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Whiteboard Marker Dispenser

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MEMS 411 Final Report

In an effort to provide a constant supply of functioning markers to classrooms, labs, and other student spaces around campus, we designed and built a device to incentivize the storage, use, and return of whiteboard markers. Our Whiteboard Marker Dispenser offers customers a visually appealing, interactive manner of ensuring that the collaborative nature of the learning experience will not be hindered by a lack of resources.

Whiteboard Marker Dispenser Team 1

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1 Introduction

1.1 Project problem statement

Currently, a lack of resources is causing both students and teachers around campus to suffer in the classroom. To be utilized as a learning tool, whiteboards require the proper markers, but oftentimes markers disappear from their assigned spaces. Even if markers are present in a space, they seldom contain enough ink to function. A constant, operable supply of whiteboard markers in a space would improve the learning experience of students, improve the teaching experience of professors, and encourage collaboration between all parties. Our Whiteboard Marker Dispenser does just that, distributing large supplies of different colored markers in an inviting, user-friendly manner that incentivizes return with a fun bear illustration. We sought to provide customers with the best method of whiteboard marker distribution and return through our innovative device.

To keep costs down and save money for technological devices, we chose to build using scrap pieces found in the machine shop. Many of the enclosure, rotation, and dispensing parts were fabricated, while all technological and fastening pieces were either bought or found. Because changes were made to the design as the process continued, pieces were not manufactured uniformly; if we wanted to mass-produce this product, we would need to simplify the manufacturing process.

1.2 List of team members

Alexander Papp, Ellen Toennies, Nicole Kawamoto, Aditya Sharma

2 Background Information Study

2.1 A short design brief description that defines and describes the design problem

As Washington University in St. Louis students, we find it particularly difficult to acquire a working whiteboard dry erase marker within the Engineering School. Teaching assistants, professors, and students all heavy rely on these markers to help the further their educations. Whiteboards on campus, however, usually provide either dry, inkless markers or no markers at all. Our product will help fix this problem by ensuring that markers are used to their full capacity, and returned once they have served their purpose.

2.2 Summary of relevant background information (such as similar existing devices or patents, patent numbers, URL's, et cetera)

Patent #	Publication date	Inventors	Title	Keywords
US5957603 A	09/28/99	Charles E. Bell	Combination support and eraser for a dry erase marker	Dry erase marker
US 5240143 A	08/31/93	Bob I. Kornegay	Pencil vending machine	Dispenser
US D309067 S	07/10/90	Frank Arrias	Automatic tampon dispenser	Automatic dispenser

Other relevant URL:

1. http://www.mekanizmalar.com/whitworth_quick_return.html

3 Concept Design and Specification

3.1 User needs, metrics, and quantified needs equations. This will include three main parts:

3.1.1 Record of the user needs interview

Table 1- User Needs interview

Customer Data: Whiteboard Marker Dispenser Customer: Dr. Malast Address: Jolley Hall, Room 110 Date: 11 September 2015			
Question	Customer Statement	Interpreted Need	Importance
What is your experience with whiteboard markers in the	Don't like them – can't be certain it will work	WMD must dispense working markers	5

classroom?	Not enough WB space Students have to write and can't listen	WMD must be compact WMD must be easy to use	3 5
Do you need different color options?	A lot of times very important (black is necessary for contrast, but colors to illustrate equations/schematics)	WMD must allow user to choose marker color	4
What dispensing capabilities would you like to see?	Out comes a set of different colors Prefers a fully mechanical system (token makes marker fall out, marker return makes token come back)	WMD must dispense multiple markers at once WMD must be robust	2 4
Where would you prefer the device to be positioned?	Steer clear of having to plug into a wall for added freedom Battery powered, possibly solar powered	WMD must be charged independently of outlet WMD must be environmentally	3 2

	Hangs from board; rolls back and forth	friendly WMD must be mobile	3
How do you feel about white board markers in comparison to chalk?	Likes better (smaller, more similar to a pen/pencil) Volume of chalk last longer than that of markers	WMD must be able to dispense other items WMD must dispense working markers	2 5
What other capabilities would you like?	Maybe a feature to figure out what to do when it jams Some incentive to return it is necessary (need market research – interview professors to see how much it would have to be worth to them to put the marker back in the dispenser) Dispenser rolls across	WMD must be low maintenance WMD must have a return feature WMD must use incentive to promote return	5 5 4

	the top of the board to travel with the lecturer	WMD must be mobile	3

Table 2- Final User Needs

Need Number	Need	Importance
1	WMD must dispense working markers	5
2	WMD must be compact	3
3	WMD must be easy to use	5
4	WMD must allow user to choose marker color	4
5	WMD must dispense multiple markers at once	2
6	WMD must be robust	4
7	WMD must be charged independently of outlet	3
8	WMD must be environmentally friendly	2
9	WMD must be mobile	3
10	WMD must be able to dispense other items	2
11	WMD must be low maintenance	5
12	WMD must have a return feature	5
13	WMD must use incentive to promote return	4

3.1.2 List of identified metrics

Table 3- Identified Metrics

Design Metrics: Whiteboard Marker Dispenser (WMD)					
Metric Number	Associated Needs	Metric	Units	Min Value	Max Value
1	1	Marker performance	Binary	0	1
2	2, 9	Volume of device	cm^3	500	2,000
3	3, 13	User satisfaction	Percentage	0	100
4	4, 5	Number of color options	Integer	1	4
5	4, 5	Number of disposed markers	Integer	1	4
6	6, 11	Number of cycles before failure	Integer	0	5,000
7	7	Electrical independence	Binary	0	1
8	8	Carbon emissions	kg/kW-h	0	3
9	9	Unanchored to wall?	Binary	0	1
10	10	Volume of dispensing compartment	cm^3	15	25
12	3, 12, 13	Likeliness of return	Percentage	0	100

3.1.3 Table/list of quantified needs equations

Table 4- Quantified User Needs

		Metric															
		Marker Performance	Device Volume	User Satisfaction	Number of Color Options	Number of dispensed markers	Cycles till Failure	Electrical Indepence	Carbon Emissions	Anchored to Wall?	Dispense Other Things	Likeliness to return	Facilitates Return	Markers Held	Need Score	Importance Weight (all entries should add up to 1)	Adjusted Score
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Dispense Working Marker	1														0.109	
2	Compact		1													0.065	
3	Ease of Use			1												0.109	
4	Color Selection				1											0.065	
5	Multiple Dispensing Capability					1										0.043	
6	Robust						1									0.087	
7	Independent Power Source							1								0.065	
8	Environmentally Friendly								1							0.043	
9	Mobility									1						0.065	
10	Dispenses Other Objects										1					0.043	
11	Low Maintenance											1				0.109	
12	Returnable			0.25								0.25	0.5			0.109	
13	# of Markers Held													1		0.087	
Units		Binary	cm^3	Percentage	Integer	Integer	Integer	Binary	Kg/kW-h	Binary	Binary	Percentage	Percentage	Interger	Total Score		
Best Value		1	500	100	4	4	5000	1	0	1	1	100	100	50			
Worst Value		0	5000	0	1	1	0	0	3	0	0	0	0	1			
Actual Value		1	3456	90	4	4	4500	1	0	1	1	90	80	20			
Normalized Score		1	0.6912	0.9	1	1	0.9	1	1	1	1	0.9	0.8	0.4			

3.2 Four (4) concept drawings

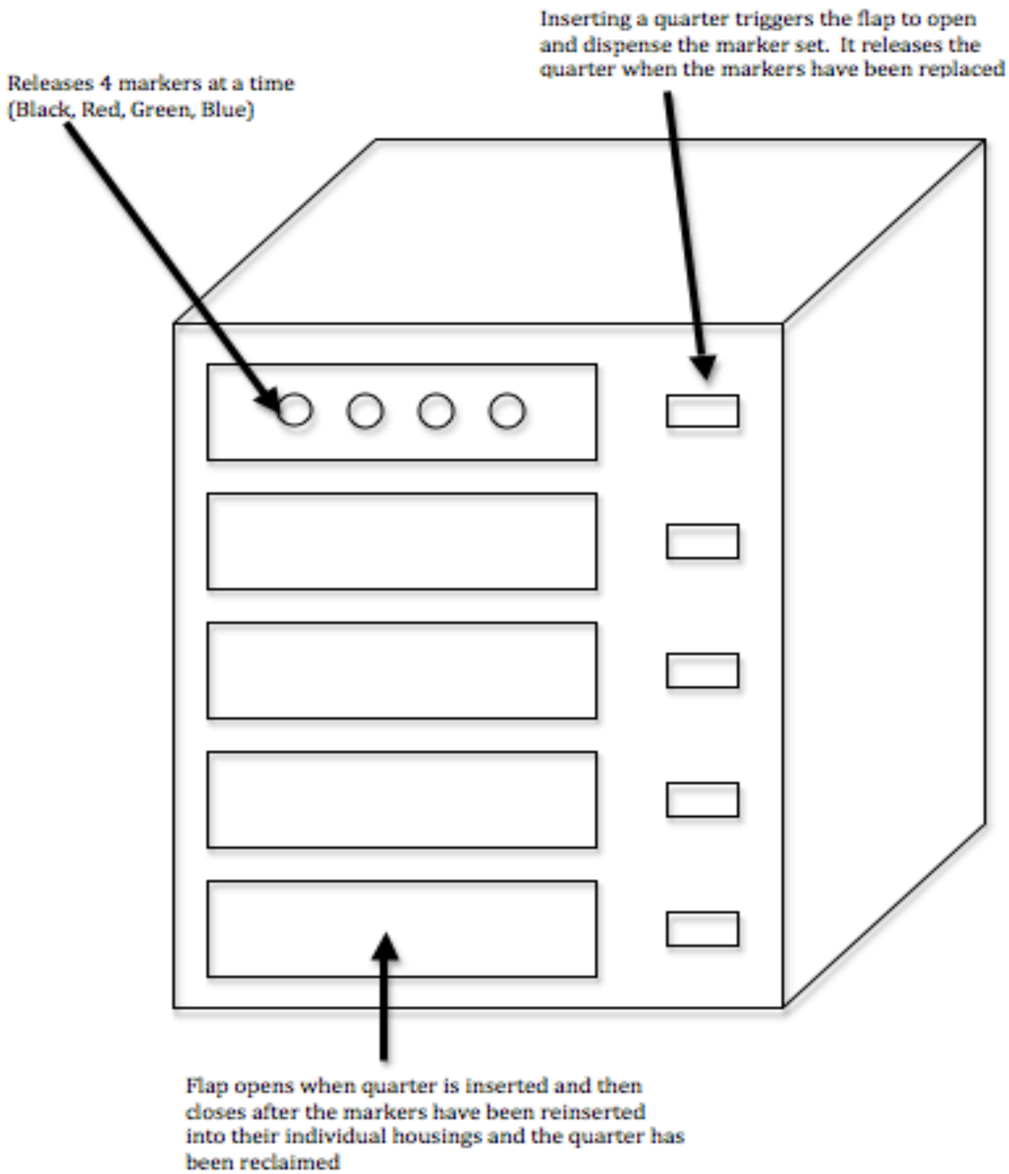


Fig. 1- Shopping Cart (Concept Drawing #1)

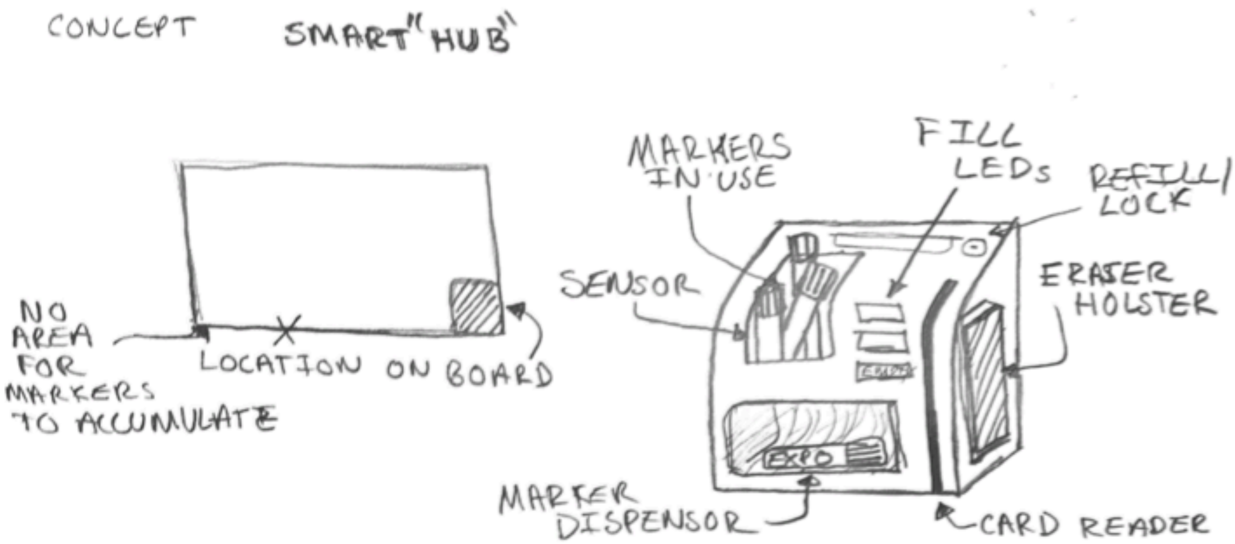


Fig. 2- Smart Hub (Concept Drawing #2)

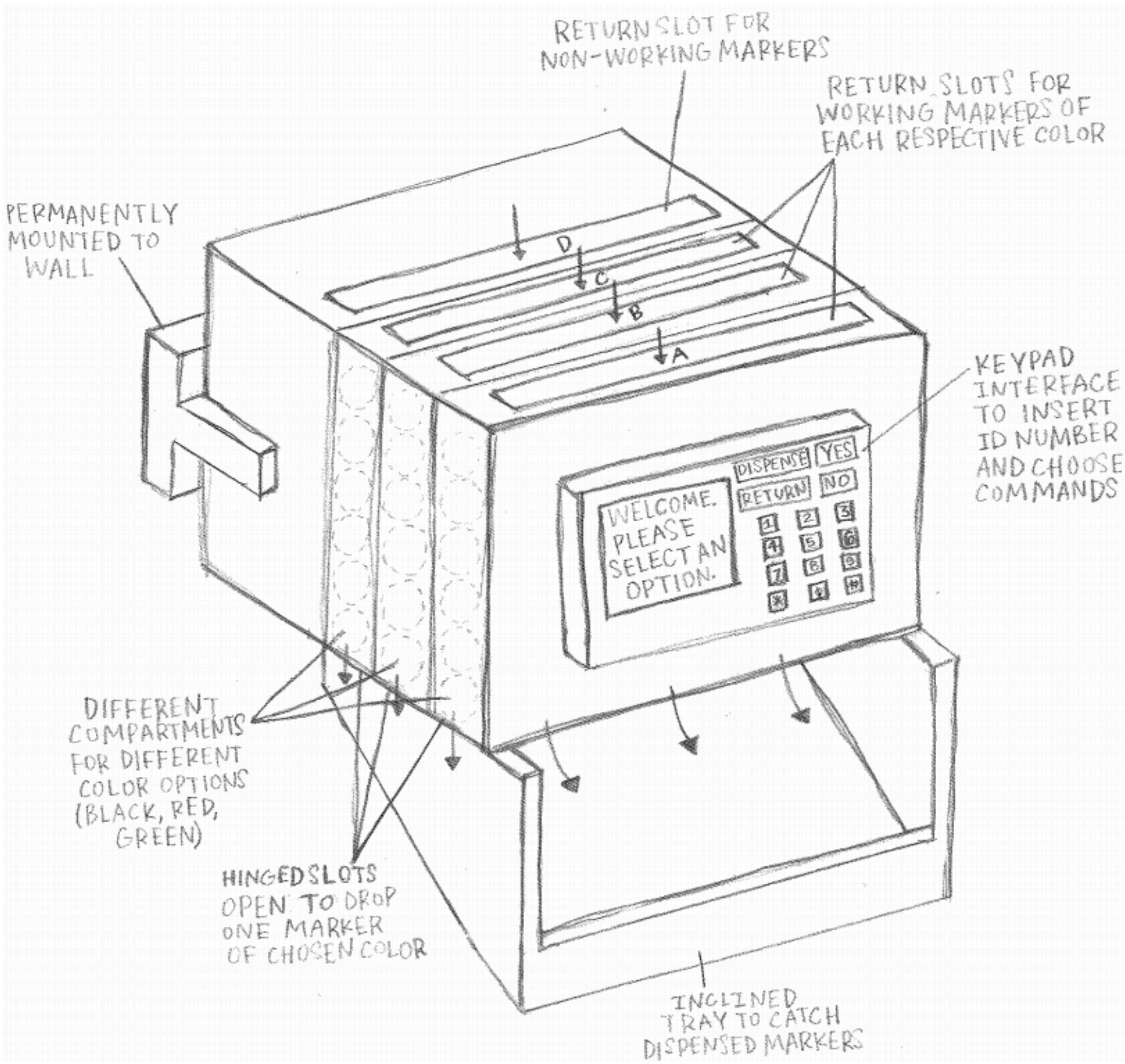


Fig. 3- Keypad Interface (Concept Drawing #3)

