Manually Grab
8. Plate Covering all the Internals

3.4 Concept #2 – "Conveyor Belt with buttons and drainage"

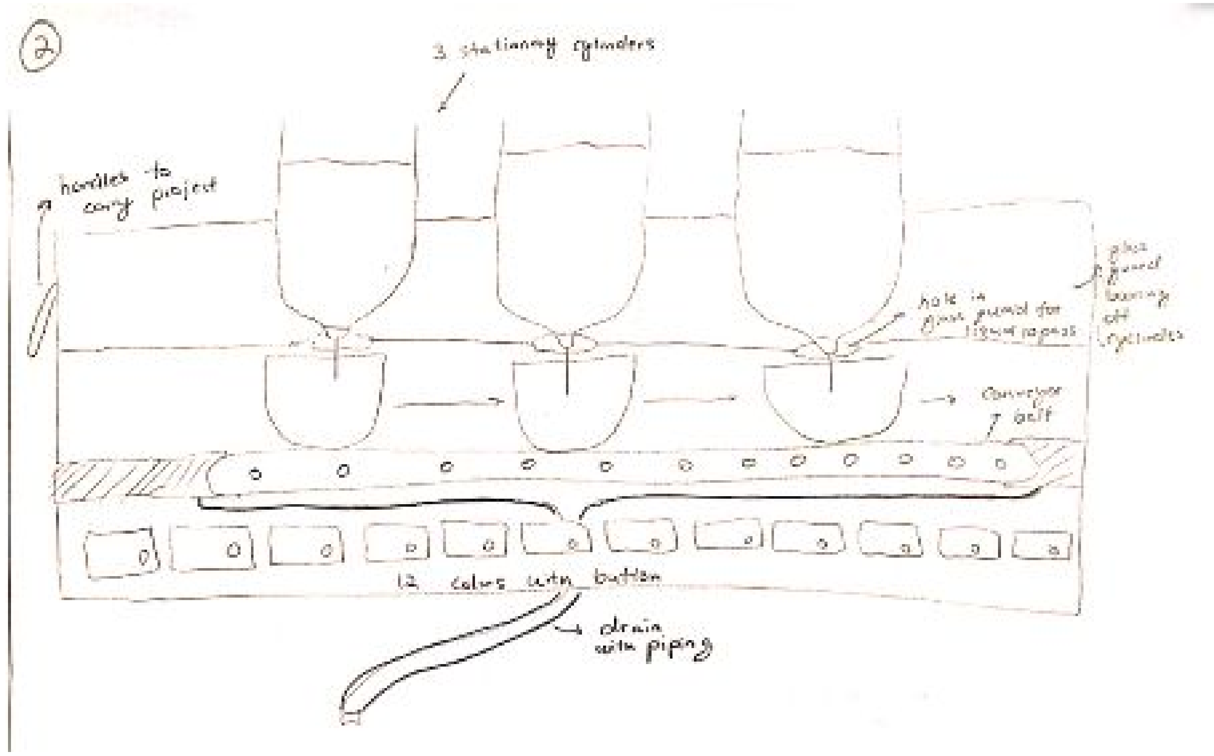


Figure 4: Concept Two - "Conveyor Belt with Buttons and Drainage"

Concept name: Conveyor Belt with Buttons and Drainage

Description: The cup is manually put onto a conveyor belt, with the cylinders remaining stationary. The project is light enough to be carried. Buttons are used to select the wanted color. A drainage is used to catch all the liquid and carry the excess liquid away. A hole is cut into the acrylic box protecting all the internals, as well as protecting children from mechanical and electrical parts.

Solutions:

1. Conveyor Belt
2. Ridges
3. Light Design
4. Flow Rate Measure
5. Program Distance
6. Piping
7. Manually Grab Cup
8. Plate covering all the internals with hole for liquid to flow through

3.5 Concept #3 – "Elevating cup with buttons and tray"

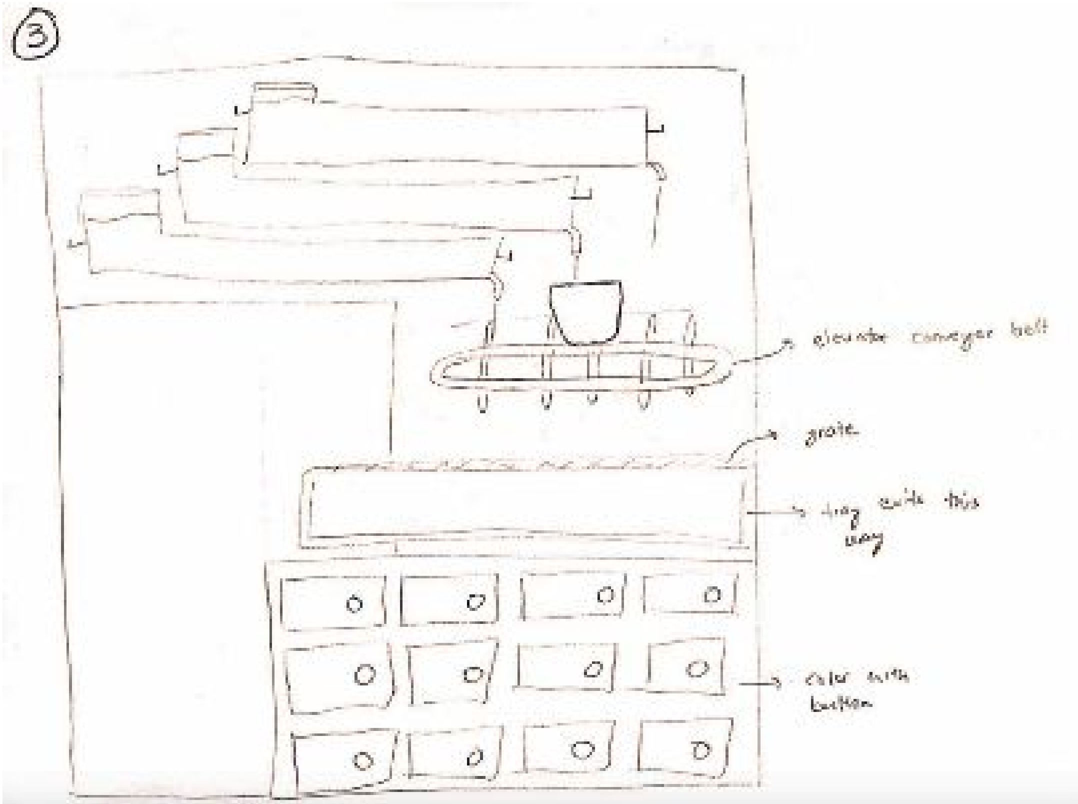


Figure 5: Concept Three - "Elevating Cup with Buttons and Tray"

Concept name: Elevating Cup with Buttons and Tray

Description: The cup is manually placed on the conveyor belt that not only moves the cup side to side, but elevates the cup up and down in order to be right underneath the different cylinder locations. The excess liquid is caught in a try with a grate on top of the try. The colors are selected via buttons on the bottom of the machine.

Solutions:

1. Conveyor belt
2. Ridges
3. Light Design
4. Flow Rate measure
5. Program by height and distance
6. Basin with grate
7. Manually Grab
8. Plate covering all the internals with hole for liquid to flow through

3.6 Concept #4 – "Wheel system with buttons and drain"

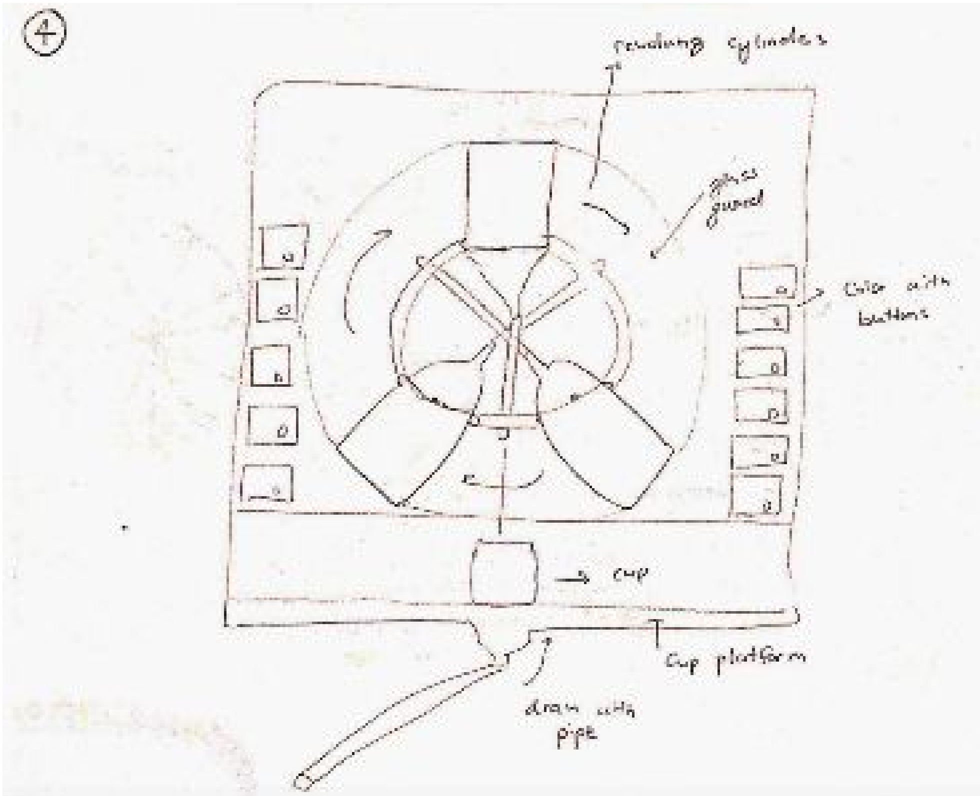


Figure 6: Concept Four - "Wheel System with Buttons and Drain"

Concept name: Wheel System and Buttons and Drain

Description: The cylinders rotate while the cup stays stationary after manually placed. The excess liquid is caught in a drain with a pipe carrying the excess liquid off. Acrylic covers all the internals of the machine to make sure the components are not a safety hazard to the user. The color is selections from buttons on the side of the rotating cylinders.

Solutions:

1. Rotate Cup
2. Holder
3. Light Design
4. Time System
5. Program Cylindrically
6. Piping
7. Manually Grab
8. Plate covering all the internals with hole for liquid to flow through

3.7 Concept #5 – "Revolving cup with color wheel and tray"

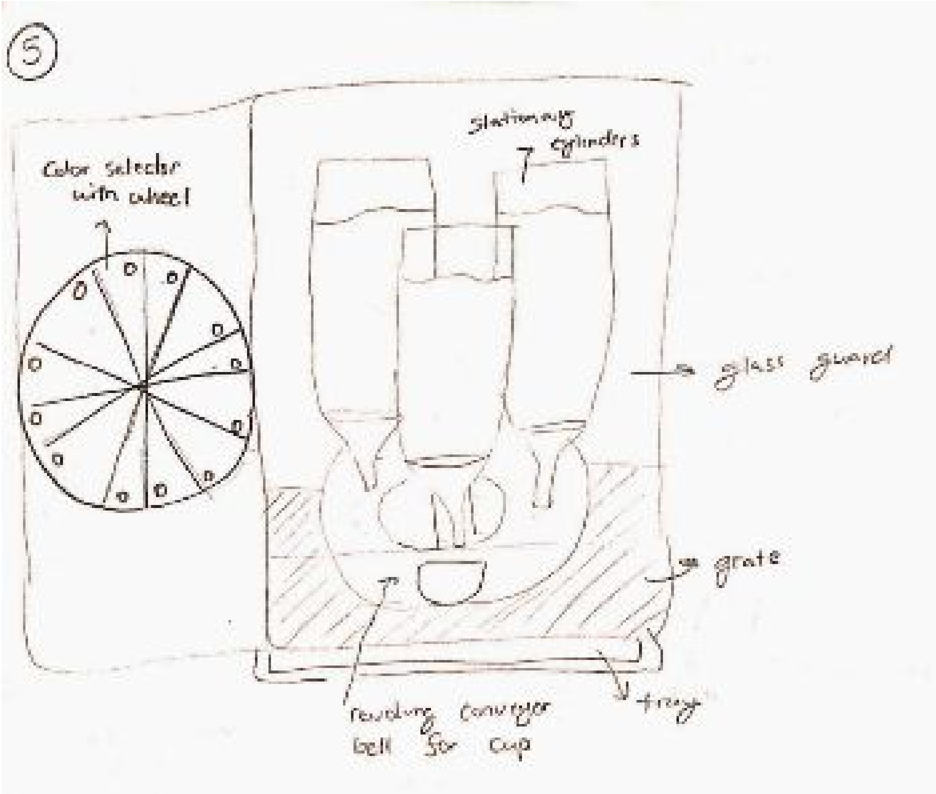


Figure 7: Concept Five - "Revolving Cup with Color Wheel and Tray"

Concept name: Revolving Cup with Color Wheel and Tray

Description: The cup is put into a conveyor belt that moves the cup into the contraption without rotating the cylinders. A guard is put around the machine to protect the user and the components. The tray catches the excess liquid and can be taken out of the machine. The colors are selected by a color wheel.

Solutions:

1. Conveyor Belt
2. Clamp
3. Heavy Base with Detachable Machine
4. Flush system
5. Program by Distance
6. Basin with Grate
7. Manually Grab
8. Rotate Cup away from Opening

3.8 Concept #6 – "Manually move cups with computer, mixer, and drain"

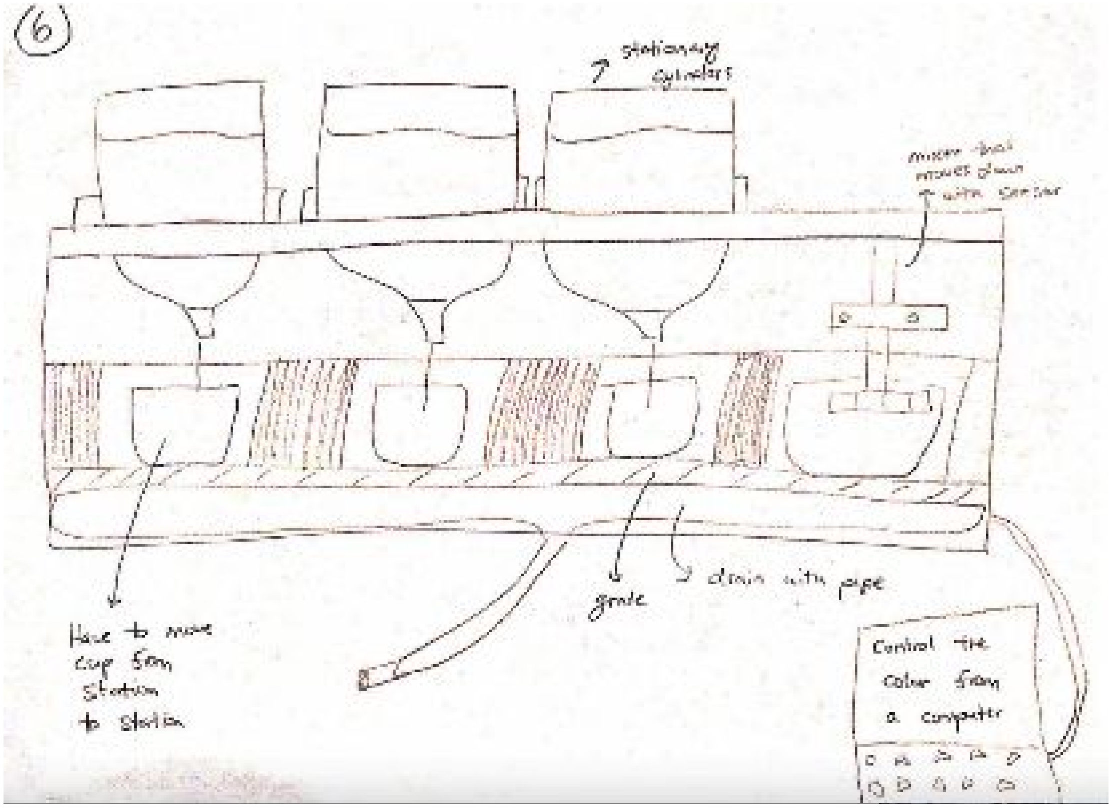


Figure 8: Concept Six - "Manually Move Cups with Computer, Mixer, and Drain"

Concept name: Manually Move Cups with Computer, Mixer, and Drain

Description: The cup is manually moved from cylinder to cylinder, with the color being selected of the computer. The excess liquid is caught by a grate and then drained out of the system. A mixer is also added to this design to mix the different dye colors. Guards are pulled down when a cup is placed underneath a specific cylinder.

