ME2110 – Section A5

Final Project Report

"The Depresants":

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Abstract

This report summarizes the design, fabrication, and performance of *The Depresant*, a robot developed for the ME 2110 competition, inspired by the movie *Inside Out 2*. The robot was engineered to complete five tasks: activating a system, collecting emotions, depositing mind manuals, raising Sadness, and egressing, all within a 40-second time limit and a $120 budget. Key engineering specifications prioritized result repeatability, precision, and modularity, leading to design features such as pneumatic pistons for actuation, a pulley system for raising Sadness, and mechanically actuated sortheads for mind manual deposition. Iterative testing and refinements, such as optimizing piston timing and integrating elliptical pipe cuts for PVC stability, significantly enhanced performance. The robot advanced from scoring 78 points in sprint 3, ultimately achieving 157 points in the final competition's second round. While wiring inconsistencies and activation issues presented challenges, the project highlights the critical role of iterative testing, engineering analysis, and teamwork in developing reliable and high-performing systems.

Introduction

In ME 2110, teams were tasked to create a robot that could consistently complete a series of predetermined tasks to accumulate points. The goal was to obtain more points than surrounding teams. This project had several inherent design challenges associated with it, including a robot that reliably completes 3 predetermined tasks with an initial 12” x 18” x 24” size requirement, a 40-second time constraint, a 3.5-minute setup allocation, and a necessity to outperform other teams. These constraints necessitated a well-designed and fabricated robot that was both modular and robust. However, due to the need to complete these tasks in a quick and efficient manner, there is an inherent tradeoff between characteristics such as speed vs. reliability, ease of fabrication vs. innovation, and modularity vs structural integrity. As such, the robot must acquire as many points as possible by activating a system, collecting emotions, raising and hanging Sadness on a 4-foot bar, reading (depositing) the mind manuals, and egressing. The team’s process to meet these specifications and optimize tradeoffs are detailed in the following sections: problem understanding, conceptual design, design overview, alternative designs, performance results, and conclusion.

Problem Understanding

Rather than starting the engineering process by formulating solutions, it is critical to consider customer needs along with the required engineering specifications. The House of Quality (HOQ), shown in Figure 1, demonstrates that the most significant customer specifications are result repeatability, precision, and system modularity, with importance values of 10, 9, and 9, respectively. After analyzing the engineering requirements by relating them to customer needs and weighting by importance, the most significant engineering requirements are the sorthead minimum rotation angle and the reach of the robot, with relative weights of 10% and 9%, respectively. The minimum rotation angle is critical to the successful performance of the Despresant robot, as the sorthead deploying the mind manuals must have a perfect angle, allowing one mind manual to reach each quadrant while holding all others back for each successive quadrant. Reach, however, is also essential, as the Depresant robot must be able to extend outwards for base, allowing the collection of emotions and deposition of mind manuals within each quadrant. Furthermore, both reach and the minimum shorthead rotation angle are also highly correlated with important customer needs like result repeatability and precision, so the design should focus on these traits as opposed to other requirements with lower technical ratings.

To meet customer needs, key engineering specifications and target values are outlined in the specification sheet presented in Table 1. One key specification is ensuring that the overall volume of the robot stays within the specified parameters of a 2 ft x 1.5 ft x 1 ft enclosure, which emphasizes the need for optimizing space for each respective mechanism. Furthermore, the function tree shown in Figure 2 splits the overarching goal of maximizing points into subtasks for each mechanism. For example, to get the emotions in check, the mechanism must be deployed, emotions must be acquired, and then the robot must return the emotions to headquarters. Lastly, the morphological chart, shown in Figure 3, presents various solutions for the bottom-level function tree subtasks. For instance, to raise Sadness, a pulley system, a scissoring mechanism, a rack and pinion, or a circular telescoping method can all be used to complete this task.

Conceptual Design

To complete the designated tasks for this project, there are 5 main functions that must be completed: activate mechanism, collect emotions, deposit mind manuals, raise Sadness, and egress back to headquarters (HQ). To activate the mechanism, it is essential to be quick and powerful. The best ways to rapidly generate this power are through the use of mousetraps and pneumatic pistons. Due to the lack of overall power associated with mousetraps, pneumatic pistons are the clear frontrunner for accomplishing this function. However, with increased speed, structural integrity and solid fabrication are paramount to maintaining accuracy and limiting errors. To collect emotions, one must successfully reach the center console, funnel the emotions into a collection device, and egress this device back to HQ. To reach the center console, one can use linear drawer slides, a drivetrain, or a 4-bar mechanism to project the collection/gathering devices. To funnel the emotions, any form of angled arm combined with the rotation of the center console is able to effectively push the emotions toward HQ. Finally, any form of movable bag, crate, or box is able to serve as a collection device and egress back to HQ. To deposit mind manuals after reaching the center console, to deposit exactly one mind manual in each quadrant, the mechanism must successfully detect each quadrant and release one manual. IR and ultrasonic sensors are available to detect quadrants; however, due to their unreliability and wired requirement, they are cumbersome to use. Mechanical detection tends to work more consistently; however, this design requires highly specific tolerance and design to work correctly. Mind manuals can be released either through solenoid actuation, sorthead actuation, or other mechanical/electromechanical methods. The sorthead actuation tends to be more consistent and coherent with mechanical detection, making it the preferred choice.