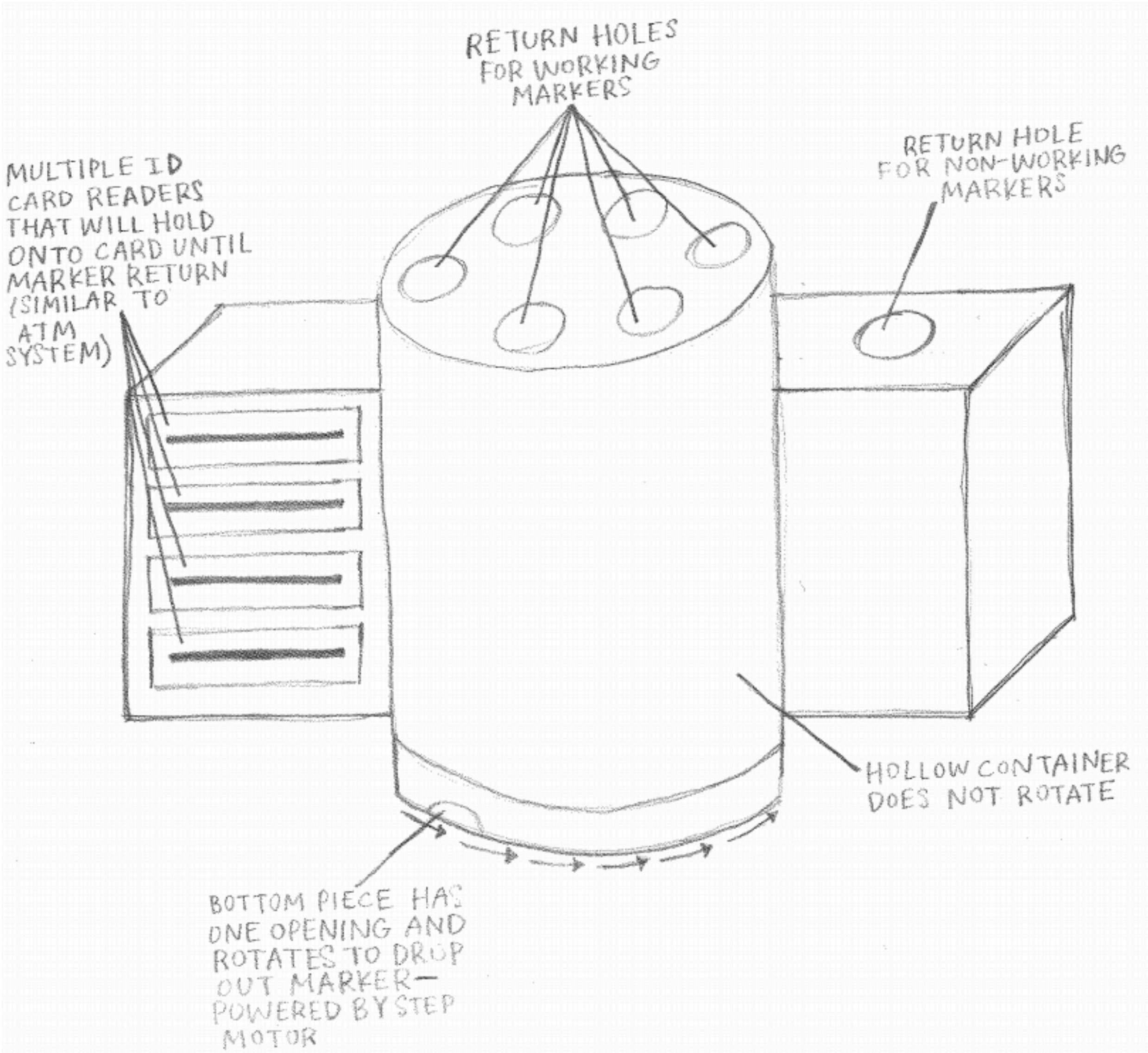


Fig. 4- Revolver (Concept Drawing #4)

3.3 A concept selection process. This will have three parts:

3.3.1 Concept scoring (not screening)

Below in Table 5 is the concept scoring for the Shopping Basket Concept #1 using the Happiness equations, also known as the Pugh Decision matrix. The method is outlined below in the following spreadsheet.

Table 5- Concept Scoring for Shopping Cart (Concept #1)

Shopping Cart Mechanism		Metric															
		Marker Performance	Device Volume	User Satisfaction	Number of Color Options	Number of dispensed markers	Cycles till Failure	Electrical Indepence	Carbon Emissions	Anchored to Wall?	Dispense Other Things	Likeliness to return	Facilitates Return	Markers Held	Need Score	Importance Weight (all entries should add up to 1)	Adjusted Score
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Dispense Working Marker	1													1	0.109	0.109
2	Compact		1												0.6912	0.065	0.045
3	Ease of Use			1											0.9	0.109	0.098
4	Color Selection				1										1	0.065	0.065
5	Multiple Dispensing Capability					1									1	0.043	0.043
6	Robust						1								0.9	0.087	0.078
7	Independent Power Source							1							1	0.065	0.065
8	Environmentally Friendly								1						1	0.043	0.043
9	Mobility									1					1	0.065	0.065
10	Dispenses Other Objects										1				1	0.043	0.043
11	Low Maintenance											1			0.9	0.109	0.098
12	Returnable			0.25								0.25	0.5		0.85	0.109	0.092
13	# of Markers Held													1	0.4	0.087	0.035
Units		Binary	cm^3	Percentage	Integer	Integer	Integer	Binary	Kg/kW-h	Binary	Binary	Percentage	Percentage	Interger	Total Score		0.881
Best Value		1	500	100	4	4	5000	1	0	1	1	100	100	50			
Worst Value		0	5000	0	1	1	0	0	3	0	0	0	0	1			
Actual Value		1	3456	90	4	4	4500	1	0	1	1	90	80	20			
Normalized Score		1	0.6912	0.9	1	1	0.9	1	1	1	1	0.9	0.8	0.4			

Table 6 below shows the happiness equations for Concept #2, the Smart Hub concept.

Table 6- Concept Scoring for Smart Hub (Concept #2)

Smart Hub		Metric															
		Marker Performance	Device Volume	User Satisfaction	Number of Color Options	Number of dispensed markers	Cycles till Failure	Electrical Indepence	Carbon Emissions	Anchored to Wall?	Dispense Other Things	Likeliness to return	Facilitates Return	Markers Held	Need Score	Importance Weight (all entries should add up to 1)	Adjusted Score
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Dispense Working Marker	1													1	0.109	0.109
2	Compact		1												0.4528	0.065	0.030
3	Ease of Use			1											0.95	0.109	0.103
4	Color Selection				1										0.25	0.065	0.016
5	Multiple Dispensing Capability					1									0.25	0.043	0.011
6	Robust						1								0.85	0.087	0.074
7	Independent Power Source							1							1	0.065	0.065
8	Environmentally Friendly								1						0.666666	0.043	0.029
9	Mobility									1					1	0.065	0.065
10	Dispenses Other Objects										1				1	0.043	0.043
11	Low Maintenance											1			0.85	0.109	0.092
12	Returnable			0.25								0.25	0.5		0.875	0.109	0.095
13	# of Markers Held													1	0.2	0.087	0.017
Units		Binary	cm^3	Percentage	Integer	Integer	Integer	Binary	Kg/kW-h	Binary	Binary	Percentage	Percentage	Interger	Total Score		0.750
Best Value		1	500	100	4	4	5000	1	0	1	1	100	100	50			
Worst Value		0	5000	0	1	1	0	0	3	0	0	0	0	1			
Actual Value		1	2736	95	1	1	4250	1	1	0	1	85	85	10			
Normalized Score		1	0.4528	0.95	0.25	0.25	0.85	1	0.666666	1	1	0.85	0.85	0.2			

Table 7 below shows the happiness equations for the Keypad interface.

Table 7- Concept Scoring for Keypad Interface (Concept #3)

Keypad Interface		Metric: Marker Performance	Device Volume	User Satisfaction	Number of Color Options	Number of dispensed markers	Cycles till Failure	Electrical Indepence	Carbon Footprint	Anchored to Wall?	Dispense Other Things	Likeliness to return	Facilitates Return	Markers Held	Need Score	Importance Weight (all entries should add up to 1)	Adjusted Score
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Dispense Working Marker	1													1	0.109	0.109
2	Compact		1												0.3856	0.065	0.025
3	Ease of Use			1											0.75	0.109	0.082
4	Color Selection				1										0.75	0.065	0.049
5	Multiple Dispensing Capability					1									0.25	0.043	0.011
6	Robust						1								0.8	0.087	0.070
7	Independent Power Source							1							1	0.065	0.065
8	Environmentally Friendly								1						0.66666666	0.043	0.029
9	Mobility									1					0	0.065	0.000
10	Dispenses Other Objects										1				0	0.043	0.000
11	Low Maintenance											1			0.95	0.109	0.103
12	Returnable			0.25								0.25	0.5		0.9	0.109	0.098
13	# of Markers Held													1	0.36	0.087	0.031
Units		Binary	cm^3	Percentage	Integer	Integer	Integer	Binary	Kg/kW-h	Binary	Binary	Percentage	Percentage	Interger	Total Score		0.671
Best Value		1	500	100	4	4	5000	1	0	1	1	100	100	50			
Worst Value		0	5000	0	1	1	0	0	3	0	0	0	0	1			
Actual Value		1	3072	75	3	1	4000	1	1	0	0	95	95	18			
Normalized Score		1	0.3856	0.75	0.75	0.25	0.8	1	0.6666666667	0	0	0.95	0.95	0.36			

Below in Table 8 is the happiness equation for concept #4, the Revolver.

Table 8- Concept Scoring for Revolver (Concept #4)

Revolver		Metric: Marker Performance	Device Volume	User Satisfaction	Number of Color Options	Number of dispensed markers	Cycles till Failure	Electrical Indepence	Carbon Emissions	Anchored to Wall?	Dispense Other Things	Likeliness to return	Facilitates Return	Markers Held	Need Score	Importance Weight (all entries should add up to 1)	Adjusted Score
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Dispense Working Marker	1													1	0.109	0.109
2	Compact		1												0.6	0.065	0.039
3	Ease of Use			1											0.85	0.109	0.092
4	Color Selection				1										0.25	0.065	0.016
5	Multiple Dispensing Capability					1									0.25	0.043	0.011
6	Robust						1								0.6	0.087	0.052
7	Independent Power Source							1							0	0.065	0.000
8	Environmentally Friendly								1						0.6666666	0.043	0.029
9	Mobility									1					0	0.065	0.000
10	Dispenses Other Objects										1				0	0.043	0.000
11	Low Maintenance											1			1	0.109	0.109
12	Returnable			0.25								0.25	0.5		0.9625	0.109	0.105
13	# of Markers Held													1	0.12	0.087	0.010
Units		Binary	cm^3	Percentage	Integer	Integer	Integer	Binary	Kg/kW-h	Binary	Binary	Percentage	Percentage	Interger	Total Score		0.572
Best Value		1	500	100	4	4	5000	1	0	1	1	100	100	50			
Worst Value		0	5000	0	1	1	0	0	3	0	0	0	0	1			
Actual Value		1	3000	85	1	1	3000	0	1	1	1	90	80	6			
Normalized Score		1	0.6	0.85	0.25	0.25	0.6	0	0.6666666	0	0	1	1	0.12			

3.3.2 Preliminary analysis of each concept's physical feasibility

Concept 1: Token

The design of Concept 1 is simple and easy to use. Similar to the system used for "renting" shopping carts at grocery stores such as ALDI, the dispenser accepts a quarter to dispense the markers and then this quarter is used as an incentive for the user to return the markers when they are finished. The flap for each marker set housing is opened by a fully mechanical system. The user has immediate access to a variety of color choices, which eliminates the need to go through a repetitive process to receive various markers. The main concern with this design is the lack of ability for the system to know when the markers are out of ink. Someone would need to replace the markers on a weekly basis to ensure that the device only dispenses working markers.

Concept 2: Smart "Hub"

A solution fully integrated into the whiteboard, this concept is likely purchased as one cohesive unit (whiteboard + Smart Hub). The hub replaces the traditional flimsy metal underneath the board with a stationary, compact container/box at the corner ("hub"). The hub has eraser holster on each side to fit a standard whiteboard eraser. The top is slightly beveled to reveal a holster for markers that are currently in use, with a sensor to determine if there are markers in there or not. There is a dispenser for new markers that after a button press are dispensed to a basin/reservoir at the base. A cartridge style vertical loader is locked in the back or side to be gravity fed into the singulator for individual dispensing and keeping track of inventory.

Concept 3: Keypad Interface

This concept requires the user to enter his or her student/faculty ID number into a battery-powered keypad before dispensing and returning each marker, charging the user an undetermined amount of money if return doesn't occur. Three different compartments hold three different color options, and a larger slot in the back exists for the return of non-working markers. Weight sensors at the base of each compartment keep track of the quantity of markers occupying each section. Loaded springs underneath the return flaps help in quickly opening/closing these slots while assuring that nothing can be removed from these openings. Coiled metal (similar to that of a vending machine) intertwined with the markers allows them to drop out the hinged slots below the apparatus. The dispensed marker then falls out of its compartment and rolls down the inclined tray. This design assures that the dispensed markers will always be working and the keypad interface aspect will easily guide the user through the retrieval process, but because of the multitude of questions asked it takes longer to function than other methods. The device is also mounted to a wall, lacking mobility.

Concept 4: Revolver

This design consists of a revolving cylinder that contains 6 working markers. As a card is inserted in the reader and then the bottom of cylinder rotates and drops a marker. There is a a place to dispose the markers that can no longer be used. A sensor then realized that a marker has been disposed and will skip it in the rotation. A step motor will move the rotating cylinder. The card readers will be similar to an ATM system. Markers can be returned to the top of the rotating cylinder. Card will be clamped in the reader until the market is returned.

3.3.3 Final summary

Concept 1 was has the advantages of easy use, multiple color options, and robust design due to the lack of electrical parts. Inserting a quarter does not require the use of sensors (Concept 2), a keypad (Concept 3), or a card reader (Concept 4), which would complicate the design while still providing incentive for the user to return the marker set. It contains few moving parts (unlike Concept 3, 4). This greatly lowers the risk of failure while also making the mechanism electrically independent (unlike Concepts 2, 3, 4) and environmentally friendly (unlike Concepts 2, 3, 4). This mechanism can also be placed on any desk or fastened to a wall near the whiteboard (unlike Concepts 3, 4). Concept 1 also automatically gives the user all necessary marker colors (unlike Concept 4) without requiring multiple steps (unlike Concept 3). The mechanism could be easily altered to dispense other items (unlike Concepts 3, 4). Since these attributes are supported by the happiness equations that gave Concept 1 a 0.881 rating, Concept 1 is the winner.