Solutions:

1. Rotate Cup
2. Ridges
3. Light Design
4. Time System
5. Program by height
6. Basin with grate, piping
7. Manually Grab
8. Close gate

4 Concept Selection

4.1 Concept Weighted Scoring Matrix/Analytic Hierarchy Process

Table 5: Weighted scoring matrix for concept selection

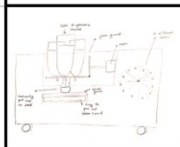
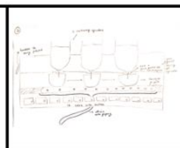
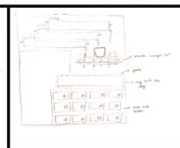
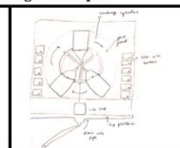
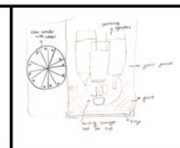
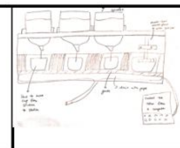
		Alternative Deisgn Concepts											
													
Selection Criterion	**Weight (%)**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**	**Rating**	**Weighted**
Mechanical safety	17.1	5	0.86	3	0.51	1	0.17	1	0.17	5	0.86	4	0.68
Cost of components	10.42	4	0.42	2	0.21	1	0.10	1	0.10	3	0.31	5	0.52
Educational	12.87	5	0.64	2	0.26	1	0.13	3	0.39	4	0.51	1	0.13
Visibility of components	9.54	4	0.38	3	0.29	1	0.10	2	0.19	4	0.38	5	0.48
Cleanliness	9.33	3	0.28	5	0.47	1	0.09	5	0.47	2	0.19	4	0.37
Intractability	6.98	4	0.28	3	0.21	1	0.07	2	0.14	4	0.28	5	0.35
Reusable Components	1.26	4	0.05	1	0.01	5	0.06	2	0.03	4	0.05	1	0.01
Age Appropriate	9.4	5	0.47	3	0.28	2	0.19	3	0.28	5	0.47	1	0.09
Speed of Mixing	5.03	5	0.25	4	0.20	3	0.15	2	0.10	4	0.20	1	0.05
Visiual Appeal	5.02	5	0.25	3	0.15	1	0.05	4	0.20	5	0.25	2	0.10
Ease of Use	7.77	4	0.31	5	0.39	2	0.16	3	0.23	4	0.31	1	0.08
Transportablility	5.26	5	0.26	2	0.11	5	0.26	3	0.16	4	0.21	1	0.05
		4.453		3.081		1.533		2.458		4.024		2.921	
	Rank	**1**		**3**		**6**		**5**		**2**		**4**	

Table 6: Analytical process for concept selection

	Mechanical Safety	Cost of components	Educational	Visibility of Components	Cleanliness	Intractability	Reusable Components	Age Appropriateness	Speed of Mixing	Visual Appeal	Ease of Use	Transportability	Row Total	Weight Value	Weight (%)
Mechanical safety	**1.00**	3.00	3.00	5.00	5.00	7.00	9.00	7.00	7.00	7.00	7.00	9.00	70.00	0.17	17.10%
Cost of components	0.33	**1.00**	3.00	0.33	3.00	3.00	9.00	3.00	3.00	5.00	3.00	9.00	42.67	0.10	10.42%
Educational	0.33	0.33	**1.00**	5.00	7.00	7.00	9.00	3.00	5.00	3.00	3.00	9.00	52.67	0.13	12.87%
Visibility of components	0.20	3.00	0.20	**1.00**	3.00	5.00	9.00	3.00	5.00	0.33	0.33	9.00	39.07	0.10	9.54%
Cleanliness	0.20	0.33	0.14	0.33	**1.00**	0.20	9.00	3.00	5.00	7.00	3.00	9.00	38.21	0.09	9.33%
Intractability	0.14	0.33	0.14	0.20	5.00	**1.00**	9.00	0.20	3.00	0.33	0.20	9.00	28.55	0.07	6.98%
Reusable Components	0.11	0.11	0.11	0.11	0.11	0.11	**1.00**	0.11	0.14	0.14	0.11	3.00	5.17	0.01	1.26%
Age Appropriate	0.14	0.33	0.33	0.33	0.33	5.00	9.00	**1.00**	5.00	5.00	3.00	9.00	38.48	0.09	9.40%
Speed of Mixing	0.14	0.33	0.20	0.20	0.20	0.33	7.00	0.20	**1.00**	3.00	3.00	5.00	20.61	0.05	5.03%
Visiual Appeal	0.14	0.20	0.33	3.00	0.14	3.00	7.00	0.20	0.33	**1.00**	0.20	5.00	20.55	0.05	5.02%
Ease of Use	0.14	0.33	0.33	3.00	0.33	5.00	9.00	0.33	0.33	5.00	**1.00**	7.00	31.81	0.08	7.77%
Transportablility	0.11	0.11	0.11	0.11	0.11	0.11	0.33	19.00	0.20	0.20	0.14	**1.00**	21.54	0.05	5.26%
												Column Total:	**409.33**	**1.00**	**100%**

Table 7: Criteria for analytical process for concept selection

Row Criterion is________ than/as column criterion

Score	Explanation
9	Extremely more important
7	Very strongly more important
5	Strongly more important
3	Moderately more important
1	Equally important
1/3	Moderately less important
1/5	Strongly less important
1/7	Very strongly less important
1/9	Extremely less important

4.2 Explanation of Winning Concept Scores

The first design Revolver with Color Wheel and Tray was our top product by the concept generation. Our most important needs were mechanical safety, educational, and cost of components. This design ranked 5, 5, and 4 respectively for those three categories. The mechanical safety was the top rating because the plate would guard the children from all of the moving parts in the system. This plate prevents injury and other issues with sharp moving parts around children. For the educational need, this concept was the first ranked one since we could see the colors in a window as they poured into the cup. This allows the children to see the colors that go into each mixed color. This concept was also highly ranked for the cost of components as our only very costly components will be our motor, gear, and valves. Other than that, the rest of the components will be fairly cheap to either acquire or make in the machine shop.

4.3 Explanation of Second-Place Concept Scores

Our second design was similar to our winner except that the cup would move around in a circle with the colors being stationary, instead of vice versa. We figured that this design was just as safe as the first one since the only exposed moving piece is the cup that the different colors would go into. In terms of educational, this design has the same window as the first design, so this concept was also highly ranked. However, since the colors do not rotate directly into view, this design would be slightly less educational, shown in the rankings. We thought this product would also be costlier as the design would require moving parts in the base of the design to move the cup and mechanical components at the top to control the colors. By separating out the mechanisms, we figured that would add cost to this product.

4.4 Explanation of Third-Place Concept Scores

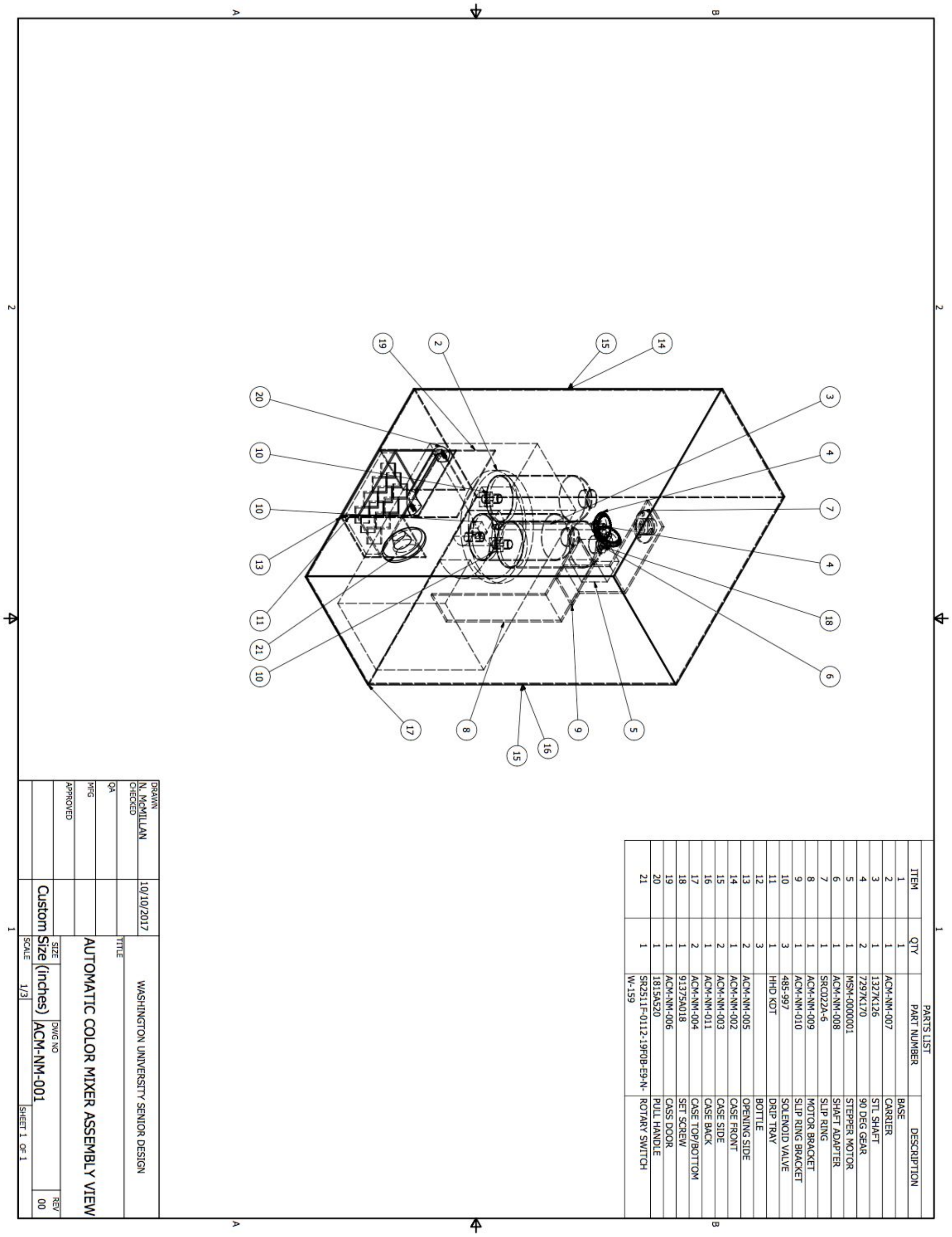
Our third-place design was Conveyor Belt with Buttons and Drainage. It was ranked 3 for safety, 2 for educational, and 2 for cost of components. We figured that this design was a little less safe as conveyor belt would be a little more dangerous to children than our previously stated designs as those hide all of the moving parts basically. In terms of educational, the lack of color wheel and use of buttons makes this design less educational most likely because we want the children to learn the secondary colors in a color wheel design. Lastly, we figured that the conveyor belt, the three distinct spouts that the colors would dispense from, and the drainage system would make the components of this design more expensive. The thing that made this concept better than our other designs is that it was highly ranked on ease of use, speed of mixing the colors, and the cleanliness of the machine.

4.5 Summary of Evaluation Results

For the automated color selector, the top weighted selection criteria are as follows: mechanical safety, educational value, cost of components, visibility of components, and age appropriateness, with percentage weightings of 17.1%, 12.87%, 10.42%, 9.54%, and 9.4%, respectively. Even though there are twelve different criteria used in the concept weighted scoring matrix, these five were chosen to be weighed the most because each of these criteria have and will play a huge role in the final finished prototype. Mechanical safety is the most important criteria for our project because since the product should be children user friendly, the safety of the product is by far the most important aspect. The next two most important criteria are how educational the design is and the cost of the design. The design has to educate children on how secondary colors and variations of those colors are made, as well as be cost effective enough for a teacher/school district to by for this specific education. The last two criteria mentioned, visibility of components and age appropriateness are both essential to the final concept. Children need to be able to see the mechanical workings of the design so as to see what colors are used to make another color, the main goal of our project. The project must also be age appropriate for children. Designing and building a project to teach children the secondary colors has to be interactive for the children and easily operable by the teacher. Concept #1 and Concept #5 ranked significantly higher than the rest of the concepts, both above 4 out of 5. Concept #2 ranked third highest, with a score of approximately 3 out of 5. Concept #4 and Concept #6 ranked below 3 out of 5, with scores of 2.458 and 2.921 respectively. Finally, Concept #3 scored last with a score of 1.533 out of 5. Moving forward with the building the prototype, Concept #1 scored the best with the weighted selection criteria; therefore, meaning the concept itself will be used for the rest of the project. Obviously, different features could be used from other concepts, but the revolving color wheel will be used from Concept #1 for the remainder of the project.

5 Embodiment & Fabrication plan

5.1 Isometric Drawing with Bill of Materials



PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1		BASE
2	1	ACM-NM-007	CARRIER
3	1	1327K126	STL SHAFT
4	2	7297K170	90 DEG GEAR
5	1	MSM-0000001	STEPPER MOTOR
6	1	ACM-NM-008	SHAFT ADAPTER
7	1	SRC022A-6	SLIP RING
8	1	ACM-NM-009	MOTOR BRACKET
9	1	ACM-NM-010	SLIP RING BRACKET
10	3	485-997	SOLENOID VALVE
11	1	HHD KDT	DRIP TRAY
12	3		BOTTLE
13	2	ACM-NM-005	OPENING SIDE
14	1	ACM-NM-002	CASE FRONT
15	2	ACM-NM-003	CASE SIDE
16	1	ACM-NM-011	CASE BACK
17	2	ACM-NM-004	CASE TOP/BOTTOM
18	1	91375A018	SET SCREW
19	1	ACM-NM-006	CASS DOOR
20	1	1815A520	PULL HANDLE
21	1	SR2511F-0112-19F0B-E9-N-W-159	ROTARY SWITCH

Figure 9: CAD representation of selected concept including Bill of Materials.

