ENGINEERING

McMaster University

Project Four – Power in Community

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial 03 & 15

Mon 53

Danielle Fong (fongd5)

Chuyuan Xie (xiec19)

Stephen Dorssers(dorssers)

Mohammad Muntazar Bhurwani (bhurwanm)

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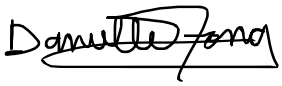
Danielle Fong 400333388



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Chuyuan Xie 400312109

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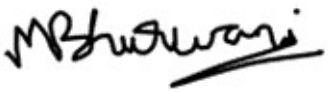
Mohammad Muntazar Bhurwani 400296770



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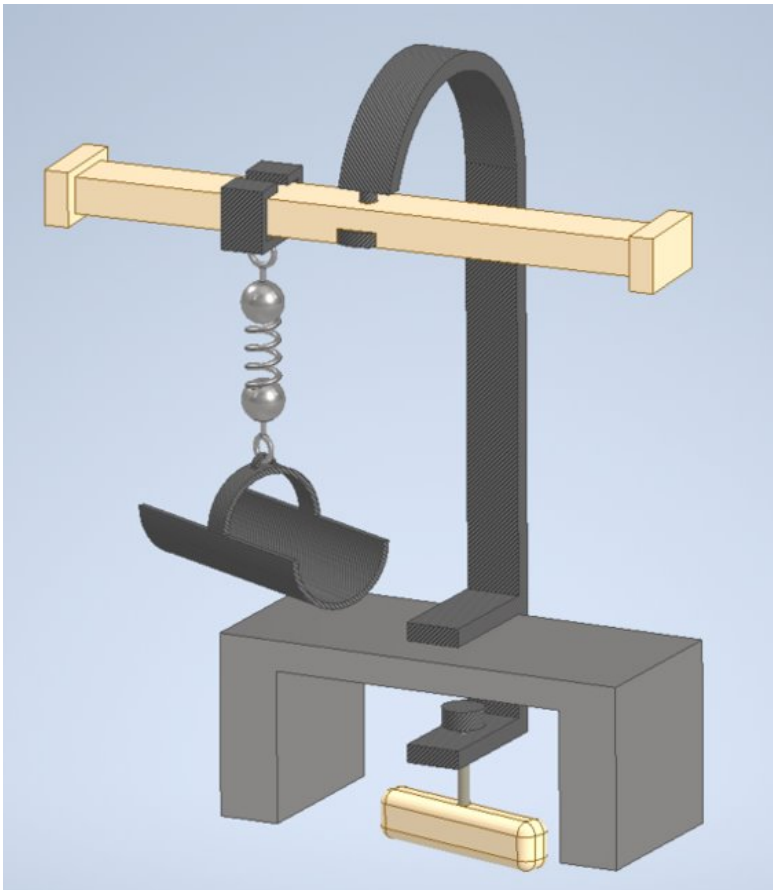
Stephen Dorssers 400330162

Executive Summary

The goal of this project was to design a device for our client, Alanna, who is diagnosed with autoimmune diseases that prevents her from painting for long periods of time. Our device, Easel Stable, was designed to support Alanna's arm and provide her stability when she's painting so she can paint for a longer duration. The design consists of a U-shaped arm support that is connected to a vertical spring that hangs on a rotatable bar. The spring can shift along the bar and be stretched when the client places her forearm on the arm support. The bar is connected to a stand with a clamp that can be adjusted by turning the gripper.



Easel Stable is a lightweight and portable design which allows the client to paint on the ground or on an easel since the clamp can be adjusted and attached to any surface. The bar and spring can be rotated, shifted, and stretched to cover every surface of a canvas. Moving forward, if given more time and resources, we could add a mechanism to control the speed of rotation for the bar that would best suit our client so she wouldn't require a lot of force to move it, but it also wouldn't be too loose and unstable to use. Furthermore, we could also implement a height adjustment to the stand so the reach is not restricted to only how far the spring can stretch.

Introduction

Our client Alanna has developed an autoimmune disease, got in a car accident causing several injuries, and was diagnosed with breast cancer several years ago. Because of these instances, she now has difficulties with gripping thin objects and holding her arm up to paint for a long period of time. However, none of these obstacles deterred Alanna's passion for art, and her artwork continues to help her stay positive. Therefore, we decided to help her to fulfill her dream of creating meaningful artwork that benefits herself and others.