At the time the concepts were created, concept 1 was the ideal candidate. However, after further thought about design, ease of use, manufacturability, and the number of cycles it had to be used, the team decided to take the "Batman" approach, where markers fall into a rotating piece and then are ejected. In order to help understand the design, Figure 5 below shows the batman piece.

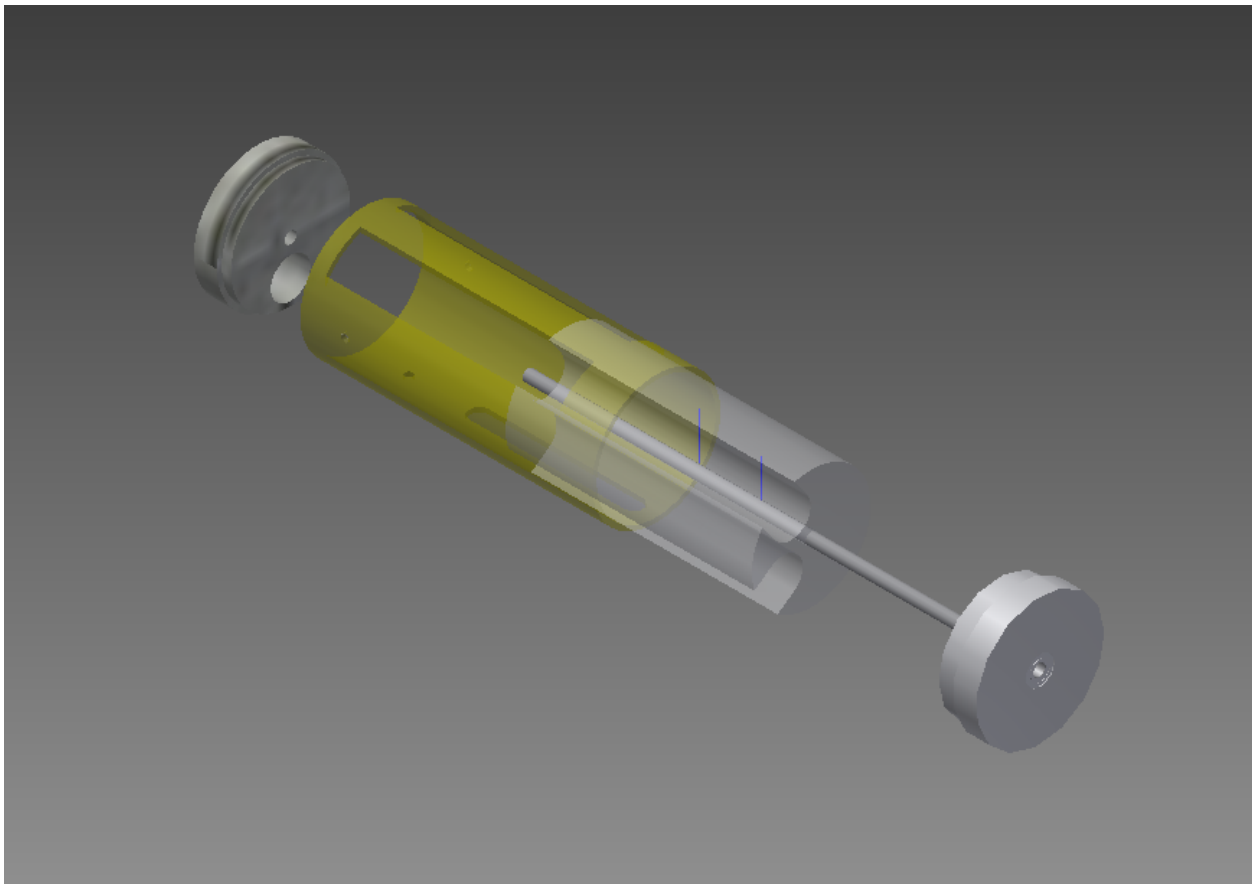


Fig. 5- Batman Concept

3.4 Proposed performance measures for the design

In order to assure that the project is successful, we quantified the following performance measures:

1) Cycles before failure due to jamming
2) Automation Accuracy
3) Robustness of Design
4) Shock absorption
5) Runs before electrical failure

3.5 Design constraints (include at least one example of each of the following)

See the following paragraphs for the design constraints broken down by section.

3.5.1 Functional

In terms of geometry, the dispenser cannot be too bulky. Too large of a design will result in a clunky eye sore at all of the white boards around the school. In order to keep size down, the machines will have to be well designed and the space within the machine will have to be well used.

The batman piece will have to rotate along its own axis. In addition, the ejecting mechanism, dubbed the "Schwang Mechanism", will have to translate rotational motion to lateral motion in order to eject the marker. The velocities and accelerations have to be slow in order to ensure accuracy and to make sure no one gets hurt if their fingers get jammed in the machine. Energy will be supplied from electric motors comprised of an Arduino system. The materials will have to be light; in this case, aluminum is the best material to use. Finally, the control system will be an automated Arduino circuit. No information will be stored of flow out of this device.

3.5.2 Safety

In terms of safety, there will be no warning on this device other than the ones telling people not to stick their fingers into the rotating pieces while they are in motion. In addition, all of the electrons will have to be sealed in order to reduce the shock hazard. No training will be needed in order to use this device.

3.5.3 Quality

This device is finely calibrated. If the calibrations were to be moved either by human forcing or just by overuse, the machine would stop working. This would result in a catastrophic failure of the device, meaning no markers for anyone. In order to maintain the device, it will need to be serviced and calibrated. The duration the device can last without calibration is unknown at this point. Further automated testing will need to be observed in order to find the 95% confidence interval for a working calibrated device.

Very little reliability information is known about this device at the current point. Tests will also need to be run to see how many runs until failure.

3.5.4 Manufacturing

In terms of manufacturing, the device still needs to be optimized for public industrialization. It was required to machine almost all of the parts by hand with a couple tight tolerances. Many different materials were used. There would need to first be a standard set of components and then standard materials in order to find which materials result in the highest reliability with the lowest cost. The assembly of the product will have to be done before selling the product. Post assembly will not be possible in our case.

3.5.5 Timing

The size and complexity of the device created results in minor time constraints. The design schedule was created and, for the most part, followed. The development schedule would be more complicated as the design would need significant altering before production and sale to the general public. The delivery dates and supply chain management was not within the scope of this project.

3.5.6 Economic

The time of manufacturing needs to be decreased in order for this product to be economically feasible. The design costs were low, but the cost of manufacturing in terms of time taken to create the product needs to be reduced significantly. No expensive machinery is necessary to create this device.

3.5.7 Ergonomic

The device currently will need a button to be added in order to allow man-to-machine interactions. No other design constraints exist in this area.

3.5.8 Ecological

No toxic products will be used in the manufacturing of this device. The motors will not be oversized to allow for the most efficient use of electrical resources.

3.5.9 Aesthetic

The plastics will allow for a clean look and allow users to see the internal pieces of the design. The aluminum will be sturdy and allow for contrast with the clear coverings. This product will be highly fashionable and usable.

3.5.10 Life cycle

The device will need to be maintained and calibrated in order to make sure the motors are in calibration. Otherwise, the device will stop working. New markers will need to be added when the old markers die and are thrown out. The device will need to be replaced if it stops working completely.

3.5.11 Legal

This will follow ISO children toys regulations for design and building considerations. This is a very stringent code that should protect the device well under many circumstances.

4 Embodiment and fabrication plan

4.1 Embodiment drawing

Below in Fig. 6 is a picture of our final embodiment image.

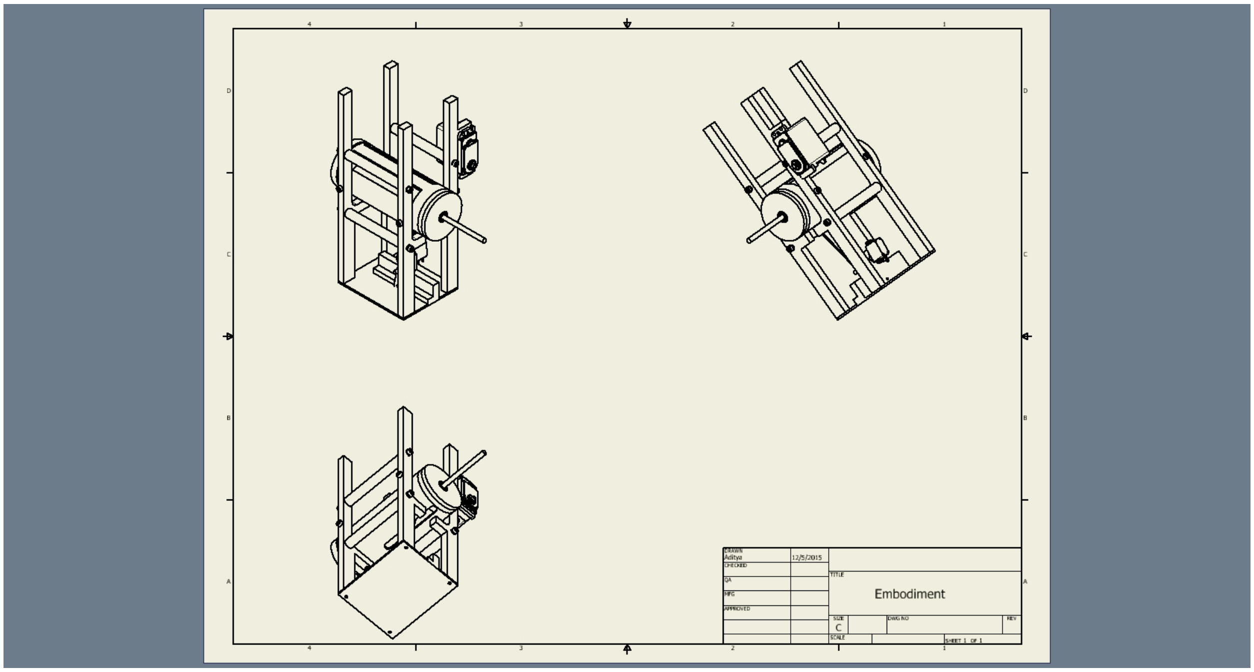


Fig. 6- Emodiment Drawings

4.2 Parts List

Table 9- Bill of Materials

ITEM	QTY	PART NUMBER	DESCRIPTION	PURPOSE	URL	PART NOTES	COST
1	1	Back Frame	Aluminum U-shaped frame	Structure	http://www.mcmaster.com/#8975k196/=101lfzz	Buy stock aluminum and mill	$1.04
2	4	Long Spacer	Aluminum rods connecting front and back frame	Structure	http://www.mcmaster.com/#8975k196/=101lfzz	Buy stock aluminum and lathe	$1.04
3	1	Front Frame	Aluminum U-shaped frame; open slot through bottom	Structure	http://www.mcmaster.com/#8975k196/=101lfzz	Buy stock aluminum and mill	$1.04
4	8	1" 10-32 Thread Machine Screw	Alloy steel socket head cap screw with locker wash	Fastener	http://www.mcmaster.com/#90342a125/=101kvm2	Buy Online	$2.10
5	1	Shell Tube	Hollow plastic cylinder enclosing batman pieces; two openings on top for marker drops	Enclosure	http://www.mcmaster.com/#8560k932/=101li5n	Buy stock optically-clear cast acrylic and lathe/mill	$9.76
6	5	7/16" 10-32 Thread Machine Screw	Black-oxide alloy steel socket head cap screw	Fastener	http://www.mcmaster.com/#91251a356/=101l86u	Buy Online	$7.66 for 50
7	1	Batman Piece	Plastic cylinder with two marker-sized indents; rotates to dispense markers	Rotation	http://www.mcmaster.com/#8560k932/=101li5n	Buy stock optically-clear cast acrylic	$9.76

						and lathe	
8	2	Ball Bearing	Steel ball bearing - ABEC-1	Fastening	http://www.mcmaster.com/#60355k43/=101lf8h	Buy from McMaster Carr	$6.25
9	1	Back Cap	Plastic cylinder constraining the batman piece inside the shell tube	Enclosure	http://www.mcmaster.com/#8560k932/=101li5n	Buy stock optically-clear cast acrylic and lathe	$9.76
10	1	Front Cap	Plastic cylinder constraining the batman piece inside the shell tube	Enclosure	http://www.mcmaster.com/#8560k932/=101li5n	Buy stock optically-clear cast acrylic and lathe	$9.76
11	1	Axle	Metal rod rotating the batman piece	Rotation	http://www.mcmaster.com/#8920k115/=101lpkl	Buy stock steel and lathe	$1.03
12	1	Quarter Scale Servo	Arduino-compatible; Rotates the axle	Rotation	https://www.servocity.com/html/hs-755mg_1_4_scale.html#.Vl0qofmrSUk	Buy Online	$31.99
13	1	Base Plate	Aluminum sheet connecting the frames and supporting the body	Structure	http://www.mcmaster.com/#8975k196/=101lfzz	Buy stock aluminum and mill	$1.04
14	1	Peg	Small aluminum cylinder; allows lever arm to force markers through front	Dispensing	http://www.mcmaster.com/#8975k196/=101lfzz	Buy stock aluminum and lathe	$1.04

			opening				
15	1	Gear (Rotating Device)	Thin, aluminum cylinder attached to peg to activate lever arm	Dispensing	http://www.mcmaster.com/#8975k196/=101lfzz	Buy stock aluminum and lathe/mill	$1.04
16	1	Small Servo motor	Small servo motor that runs the Schwang device	Dispensing	http://www.tme.eu/en/details/t010160/arduino-development-kits/arduino	Buy Motor on Amazon.com	$3.37
17	1	Lever Arm	Aluminum arm that moves linearly with the peg, forcing the marker out of the front opening	Dispensing	http://www.mcmaster.com/#8975k196/=101lfzz	Buy stock aluminum and mill	$1.04

4.3 Draft detail drawings for each manufactured part

Below in Fig. 7 is the detailed drawing of the back frame.

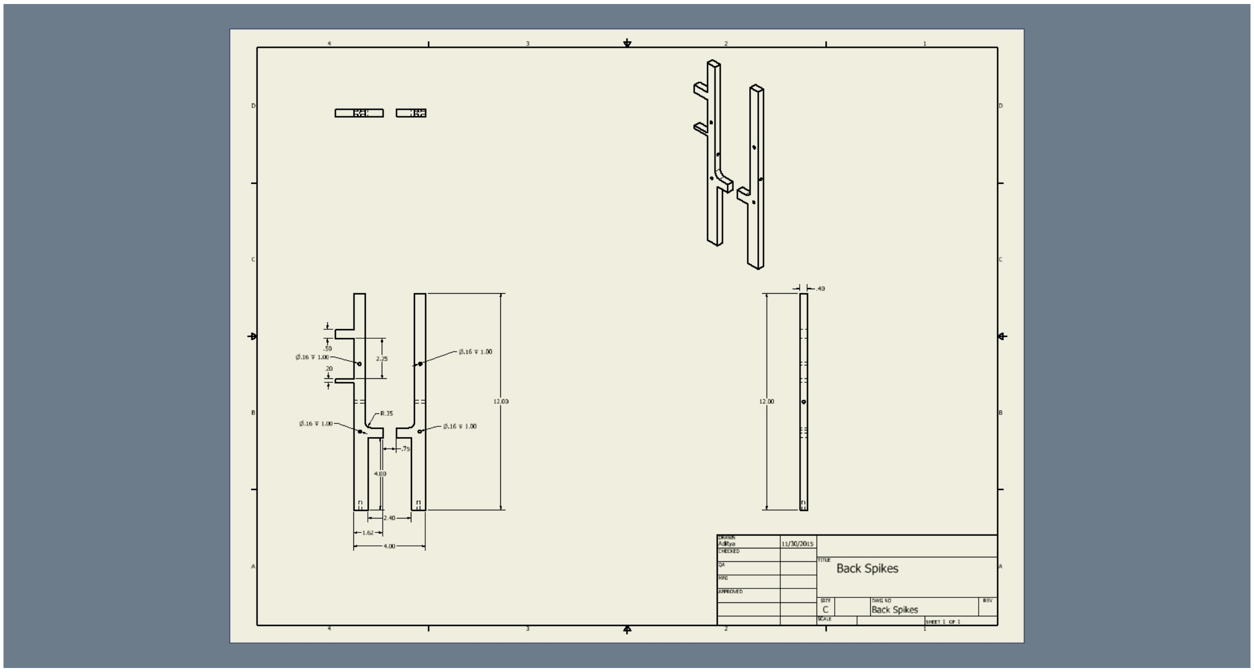


Fig. 7- Back Frame

Below in Fig. 8 is a detailed drawing of the long spacer.