5.2 Exploded View

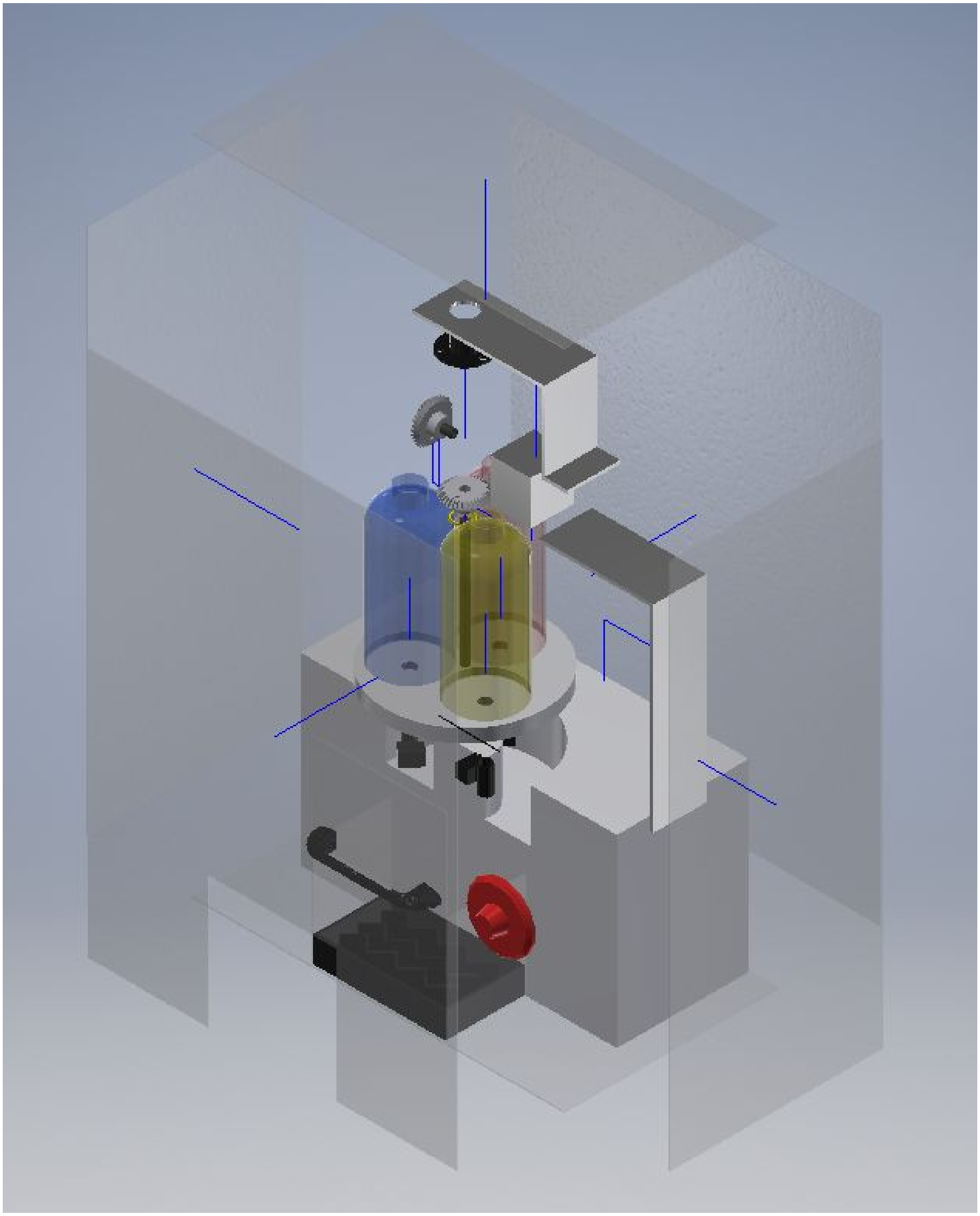


Figure 10: Isometric Exploded AutoCAD Inventor View

5.3 Additional Views

Figure 11: Front View on AutoCAD Inventor

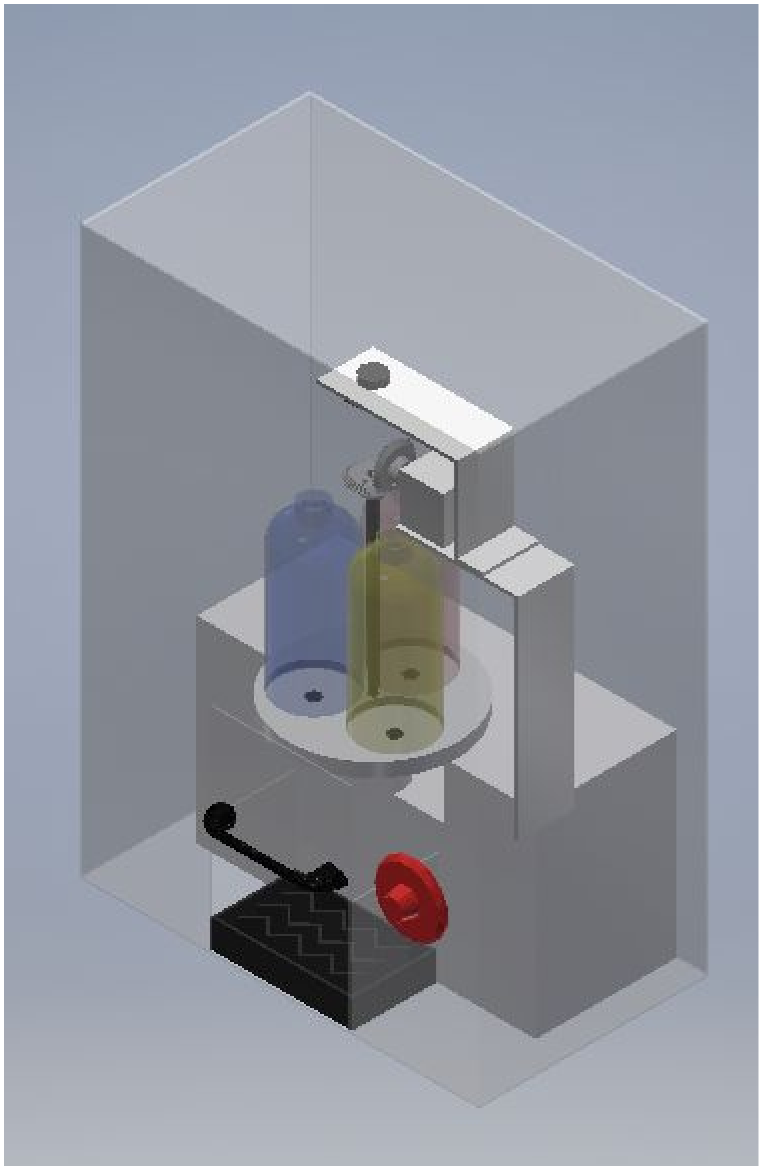


Figure 12: Zoomed-Out Isometric View on AutoCAD Inventor

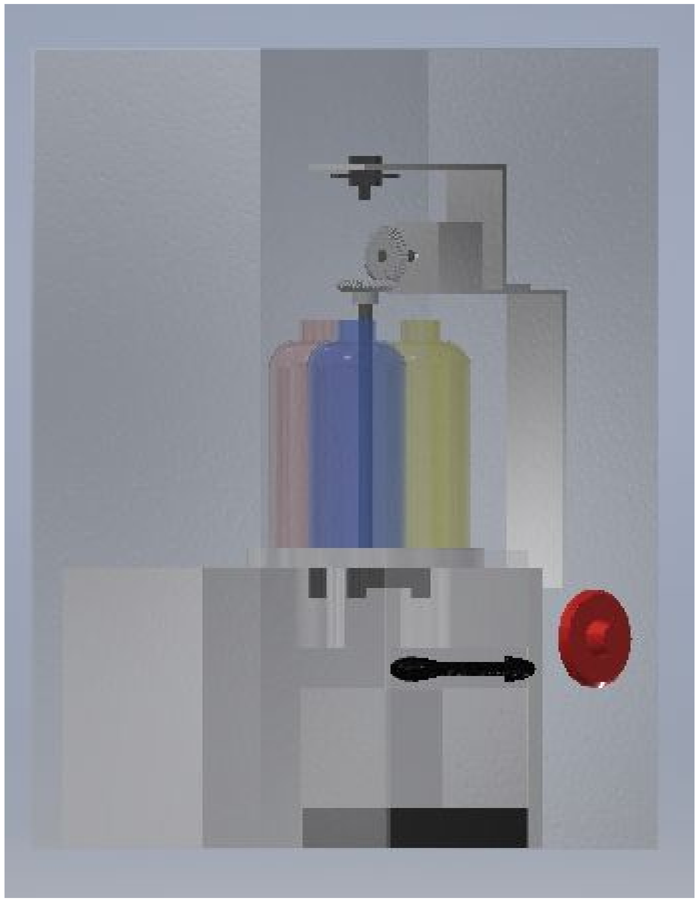


Figure 13: Left Front Corner View on AutoCAD Inventor

6 Engineering Analysis

6.1 Engineering Analysis Results

6.1.1 Motivation

The code we used for our design dealt with the safety of children's toys. This is especially important for our project as its primary audience is young children. This code was consulted during the design phase in order to ensure an unforeseen hazards are properly addressed. The main result of this consultation was the development of a casing system which prohibits easy access to possible pinch points. This analysis is important at this time of the design process because the material of the shaft needs to be able to support the axial force and torque created when the cylinders holding the different colors sits halfway up the shaft. We hope to obtain how exactly the axial force and torque around and down onto the shaft will act in the rest of the system that is the Automated Color Selector.

6.1.2 Summary Statement of the Analysis

The analysis performed was a stress analysis of the main shaft. This shaft is used to support the rotating disk which holds the liquid bottles as well as attach to the motor in order to rotate the aforementioned disk. To perform the analysis, a moment was placed at the bottom of the shaft while the top was fixed in place. This accurately simulates the moment caused by rotating the disk loaded with liquid bottles. A force was also placed at the bottom of the shaft in the axial direction in order to replicate axial forces due to the supported weight. Analysis showed the shaft would not undergo significant stress and could be built out of any common metal without failure. The original diameter of the shaft was 5/16 inches. For the retesting of the shaft, the smaller diameter used was 3/16 inches. The second analysis showed the part of the shaft with the decreased diameter has a greater chance of failure.

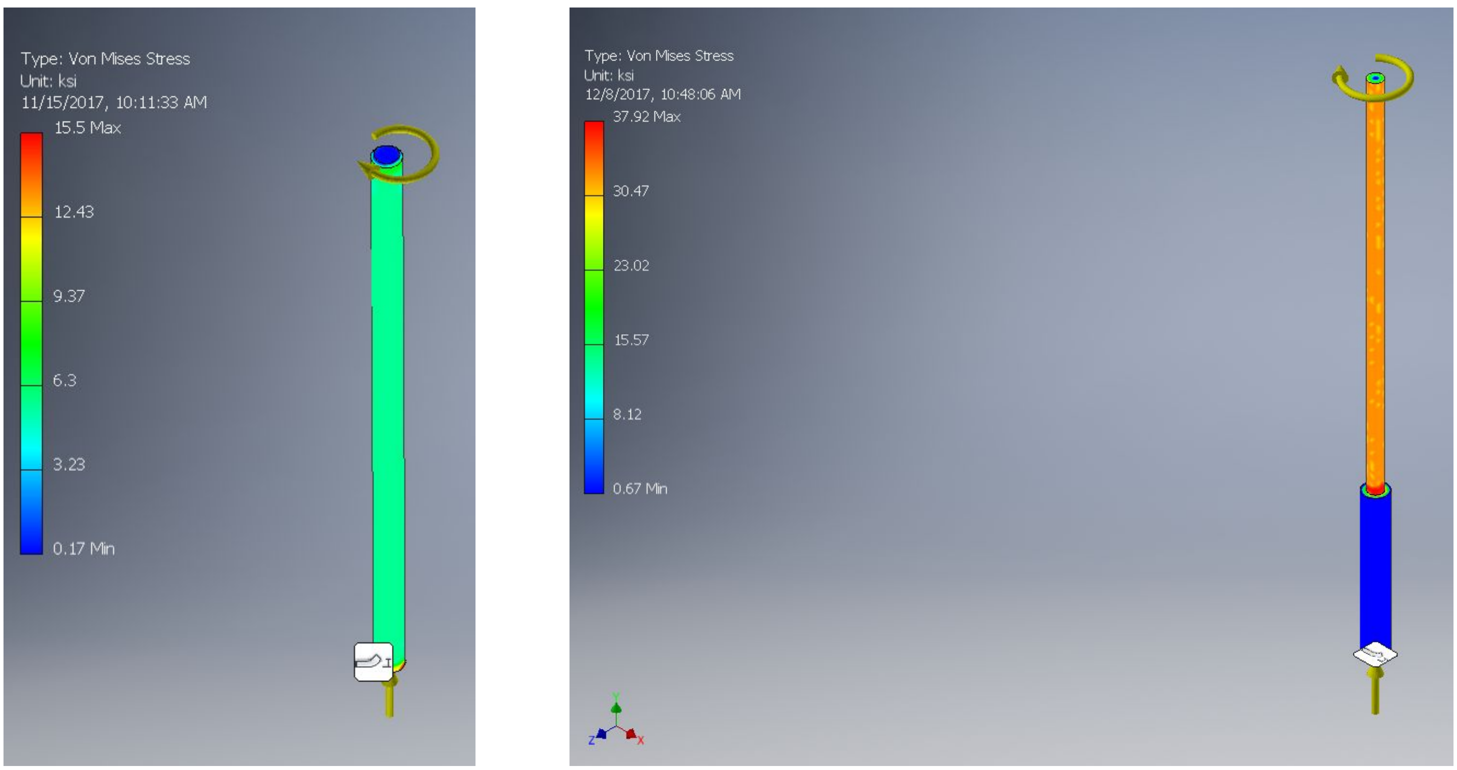


Figure 14: Before and After Engineering Analysis of Torque and Forces on Shaft on Solidworks

6.1.3 Methodology

The main analysis was performed within solidworks motion via stress analysis of the main shaft with a forced attached to its bottom and a moment to its top. For this testing, everything was done on the computer. However, further tests were carried out for the color mixing portion of the project to ensure that the three primary dies could produce the twelve colors desired in the project scope. The axial force applied to the shaft on SolidWorks was 8.8 lbf, the estimated force from the weight of the water bottles. The torque applied to the shaft via SolidWorks was 24 lbf in 8.8 lb applied 2.75 inches away from the shaft, the shaft picked to be made out of aluminum for the simulation. For the second simulation after adjusting part of the shaft diameter, the axial force and torque values tested are the same as the initial stress analysis.

6.1.4 Results

The results of the first simulation of the testing showed very little stresses throughout the bar, with stresses throughout the shaft averaging around 6.3 ksi (As seen on Fig 14). These results make sense for a few major reasons. Mainly, the force supplied by the motor is very small, the aluminum is fairly rigid, and the diameter of the shaft being used is large enough to support much more force. After changing the diameter of part of the shaft, the part with the smaller diameter experiences an average stress of 32 ksi. This also makes sense because making the shaft smaller will cause a great amount of stress on the part of the shaft with the smaller diameter, as shown above in Figure 14, the image on the right.

6.1.5 Significance

The analysis supports moving forward with the project without making any changes. If any, the diameter within the main shaft could be lessened slightly, but as it is made of a light material, aluminum, and would not change much about the final weight, the group decided to leave it as it. In addition, the extra diameter ensures that there is no risk of the product having a catastrophic failure while being used around children. However, to show how a smaller diameter would affect the perceived axial force and torque, images of the first simulation and the second simulation with a shaft have a smaller diameter is shown below above in Figure 14.

6.2 Product Risk Assessment

6.2.1 Risk Identification

a. Risk 1: Getting hand stuck in the gearing mechanism
   i. Description: This would occur if somebody stuck their hand up the area where the material comes down from, or from the top in the area all the way into the gears. Kids being curious about the movements could cause them to reach up into the gears, and adults trying to get something that is stuck in the gears could lead to them reaching down into the gears. The environmental factor that would affect this the most is distractions by multiple kids and people's lack of attention to this inherent danger with gearing. Depending on how far they stick their hands into the gear can affect the severity as the further they stick their hand, the more significant injury that could occur.

   ii. Impact: 4, Significant. This is significant as it can cause someone to get hurt ranging from cutting their hand, breaking their bone, or losing the tip of a finger. This range comes from how far into the gear did they stick their hand into the gearing.
   iii. Likelihood: 2, Low-Medium. This is not very likely as someone would have to actively try to stick their hands up and around the enclosure in the opening where the liquid comes out, and we put a guard to pull down during operation to keep people's hands out. To change the liquids you would not need to stick your hands in the areas of the gears so it would take somebody acting in a way that the machine was not intended to get this to happen.

b. Risk 2: Getting a finger stuck in a valve that will move
   i. Description: This would occur if somebody stuck their finger up a valve from the opening underneath, and somebody operated the machine. Again, this would happen from kids being curious and sticking their fingers up in areas where they shouldn't. Environmental factors that could impact this would be if there is a line of impatient children, and one sticks their hand into the valve then the kid behind him operates the machine. The severity of this incident is pretty standard as it would likely dislocate the kids finger, but it would be hard to injure them any more than that.
   ii. Impact: 3, Moderate. A dislocated finger is only a moderate risk as this is a common injury that doesn't have much long term effect. This is less severe than other issues so I made it a moderate impact as losing the tip of your finger would have much more impact on your life.
   iii. Likelihood: 1, Low. This is not very likely as we have put a guard in place to keep hands out of the operation. Also, people should have no need to stick their fingers into the valves so under normal operating conditions this should not occur.

c. Risk 3: Electrocution
   i. Description: This is a standard electrocution risk among any machine that plugs into a wall. The electrocution would occur from an arc spark that occurs when plugging the machine into a wall or unplugging it from a wall. The environmental factor that could occur whenever you are plugging or unplugging machines from walls a risk of an arc spark is possible so it is an inherent danger of using electricity. This could severity could range from just a little jolt to a possible death depending on many factors such as is water being around the circuit could affect the severity.
   ii. Impact: 2, Mild. While death is a possible impact, it is a very low likelihood that it would get that bad. Because of this we deem a small jolt which is the most likely of all the possibilities to be a low impact risk as it has little or no long term health effects.

    iii. Likelihood: 1, Low. This is very unlikely as electric plug technology has come far enough that arc sparks rarely happen. This is still a risk, but it's a risk of plugging anything into a wall. We are not taking any precautions with this as they are pretty standard today.

d. Risk 4: Hand gets caught in the pull down guard
    i. Description: This would happen if someone put the cup in the guard with one hand and pulled the pull guard down with their other hand before removing their one hand. This could only occur if somebody was distracted and didn't realize they were pulling the guard down on their hand or somebody else's hand. An failure of the device would be if the guard fell on its own rather than being pulled down on this. We are going to prevent this risk by creating a smooth edge on the bottom of the guard to keep this from being an issue. The severity of this injury is pretty much just a minor skin cut.
    ii. Impact: 1, Insignificant. This risk is not that bad as minor cuts and lacerations do not have any long term effect. The worst thing that could happen is an infection if they did not treat their cut, but that is not a direct effect from our product.
    iii. Likelihood: 1, Low. This is unlikely to happen as we are smoothing the bottom of the guard to prevent this such injury. The guard could still potentially fall, but not with enough blunt force to cause any injury from the height it would fall from with a smooth edge.

e. Risk 5: Pinching your finger on the hatch when changing the liquid
    i. Description: This would occur when changing the liquid, and placing your hand near any of the moving hinges while opening or on the free sides when closing. This is possible with any hinging mechanism and is not unique to our machine. Environmental factors are just not noticing your hand is in a place where the machine is moving or just a simple mistake of not paying attention to where you put your hand because you were distracted by a child. The severity of this injury would be a blood blister to a cut.
    ii. Impact 1, Insignificant. These injuries are common injuries that occur from everyday life so they would not impact anybody in the long term or short term really. This is an inherent risk in opening or closing anything. A blood blister is painful, but does not impact one's life.
    iii. Likelihood 4, Medium-High. This is possible on anything that opens or closes, so it is very apparent. Also, the lack of attention that people take when opening things is high as it is something people do regularly. The severity of injury is low so people are not super concerned with paying attention to this.

f. Risk 6: Running the Machine with the hatch open and your hand in the liquid container
    i. Description: This would occur if somebody opened the hatch to change the liquid and stuck their hand into a liquid container while refilling the container. Then,

somebody else would operate the machine causing the container to move.The environmental factor that could impact this would be if an impatient kid decided to operate the machine while somebody was working on changing the liquids inside the machine. The severity of injury would probably be anywhere from a cut on the wrist to a dislocation of the wrist. Depending on how far they stuck their wrist into the machine.

ii. Impact: 4, Significant. This could be a significant issue as this injury is very painful and can affect somebody's life for a while as a dislocation would take awhile to heal up, and their wrist wouldn't be the same.

iii. Likelihood: 1, Low. This is unlikely as somebody would have to actively operate the machine while somebody else was doing maintenance on the machine. We think people would not do this even if it were children as they would realize it is not time to operate the machine.