Design Overview

The final design consists of 5 main subsystems: actuation, raising Sadness, gathering emotions, depositing mind manuals, and egress. As shown in Figure 4 , the robot begins its cycle by actuating a pneumatic piston which is attached to the base mechanism depicted in Figure 10. This piston makes contact with the back of the mind manuals assembly, launching the system towards the center console. The piston is controlled by an Arduino code that activates 15ms after connection of the banana plugs, exceeding the target 0.5s actuation time. In addition, the piston provides sufficient power for the rails to extend to their maximum of 54.5”, which meets the target requirement of a 54” reach. The second portion of actuation is activating the motor for Sadness. As displayed in Figure 8, this motor turns a spool, which is tethered to a pulley system, allowing the telescoping PVC system to extend towards the 4’ bar. To ensure accuracy with each attempt, the Sadness mechanism utilizes elliptical cuts at the end of each pipe, guiding the next pipe in the correct direction. In addition, the pulleys started 2.5” above the ends of the pipe to ensure proper stability at maximum extension. To ensure the pulley system has enough force to raise Sadness the requisite 4’, the motor-powered spool rests at a 90-degree angle relative to the base of the PVC, ensuring minimal friction and biting of the string on the holes of the pipe. Also, additional holes were geometrically cut out of each pipe, reducing the weight of each piece and hence reducing friction. To hang Sadness off the end of this mechanism, a horizontal bolt was placed at the end of the final tube, providing a solid base to hang Sadness using a loop, as further demonstrated in Figure 11. Once the pneumatic piston has been actuated and Sadness has begun its ascent, the mind manuals and emotions mechanisms will begin to operate. The emotions mechanism uses a laser-cut extending arm attached to a spring-loaded hinge initially held down by a block attached to the base. This setup allows the arm to extend 11.5” past the end of the drawer sliders once actuated, which meets the target value of 10”. Once the piston is actuated, the arm will release, allowing it to rotate and translate towards the center console. As shown in

Figure 7, once the arm has reached the middle, its inclined design will cause emotions to funnel towards its base, where they fall into a 1.8-gallon collection bag, which is 0.8 gallons greater than the target. During this operation, the mind manuals assembly will begin to individually deposit mind manuals into each quadrant of the console. This system features a mechanically actuated sorthead device. As shown in Figure 6, the sorthead initially functions as a stopper, preventing the mind manuals from spilling out of the assembly. However, when the sorthead makes contact with one of the walls of a quadrant, it rotates 55 degrees, meeting the target 65, this creates an opening for a mind manual to take. Once the wall has passed, a rubber band returns the sorthead to its original position, at which point, the cycle will continue. This design takes advantage of a pivot point that is perfectly concentric with the outer arc of the sorthead head; this geometry ensures the distance between the center of the pivot and the contact point with the mind manual walls stays constant throughout its rotation, preventing any snagging in the system and optimizing reliability without compromising on speed. The cumulative MDF associated with the mind manuals and emotions assembles sums to 38.84 in^3, resulting in a weight of 0.84 lbs, far under the target value of < 2 lbs. The additional weight of the collection bag is negligent and is thus omitted from the calculation. Attaching both the mind manuals and emotions assemblies at the end of the drawer slides provides increased structural integrity as they support each other while remaining modular enough to complete their tasks separately and simultaneously.

Alternative Designs

In addition to the Depresant, there are 3 other designs that were considered: Brush, Slant, and Box. As described in Figure 14, the brush design features a rotating brush emotions collection arm, a mechanically actuated rotating mind manuals dispenser, and a scissor extending Sadness raise. Due to the large surface area covered by the brush and the consistent nature of the scissor extension, this design scored 4/4 points in the results repeatability metric, as shown in Figure 5; however, due to the heavy use of 3d printing required to create this design, it falls short on manufacturing and ease of repair, scoring just a 2/4 on both. Despite these shortcomings, the Brush design still received 75% of the total available points, making it the second-highest-scoring design overall. The Slant design is the next highest scoring, receiving 72% of potential points. This design, shown in Figure 15, makes use of rubber bands to actuate the mechanism to collect emotions. In addition, it raises Sadness via a linearly actuated rail pulley system and utilizes an ultrasonic sensor paired with a revolving dispensing mechanism to deposit mind manuals. The final design is Box, which is the only mobile design. In addition to having a unique travel method, Box also features a drawer slide mechanism to raise Sadness, a pneumatic piston actuated emotions arm, and a mechanically actuated mind manual dispenser as described in Figure 16. The use of a wheelbase to close the distance allows for the use of an additional piston to actuate the emotions arm, allowing Box to consistently push its arm as far as needed. In addition, the use of a wheelbase frees up drawer slides to raise Sadness. The sturdy nature of these slides helps ensure a perfectly vertical ascent each time. In addition, the wheeled nature of this design accentuates its egress abilities, scoring it a 4/4 on mechanism retractability. However, due to the increased number of failure modes associated with a moving robot, this design lags in precise positioning (1/4) and results in repeatability (1/4). These characteristics result in the lowest overall scoring design, with only 56% of all potential points captured.

Performance Results

To ensure that the robot would be capable of completing all tasks at hand, adequate testing was conducted to identify potential weaknesses and refine the robot design for optimal functionality. This data is shown in Table 3, allowing the Depresant team to monitor progress and allocate time to make adjustments based on test results.

The data relating to points scored for each sprint and the final competition is shown in Table 4. The robot design was changed a total of three times: once after sprint one, once after sprint two, and once after sprint three, with the final design being the one used in the competition. In round one of the ME 2110 final competition, The Depresant robot received a disqualification due to the robot not activating when the track activated. This happened due to a faulty small power cable, resulting in insufficient voltage for the Arduino board to provide the necessary actuation energy to run the mechatronics components. In the second round, The Depresant robot scored a total of 157 points. The point breakdown is the following: activation: 10 points, Depositing Mind Manuals: 48 points, Gathering Emotions: 72 points, and raising Sadness: 27 points. This performance advanced the Depresants to round three. However, during round three, The Depresant robot was disqualified for a second time due to repeated activation of the robot without the track being powered on. The exact cause of this issue remains uncertain;

however, it is likely attributed to faulty wiring that may have caused a short circuit in the Arduino or inconsistencies between the tracks used in the competition.

Conclusion

The development of *The Depresant* robot for ME 2110 demonstrated the team's ability to balance innovation, iterative testing, and collaboration under competitive constraints. Through a carefully structured design process, the team addressed key challenges while prioritizing qualities including modularity, reliability, and precision. The final design incorporated several well-engineered systems, including pneumatic pistons for actuation, a pulley system for Sadness raising, a spring-loaded arm for Emotions collection, and mechanically actuated sorthead for Mind Manuals deposition. These subsystems showcased a blend of creativity and technical rigor, resulting in substantial improvements between sprint 3 and the final competition. In addition, as shown in table 2, the final cost for the "Depresant" was $109.96, which is just over $10 under the limit.

Despite these achievements, challenges such as unintentional activation and Sadness accuracy underscore areas of improvement, particularly in system integration and reliability, especially under competitive conditions.