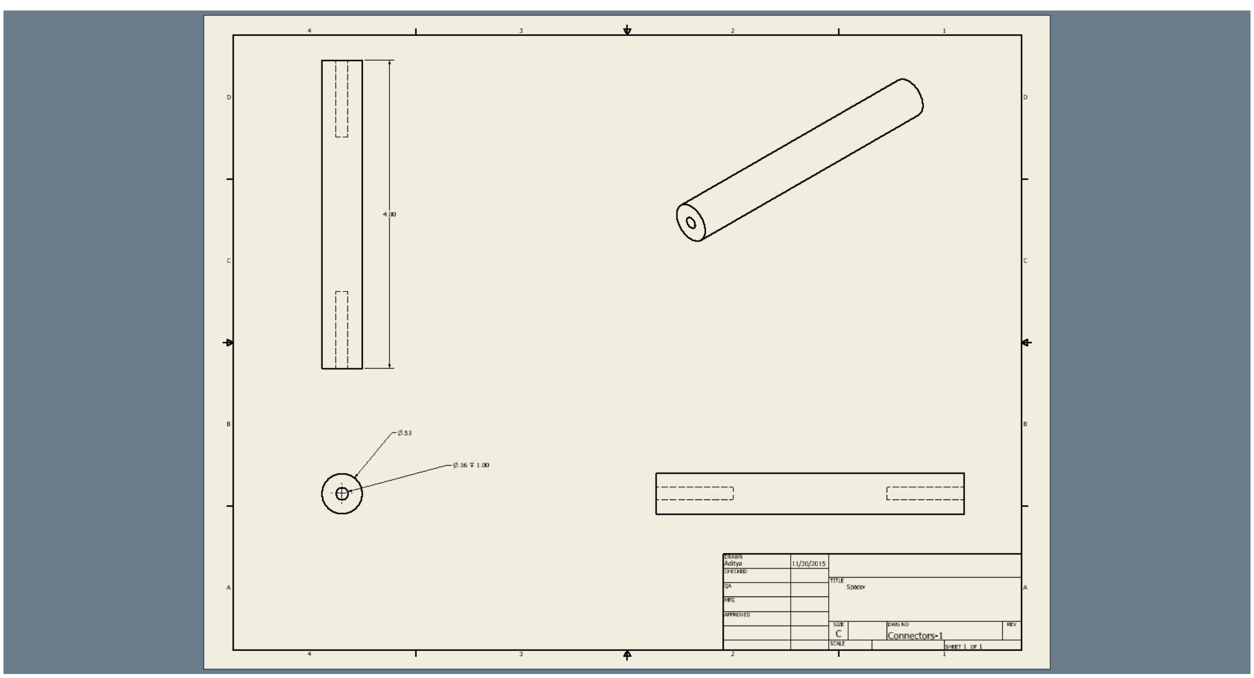


Fig. 8- Long Spacer Detailed Drawing

Below in Fig. 9 is a detailed drawing of the front frame.

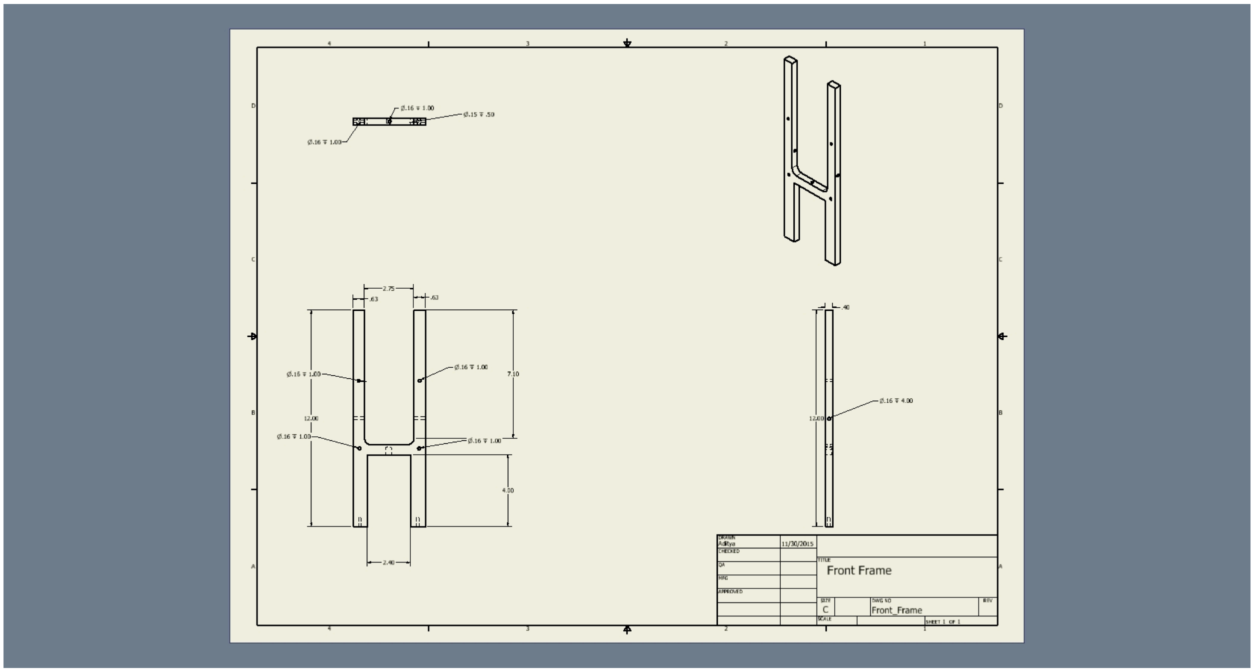


Fig. 9- Front Frame Detailed Drawing

Below in Fig. 10 is a detailed drawing of the shell tube.

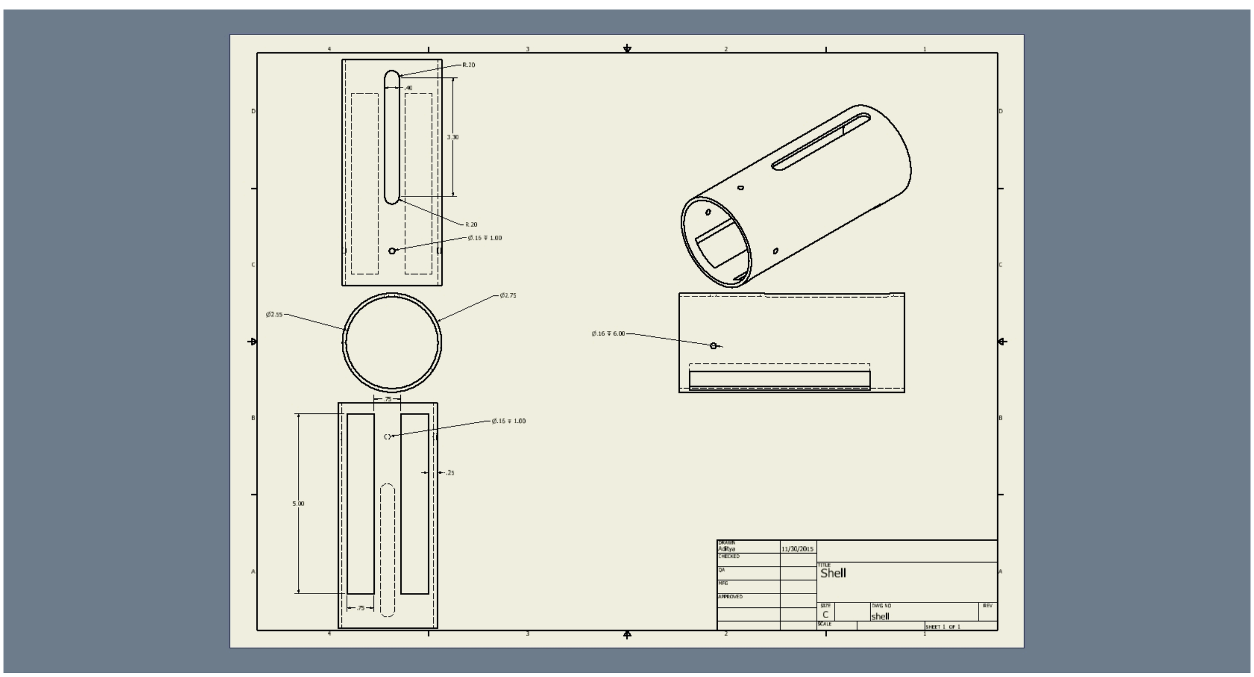


Fig. 10- Shell Detailed Drawing

Below in Fig. 11 is a detailed drawing of the batman piece.

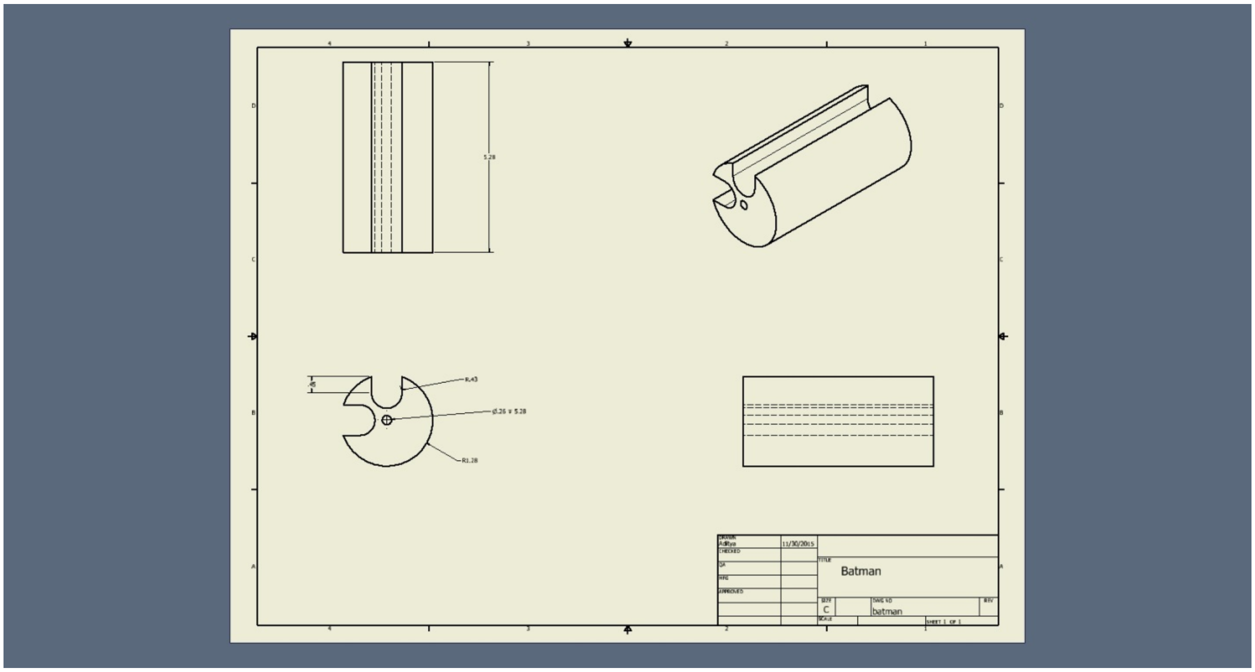


Fig. 11- Batman Piece Detailed Drawing

Below in Fig. 12 is the back cap detailed drawing.

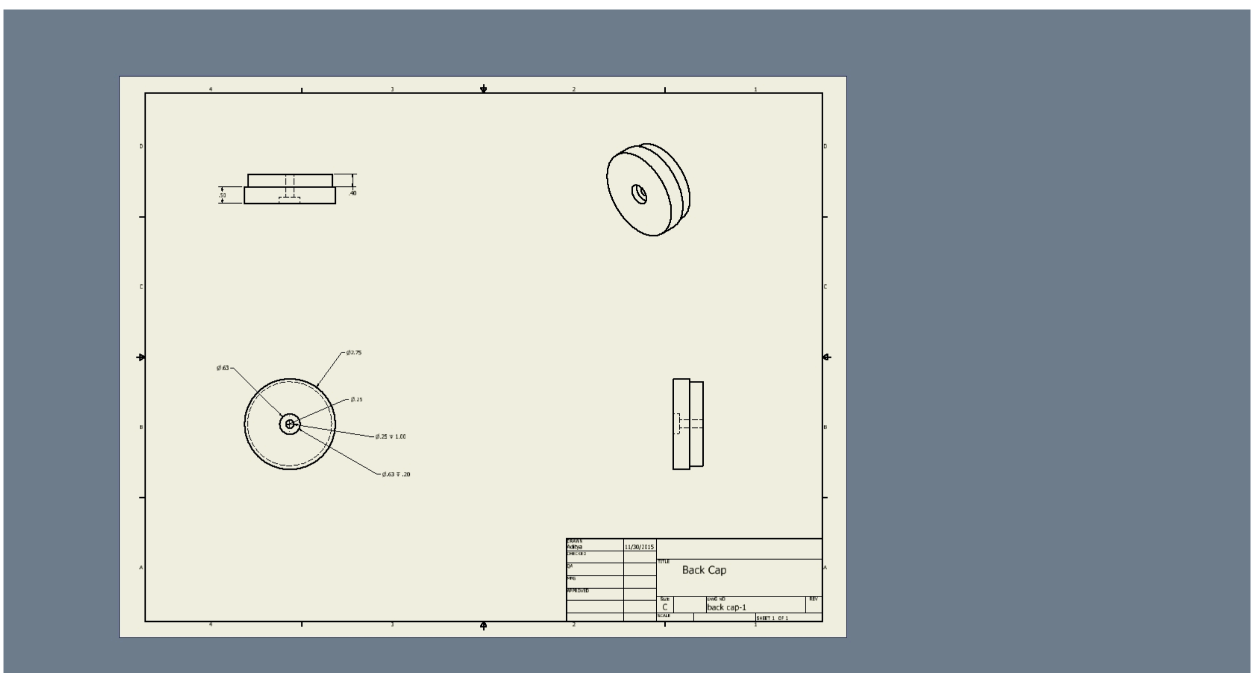


Fig. 12- Back Cap Detailed Drawing

Below in Fig. 13 is the front cap detailed drawing.