6.2.2 Risk Heat Map

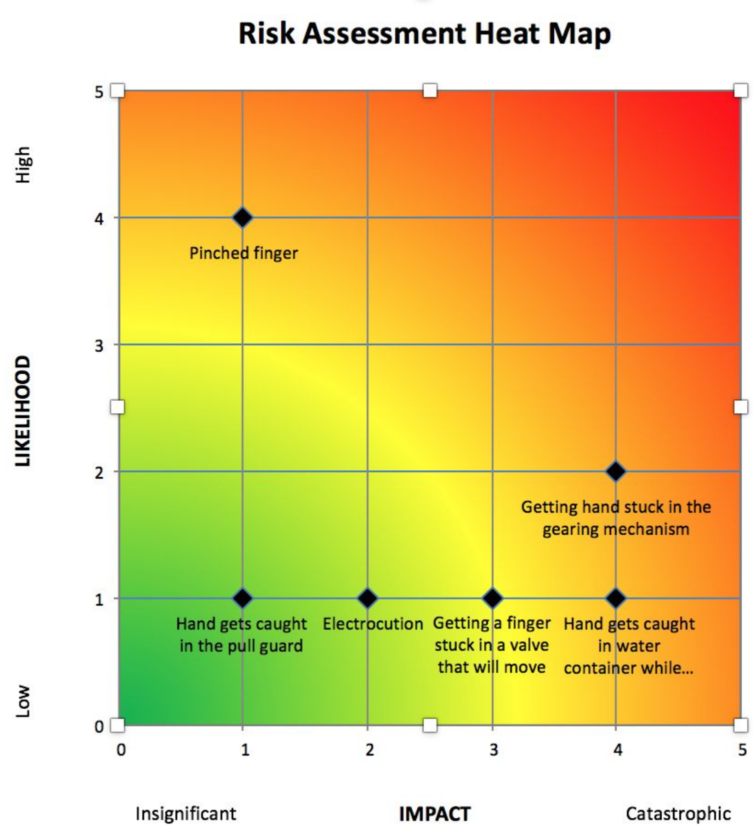


Figure 15: Risk Assessment Heat Map Graphic

6.2.3 Risk Prioritization

Based on the Heat Map, we are prioritizing preventing getting hands stuck in the gearing mechanism and pinching your finger in the hatch when refilling the liquid. We did not deem the other risks as very likely relative to those two, so we are not as worried about them. Getting a finger caught in the gears is not very likely, but it is very catastrophic as you could lose the tip of a finger. To prevent this, we have placed a pull guard to keep hands out of the gearing from below without reaching in areas that have no reason to and not pulling the guard. Additionally, there is no need to ever reach into the guards from above when changing the liquids out so that too is very unlikely. Therefore, we are going to have the guard and place a warning label on the machine to tell people not to put fingers near any gears when operating. In terms of pinching your finger on the hatch. The consequences are low, but it is fairly likely. Therefore, we are not necessarily designing a safety mechanism, but we are going to put a warning label near the hatch to remind people to watch their fingers when opening and closing the hatch to refill the liquid.

7 Design Documentation

7.1 Performance Goals

1. Under one minute for 1 cup of mixing from placement of the cup to retrieving of the cup.
2. Be able to produce 6 of our 12 colors on the color wheel without maintenance or manual adjustments between color runs.
3. Color test for accuracy of our mixing by Dr. Potter to show that we were able to create shades of the colors.
4. Sense the cup to know that is in the correct place so that the liquid does not end up inside of the drain.
5. Can refill the bottles with no tools in under 2 minutes.

7.2 Working Prototype Demonstration

7.2.1 Performance Evaluation

In its final testing, the prototype was able to meet 3.5 out of 5 performance goals. It very definitely took under one minute per cup, created visibly accurate colors, and could be refilled in under two minutes without any tool, but due to the quality of the light sensor and the group's understanding of how it worked and should be wired, the prototype was unable to sense the presence of a cup. Further, the machine was able to make six of the twelve colors without any maintenance between runs, but as seen in the video, the stepper motor was not strong enough to turn the rotating platform by itself. Instead, a group member was forced to help it by adding force manually to the rotation. With a higher quality light sensor and a stronger stepper motor, the prototype would have hit all of the goals easily.