Looking ahead, leveraging lessons from this project, such as iterative testing approach and design for robustness will position each member of the team for greater success in future design challenges. This experience highlights the value of engineering principles, collaboration, and adaptability in complex design problems

Appendix 1

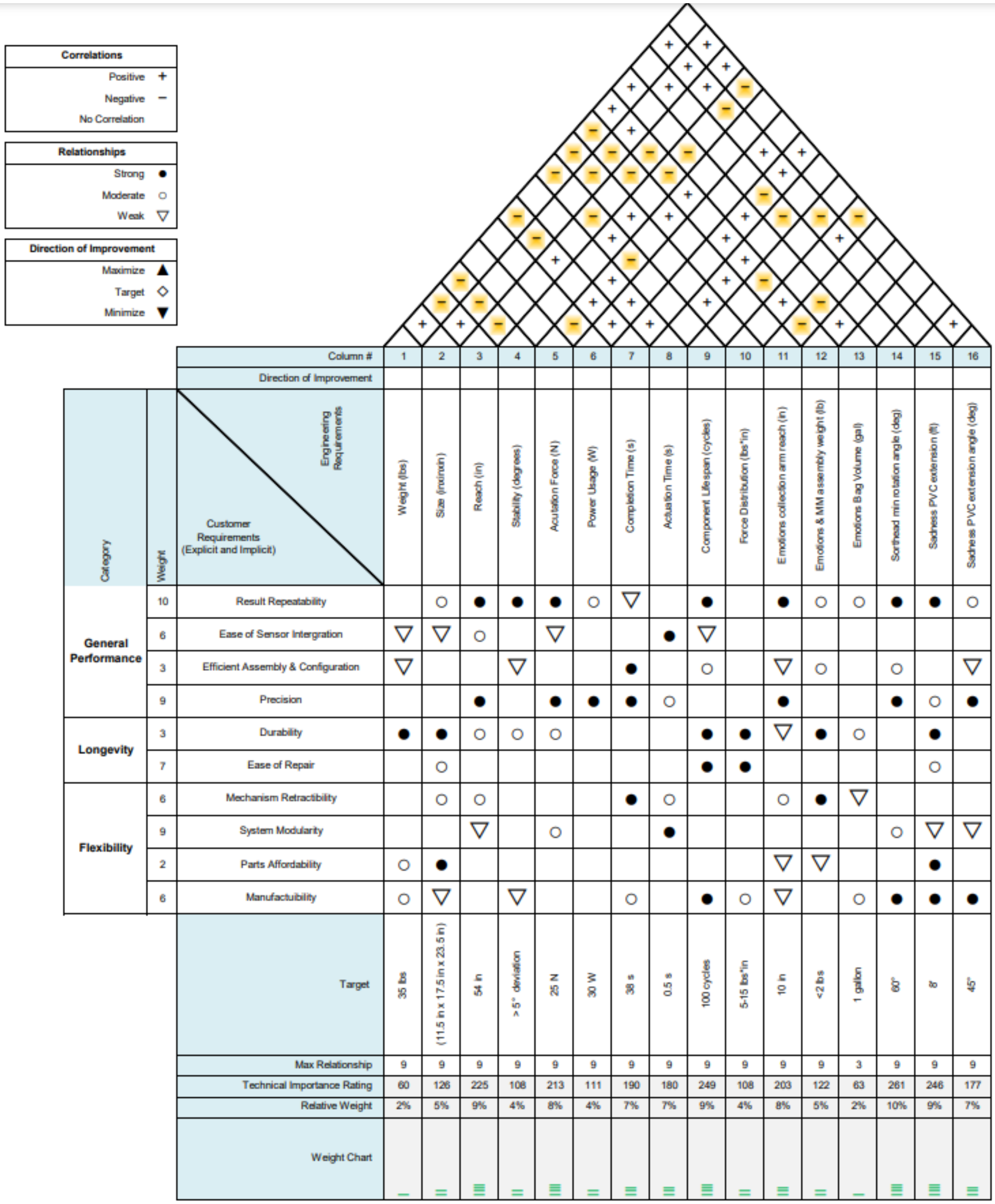


Figure 1: House of Quality for The Depressants Robot with customer an engineering requirements

Table 1: Specification Sheet for the preferred alternative design of The Depresants robot

		Specification		**Issued:**
		For: ME 2110 Sprint One - Score at least 70 points		
Changes	**D/W**	**Requirement**	**Responsibility**	**Source**
N/A	D	Gather the emotions from the various zones into the Long Term Storage.	All Teams	ME 2110 Final Project Specifications
N/A	D	Read the Mind Manuals - No additional manuals in the same zone.	All Teams	ME 2110 Final Project Specifications
N/A	D	Help Sadness Climb Back to Headquarters - Only raising her for Sprint 1.	All Teams	ME 2110 Final Project Specifications
		Geometry		
N/A	D	Weight < 11 lb	Design Team	House of Quality
N/A	D	The robot must be designed to fit within a 2 ft x 1.5 ft x 1 ft enclosure.	Design Team	ME 2110 Final Project Specifications
N/A	W	Make use of retractable mechanisms for easy reset between rounds.	DesignTeam	ME 2110 Final Project Specifications
		Quality Control		
N/A	D	Ensure repeatability of results – adequate testing without catastrophic failure, 99% success rate	All teams	Programming Team
N/A	W	Ensure maximum code efficiency, use various test cases to ensure zero errors	Mechatronics Team	Programming Team
N/A	D	Robot must be capable of performing multiple tasks, including lifting, collecting, and moving, within a 40-second time frame.	Mechatronics Team	ME 2110 Final Project Specifications
		Materials		
N/A	D	PVC Pipe – 2 to 3 tubes	Design Team	Standard
N/A	D	2 - 3 Drawer Sliders - Get Your Emotions in Check task arm extension.	Fabrication Team	Standard