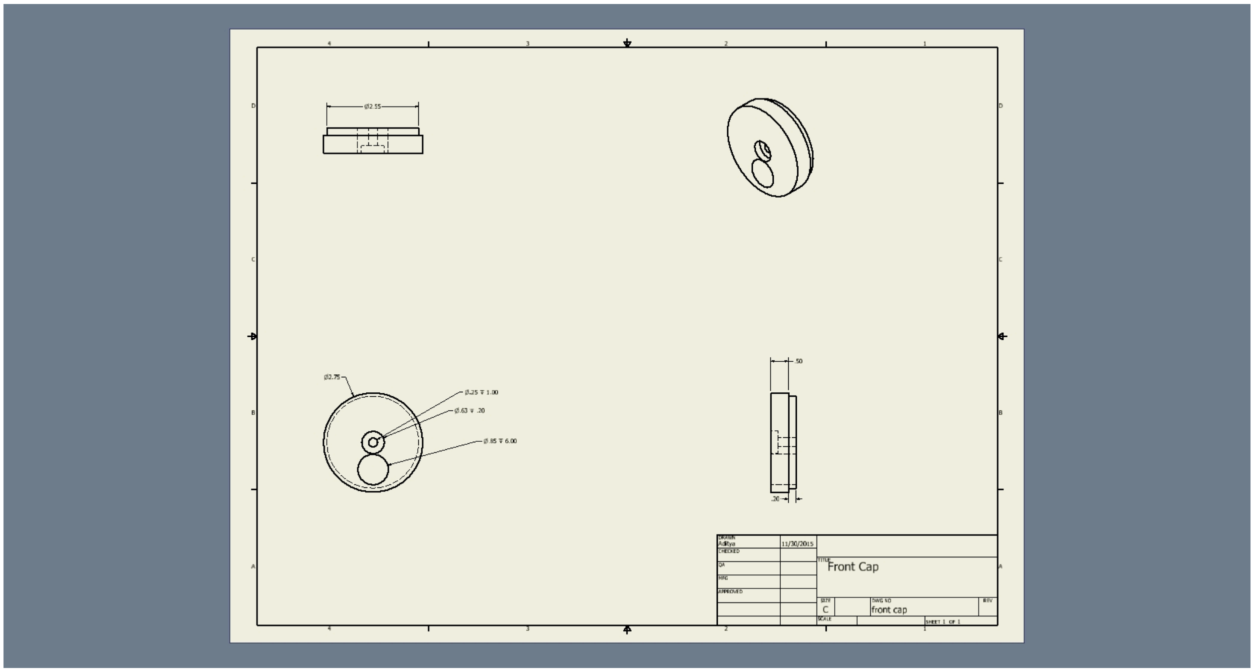


Fig. 13- Front Cap Detailed Drawing

Below in Fig. 14 is a detailed drawing of the axle.

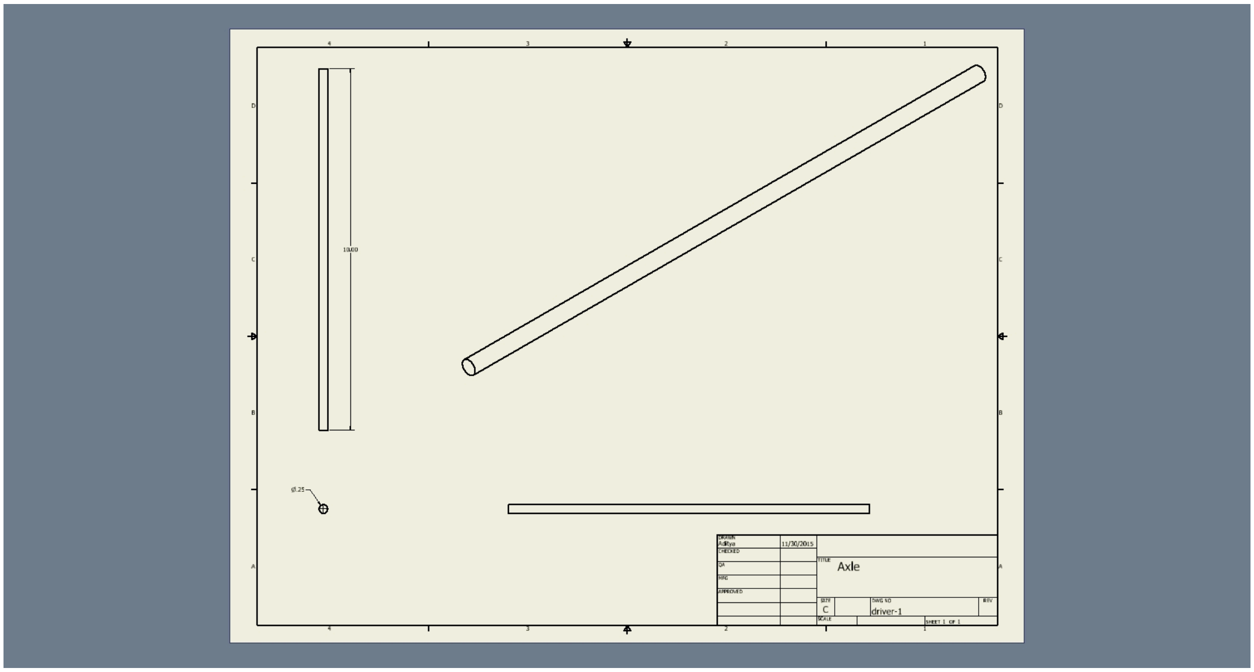


Fig. 14- Axle Detailed Drawing

Below in Fig. 15 is the detailed drawing of the base plate.

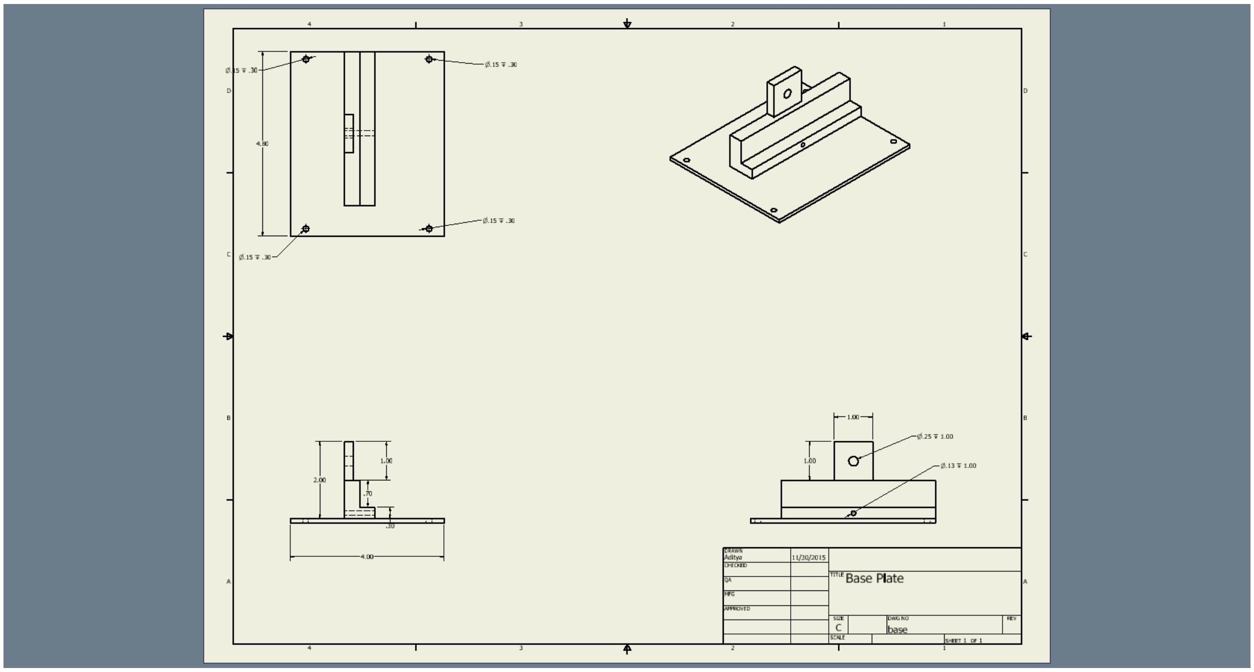


Fig. 15- Base Plate detailed drawing

Below in Fig. 16 is a detailed drawing of the gear used to eject the marker.

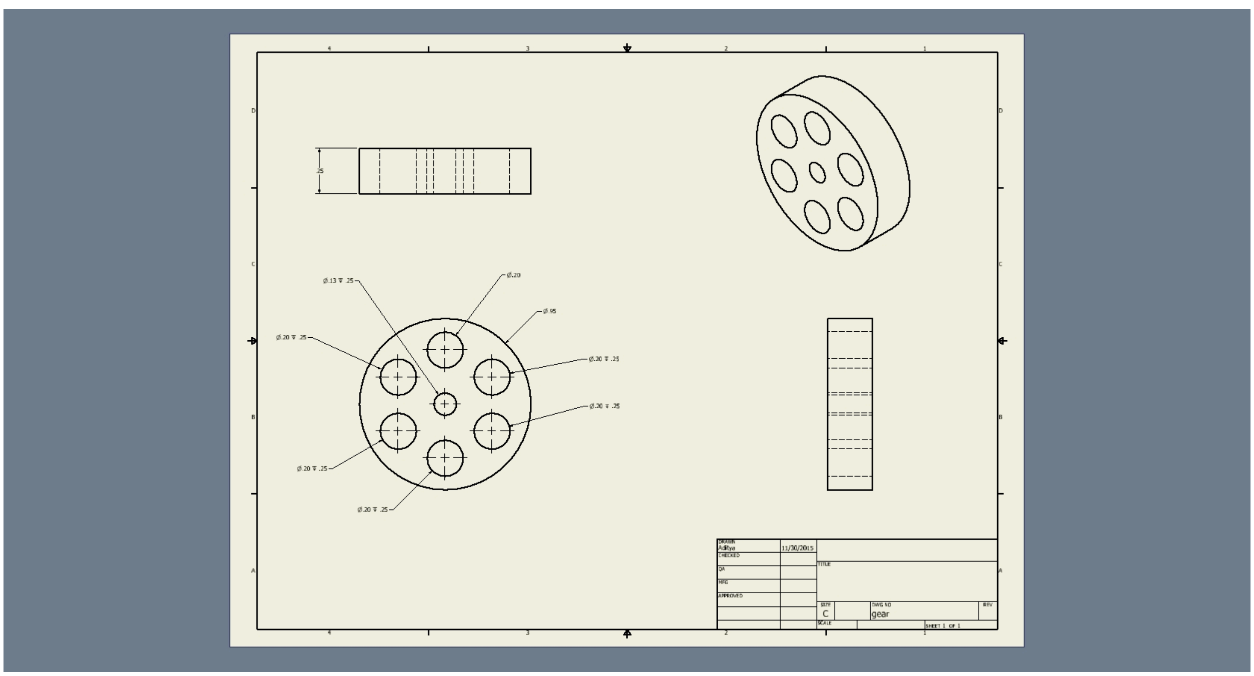


Fig. 16- Gear Detailed Drawing

Finally, below in Fig. 17 is a detailed drawing of the peg that fits into the gear and ejects the marker.

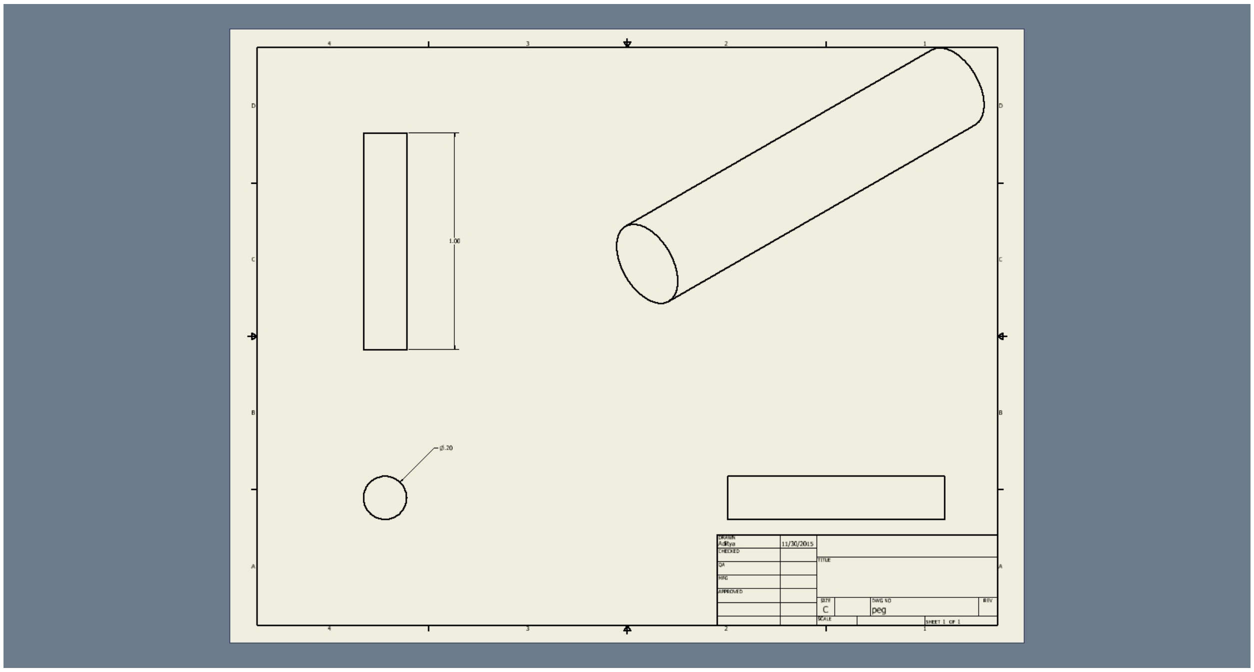


Fig. 17- Peg Detailed Drawing

4.4 Description of the design rationale for the choice/size/shape of each part

Part 1- The Batman Assembly

It was important for the user to be able to choose between two different colors of markers while using our device. This is why the batman piece was created; two markers can be held, and depending on the needs of the user, the appropriate marker can be dispensed. In order to design the batman piece, the markers needed to be held. Calculations for the volume and area were considered as followed.

Table 10- Design Rationale based on a dry erase marker

Diameter of Marker	.5 inches
Length of Marker	5 inches
Volume of Marker	3.92 inches^2
Tolerance	.1 inches

The volume of the marker was found using Eq. 1.

$$v = \pi r^2 h \quad (1)$$

Here, *V* is the volume of the marker [in^2], *r* is the radius of the marker [in], and *h* is the height of the marker [in]. The batman piece was milled out with a loose fit tolerance in order to make sure that the markers would slide right out of the piece.

Part 2- Schwang Mechanism

This is a linear actuator that had to translate rotational motion from a servo motor to linear motion. Figure 18 shows the mechanism that was used.

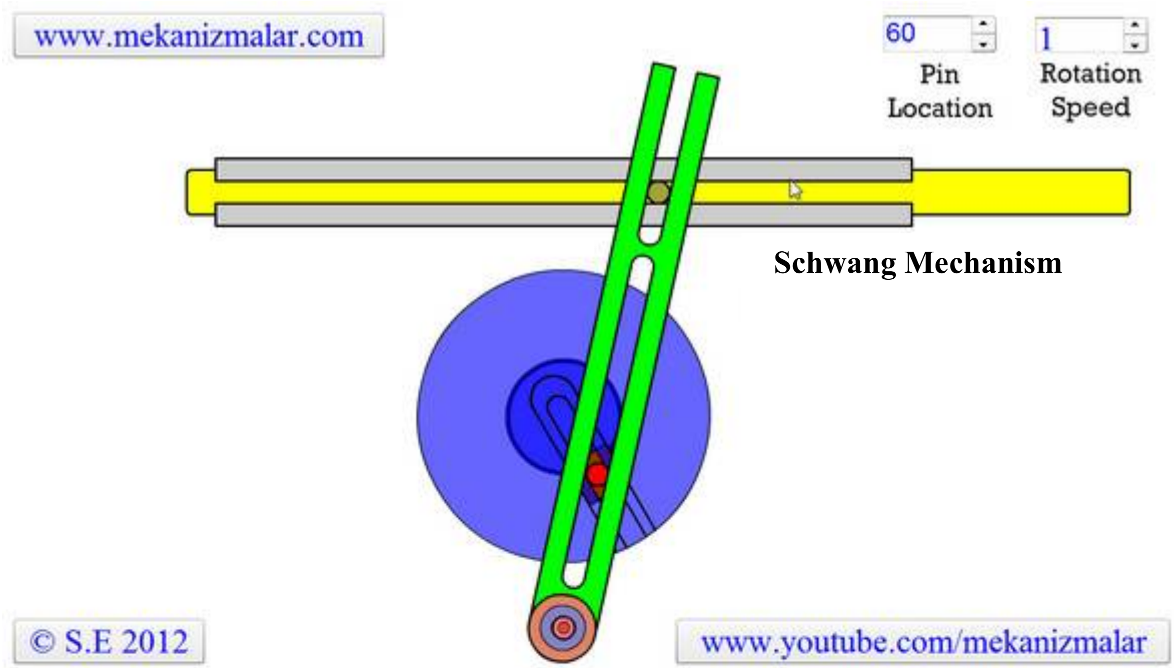


Fig. 18- Schwang Mechanism

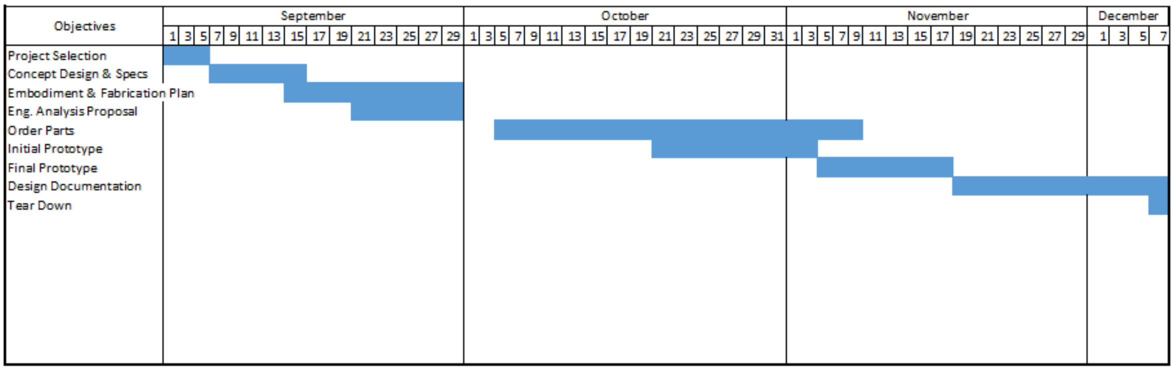
This allows the markers to be ejected without using too much space and increasing the size of our project. This mechanism expels a marker 1 inch out of the mouth of the device.