7.2.2 Working Prototype – Video Link

https://youtu.be/tm1xnFV8YW0

7.2.3 Working Prototype – Additional Photos

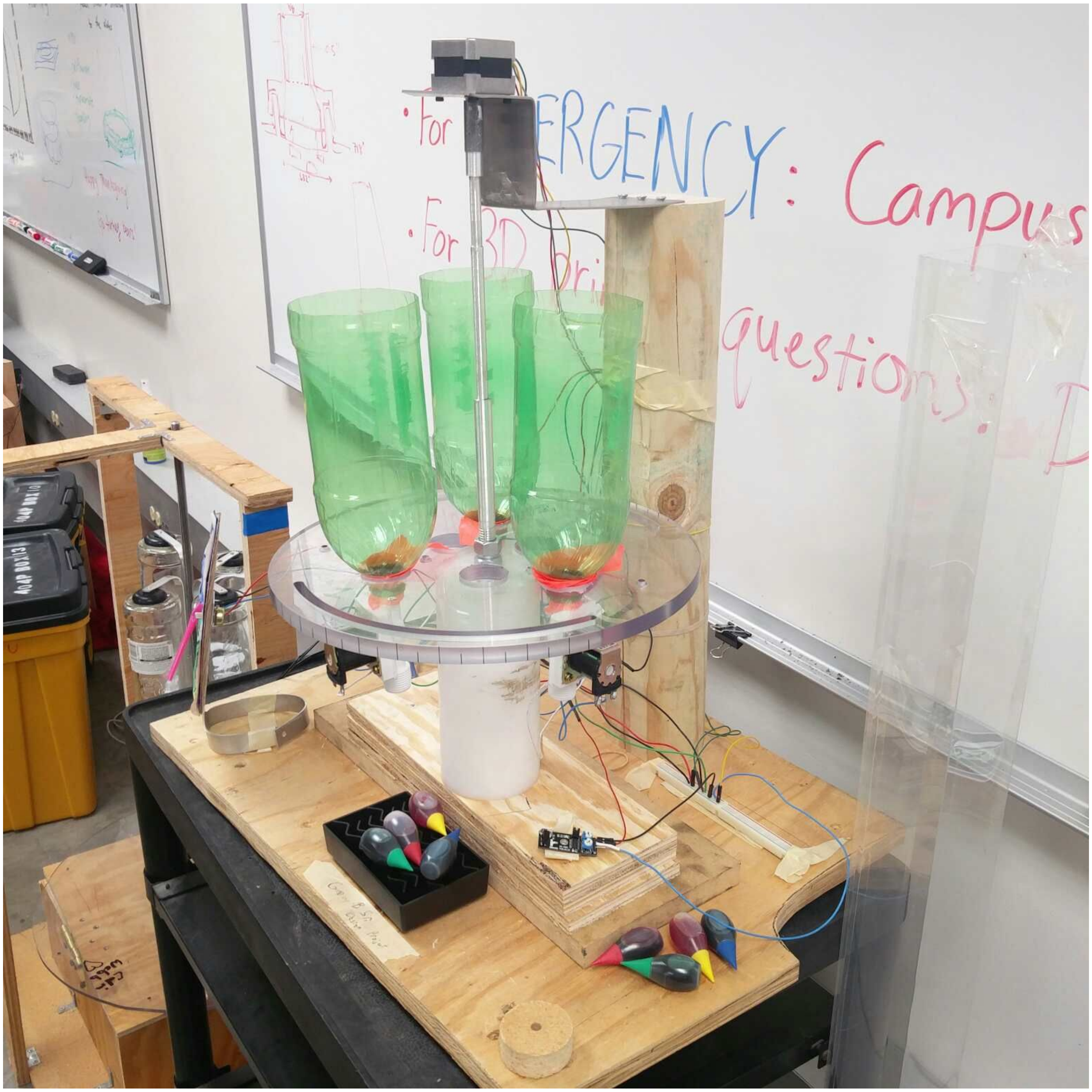


Figure 16: Isometric View of Working Prototype

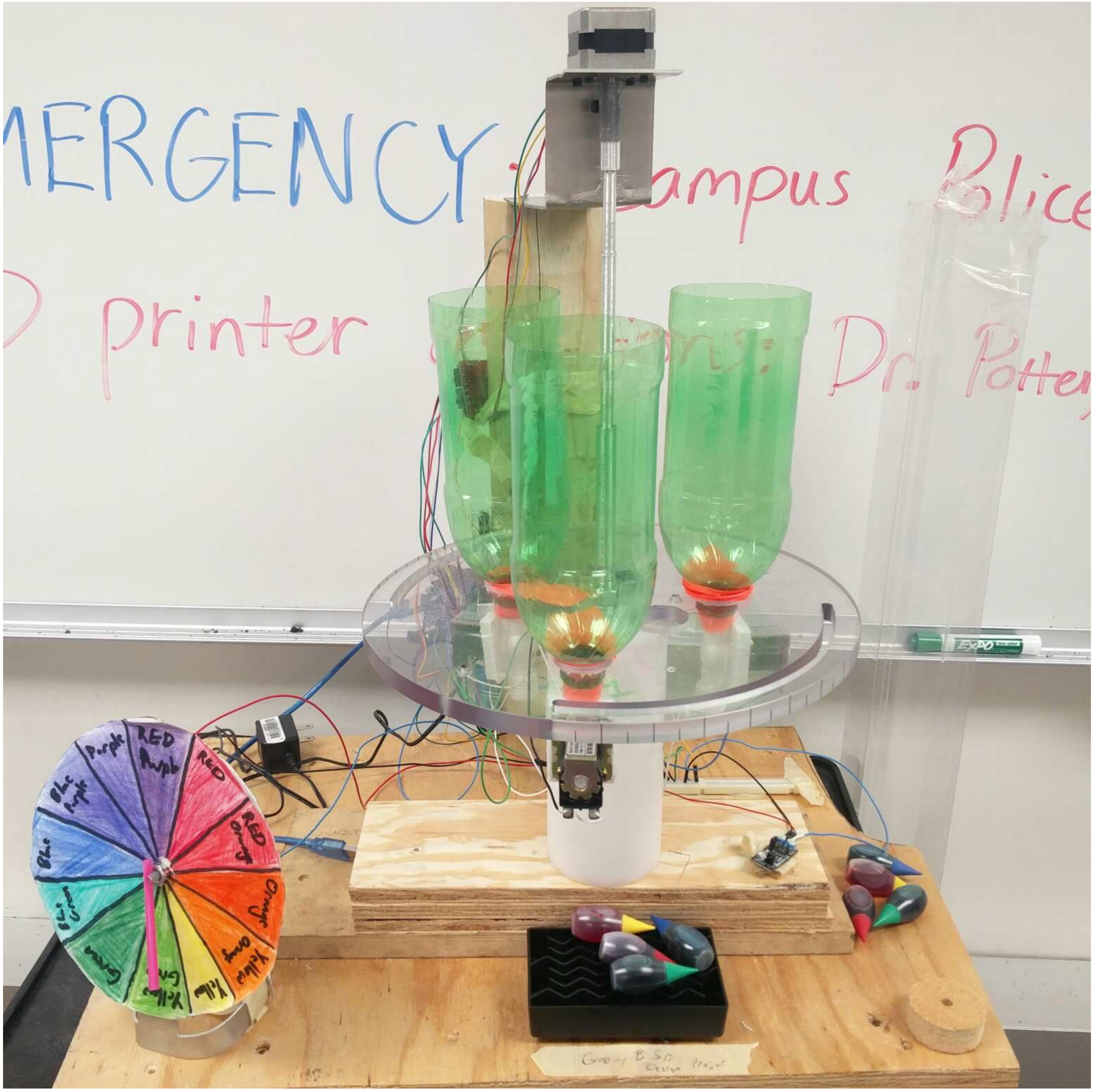


Figure 17: Front View of Working Prototype

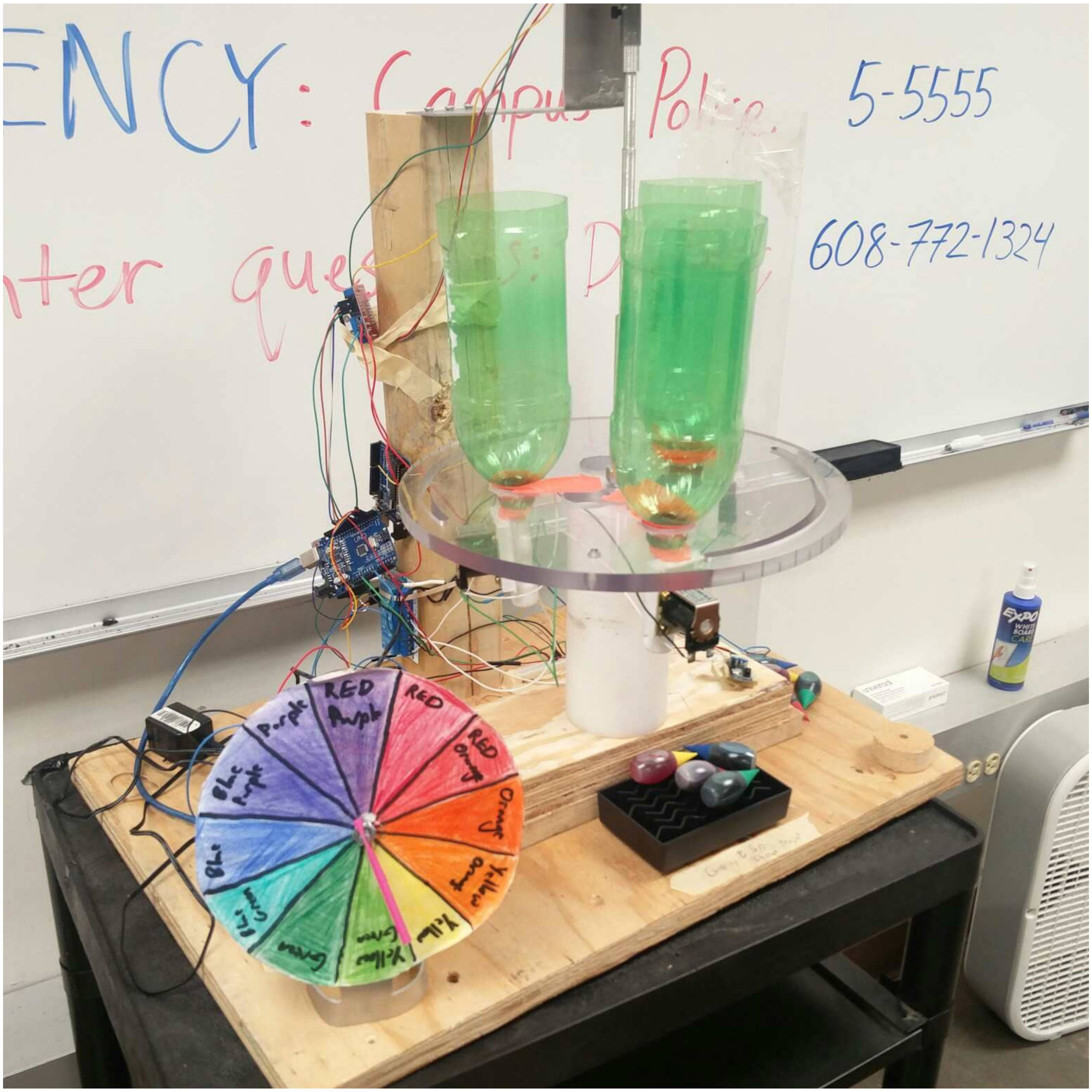


Figure 18: Left Corner View of Working Prototype

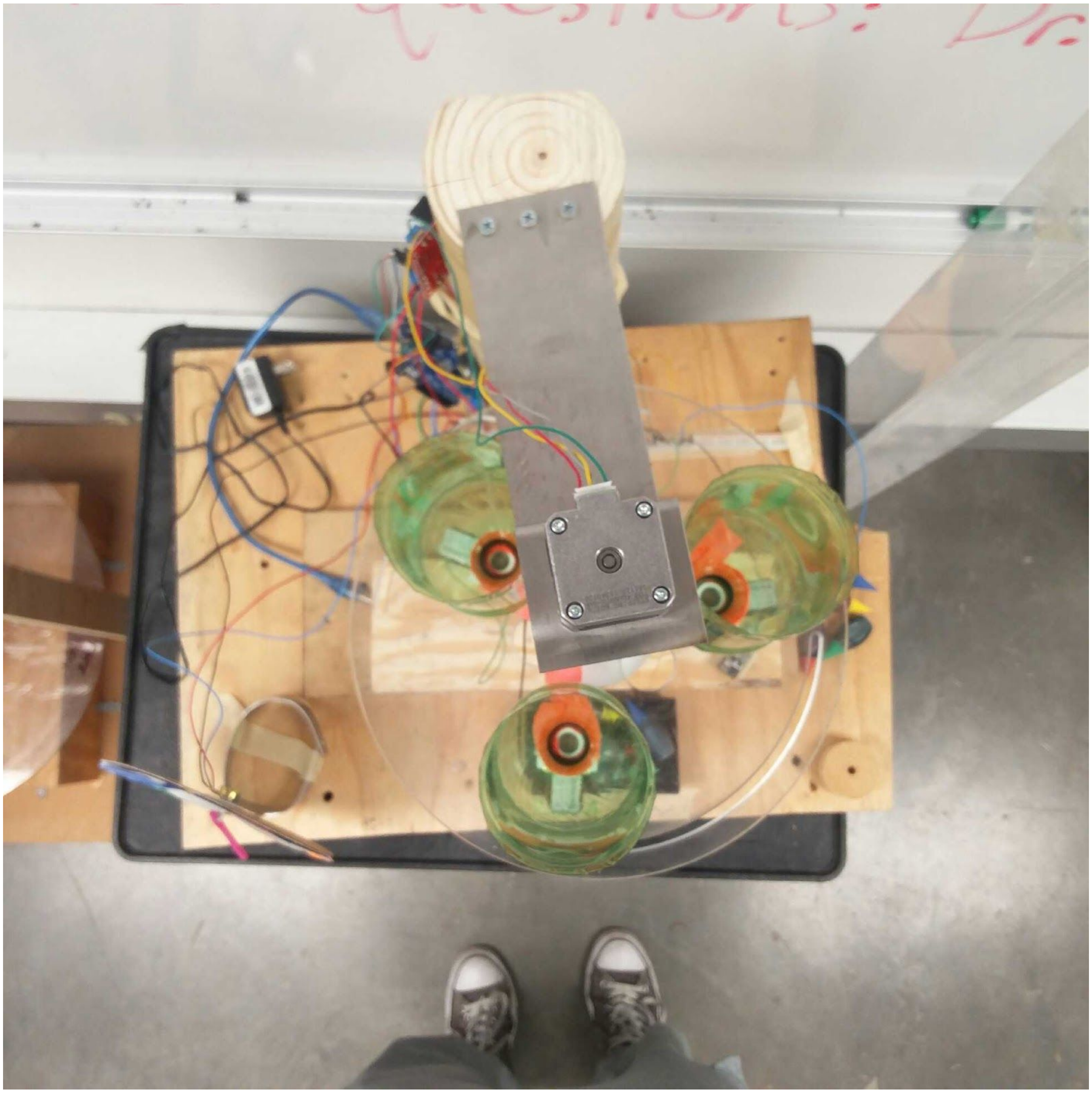


Figure 19: Top View of Working Prototype

7.3 Final Presentation – Video Link

https://youtu.be/tm1xnFV8YW0

8 Discussion

8.1 Design for Manufacturing – Part Redesign for Injection Molding

8.1.1 Draft Analysis Results

From the initial manufacturing, there are a few parts that could be slightly redesigned for injection molding for both simplicity and price. Mainly, the outer casing is a prime candidate, but there are several smaller, intricate pieces that could also warrant this change. These include the drip tray, the dial, and the connector between the engine and the shaft. Specifically for this last connector, creating a connection between the motor and the shaft would allow for the return to the original ninety degree connection.

8.1.2 Explanation of Design Changes

The only necessary design changes to allow for injection molding would be to add slight slopes to the vertical surfaces to allow for easier removal. Moreover, the use of an injection molded connector piece between the shaft and the motor would allow for a return to the original design. The other integrations of injection molding would either make the production process easier or cheaper.

8.2 Design for Usability – Effect of Impairments on Usability

8.2.1 Vision

Considering the the automated color selector depends on the ability to differentiate between different colors, a vision impairment would most definitely influences the design of the project. Children with varying shades of color blindness will not be able to differentiate between red/green, etc; however, these children can see what colors make the color(s) they cannot differentiate seeing, leading to learning more about their disease. For our current design, the entire project is open, showing which primary colors are used to make the different shades of the secondary colors. We have already had to modify our design before to account for this impairment.

8.2.2 Hearing

A hearing impairment would cause the user of the device to not be able to hear the motor running, potentially causing harm to the user. Even though all the mechanical parts of the project are able to be seen by the user, that is not enough to suggest the machine is off when in actuality, the color selector is running. To combat for this, lights could be added to the project. When the project is turned on but not running, the light could be green. When the project is turned on and running, the light could be flashing red. When the device is unplugged and turned off, the light could also be off.

8.2.3 Physical

A physical impairment would not be affected by the current design of the automated color selector because when using the device, the only movement necessary is turning the selector to the desired color, closing the guard before the machine starts running, and then picking up the cup after the machine has mixed the desired color. When the device is turned off and is needed to be moved, physical impair the ability to move the device. However, this does not apply to the project when using the automated color selector. The only physical impairment that would affect the use of our machine is if a child did not have the use of his limbs. If this were the case, we could create a voice recognition system to recognize the colors he or she said. Therefore, we would use a system similar to Siri on the iphone to recognize what was said then send a message to our machine.

8.2.4 Language

A language impairment would also not affect the usability of our device. The only questionable design decision would be using the names of the varying colors instead of a picture of the color. We were already going to use pictures of the color as to show how the colors by the selectors match the color mixed by the automated color selector. If we decided to use the name of the color instead of a picture, a language impairment would definitely impact the usability of the design. To reiterate one last time, we are going to use pictures of the colors, which is currently in our design. Therefore, a language impairment is moit for the operation of the machine. The warning labels are going to be in english however, so someone who does not speak english may not be able to read the warnings. If this product was to go to market we would probably put the warnings in Spanish as well to accommodate the second most popular language in America. However, due to none of us being bilingual we will not do that for our project.

7.2 Overall Experience

7.2.1 Does your final project result align with the initial project description?

Our project did align with our initial project description. Our machine when operated can produce the 12 shades of primary and secondary colors by combining dyed liquid and diffusing into the selected color. Our project is safe as it does not require children to put there hands in dangerous parts of the machine. The motion detector can sense the cup, once it is placed. Also, they can choose the desired color on the variable resistor switch and color wheel to the selected color. This project is relatively cheap and could be mass produced for teachers on a budget to teach the kids which 3 primary colors go into making the secondary colors.

7.2.2 Was the project more or less difficult than you had expected?

The coding was more difficult than we expected. Looking back at the code, we thought it would be much simpler. However, due to the numerous electrical components that we needed to combine made it a little more difficult to get all the moving parts to work together. Additionally, we thought that wiring the system would be a little smoother as we were planning on using the slip ring from above, but that would have taken a much larger apparatus.

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

For our project, the automated color selector, did not work exactly as planned. For our project, our group wanted to use gears to connect the moving shaft to the motor controlled by an arduino. Instead, our group had to reconfigure this portion of the project to connect the motor to the shaft via a connector. Our group wishes the 90 degree gears would have worked, leading to a better performance of our original idea. But fortunately, the redesign works fine for the function needed. Our group also wished our code for the arduino and electrical components used for the project would have performed better. For our final prototype, from watching the contraption work, all the components other than the light sensor were functional, just not necessarily as we wanted them to. Mainly, moving forward we would want to upgrade our stepper motor, solenoids, and light sensor to higher quality parts, but in order to stay within our budget we had to work with what we could afford.

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

I wouldn't say that we were missing critical information when evaluating concepts. However, we really only varied the mechanisms of movement in our concept evaluation. We did not necessarily have the electrical engineering background to evaluate different ways to wire and power our device. It would have been helpful to keep that part of the project in mind when evaluating which mechanical mechanism we would use for our project.

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

An engineering analysis on how much torque our motor could produce would have helped us determine how large of bottles we could use based on the amount of liquid the motor could spin. We didn't really do any analysis on the motor as we just used the manufacturer's guidelines for the motor analysis. However, this could have been problematic if those guidelines proved unreliable.

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

At this point the most relevant code used for our project is ASTM F963, a standard basically stating that the project has to be safe for children to be around and operate. This code influenced revision of the design because ultimately, if this design was going to be mass produced, the project would have a guard to be closed around the cup, as well as a casing around the entire project, to ensure that anyone operating the machine could not get there hand or anything else stuck inside the machine while the machine is on and operating. For the prototype, the casing and guard are not on strictly because we are the only ones who are going to operate the machine and for budget reasons. Also from the standard, if the project was going to be mass manufactured, all the corners and sharp areas of the project would be rounded as well to make the project safer for children to be around and operate.

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

We had to consider if the output of our device was sustainable and nontoxic to the environment. This is because the output is likely to become waste from our project. The dyed mixture if not used to make art would be thrown away so we needed to consider the sustainability of this. Due to our projects choice of using food coloring and water as our dyes, we were not concerned with what happened to the waste of our machining.

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

The group should have put more time into testing the light sensor before addinging it into the prototype to ensure that we knew how to incorporate it best. On the other hand, we would have spent less time in the concept selection portion of the class because our final design was our initial design with only a few slight tweaks to get the machine to actually run.

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

Ordering the parts in a timely manner was harder than expected. There was a rather fast turn around between ordering parts and building our assembly, so there was not much time for redesign. Therefore, the part ordering had to be done much more carefully than expected as we did not account for a lack of time to troubleshoot our design from the time it was assembled to the prototype demo. It was much easier to assemble the actual device than anticipated. We originally thought that may take weeks, but instead it only took a few very long days to get the machine put together.

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

The actual machining of the parts was much simpler than we imagined. We were lucky that both Mike and Mark had extensive experience machining parts so they were very efficient with the ways to create the machined parts such as the shaft, brackets, and spinning plate. Getting the motor to work with gears proved to be too hard to assemble, so we shifted the position of the motor to no longer need the gears. Therefore, we were able to make a few quick redesigns to make the gears unnecessary since they were not meshing well.

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

If we had a much larger budget, we probably would have nicer appearing materials in our project such as a nice casing, better bottles, and more reliable electrical components. In terms of our approach, we probably would have bought more options for electrical components and tested which one worked best with our project. This would have been helpful in troubleshooting the code as we could see if the unreliability of our components was the problem or if it was the coding causing the malfunction.

7.2.12 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 to retake the course and do the same project, we would start machining and coding earlier. Also, we would probably try to get our parts ordered sooner than we did so that we didn't have to scramble for as many electrical components such as relays and LED detectors. The class sort of put us behind schedule based on when we would have ideally ordered parts to give us more time to troubleshoot.

7.2.13 Were your team member's skills complementary?

Yes, they were. Nick was really good with the design component on the computer and with the wiring of the components. Mark and Mike were very skilled with running the mills, band saws, and drill presses to machine all of the parts needed. Andrew was good at doing the research necessary to figure out the wiring and coding of the various components of our project.

7.2.14 Was any needed skill missing from the group?

It would have been more helpful if anybody in our group was more familiar with arduino coding as that appeared to take a lot more research to figure out how to than was probably necessary. Nobody in our group really had much background in computer science or coding in general so there were a few obstacles we had to overcome for this aspect of the project.

7.2.15 Has the project enhanced your design skills?

Yes, the project has enhanced our design skills. For every area of the project, from designing to building to coding, each member of our group has been able to refine one or multiple skills in each of these areas. The automated color selector was not only just mechanical; the project was also had electrical and coding components, leading to greater understanding of all of these different areas. While the mechanical aspect of the project experienced the least amount of enhanced skills, the coding and electrical parts experienced the most enhanced skills.

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

Yes, design processes are a little overwhelming the first time you accept one. However, this class made it less daunting to design and build a project from start to finish. The use of intermediate steps and assignments helped narrow the task down into something more doable. Rather than focusing on the large task at hand as a group, we learned how to focus on smaller goals which work to accomplish the larger task at hand.

7.2.17 Are there projects you would attempt now that you would not have attempted before?

Yes, I would say after doing this project, our group would be more comfortable approaching projects that take arduino code to run. Before this project, none of us really knew that much about how to wire or code arduino's, but this project showed us the power and simplicity of this component. Many things can be done with an arduino, and as a group we feel much more comfortable with the coding and electrical components of projects than we did at the beginning of the semester. Therefore, we would be more willing to attempt a more electrical and coding involved project.