N/A	D	1 - 2 Wood Planks - base of the robot	Design Team	Standard
		Maintenance		
N/A	W	Robot must be able to withstand environmental degradation for at least 65 rounds.	Design Team	Standard
N/A	D	Sensor recalibration every 45 minutes	Mechatronics Team	Standard
N/A	W	Robot reset time < 4 mins per round	Design Team	ME 2110 Final Project Specifications
		Energy		
N/A	D	Must stay between the specified arduino limit between 7 and 12 volts.	Mechatronics Team	ME 2110 Final Project Specifications
N/A	D	Must use > 5 mousetraps and 2 motors at the maximum.	Fabrication Team	ME 2110 Final Project Specifications
N/A	W	Robot maximum operating temperature should not exceed 125°F	All Teams	Standard
		Assembly		
N/A	W	Modularity in robot design allows for repairs > 5 minutes.	Fabrication Team	House of Quality
N/A	W	The robot can be fully assembled in > 20 minutes.	Fabrication Team	House of Quality
		Displacement		
N/A	W	The robot moves smoothly with a speed ranging from 1.5 to 2 ft/s	All Teams	House of Quality
N/A	D	The robot must remain within its designated zone while executing tasks.	All Teams	ME 2110 Final Project Specifications
N/A	D	Robot must extend upwards without risk of beam deflection or torsion.	Fabrication Team	Standard
		Signal Processing		
N/A	D	Sensors must provide feedback within 0.5 seconds to minimize latency in the actuation of robot mechanisms.	Mechatronics Team	Standard

N/A	D	The robot must accurately process sensor inputs to detect the retrieval of objects.	Mechatronics Team	Standard

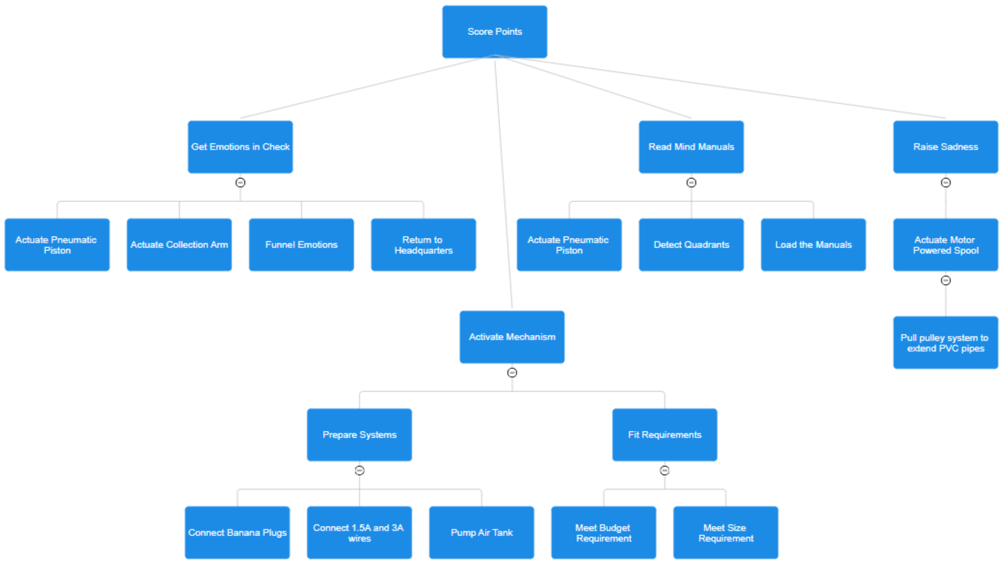


Figure 2: Function Tree for The Depressants Robot, subtasks of specific processes

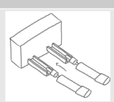
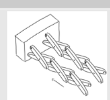
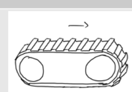
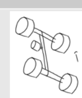
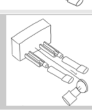
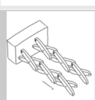
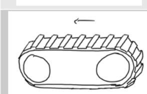
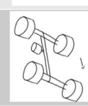
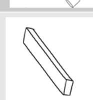
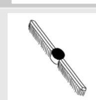
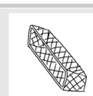
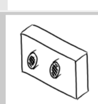
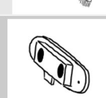
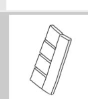
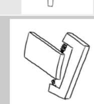
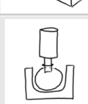
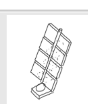
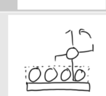
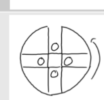
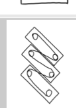
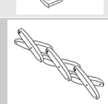
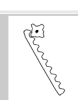
	Solutions			
Product Sub-Function	1	2	3	4
Deploy Mechanism				
Retract Mechanism				
Acquire Emotions				
Detect Quadrants				
Place Emotions				
Raise Sadness				

Figure 3: Morphological Chart For The Depressants Robot providing viable design alternatives for each subtask

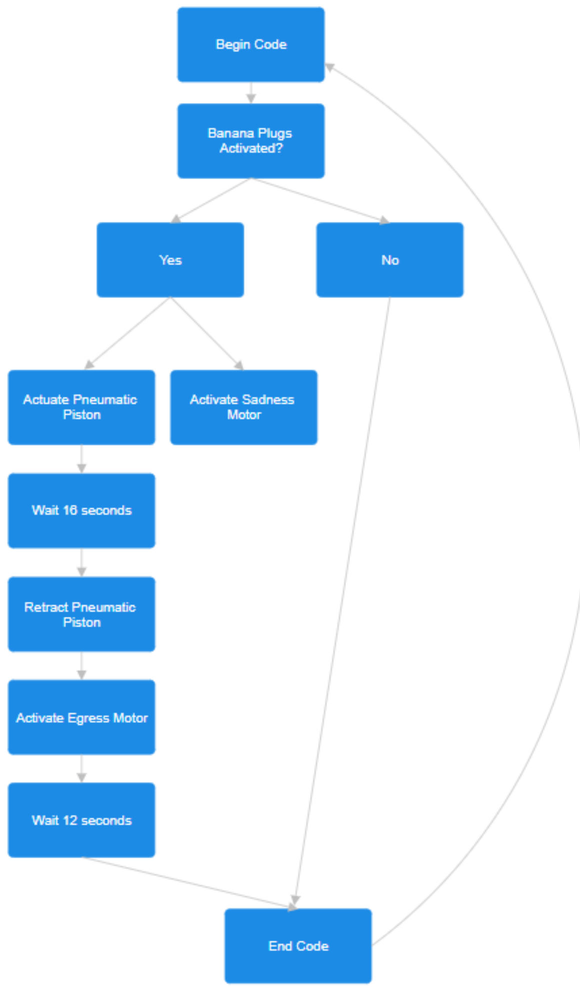


Figure 4: Flow Chart outlining the sequence of processes, from triggering to shutdown.