Aluminum was used to keep the device structurally sound and light weight. The clear plastic helps the device look interesting and aesthetically pleasing while still functional and lightweight. The clear plastic is transparent and helps the user understand what is occurring inside the device.

4.5 Gantt chart

Table 11 shows our Gantt chart, which breaks down the time spent on each part of the project.

Table 11- Gantt chart



5 Engineering analysis

5.1 Engineering analysis proposal

5.1.1 A form, signed by your section instructor (insert your form here)

ANALYSIS TASKS AGREEMENT

PROJECT: Whiteboard Marker Dispenser

NAMES: Nicole Kawamoto (NK), Ellen Toennies (ET), Aditya Sharma (AS), Alexander Papp (AP)

INSTRUCTOR: Prof. Malast

The following engineering analysis tasks will be performed:

Before prototype is built

- Feasibility analysis (NK)
- Stress and strain simulation (AS)
- Tolerance analysis (ET)
- Part sizing optimization (NK, ET, AS, AP)

After prototype is built

- Wall attachment testing and analysis (ET)
- Test cycles until failure (AP)
- Product demonstration / focus group / user testing (NK, ET, AS, AP)
- Optimize free space / minimizing (NK)

The work will be divided among the group members in the following way:

Responsibilities are indicated by the parentheses with the initials of the group member next to their designated analysis task.

Instructor signature: ________________; Print instructor name: ________________

(Group members should initial near their name above.)

Fig. 19- Engineering analysis form; forms were turned in online and not signed

5.2 Engineering analysis results

5.2.1 Motivation

Our before analysis consisted of sizing calculations and material analysis to determine the changes that needed to be made to our initial concept.

Due to the relatively small size of our device and the need for multiple parts with tight tolerances, several calculations were necessary for the device to operate consistently for many cycles without failure. Some major areas of concern were that the device needed to allow the markers to smoothly drop into the dispenser without jamming and to push the marker out of the enclosure. These calculations were critical at this point in our project because all of our parts needed to be machined to these specific dimensions for the device to work.

In addition, we needed to complete a material analysis before we started to build our prototype in order to ensure that our device was robust and fit our user's needs. The material of each part need to be able to withstand many iterations without failing in order to fulfill the user request for a low maintenance solution. Also, the material needed to be aesthetically appealing and capable of withstanding the stress and strain of the device.

Overall, these analyses allowed us to alter our original design and several iterations of working prototypes until we arrived at our final design.

5.2.2 Summary statement of analysis done.

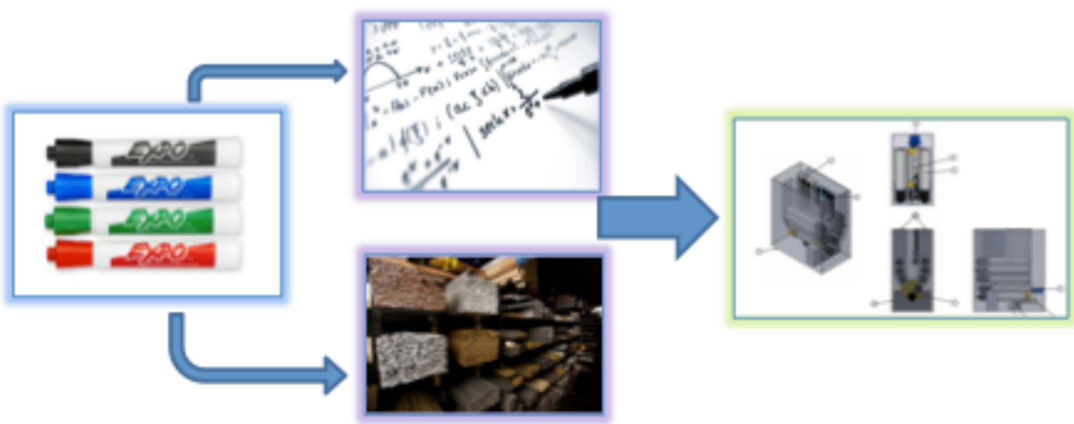


Fig. 20- Summary flowchart of analysis done

1. **Identifying User Needs**
   First, we reviewed the design brief for a whiteboard marker dispenser and identified important features within our design group. We also conducted user needs interviews and market research to identify the most necessary characteristics that our design needed. We then compared this list of features with several concept drawings, and we combined the best parts of each design to create one initial design concept.

2. **Pre-Prototyping Analyses**
   a. **Calculations**
   Our calculations consisted of mechanical tolerances and part sizing. For the tolerances, we referred to a design tolerance range for machining processes to determine the acceptable range for drilling and milling materials. The figure that we used to determine these ranges is included in Section 5.2.3. For the part sizing calculations, we focused on the equations for sizing the Batman piece and the Schwang mechanism since these calculations were the critical dimensions. These calculations are outlined in Section 4.4.

   b. **Material Selection**
   For the material selection, we compared material properties and tested the stress and strain of several different materials. We focused on cheap and accessible materials: plastic Legos, cardboard, pine wood, aluminum, and optically clear cast acrylic. Each of these materials were used in different prototyping iterations due to their varied accessibility. Documentations of each iteration are included in Section 5.2.4.

3. **Building and Improving**
   Based on the analyses completed in the previous step, we began to construct our initial prototype using the critical dimensions, tolerances, and materials we determined to be best. Throughout each prototyping iteration, we repeated these calculations and continuously reevaluated our material options in order to perfect our final design.

5.2.3 Methodology

As previously stated, our pre-prototype analysis consisted of calculations and material selection in order to determine the critical dimensions and type of material to use for machining our parts. The tolerance ranges were determined using Fig. 21 below for drilling holes and milling. The part sizing calculations were computed using the equations in Section 4.4. For material selection, a variety of materials were machined and compared for qualities of appearance and durability.

RANGE OF SIZES		TOLERANCES ±								
FROM	THROUGH									
0.000	0.599	0.00015	0.0002	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005
0.600	0.999	0.00015	0.00025	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006
1.000	1.499	0.0002	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008
1.500	2.799	0.00025	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.010
2.800	4.499	0.0003	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008	0.012
4.500	7.799	0.0004	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.010	0.015
7.800	13.599	0.0005	0.0008	0.0012	0.002	0.003	0.005	0.008	0.012	0.020
13.600	20.999	0.0006	0.001	0.0015	0.0025	0.004	0.006	0.010	0.015	0.025

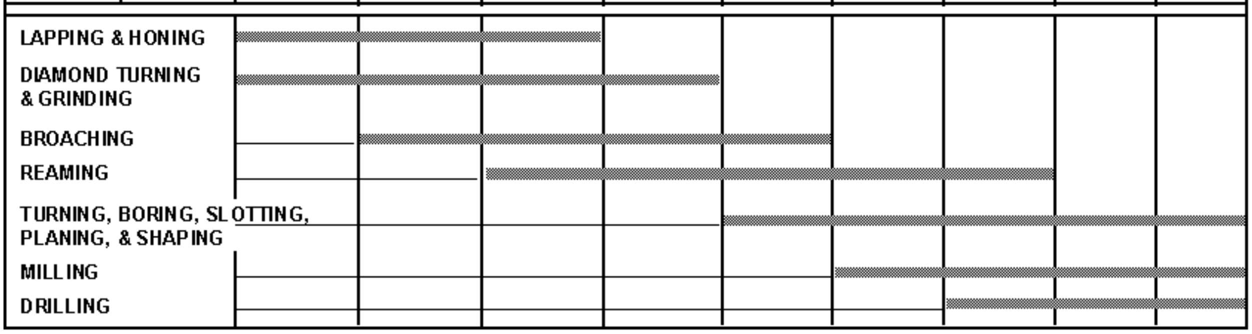


Fig. 21- Tolerance range for machining processes

5.2.4 Results

Our analysis affected our initial prototype and the changes we made with each iteration. Our final design was made out of optically clear cast acrylic and aluminum. Throughout the process of machining various parts and testing how the pieces fit together, we also made several design changes to the shape and dimensions of the parts. Our design was altered as a result of our analyses as follows:

Initial Prototype:

Our initial prototype utilized cheap, available materials in order to allow this first prototype to be made quickly. We also knew that this first device would have design issues that would need to be resolved. Therefore, we decided to not invest too much money and time into machining and 3-D printing all of the parts before finalizing our decisions on types of mechanisms and dimensions. The initial prototype consisted of Lego's, 3-D printed parts, and a cardboard enclosure. The integral component of this prototype was the 3-D printed Batman pieces. We started with two separate Batman pieces that we aligned on an axle. We realized that the device would fail if these two pieces became misaligned, so we altered this feature in future designs. Also, this prototype depended on a Lego pieces for the marker chutes since these parts were not vital and depended on the size of the Batman mechanism. The marker was dispensed using a Lego gear rack and pinion mechanism. This mechanism worked, but we decided to continue investigating better mechanisms that could induce linear motion with a rotating motor in a compact space. Since we wanted the working mechanism to be easily viewable for our initial demonstration, we attached the parts to a temporary cardboard base and backboard.

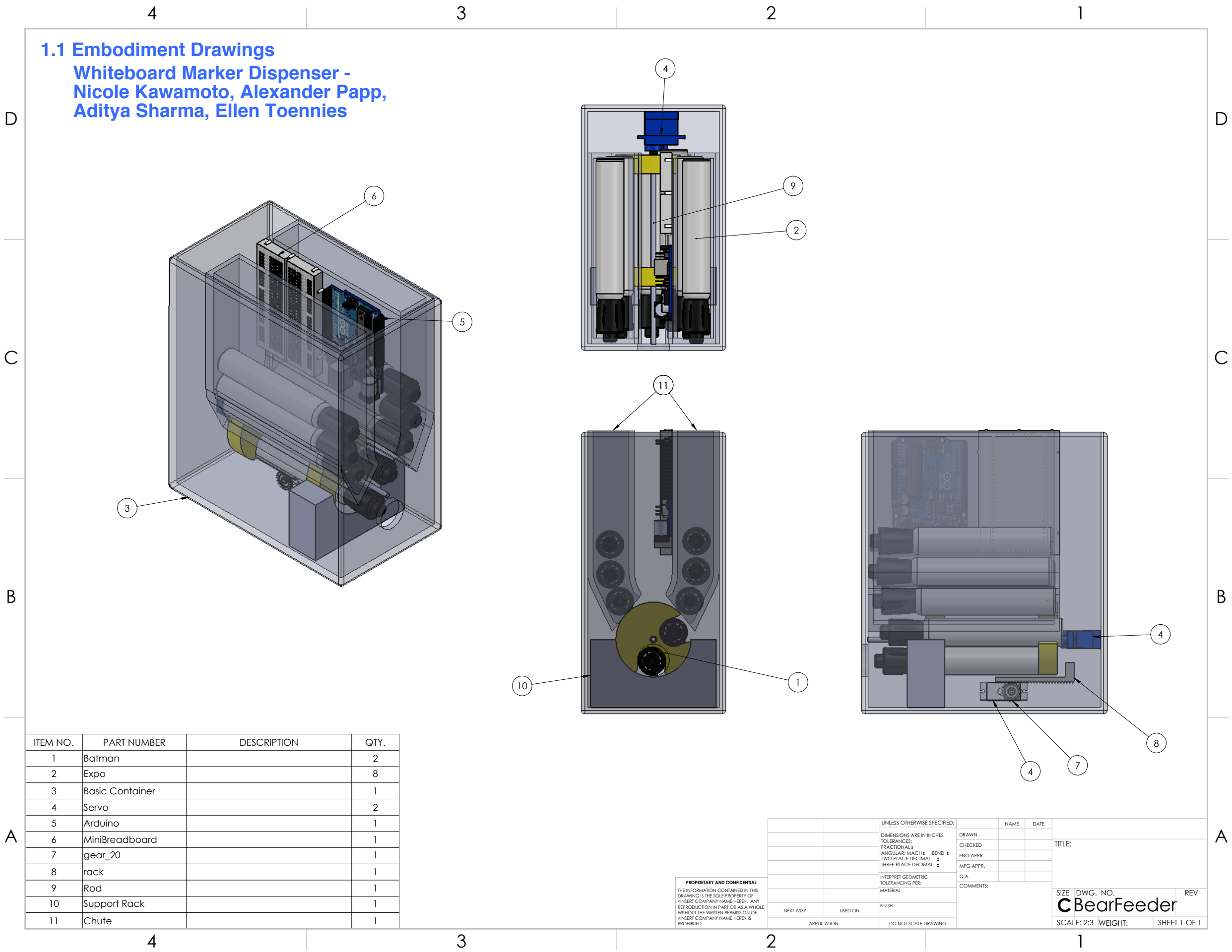
Prototype 1:

Our second iteration featured a single Batman piece that was the length of a standard whiteboard marker. This piece spun on an aluminum axel within an aluminum enclosure with cutouts for the marker chutes and the dispenser channel. These parts required tight tolerances so that the Batman piece could rotate smoothly within the aluminum enclosure. For this prototype, we continued to use the Lego gear rack and pinion mechanism to push the whiteboard out the enclosure since we did not view any significant problems with it in the previous prototype. We built the marker chutes out of aluminum sheets; however, the bending method we used to shape the chutes was not precise. This caused the two chutes to not be identical, so the markers would catch on the certain parts of the chute that did not have a uniform opening for the markers. For this iteration, we replaced the temporary cardboard enclosure with machined wood enclosure that held up the main cylinder and held the marker chutes in place. We found that the wood pieces were not rigid enough to hold the parts in place. It was also impossible to machine the wood pieces to the tight tolerances that the device needed. This influenced our decision to make our entire enclosure out of a uniform material for our final prototype.