Appendix A - Parts List

	Part	Source Link	Supplier Part Number	Color, TPI, other part IDs	Unit price	Tax ($0.00 if tax exemption applied)	Shipping	Quantity	Total price
1	Solenoid valve	http://www.mouser.com/ProductDet	485-997	White	$6.95	$0.00	$5.00	3	$20.85
2	Stepper motor	http://www.oddwires.com/nema17-	MSM-0000001	Silver	$12.95	$0.00	$5.00	1	$12.95
3	Motor controller	http://www.oddwires.com/l298n-	CIC-0000010	Red	$3.95	$0.00	$0.00	1	$3.95
4	Arduino	https://www.sparkfun.com/products/	DEV-13975	Red	$19.95	$0.00	$5.00	1	$19.95
5	Power supply	https://www.sparkfun.com/products/	TOL-00298	Black	$5.95	$0.00	$0.00	1	$5.95
6	90 deg gears	https://www.mcmaster.com/#7297k	7297K14	Silver	$5.30	$0.00	$5.00	2	$10.60
7	Handle	found	-	-	$0.00	$0.00	-	1	$0.00
8	Drip tray	http://www.discountcoffeeequipment	HHD KDT	Black	$2.99	$0.00	$5.00	1	$2.99
9	Slip ring	https://www.adafruit.com/product/7	736	Black	$14.95	$0.00	$5.00	1	$14.95
10	Rotary switch	http://www.mouser.com/ProductDet	105-SR2511F-12EN	Silver	$4.24	$0.00	$0.00	1	$4.24
12	Acrylic	https://www.mcm	8560K177	Clear	$43.29	$0.00	$0.00	1	$43.29
Total:									$139.72

Figure 20: Parts List for the Automated Color Selector

Appendix B - Bill of Materials

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1		BASE
2	1	ACM-NM-007	CARRIER
3	1	1327K126	STL SHAFT
4	2	7297K170	90 DEG GEAR
5	1	MSM-0000001	STEPPER MOTOR
6	1	ACM-NM-008	SHAFT ADAPTER
7	1	SRC022A-6	SLIP RING
8	1	ACM-NM-009	MOTOR BRACKET
9	1	ACM-NM-010	SLIP RING BRACKET
10	3	485-997	SOLENOID VALVE
11	1	HHD KDT	DRIP TRAY
12	3		BOTTLE
13	2	ACM-NM-005	OPENING SIDE
14	1	ACM-NM-002	CASE FRONT
15	2	ACM-NM-003	CASE SIDE
16	1	ACM-NM-011	CASE BACK
17	2	ACM-NM-004	CASE TOP/BOTTOM
18	1	91375A018	SET SCREW
19	1	ACM-NM-006	CASS DOOR
20	1	1815A520	PULL HANDLE
21	1	SR2511F-0112-19F0B-E9-N-W-159	ROTARY SWITCH