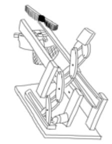
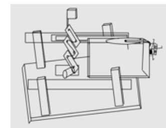
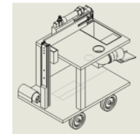
Criteria	Importance	Depressant		Brush		Slant		Box	
Concept									
Precision	9	4	36	3	27	4	36	2	18
Ease of Sensor Integration	6	4	24	3	18	1	6	1	6
Mechanism Retractability	6	4	24	3	18	3	18	4	24
Ease of Repair	7	2	14	2	14	3	21	4	28
Durability	3	2	6	3	9	2	6	4	12
Parts Affordability	2	3	6	3	6	4	8	3	6
System Modularity	9	3	27	3	27	3	27	1	9
Manufacturability	6	4	24	2	12	3	18	4	24
Result Repeatability	10	4	40	4	40	3	30	2	20
Efficiency of assembly and configuration	3	3	9	4	12	2	6	4	12
Total			210		183		176		159
Relative Total			0.86		0.75		0.72		0.65

Figure 5: Evaluation Matrix: Comparing and scoring design alternatives based on key customer criteria to identify the optimal solution.

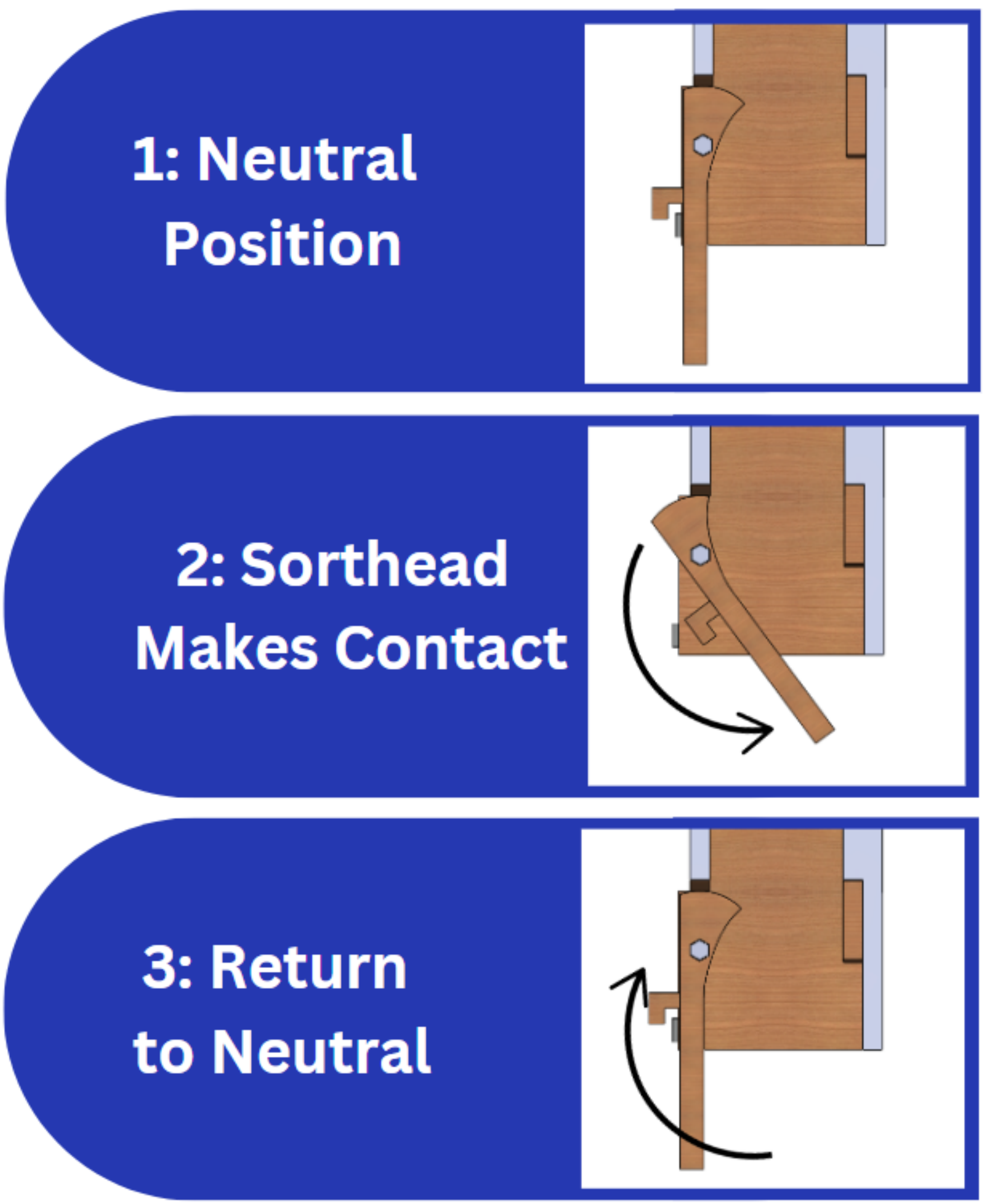


Figure 6: Depositing Mind Manuals Graphic

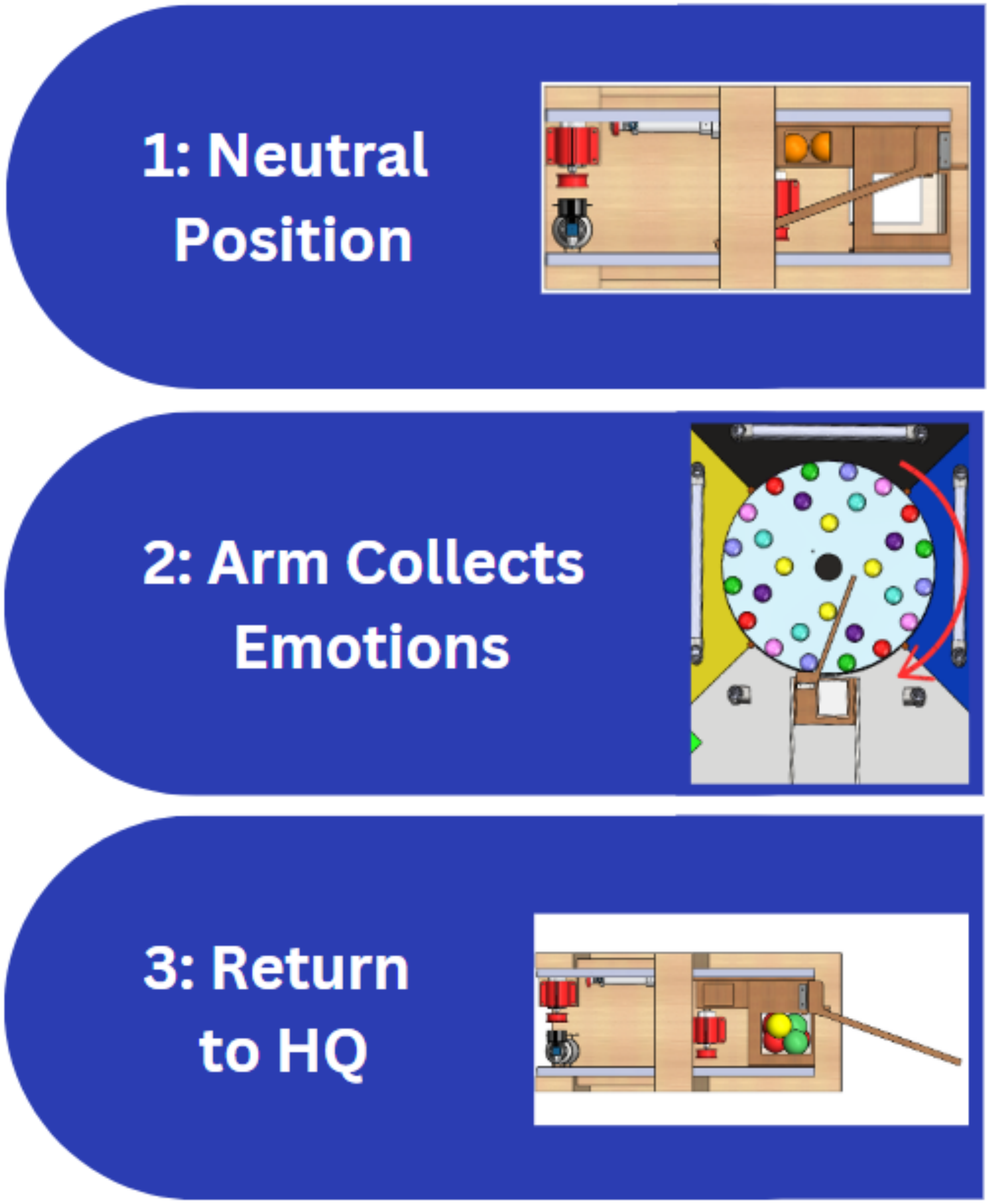


Figure 7: Collecting Emotions Graphic

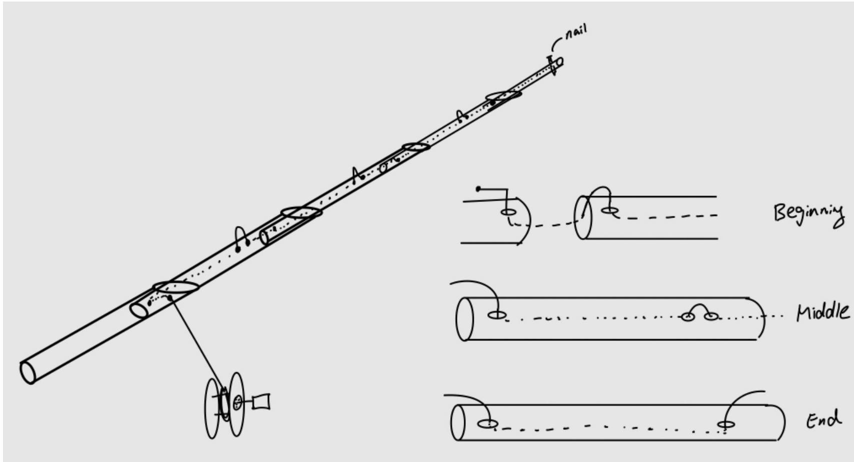


Figure 8: Raising Sadness PVC Graphic of Mechanism

Figure 9: Final Design of “The Depresant”

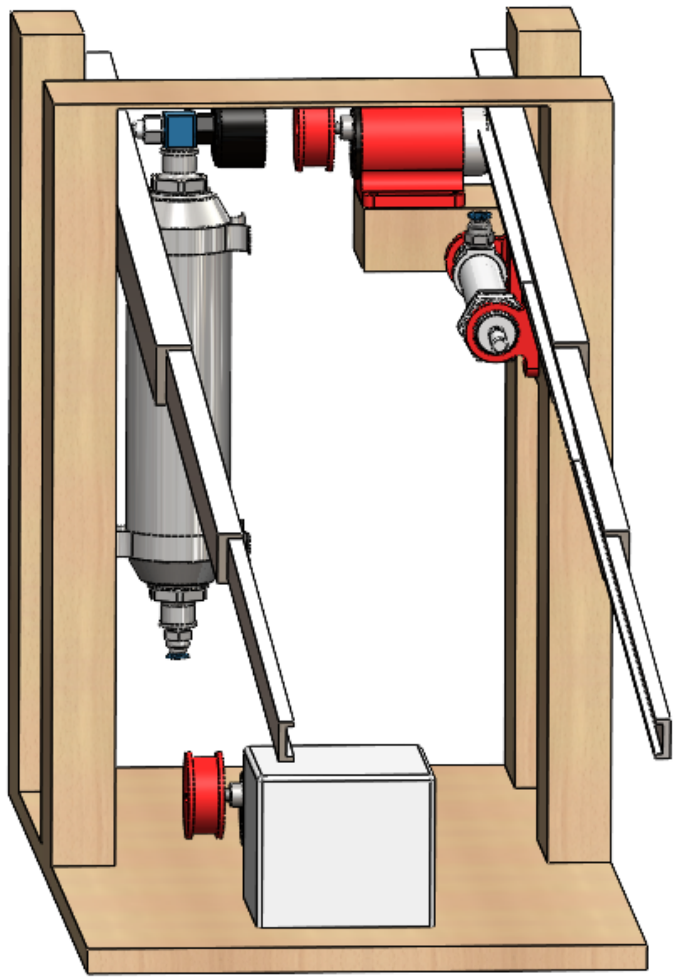


Figure 10: Base Mechanism of “The Depresant”