Our goal was to design a lightweight, durable solution to support the weight of Alanna's arm when she's painting. It should also provide her control when she's painting and provide an easier grip with thinner brushes in her hands so she can paint intricate designs without any pain and difficulty. Furthermore, the solution should give comfort to Alanna when she's painting, allowing her to paint for a longer period and complete more of her artwork, so she can express herself freely through her artwork and share a message of positivity with the world.

The design should be light enough for the client to easily move it around, and comfortable when in use because the main goal is to allow the client to work for a longer period to complete more of her artwork. Some more objectives would be making the product stable so it will not shift easily when force is applied, portable for the client to use it anywhere she likes, and durable so the device can withstand prolonged use. Some of the constraints are that the device must be within a 5-10 lbs range as this is the max weight that Alannah can lift.

We conducted research and learnt about our client's difficulties with her hand from a medical document named "Give Grip Strength A Hand" [1]. We then found an existing commercial product called "Active Hands" [2], which allows the users with poor hand function to grip objects from pencils to garden tools and many more, realising that might help her. This product is related to our client's situation and inspired us making one of our initial designs. Also, a patent named Adaptive Arm Support Systems and Methods for Use inspired us to make an arm support for the client [3].

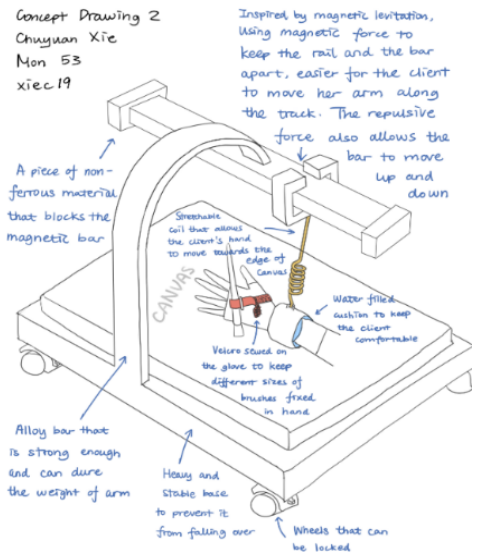
Conceptual Design

Morph Charts

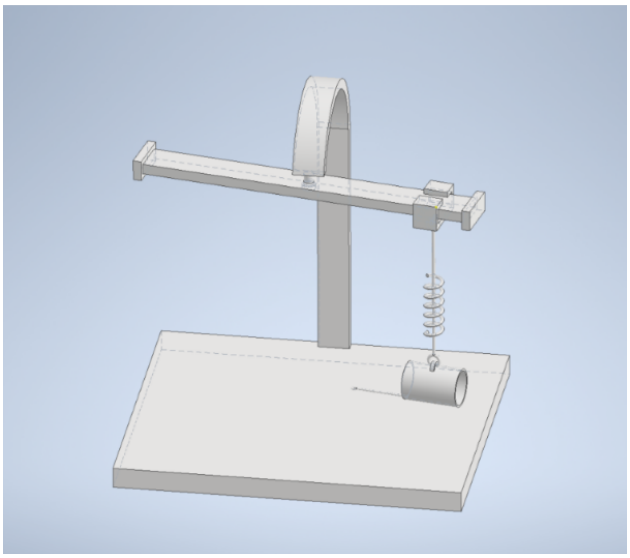
Functions	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5	Mean 6	Mean 7	Mean 8	Mean 9
Allows to hold thin objects	Gripper	Handle	Strap	Magnet	Grooves	Glue	Sandpaper	Straw-like tube	Add a wide handle to object
Support and stabilize arm	Adjustable stand with place to put arm	Table or platform that can be rested on	Shoulder strap arm support	Long bar that arm can be rested on	Hanging strap that user can place arm into	Exoskeleton for arm			
Provide comfort to user	Cotton fabric	Cushion	Feathers	Sponges	Foam	Ergonomic shape	Bean bag	Water filled cushion	
Device can withstand prolonged use	Strong materials (high young's modulus)	Interwoven structure	Waterproof coating spray	Triangular structure	Honeycomb structure	Metal coating			

The morph chart allows us to list all the functions we envision to see in our design solution while noting down every possible mean for us to accomplish that. It opens a wider range of creativity while ensuring we keep in mind the design objectives and needs of the client. The matrix allows us to explore different combinations and alternatives of achieving our end goal.