Figure 21: Bill of Materials for the Automated Color Selector

Appendix C - CAD Models

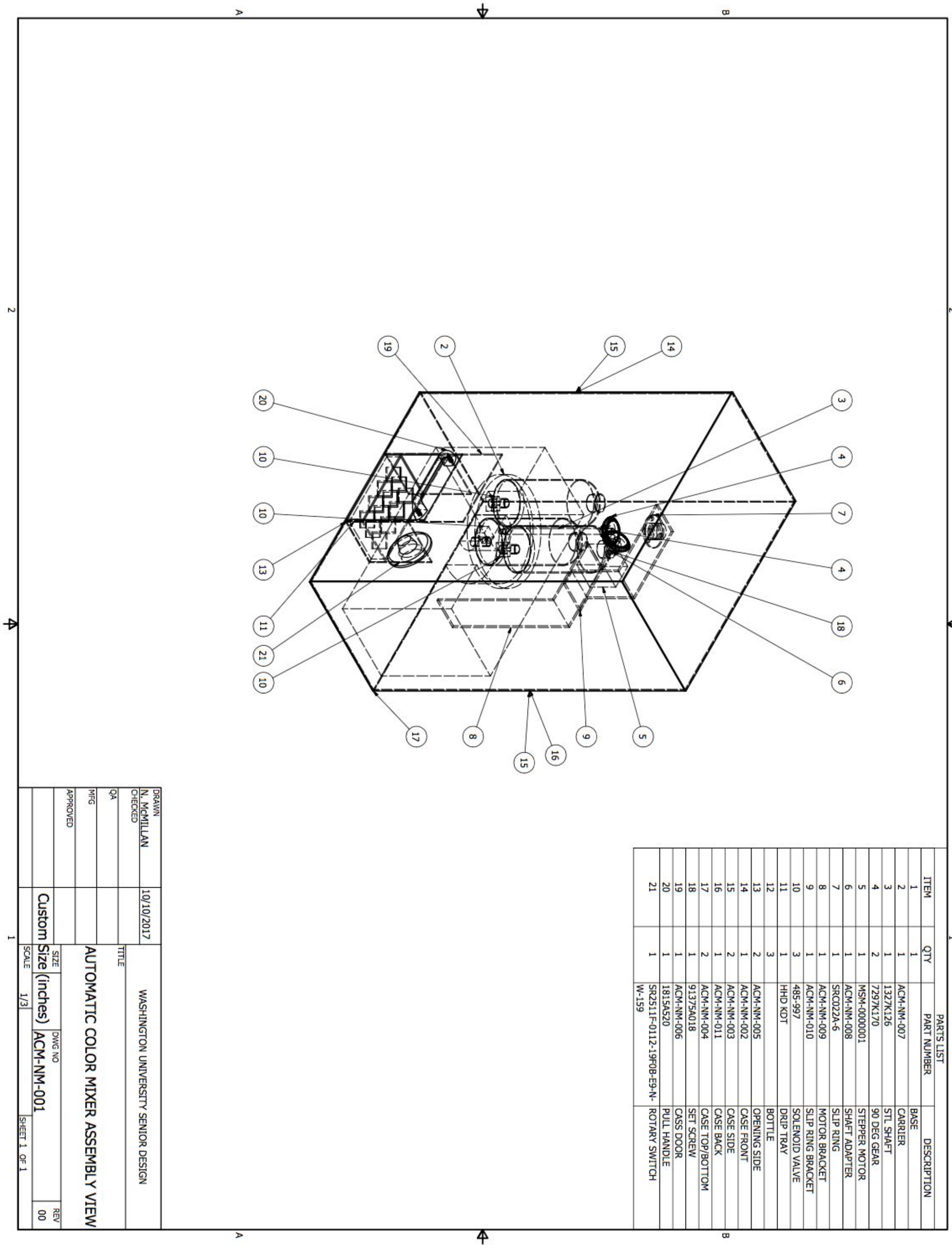


Figure 22 : Automatic Color Selector Assembly View

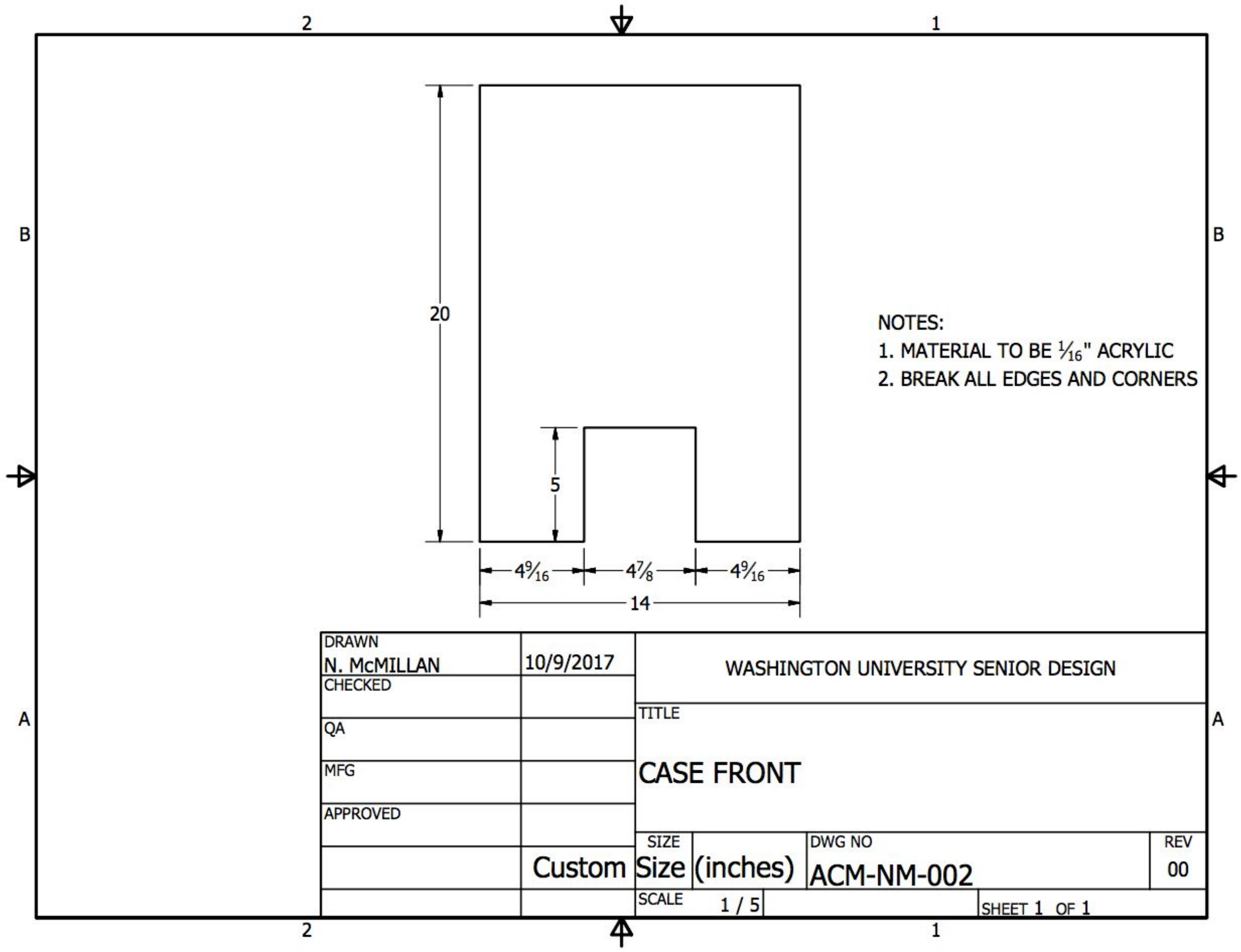


FIGURE 23: AUTOMATIC COLOR SELECTOR CASE FRONT

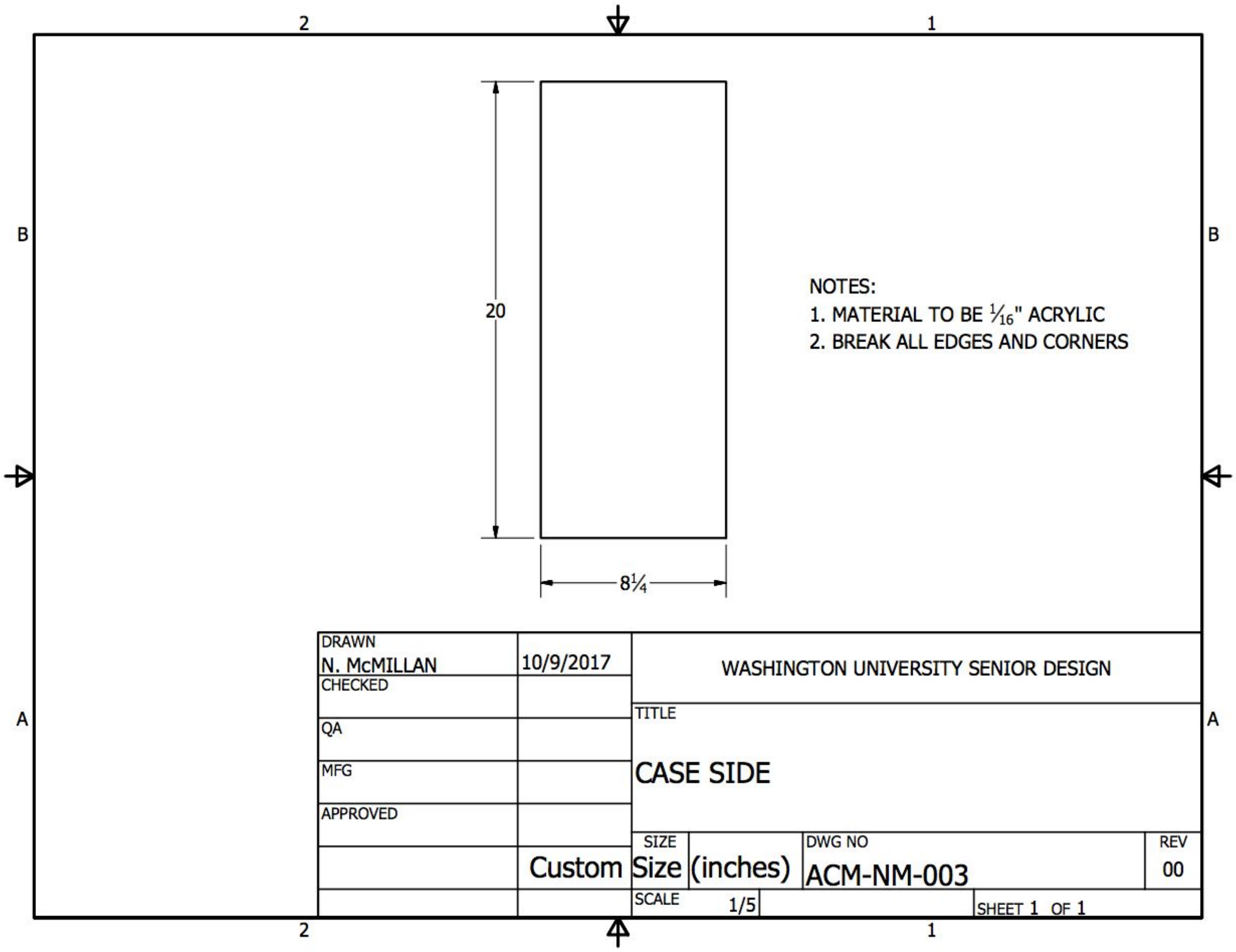


FIGURE 24: AUTOMATIC COLOR SELECTOR CASE SIDE

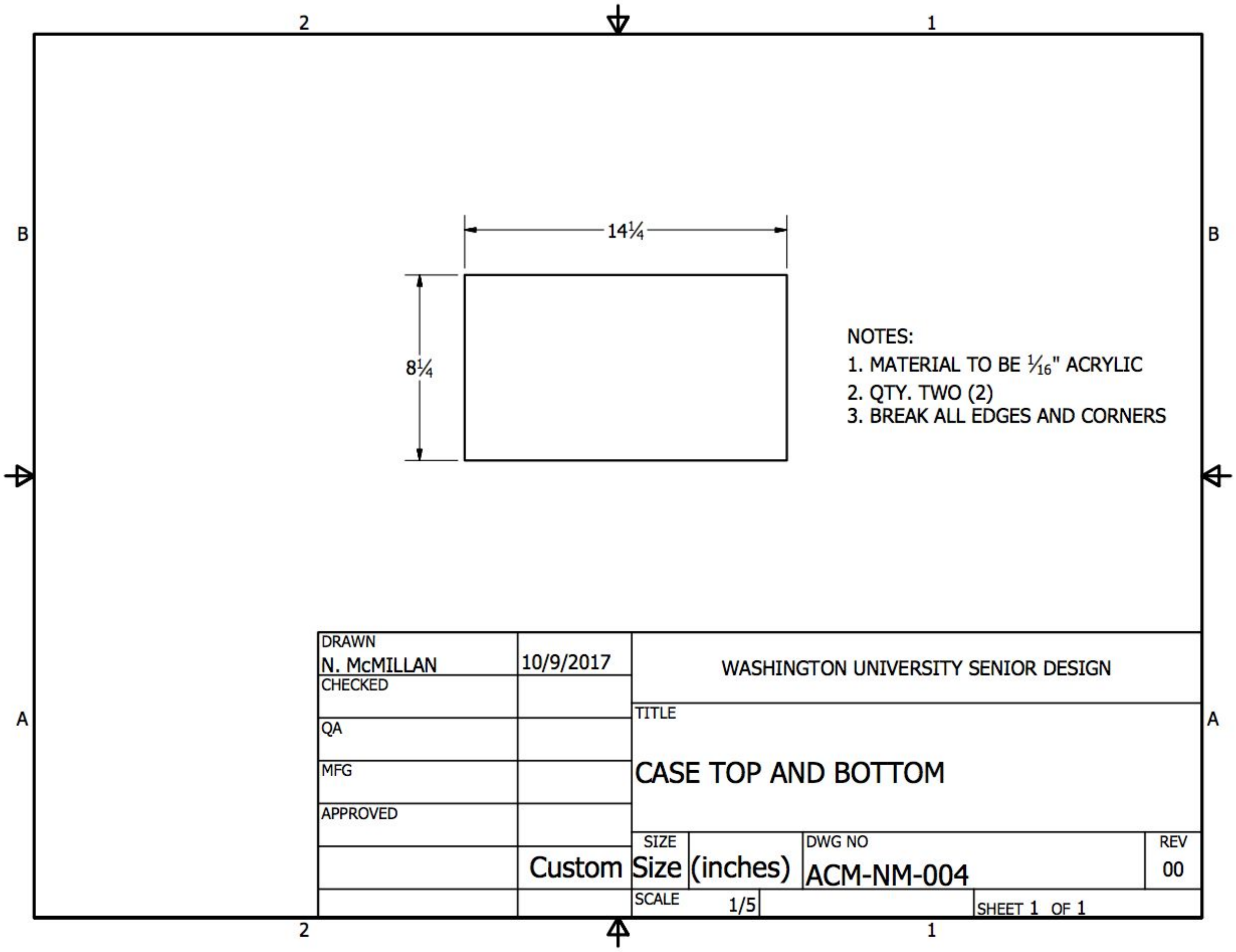


Figure 25: Automatic Color Selector Case Top and Bottom

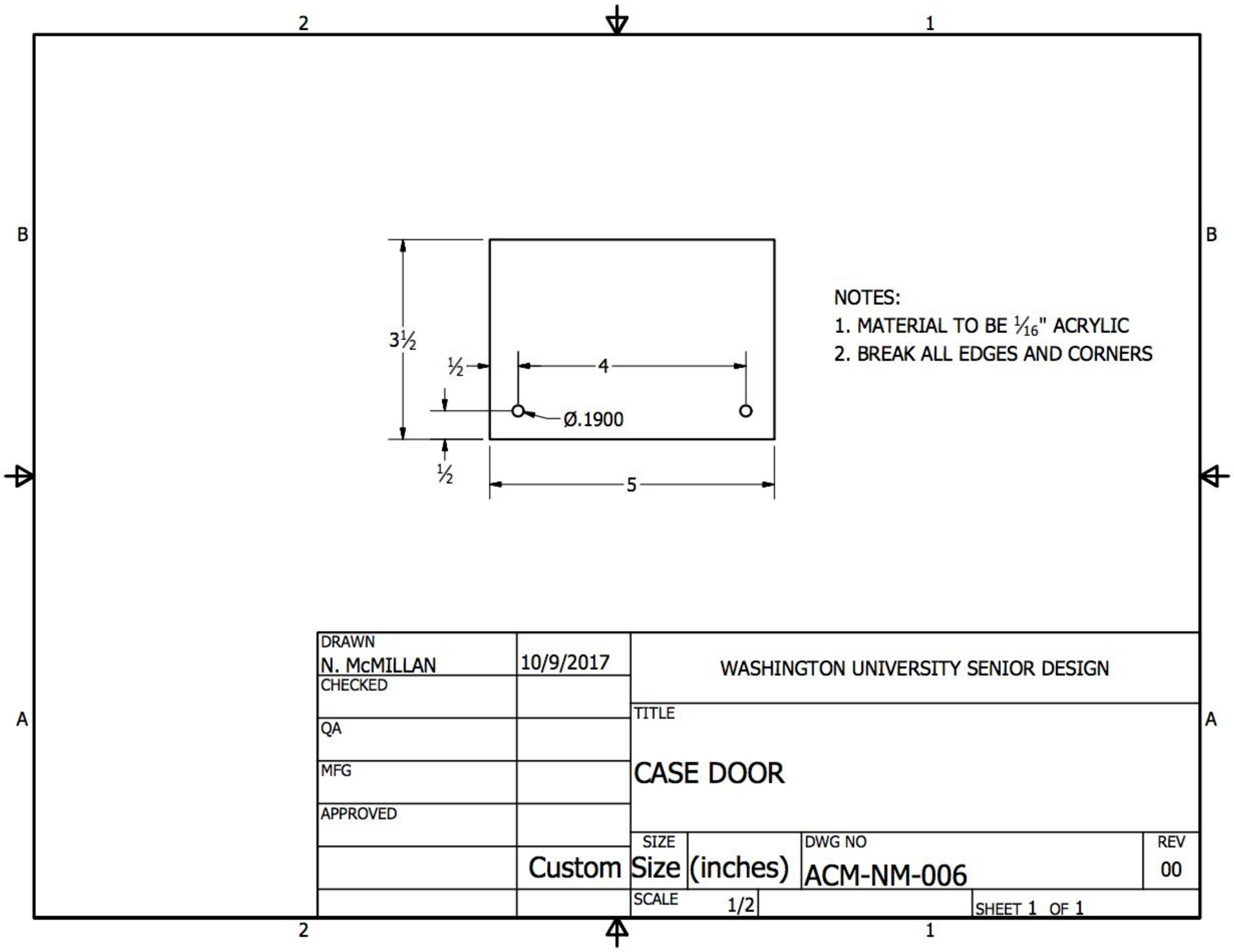


FIGURE 26: AUTOMATIC COLOR SELECTOR CASE DOOR

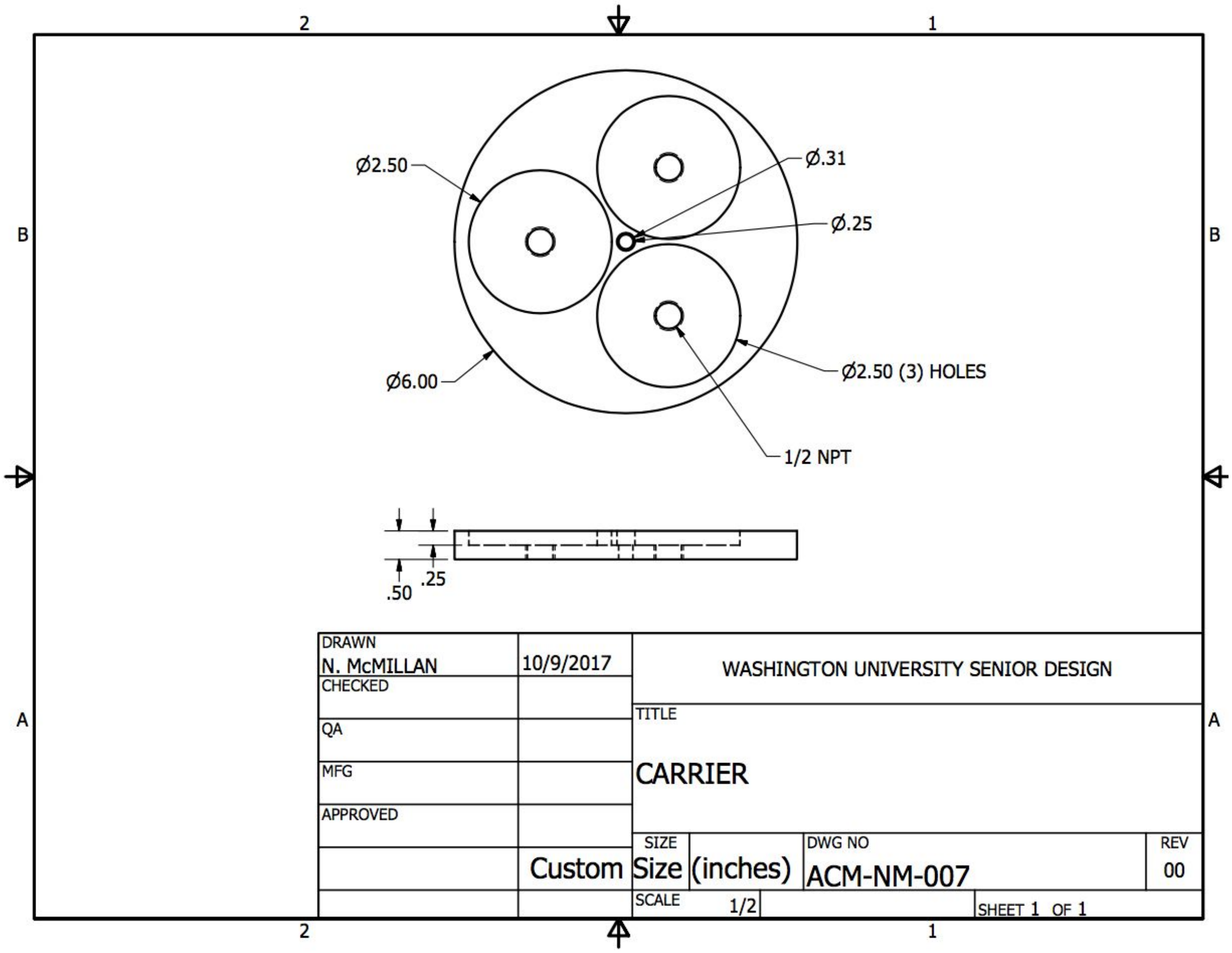


Figure 27: Automatic Color Selector Carrier made out of acrylic

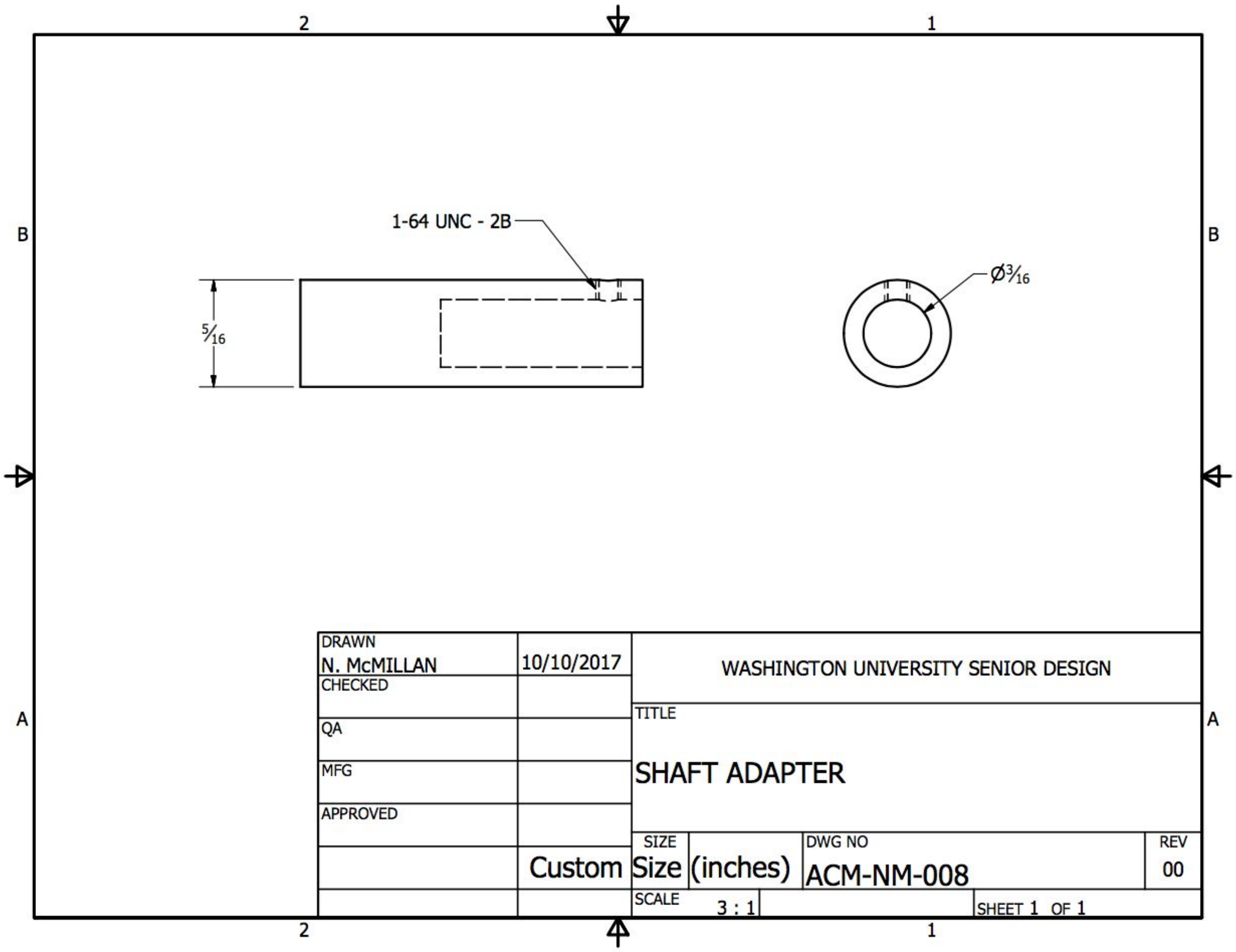


Figure 28: Automatic Color Selector Shaft Adapter made out of aluminum

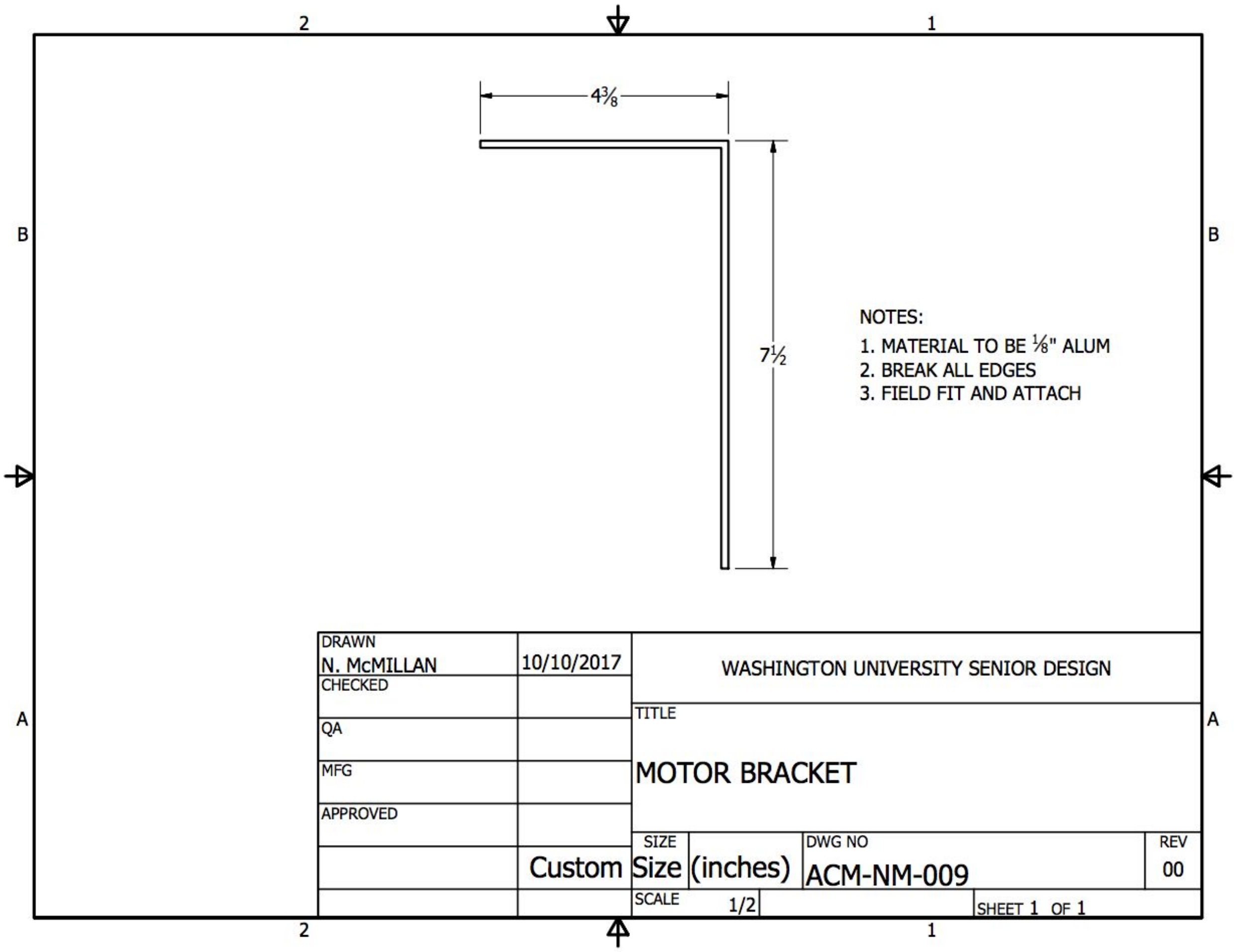


FIGURE 29: AUTOMATIC COLOR SELECTOR MOTOR BRACKET

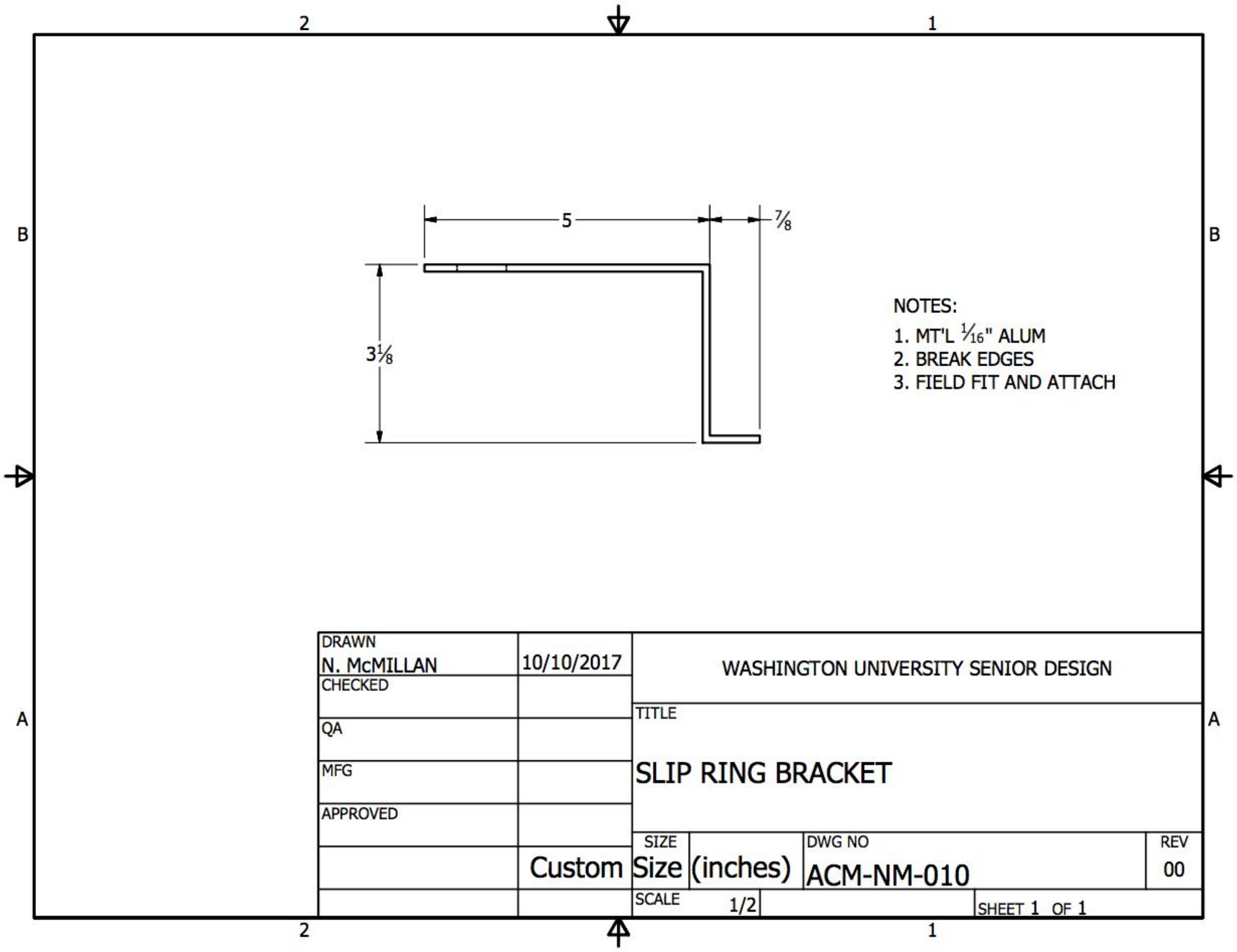


Figure 30: Automatic Color Selector Slip Ring Bracket

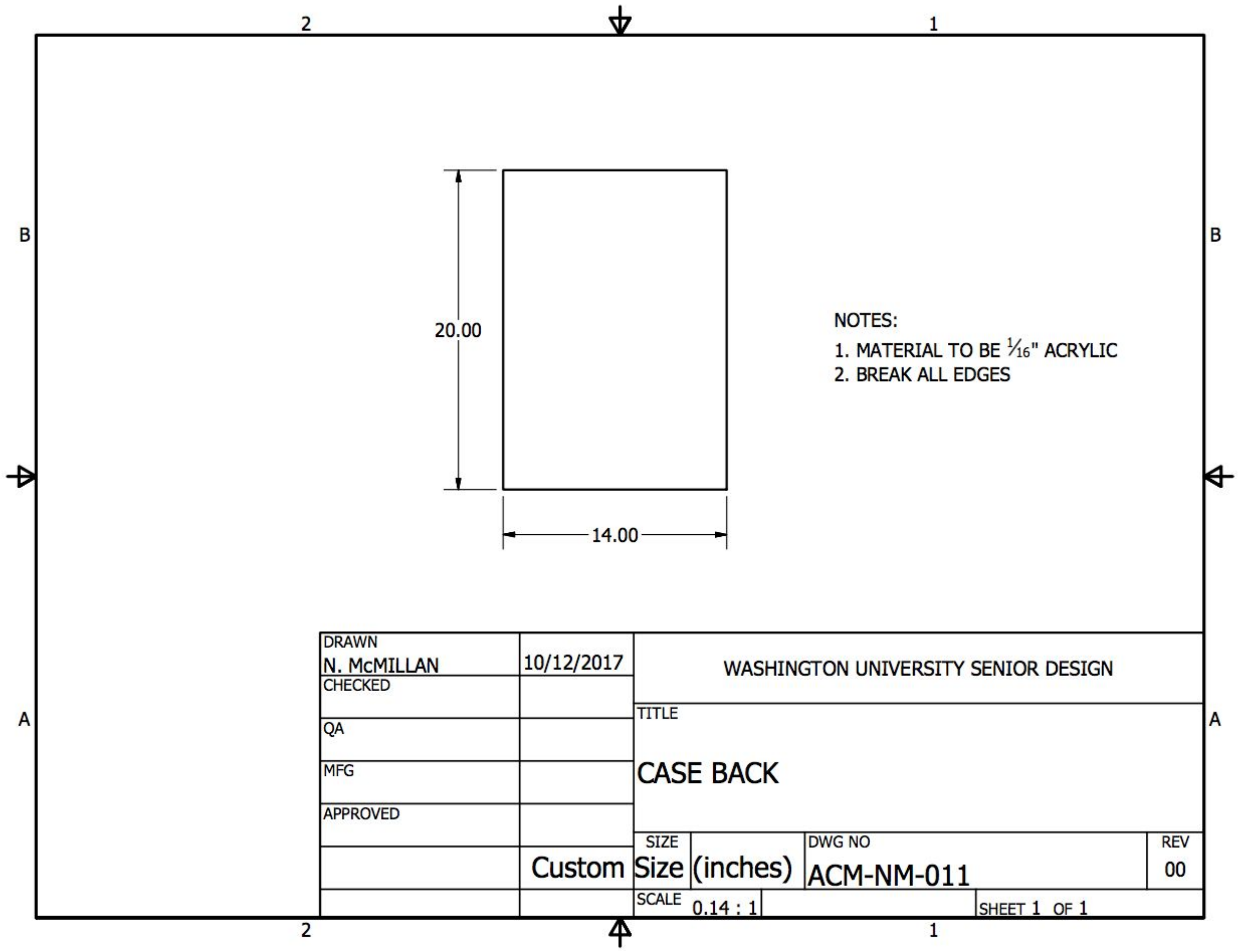


FIGURE 31: AUTOMATIC COLOR SELECTOR CASE BACK

Appendix D: Arduino Code

```
#include <Stepper.h> //stepper motor import

#define Relay2 2 //red valve
#define Relay3 3 //blue valve
#define Relay4 4 // yellow valve

const int stepsPerRevolution= 200; //steps for one revolution

int blue = 0;
int red = 0;
int yellow = 0;
int totalTime= 10000; //10 seconds
int fake = 0;

Stepper myStepper(stepsPerRevolution,8,9,10,11);

void setup() {
   myStepper.setSpeed(20);
   pinMode(Relay2,OUTPUT);
   pinMode(Relay3,OUTPUT);
   pinMode(Relay4,OUTPUT);
   Serial.begin(9600);
}

void loop() {
  if (Serial.available() > 0){ // in an ideal setting, this is where our light sensor
  if (Serial.read() > 0){      // code would go
  int sensorValue = analogRead(A1);
  Serial.println(sensorValue);

  if ((sensorValue >= 0) && (sensorValue <85)){ // red
  red = totalTime;
  digitalWrite(Relay2,HIGH); //open red channel

  delay(red);                    //Wait red Second
 //close red channel
  digitalWrite(Relay2,LOW);
    }

  else if ((sensorValue >=85) && (sensorValue < 170)) {//red orange
  red = (2 * totalTime) / 3;
  yellow = totalTime / 3;
```

```
digitalWrite(Relay2,HIGH); //open red channel
delay(red);                    //Wait red Second
digitalWrite(Relay2,LOW); //close red channel
delay(2000);
myStepper.step(-67); //move to yellow
delay(2000);
digitalWrite(Relay4, HIGH); //open yellow channel
delay(yellow);              //Wait yellow seconds
digitalWrite(Relay4, LOW); //close yellow channel
delay(2000);
myStepper.step(67);// move back to red
  }

else if ((sensorValue >=170) && (sensorValue < 255)){ //Orange
red = totalTime / 2;
yellow = totalTime / 2;
digitalWrite(Relay2,HIGH); //open red channel
delay(red);                    //Wait red Second
digitalWrite(Relay2,LOW); //close red channel
delay(2000);
myStepper.step(-67); //move to yellow
delay(2000);
digitalWrite(Relay4, HIGH); //open yellow channel
delay(yellow);              //Wait yellow seconds
digitalWrite(Relay4, LOW); //close yellow channel
delay(2000);
myStepper.step(67);// move back to red
}

else if ((sensorValue >=255) && (sensorValue < 340)) { //Yellow Orange
red = (2*totalTime)/3;
yellow = totalTime/3;
digitalWrite(Relay2,HIGH); //open red channel
delay(red);                    //Wait red Second
digitalWrite(Relay2,LOW); //close red channel
delay(2000);
myStepper.step(-67); //move to yellow
delay(2000);
digitalWrite(Relay4, HIGH); //open yellow channel
delay(yellow);              //Wait yellow seconds
digitalWrite(Relay4, LOW); //close yellow channel
delay(2000);
myStepper.step(67);// move back to red
}
```

```
else if ((sensorValue >=340) && (sensorValue < 425)){ //Yellow
yellow = totalTime;
myStepper.step(-67); //move to yellow
delay(2000);
digitalWrite(Relay4, HIGH); //open yellow channel
delay(yellow);            //Wait yellow seconds
digitalWrite(Relay4, LOW); //close yellow channel
delay(2000);
myStepper.step(67);// move back to red
}

else if ((sensorValue >=425) && (sensorValue < 510)){//Yellow Green
blue = totalTime/3;
yellow = (2*totalTime)/3;
myStepper.step(67); //move to blue
delay(2000);
digitalWrite(Relay3,HIGH); //open blue channel
digitalWrite(Relay3,HIGH);
delay(blue);                 //Wait blue Second
digitalWrite(Relay3,LOW); //close blue channel
delay(2000);
myStepper.step(-134);// move to yellow
delay(2000);
digitalWrite(Relay4, HIGH); //open yellow channel
delay(yellow);                 //Wait yellow Second
digitalWrite(Relay4, LOW); //close yellow channel
delay(2000);
myStepper.step(67);// move back to red
}

else if ((sensorValue >=510) && (sensorValue < 595)){//Green
blue = totalTime/2;
yellow = totalTime/2;
myStepper.step(67); //move to blue
delay(2000);
digitalWrite(Relay3,HIGH); //open blue channel
delay(blue);                 //Wait blue Second
digitalWrite(Relay3, LOW); //close blue channel
delay(2000);
myStepper.step(-134);// move to yellow
delay(2000);
digitalWrite(Relay4, HIGH); //open yellow channel
delay(yellow);                 //Wait yellow Second
digitalWrite(Relay4, LOW); //close yellow channel
delay(2000);
```

```
myStepper.step(67);// move back to red
}

else if ((sensorValue >=595) && (sensorValue < 680)){ //Blue Green
blue = (2*totalTime)/3;
yellow = totalTime/3;
myStepper.step(67); //move to blue
delay(2000);
digitalWrite(Relay3,HIGH); //open blue channel
delay(blue);                 //Wait blue Second
digitalWrite(Relay3, LOW); //close blue channel
delay(2000);
myStepper.step(-134);// move to yellow
delay(2000);
digitalWrite(Relay4, HIGH); //open yellow channel