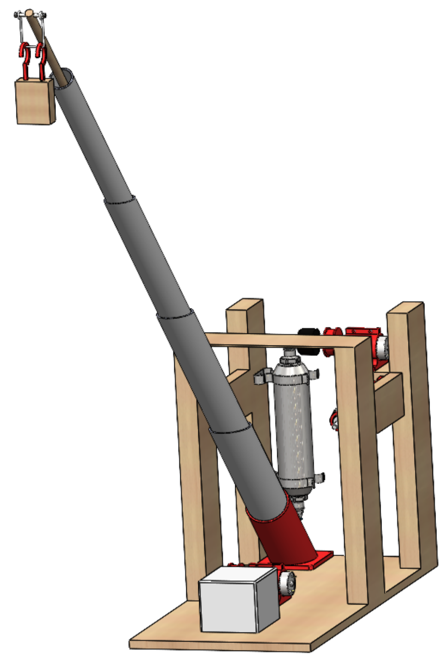


Figure 11: Raising Sadness via a telescoping PVC pipes

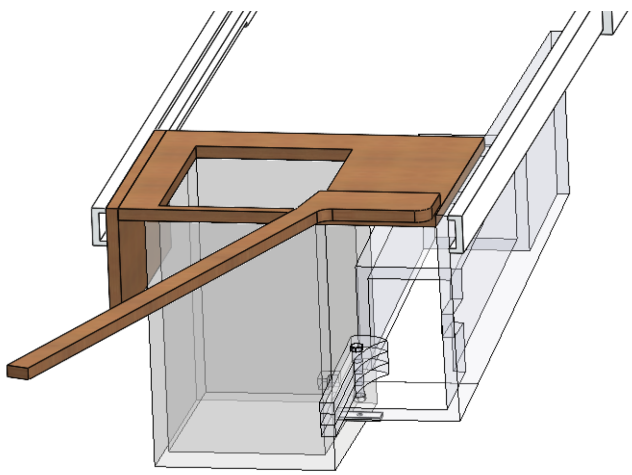


Figure 12: Collecting Emotions via a mechanical spring-loaded system

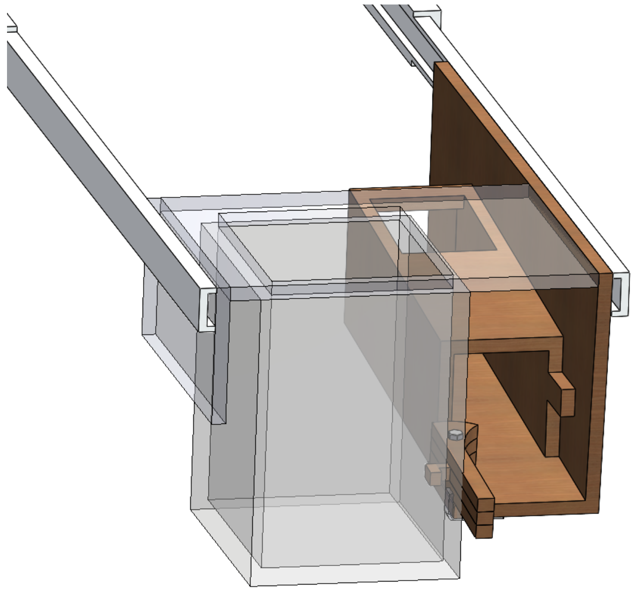


Figure 13: Dispensing Mind Manuals via a mechanical detection system using a rubber-band actuation.

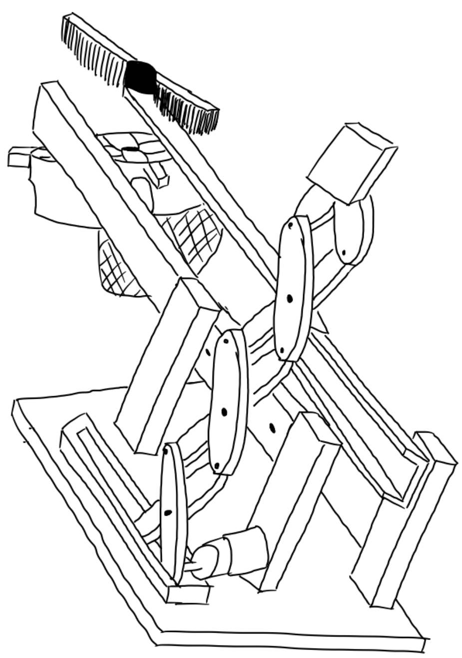


Figure 14: Conceptual Design Alternative Design 1 (Brush Alternative) for The Depressants Robot

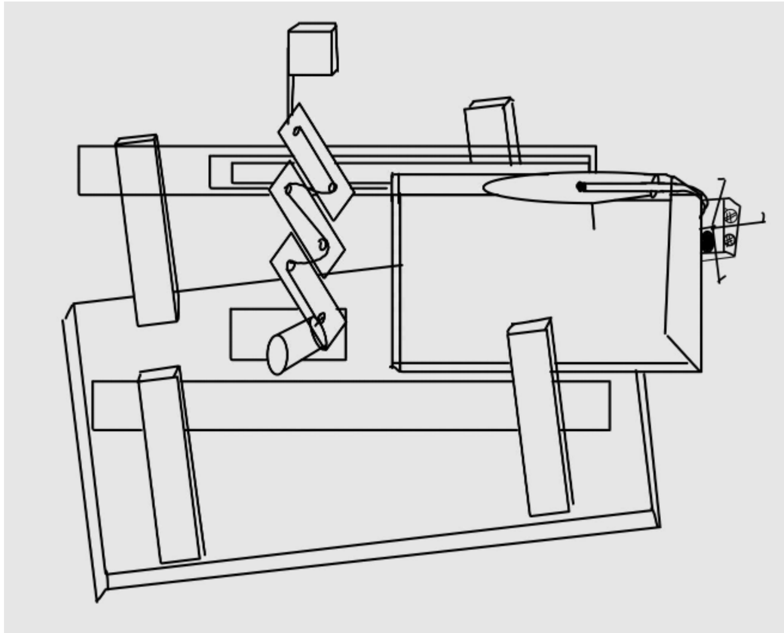


Figure 15: Conceptual Design Alternative Design 2 (Slant Alternative) for The Depressants Robot