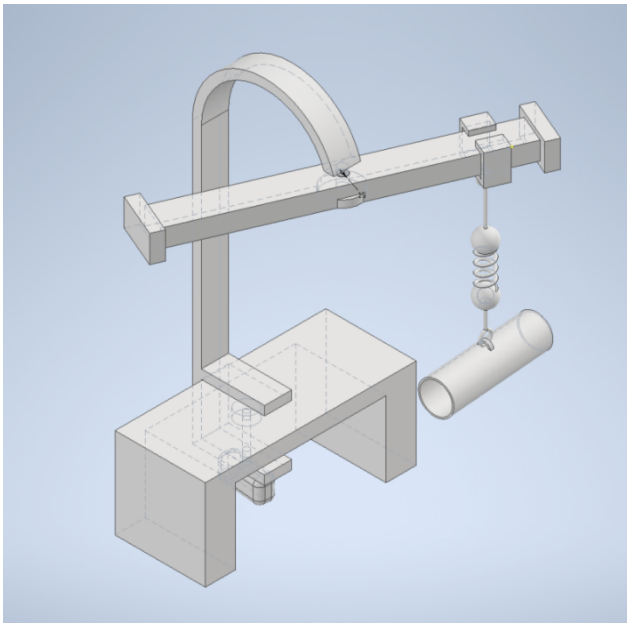
Design Ideation



Initial Sketching



Initial Prototype



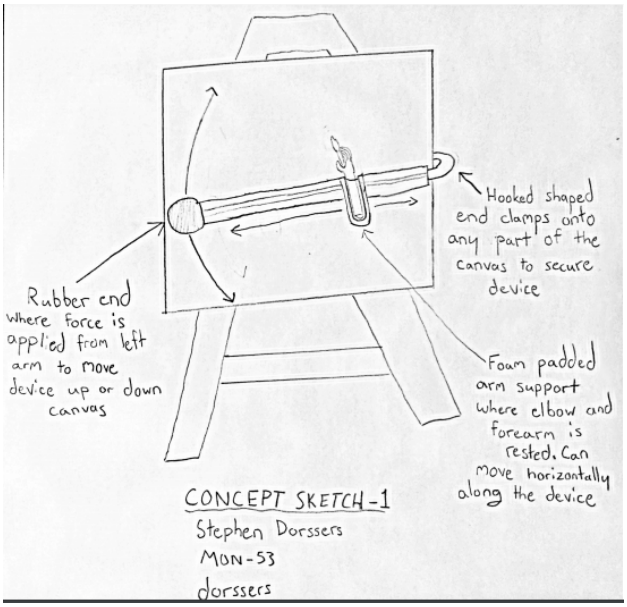
Refined Prototype

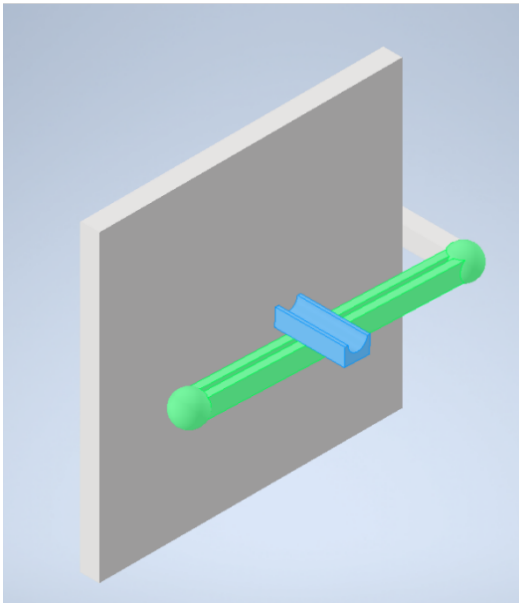
For the initial prototype, we decide to design a stretchable strap that fits the client's hand and brushes in stead of Velcro, increasing the length of the bar and use a smaller base that can attach to the table. The interviewer suggested to ensure the part around the wrist is waterproof or washable, and make sure the rail at the top can reach all positions of the canvas.

There are a couple features changed in the refined prototype, notably the device can now be screwed to a base using a clamp so that the client can move the device to different places in her studio where she places the base. This refinement came from Professor Bosco's suggestion to make the device more portable (portability is an objective of the design) as the original design had a permanent, unattachable base that would be too heavy for the client to move (since 5-10 lbs is the client's constraint to lift objects). The length of the tube that acts as the arm support for the client was extended in length to fit the client's forearm so that her arm could be fully supported during painting (this was also a design objective). This refinement was made due to peer feedback. Our group also decided on a cotton, removable lining to add to the arm support to make it comfortable (objective) and washable as suggested by one of the science students.