delay(yellow);                //Wait yellow Second
digitalWrite(Relay4, LOW); //close yellow channel
delay(2000);
myStepper.step(67);// move back to red
}

else if ((sensorValue >=680) && (sensorValue < 765)){// Blue
blue = totalTime;
myStepper.step(67); //move to blue
delay(2000);
digitalWrite(Relay3,HIGH); //open blue channel
delay(blue);                 //Wait blue Second
digitalWrite(Relay3, LOW); //close blue channel
delay(2000);
myStepper.step(-67);// move back
}

else if ((sensorValue >=765) && (sensorValue < 850)){ // Blue Purple
blue = (2*totalTime);
red = totalTime/3;
digitalWrite(Relay2,HIGH); //open red channel
delay(red);                  //Wait red Second
digitalWrite(Relay2,LOW); //close red channel
delay(2000);
myStepper.step(67);// move to yellow
delay(2000);
digitalWrite(Relay3, HIGH); //open blue channel
delay(blue);                 //Wait blue Second
digitalWrite(Relay3, LOW); //close blue channel
delay(2000);
```

```
 myStepper.step(-67);// move back to red
 }

 else if ((sensorValue >=850) && (sensorValue < 935))
 {// Purple
   red = totalTime/2;
   blue = totalTime/2;
 delay(2000);
 digitalWrite(Relay2,HIGH); //open red channel
 delay(red);                //Wait red Second
 digitalWrite(Relay2,LOW); //close red channel
 delay(2000);
 myStepper.step(67);// move to yellow
 delay(2000);
 digitalWrite(Relay3, HIGH); //open blue channel
 delay(blue);                //Wait yellow Second
 digitalWrite(Relay3, LOW); //close blue channel
 delay(2000);
 myStepper.step(-67);// move back to red
 }

 else if ((sensorValue >=935) && (sensorValue <= 1023)) {// Red Purple
 blue = (2*totalTime)/3;
 red = totalTime/3;
 delay(2000);
 digitalWrite(Relay2,HIGH); //open red channel
 delay(red);                //Wait red Second
 digitalWrite(Relay2,LOW); //close red channel
 delay(2000);
 myStepper.step(67);// move to yellow
 delay(2000);
 digitalWrite(Relay3, HIGH); //open blue channel
 delay(blue);                //Wait blue Second
 digitalWrite(Relay3, LOW); //close blue channel
 delay(2000);
 myStepper.step(-67);// move back to red
 }
 delay(10000);
 }
}
}
```

Annotated Bibliography

ASTM F963-17, Standard Consumer Safety Specification for Toy Safety, ASTM International, West Conshohocken, PA, 2017.

This standard was used for the Automated Color Selector because the standard applies to children's safety for toys, which is relevant for Group B's project. Considering children could be using this project in conjunction with teachers, the standard was necessary for the project.

"Automatic Water Color Paint Paint Mixing Machine Y-30a3." *Www.alibaba.com*, Alibaba.com, 7 Dec. 2017, www.alibaba.com/product-detail/automatic-water-color-paint-paint-mixing_1575775948.html?spm=a2700.7724857.main07.32.2bd13975qNl7Sv&s=p

This product is similar to the Automated Color Selector strictly because this of the automation and because of the mixing capability, something that was an option for the project at the beginning of the semester. The automated portion of this product gave the group ideas about how to make the Automated Color Selector automated.

"Control High Voltage Devices - Arduino Relay Tutorial." HowToMechatronics, 5 Sept. 2016,www.howtomechatronics.com/tutorials/arduino/control-high-voltage-devices-arduino-relay-tutorial/

Similarly to the sources cited from the arduino website, this web page clearly defined how to wire and code relays. From their advice on wiring a two-relay board, we were able to wire a four-relay board correctly. In addition, the coding that was given clearly showed how to open and close the relays.

"Mixing Mate 10-090 Gallon Size Paint Can Lid: Home Improvement." *Amazon.com: Mixing Mate 10-090 Gallon Size Paint Can Lid: Home Improvement*, Amazon.com, 7 Dec. 2017, www.amazon.com/dp/B00B2H7JM2/ref=asc_df_B00B2H7JM25152721/?tag=hyprod-20&creative=394997&creativeASIN=B00B2H7JM2&linkCode=df0&hvadid=193152739170&hvpos=1o2&hvnetw=g&hvrand=6306139108390413145&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9022860&hvtargid=pla-311423294285

This product is similar to the Automated Color Selector because the mixing capability was an option for the project at the beginning of the semester. This product was helpful with the group's project because of all the mechanical features associated with this product.

"Multifunctional Computerized Color Mixing Machine For Wholesales." *Www.alibaba.com*, 7 Dec. 2017, www.alibaba.com/product-detail/Multifunctional-computerized-color-mixing-machine-for_60508263406.html?spm=a2700.7724857.main07.201.2bd13975KiBvB.

This product is similar to the Automated Color Selector because the product is computerized and can be used to mix powdered paint. This product was helpful for the senior design project because the computerized portion is essentially automated and early on in the semester, dry paint powders were an option for the contraption.

"Stepper Speed Control." Arduino.cc. www.arduino.cc/en/Tutorial/StepperSpeedControl

This code, which was published on the arduino website as a guide for using stepper motors, was critical in making the device run. It clearly defined how to set up a stepper motor and have it run correctly.

Villaseñor, Jose A. *Paint Agitating System*. 15 Nov. 2016.

This patent is relevant to our project because for the Automated Color Selector at the beginning of the semester during the designing phase, Group B was contemplating having an automated mixing feature that would mix paint or dyes. From this patent, Group B decided to explore water-based paints or dyes that would mix without needing any mixing.