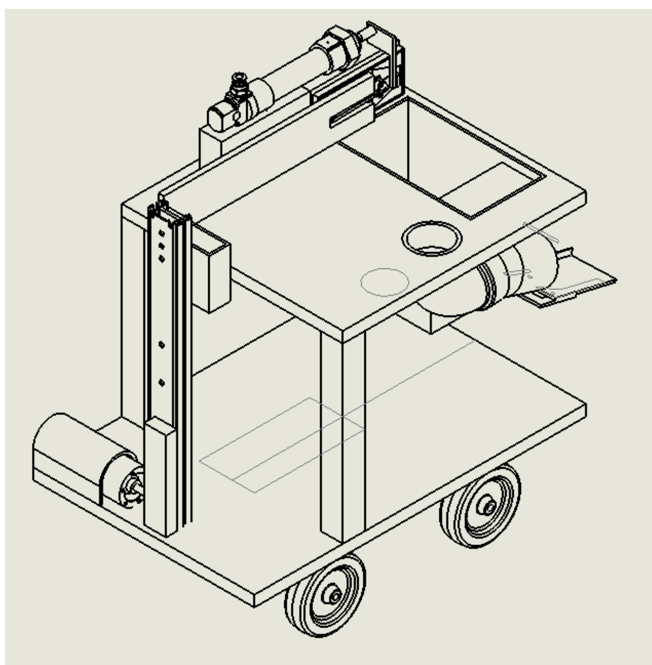


Figure 16: Conceptual Design Alternative Design 3 (Box Alternative) for The Depressants Robot

Table 2: Bill of Materials and Initial Component List

Bill of Materials: Project/Product Development									
Project:	*ME 2110 Final Project - The Depresants*								
Engineering Team:	"The Depressants"			*Arsh Ali* *Isiah Boktor* *Luke Kim* *Jinwei Zhang*					
Date: 11/13/2024									
				Functional Analysis	**Mfg. + Other Analysis**				
Module/ Part #	**Description/Name**	**Qty**	**Unit Cost**	**Function**	**Mfg. Process**	**Dimensions**	**Mass**	**Material**	**Other Physical Properties**
030699335855	Inside Corner Brace - Zinc Plated	4	$ 3.97	Reinforces right-angle joints	Zinc-plated steel	2.5 in.	Light (approx. 0.3 lb)	Zinc-plated steel	N/A
090489695019	3-8ft Select Structural Lumber	4	$ 1.65	Structural wood support	Treated lumber	2x3, 8 ft	Approx. 8 lbs	Wood	N/A
885785122860	Drawer Slide - Full Extension	1	$ 18.98	Full extension drawer stability	Cold-rolled steel, zinc-plated	22 in.	Approx. 1 lb	Zinc-plated steel	N/A
887480253313	Wood Screw - Zinc Flat Head #4 Pack	1	$ 1.38	Secures wood to wood	Zinc-plated steel	#4 x 1/2 in.	Minimal	Zinc-plated steel	N/A
887480276916	Wood Screw - Zinc Flat Head #10 Pack	2	$ 1.38	Secures wood to wood	Zinc-plated steel	#10 x 4 in.	Minimal	Zinc-plated steel	N/A
887480252910	Lock Nut Zinc Plated 1/4 in.	2	$ 1.38	Secures connections in wood	Zinc-plated steel	1/4 in.	Minimal	Zinc-plated steel	N/A
AUC	Hex Bolt - Galvanized 1/4 x 2	4	$ 0.58	Secures wood to wood	Galvanized steel	1/4 x 2 in.	Approx. 0.2 lb	Galvanized steel	N/A
887480018820	Screws - Zinc Flat Head #10	1	$ 7.97	Secures wood to wood	Zinc-plated steel	#10 x 1 in.	Light	Zinc-plated steel	N/A
611942109456	1-1/2 in. PVC Pipe	1	$ 4.98	Extension Component	PVC	1-1/2 in. x 2 ft	Approx. 0.6 lb	PVC	N/A
611942112753	3 in. PVC Pipe - Foam Core	1	$ 9.91	Extension Component	PVC	3 in. x 2 ft	Approx. 0.5 lb	PVC	N/A
611942112579	1/2 in. PVC Pipe	1	$ 2.31	Extension Component	PVC	1/2 in. x 2 ft	Approx. 0.2 lb	PVC	N/A
611942112562	1 in. PVC Pipe	1	$ 4.24	Extension Component	PVC	1 in. x 2 ft	Approx. 0.4 lb	PVC	N/A
Wood Sheet	BCX Sanded Plywood	1	$ 16.75	Base wood	Sanded Lumber	1/2 in. x 2 ft. x 4 ft.	Apporox. 7 lbs	Wood	N/A
Zach's Print Shop #1	Custom Spools	2	$ 2.81	Egress and Raise Sadness	3D Print	4" Diameter	Minimal	PLA	N/A
B00J7RVG8M	TETRIX MAX Motor Hub	2	$ 3.25	Protect Spool from stripping	Insert Molding	0.8" Diameter	Minimal	Steel	N/A
	TOTAL		**$ 109.96**						

Table 3: Final Testing Data

Testing	Actuation	Emotions	MM	Sadness	Total
Trial 1	10	0	0	16	26
Trial 2	10	45	48	7	110
Trial 3	10	45	48	7	110
Trial 4	10	4	0	7	21
Trial 5	10	6	0	16	32
Trial 6	10	45	48	7	110
Trial 7	10	45	48	27	130
Trial 8	10	45	48	27	130
Trial 9	10	45	48	27	130
Trial 10	10	45	48	27	130
Average	10	32.5	33.6	16.8	92.9

Table 4: Final Competition Data

Final Comp	Actuation	Emotions	MM	Sadness	Total
Round 1	0	0	0	0	0
Round 2	10	72	48	27	157
Round 3	0	0	0	0	0
Average	3.3	24	16	9	52.3