Final Prototype:

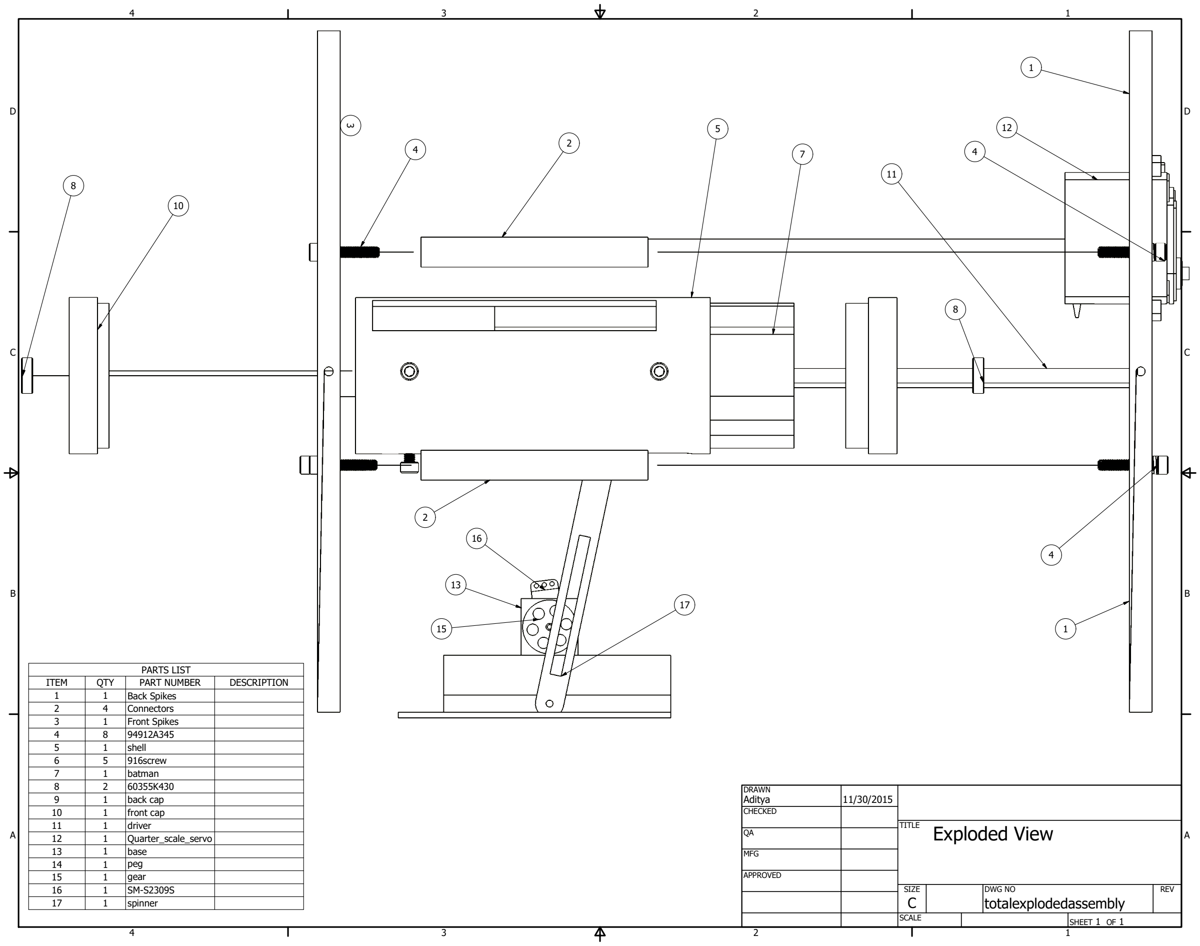
For our final prototype, we machined all parts from optically clear cast acrylic and aluminum. We decided that this would be the most robust material selection. We maintained the same dimensions and design of the Batman piece and cylinder enclosure from Prototype 1, but we recreated the parts with the optically clear cast acrylic. The Batman piece spun on the same aluminum axel with the rotation of a servo motor programmed by an Arduino. We also replaced the wood enclosure pieces with optically clear cast acrylic in order to make as many of the parts transparent. This added to the aesthetic of the device and would allow users to see their marker move from the holding chute to the dispenser channel. Since we replaced the wood enclosure with the more rigid acrylic material, we needed to adjust the dimensions and tolerances to accommodate the strain on the piece from the aluminum base. For this final product, we replaced the Lego gear rack and pinion mechanism with a much more efficient and compact Schwang mechanism. This new mechanism was machined out of aluminum and integrated into the aluminum base plate. Another Arduino-controlled servo motor was attached to the Schwang mechanism to push the whiteboard marker out of the enclosure for the user. As we expected, the final prototype satisfied the relevant metrics and performed for our final demonstration.

5.2.5 Significance



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Batman		2
2	Expo		8
3	Basic Container		1
4	Servo		2
5	Arduino		1
6	MiniBreadboard		1
7	gear_20		1
8	rack		1
9	Rod		1
10	Support Rack		1
11	Chute		1

Fig. 22- Embodiment drawing before analysis



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Back Spikes	
2	4	Connectors	
3	1	Front Spikes	
4	8	94912A345	
5	1	shell	
6	5	916screw	
7	1	batman	
8	2	60355K430	
9	1	back cap	
10	1	front cap	
11	1	driver	
12	1	Quarter_scale_servo	
13	1	base	
14	1	peg	
15	1	gear	
16	1	SM-S2309S	
17	1	spinner	

Fig. 23- Embodiment drawing after analysis

The major differences between our initial and final design were the Batman pieces, marker chutes, and dispensing mechanism. For the Batman piece, size calculations influenced the decision to use only one Batman piece and to extend the length to accommodate the full length of a standard whiteboard marker. This eliminated the possibility of failure if the marker did not drop directly into the opening in the Batman piece from the marker chute. For the marker chutes, we started with a design that utilized two separate full enclosures for each colored marker supply. Geometric sizing analysis revealed that the angles were too sharp to allow the markers to smoothly move through the chutes. Furthermore, the feasibility analysis showed that the aluminum sheets would not be an acceptable material since they could not be machined to the tolerances needed to accommodate the markers. The final prototype did not feature distinct marker chutes. Rather, a thin acrylic piece was attached to the cylinder enclosure that contained each colored marker supply and fed the markers into the Batman piece. This piece was easier to machine and more durable. Lastly, the marker dispensing mechanism was changed from the Lego gear rack and pinion to the Schwang mechanism. The Lego assembly was too large and not as robust as we desired. The new Schwang mechanism allowed the marker to be dispensed without adding too much additional mass or height to the device. The new mechanism also complied with the desire to have base made of machined parts out of uniform materials.

5.2.6 Summary of code and standards and their influence

Relevant codes and standards are included in Table 12 below. Note that the hyperlink in the "Standard #" column will take you to the web page for the cited code or standard. We focused on standards used for toys so that we can ensure the highest level of safety for any user.

Table 12- Summary of relevant codes and standards

Standard #	Organization	Title	Keywords
ISO 868	ISO	Plastics and ebonite — Determination of indentation hardness by means of a durometer (Shore hardness)	Plastic hardness
ISO 4287	ISO	Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters	Surface texture
ISO 8124-1:2014	ISO	Safety of toys — Part 1: Safety aspects related to mechanical and physical properties	Mechanical and physical properties
ISO 8124-2:2014	ISO	Safety of toys — Part 2: Flammability	Flammability

We referred to the International Organization for Standardization (ISO) for relevant standards for our whiteboard marker dispenser. After our review of several sets of standards, the ISO codes were the most accessible and thorough. Our device has child-like features, can be altered into a children's toy, and needs to be safe for users of any age. Therefore, we decided that a set of standards created for toys would be the best for our device. We want to ensure the greatest level of safety, and the ISO standards provide that. ISO 868 and IS0 4287 focus on the materials that make up the dispenser. These standards define the process for testing the hardness of plastics as well as the parameters for documenting surface texture properties. The major category of standards that we focused on was ISO 8124-1:2014, which outlined the safety aspects related to the mechanical and physical properties of the device. This extensive list of standards addresses all of the major risk factors outlined in Section 5.3. Some of the properties and scenarios we needed to be aware of are normal use, reasonable foreseeable abuse, material, small parts, edges, and points. These standards also outlined the required testing for these different properties. We need to test the function of our device under the expected use of a user requesting and borrowing a single whiteboard. However, we also need to realize that some users will intentionally or unintentionally misuse the device, especially since it is intended for unmonitored use in a university classroom or study room. Therefore, it is our obligation to test and prevent sharp edges and points and any other aspects of our design that could endanger any user. Lastly, we referred to the flammability standard for toys, ISO 8124-2:2014. We needed to test the power source that operated the automated mechanisms since this was the only potential flammable component.

While we referenced these codes while creating our final prototype, we want to reiterate that our product is not fully safe for consumer use. Due to our manufacturing and testing constraints, we were not able to prepare our final product to point at which it would be ready for mass production. Still, our final product complies with the listed standards and fulfills the purpose of the provided a user-friendly device to dispense working whiteboard markers.

5.3 Risk Assessment

5.3.1 Risk Identification

Our primary risk factors were reasonable foreseeable abuse, small parts, sharp edges, sharp points, and flammability. While these were not huge concerns, they are factors that require attention in order to ensure the highest level of safety. Since this device is user-operated and is intended to sit in classrooms or study rooms unattended, the device has the risk of endangering a user who misuses it. Additionally, the components of the device also contribute other risk factors. There are several small parts, screws and spacers that pose a hazard to users, especially a child. The device also contains blunt edges and points. Lastly, the motors and automation components pose a potential risk of flammability.

5.3.2 Risk Analysis

According to the ISO standards discussed in Section 5.2.6, the device should undergo the following regulated tests: small parts tests, sharp-edge test, sharp-point test, and reasonably foreseeable abuse tests. Since we did not have full access to these testing procedures or the required apparatus, we decided to direct our attention at eliminating these risk factors. The risk of flammability is negligible since the motors are small and the power source is not large enough to cause any malfunctions. The device would fail before the power source pose an actual threat of flammability.

5.3.3 Risk Prioritization

Our plan for dealing with the applicable risk factors was to eliminate or alter features that posed any type of significant risk. To address reasonable foreseeable risk, we plan to completely enclose the device so that the moving mechanisms are covered. The opening for re-loading new whiteboard markers will be locked so that only authorized personnel can access the inside of the device. The small, smooth opening that dispenses a marker will be the only opening accessible by normal users. To address small parts, any necessary small parts will be securely fastened to the enclosure or hidden inside of it. Lastly, all sharp edges and points on the outer enclosure were sanded down and eliminated to make any potential risk negligible.

Overall, we believe that our device offers very minimal risks to any potential user. The device is low-powered and fully enclosed. Even though we had limited access to standardized testing procedures and apparatus, we believe that we considered all aspects capable of causing harm to a user and dealt with them accordingly.

6 Working prototype

6.1 A preliminary demonstration of the working prototype

6.2 A final demonstration of the working prototype

6.3 At least two digital photographs showing the prototype

Fig. 24- Front and isometric views of the final prototype

The two photos above show the complete, assembled final prototype from both a front and isometric perspective. Aluminum U-brackets with attached acrylic sheet walls support the system while creating an open structure. The two vertical stacks of markers, separated by color, feed into their respective slots in the batman piece by means of marker-sized openings in the shell tube. A combination of a servo motor, axle, and gears allows the batman piece to rotate within the shell tube to the desired location. Once a marker reaches the bottom of the shell tube, the Schwang mechanism located below expels it from the mouth of the bear on the front cap. Another servo motor, located on top of the base plate, drives this process. Users can return a marker by simply realigning it with the same opening on the front cap and pushing it completely into the mouth of the bear.

6.4 A short video clip that shows the final prototype performing

The following 3 video clips show different segments and views of the whiteboard marker dispensing process in action.

https://www.youtube.com/watch?v=URFoV6663yQ

This video clip above demonstrates the loading and rotation of the batman piece from a side view. A maximum of 7 markers are stacked on both sides of the device, with each stack containing markers of only a single color. Once one marker falls into its respective opening in the batman piece, no other markers of that color can enter the shell tube until the initially chosen marker is completely used up and no longer returned to the device. The process of turning the batman piece occurs by means of a quarter scale servo motor hooked up to an Arduino. The electronic system dictates the position to which the batman piece should rotate based on the needs of the user. This process of obtaining a marker from the stack and rotating it down to the expelling position takes less than 5 seconds.

https://www.youtube.com/watch?v=5OPnQZqaOtg

The clip located above shows the same process of loading and rotating the batman piece, but from a front view. From this angle, it is easier to observe the incentivized component of our device, the front cap. This piece is decorated as the face of a bear, with the opening through which a requested marker will be expelled disguised as the mouth of the bear.

https://www.youtube.com/watch?v=QDfKDKmRVgY

This final video clip shown above exhibits an animation of the Schwang mechanism, which works to expel the requested marker out of the opening in the front cap from its position at the bottom of the shell tube. In an effort to optimize space, we positioned the lever arm used in the Schwang mechanism on its side in the final prototype as opposed to having it stand vertically as shown here in this animation video clip.

6.5 At least four (4) additional digital photographs and their explanations

Fig. 25- Top view of the final prototype

The photo above shows a top view of the final prototype, giving a clear view of the stacking mechanism involved. The whiteboard markers are constrained on all sides by clear acrylic walls; the two inner most walls are separated by a delicately measured spacer.

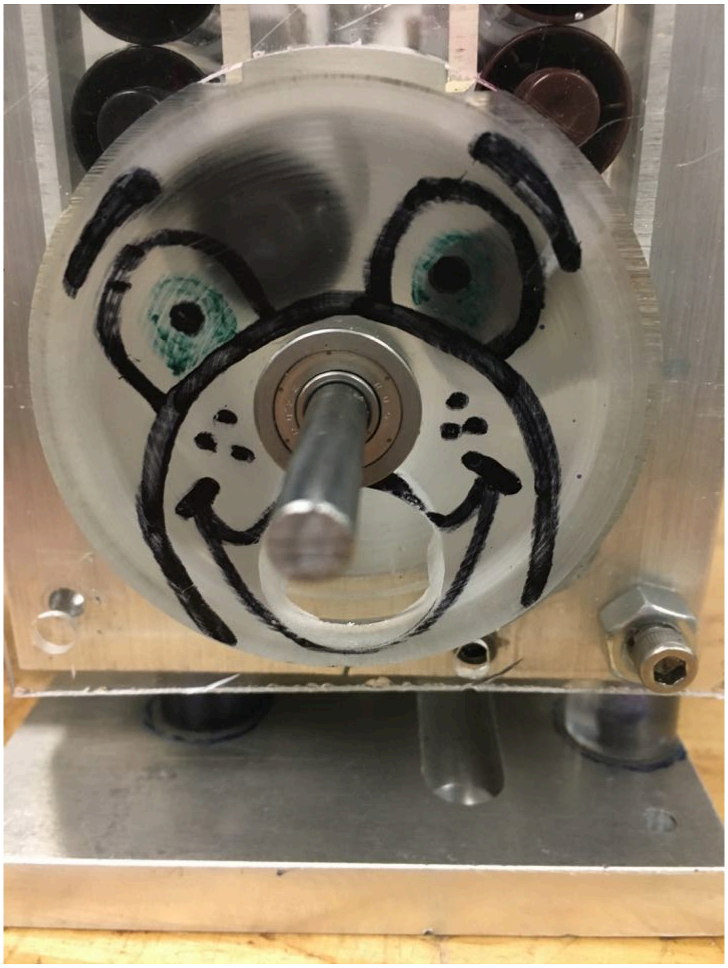


Fig. 26- Close-up view of the front cap with bear illustration

The above photograph focuses on the front of the front cap piece, which encloses the batman piece within the shell tube. After the requested marker rotates to the bottom of the tube, a peg forces the marker out of an opening on the front cap, where the user grabs it. The opening is disguised as the mouth of a bear, which adds incentive for users to try the machine and also return their markers to the correct place when finished using it.

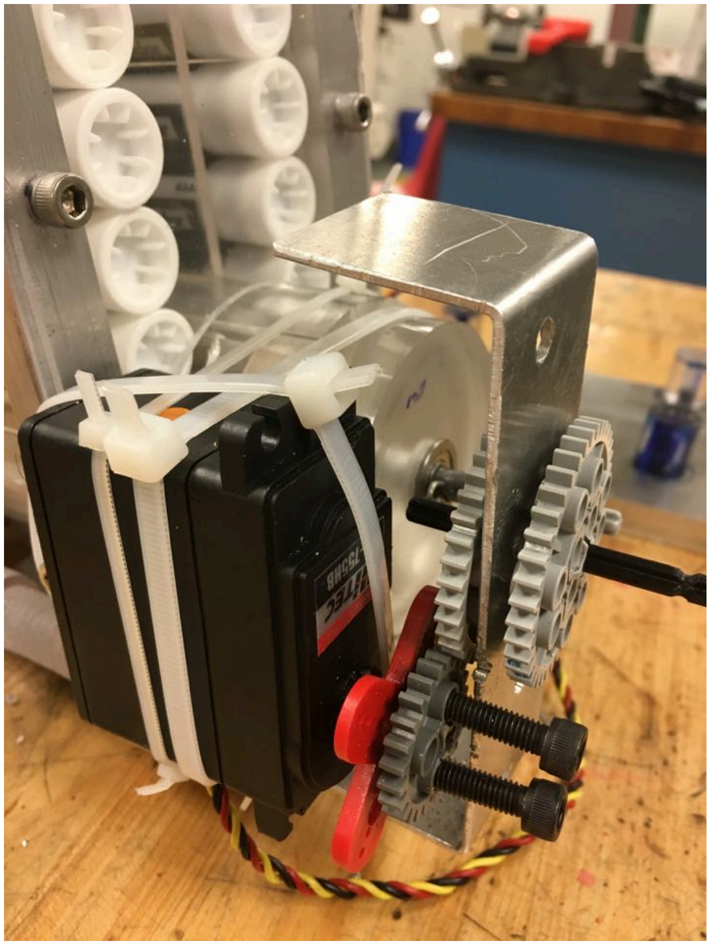


Fig. 27- Back view of the servo motor, axle, and gear combinations used to drive the batman piece

Above, the mechanism for rotating the batman piece is shown in detail. A servo motor attached to an Arduino breadboard turns a set of gears, taking advantage of the gear ratio laws to improve torque. The final gear is fitted around an axle, which causes the batman piece to rotate when spun.

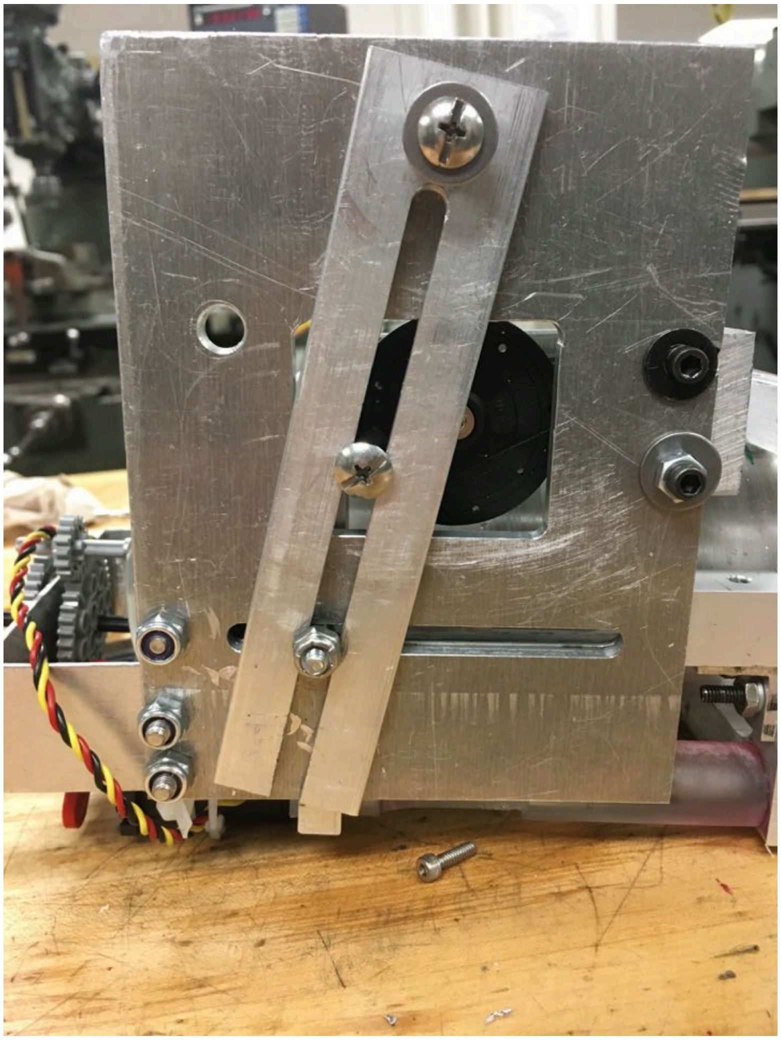


Fig. 28- Bottom view of the lever arm and servo motor used to expel the marker

This picture above displays the components needed to drive the Schwang mechanism from a bottom view. A servo motor rotates, moving the middle screw along with it and thus translating the lever arm back and forth; the top screw is statically mounted to the base plate. When the lever arm moves forward, it moves the bottom screw forward as well. This bottom screw is attached to a peg, which penetrates the shell tube from underneath and pushes the marker from behind. The movement gives the mechanism enough force to expel the requested marker from the front opening of the device.

7 Design documentation

7.1 Final Drawings and Documentation

7.1.1 A set of engineering drawings that includes all CAD model files and all drawings derived from CAD models. See Appendix C for the CAD models.

Engineering drawings including CAD model files and drawings derived from CAD models are separately uploaded to the "Whiteboard I (Papp, Toennies, Kawamoto, Sharma)" file exchange.

7.1.2 Sourcing instructions

Table 13- Part Details

Part	Use	URL	Cost
Back Frame	Structure	http://www.mcmaster.com/#8975k196/=101lfzz	1.04
Long Spacer	Structure	http://www.mcmaster.com/#8975k196/=101lfzz	1.04
Front Frame	Structure	http://www.mcmaster.com/#8975k196/=101lfzz	1.04
1" 10-32 Thread Machine Screw	Fastener	http://www.mcmaster.com/#90342a125/=101kvm2	2.10
Shell Tube	Enclosure	http://www.mcmaster.com/#90342a125/=101kvm2	9.76
7/16" 10-32 Thread Machine Screw	Fastener	http://www.mcmaster.com/#91251a356/=101l86u	7.66 for 50
Batman Piece	Rotation	http://www.mcmaster.com/#91251a356/=101l86u	9.76
Ball Bearing	Fastener	http://www.mcmaster.com/#91251a356/=101l86u	6.25
Back Cap	Enclosure	http://www.mcmaster.com/#8560k932/=101li5n	9.76
Front Cap	Enclosure	http://www.mcmaster.com/#8560k932/=101li5n	9.76
Axle	Rotation	http://www.mcmaster.com/#8920k115/=101lpkl	1.03
Quarter Scale Servo	Rotation	https://www.servocity.com/html/hs-755mg_1_4_scale.html#.Vl0qofmrSUk	31.99
Base Plate	Structure	http://www.mcmaster.com/#8975k196/=101lfzz	1.04
Peg	Dispensing	http://www.mcmaster.com/#8975k196/=101lfzz	1.04
Gear (Rotating Device)	Dispensing	http://www.mcmaster.com/#8975k196/=101lfzz	1.04
Small Servo Motor	Dispensing	http://www.tme.eu/en/details/t010160/arduino-development-kits/arduino/small-dc-motor/?brutto=pl&currency=USD&gclid=CjwKEAiAhPCyBRCtwMDS5tzT03gSJADZ8VjRzqbs6FlASvpkvyr-PHi-	3.37

		RkSxYqpmdeyE6WriGKY3EBoCKMnw_wcB	
Lever Arm	Dispens ing	http://www.mcmaster.com/#8975k196/=101lfzz	1.04
Total			**98.7 2**

All parts were obtained either through scrap pieces in the student machine shop or through previous ownership by a group member, but the URLs listed above would allow another to refabricate the device with similar pieces. To reach the website for each part, follow the hyperlink associated with each row. Details about assembly of the final prototype are included in the "CAD Assembly" file uploaded to the "Whiteboard I (Papp, Toennies, Kawamoto, Sharma)" file exchange.

7.2 Final Presentation

7.2.1 A live presentation in front of the entire class and the instructors

Fig. 29- Introductory Slide from the Final Presentation

7.2.2 A link to a video clip version of 1

https://www.youtube.com/watch?v=AghzTB658Zw

7.3 Teardown

TEARDOWN TASKS AGREEMENT

PROJECT: White Board Market Dispenser

NAMES: Aditya Sharma___ (AS) INSTRUCTOR: Dr. Malast_______

Ellen Toennies___(ET)

Nicole Kawamoto (NK)

Alexander Pap (AP)

The following teardown/cleanup tasks will be performed:

Our final prototype was created from aluminum and optically clear acrylic plastic, both of which are non-toxic. This means our prototype can be disassembled and thrown away in a trash can. All of the pieces were milled or drilled and cannot be salvaged. The electronics can be reused for future projects. The shop will be cleaned and all scrap pieces will be replaced in their proper cabinets. Due to its size it will probably be kept by one of the group members.

Instructor comments on completion of teardown/cleanup tasks:

Instructor signature: [signature]

Print instructor name: _Mary Malast_______________

Date: ___12/7/2015_____________

(Group members should initial near their name above.)

Fig. 30- Teardown Instructions

8 Discussion

8.1 Using the final prototype produced to obtain values for metrics, evaluate the quantified needs equations for the design. How well were the needs met? Discuss the result.

The Pugh Decision Matrix shown below gives the metrics for the final prototype.

Final Prototype		Metric															
		Marker Performance	Device Volume	User Satisfaction	Number of Color Options	Number of dispensed markers	Cycles till Failure	Electrical Indepence	Carbon Emissions	Anchored to Wall?	Dispense Other Things	Likeliness to return	Facilitates Return	Markers Held	Need Score	Importance Weight (all entries should add up to 1)	Adjusted Score
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13			
1	Dispense Working Marker	1													1	0.109	0.109
2	Compact		1												0.7	0.065	0.046
3	Ease of Use			1											0.95	0.109	0.103
4	Color Selection				1										0.25	0.065	0.016
5	Multiple Dispensing Capability					1									0.25	0.043	0.011
6	Robust						1								0.85	0.087	0.074
7	Independent Power Source							1							1	0.065	0.065
8	Environmentally Friendly								1						0.666666	0.043	0.029
9	Mobility									1					1	0.065	0.065
10	Dispenses Other Objects										1				1	0.043	0.043
11	Low Maintenance											1			1	0.109	0.109
12	Returnable			0.25								0.25	0.5		0.9875	0.109	0.107
13	# of Markers Held													1	0.4	0.087	0.035
Units		Binary	cm^3	Percentage	Integer	Integer	Integer	Binary	Kg/kW-h	Binary	Binary	Percentage	Percentage	Interger	Total Score		0.812
Best Value		1	500	100	4	4	5000	1	0	1	1	100	100	50			
Worst Value		0	5000	0	1	1	0	0	3	0	0	0	0	1			
Actual Value		1	1500	95	2	4	4250	1	1	0	0	100	100	20			
Normalized Score		1	0.7	0.95	0.25	0.25	0.85	1	0.666666	1	1	1	1	0.4			

Fig. 31- Metric Evaluation for the Final Prototype

The final prototype holds 20 markers of 2 different colors, encourages return with incentive, ensures that the marker dispensed will be fully functioning after no more than 2 tries, is electrically independent, and possesses a compact volume of 1500 cm^3. Although it does not have the capability to attach to a wall, this factor could easily be accounted for in future designs given more time to improve. This machine does not dispense items other than markers, but we believe that our focus shifted as we continued the design process, so this was no longer a goal. Because 2 color options are available, user satisfaction would be fairly high. The number of cycles until failure would be more of an experimental parameter, so our guess here of 4250 is based on the number of mechanical components this final prototype had in comparison to other options we examined. Because of its electrical independence, this device also scores low in the carbon emissions category.

8.2 Discuss any significant parts sourcing issues? Did it make sense to scrounge parts? Did any vendor have an unreasonably long part delivery time? What would be your recommendations for future projects?

We had no significant part sourcing issues given that much of our design depended on fabricating custom parts. Given the robust, non-invasive nature of our device, it made sense to scrounge for parts. Many of the pieces we fabricated were small, while the majority of the others were from sheet metal. Because of these reasons, scrounging in the machine shop proved lucrative. Because the vendors for a few specific Arduino components required unreasonably long part delivery times, we employed pieces from a personal set already owned by a group member. Recommendations for future projects would include streamlining the manufacturing process by making all of the similar parts out of the same material and in the same manner at the same time. We were somewhat constricted by the scrap supply in the machine shop, so not all parts match exactly. This would enable the device to be fabricated much more quickly and with much greater reliability given the tight tolerances of the instrument.

8.3 Discuss the overall experience:

8.3.1 Was the project more of less difficult than you had expected?

Overall, the project was about as difficult as we expected. Some parts, however, proved more difficult. Because we had little experience actually building things that we designed, we ran into some setbacks when it came time to assemble the final working prototype. We did feel very adequately prepared for all design components of this project, and we were still able to produce a working prototype while continuing the learning process all semester.

8.3.2 Does your final project result align with the project description?

Yes. As defined by the user needs specified by our customer at the beginning of the design process, our final project met all intended goals.

8.3.3 Did your team function well as a group?

Yes! Our personalities worked very well together and highlighted the strengths of the group. In addition, because the group had diverse personalities with different specialties, we were able to learn from our partners and improve our skill sets. We all got to know each other much better throughout the course of this project.

8.3.4 Were your team member's skills complementary?

Yes. As touched on above, we all brought different skills to the table. Alexander had ample experience in designing and building prototypes, both through computer software and the machine shop. Nicole specialized in technological aspects, drafted the presentation, and spearheaded much of the communication with the professors. Aditya possessed a lot of strengths in coding and drafting while always driving discussion among the group members during the design process. Ellen added a strong organizational background to the final report and was always eager to learn how to tackle the challenges which none of the group members had prior experience in.

8.3.5 Did your team share the workload equally?

Yes. We divided up the workload so each member had the same depth of tasks and the same expected time commitment. Because of prior strengths, the tasks themselves differed greatly throughout the course of the semester.

8.3.6 Was any needed skill missing from the group?

No. With collaboration, we were able to perform all tasks.

8.3.7 Did you have to consult with your customer during the process, or did you work to the original design brief?

We consulted with our customer in order to obtain the original user needs. As our design developed and changed throughout the scope of the process, we met with our customer to keep him updated and ask his opinions. In addition, our customer was present for input at the showings of all prototypes.

8.3.8 Did the design brief (as provided by the customer) seem to change during the process?

Yes. While at the beginning of the process the customer desired a device that could dispense many different items to accommodate classrooms with different types of boards, we agreed upon narrowing the scope and specializing our product to focus solely on the dispensing of white board markers.

8.3.9 Has the project enhanced your design skills?

Yes. Because we had little prior experience with implementing designs, any exposure in this category proved very helpful. On the other hand, however, the project threw group members into quite a challenge without offering much of a manufacturing opportunity to from learn beforehand.

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

Yes. Each member of our group feels more comfortable within the realm of design and would now apply this knowledge more readily in the real world. The group members enjoyed letting their strengths shine within the context of a team, however, and would want to continue to be a part of similar design groups if at all possible.

8.3.11 Are there projects that you would attempt now that you would not attempt before?

Yes. After receiving some much-needed manufacturing experience through this project, we feel more confident in our skills and are more excited about the design process as a whole.

9 Appendix A - Parts List

The Parts List can be seen on page 51 Table 3

10 Appendix B - Bill of Materials

The Bill of Materials can be seen on page 25 on Table 9

11 Appendix C - CAD Models

The CAD models can be found on the “Whiteboard I (Papp, Toennies, Kawamoto, Sharma)” Blackboard File Exchange

12 Annotated Bibliography (limited to 150 words per entry)

References and summary documents consulted for Background Information Study are included in Section 2.2.

Codes are referenced in Section 5.1.2.6.

Images used in Section 5.1.2.2:
amazon.com
designtheproduct.com
glassfittings4less.co.uk

Images used in Section 5.2.3:
adcats.et.byu.edu