Science students give out several feedbacks on our refined prototype as well. The bar could be dangerous if it rotates in a high speed, and it might be hard for the client to screw in clamp to the base.

Design Alternatives





For the design with moveable arm support attached to canvas, peers suggested us to find a better way to clip the device onto the canvas, maybe by attaching it to both sides and find a way to allow the device to move up and down a canvas. The interviewers suggested to make sure that the bundle can rotate to reach all the degrees of freedom, potentially adding another handle to be placed on another part of the canvas, and not to limit the location of the bundle so it can be used on different parts of the canvas.

Refer to Appendices Section 3 to view more design alternatives.

Decision Matrices

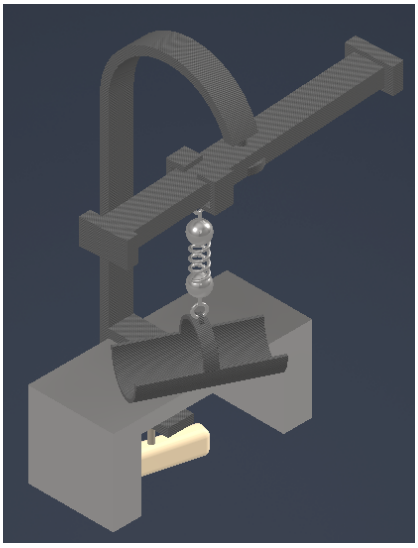
Design Objectives, Functions, Constraints	Priority (5 = most important)	Moveable arm support attached to canvas.	Hand gripper to hold various paint brush sizes	Magnetic levitation bar with water-filled cushion	Arm support with gripper.
(C)Less than 5-10 lbs needs to be lifted	2	3 (multiply score by priority and add to get total)	3	3*2 = 6	2*2 = 4
(O)Comfortable gripping of paintbrush	3	0	3	2*3 = 6	1.5*3 = 4.5
(O)Stabilize arm	5	3	0	3*5 = 15	3*5 = 15
(O) Portability	1	2	3	2*1 = 2	1*1 = 1
(O)Durable and can be used for a long period of time	4	3	3	3* 4 = 12	2*4 = 8
Total		**35**	**30**	**41**	**32.5**

Our team chose to use a decision matrix along with priorities assigned to the functions and objectives stated. This allowed us to weigh the criteria we would like to see, relatively among all 4 of the design solutions. By ranking and calculating the final score, we arrived at 2 solutions that we ranked highest even outside of the matrix due to the concepts involved.

Keeping in mind the client's needs, the criteria were chosen such as stabilising the arm and a durable solution that is comfortable in long time use. We also had to ensure that the paintbrush is gripped well to allow finer painting. The device must also be portable and not hard to carry or move, which would otherwise defeat the purpose of a design solution. We wanted to focus on allowing the client to have stability when painting so she could paint for a longer duration, allowing her to complete her artwork. With these main objectives in mind, we decided to score stability for the arm and durability for the solution to be used for a long time as our top priorities.

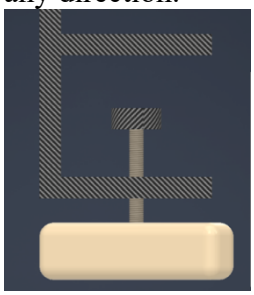
As for the metrics, we used a scale from 0-3 to rank how each design solution fared against the criteria put forward.

Final Proposed Design



Our final design solution ‘Easel Stable’ is shown in the picture after multiple refinements and improvements were implemented on earlier sketches.

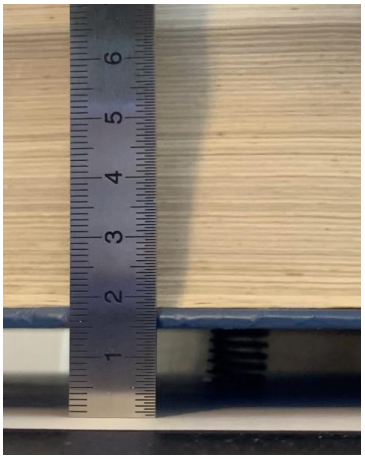
It consists of a U-shaped arm support hanging from the base by a stretchable spring. This open design allows the client’s arm to be placed comfortably without being pressed on or constrained from all sides. The spring allows her to adjust the height from the stand to paint in any position she requires. The spring hangs onto a sliding connector that contains a slit through the middle. The purpose of the slit is to ensure the connector can slide through the entire length of the arm, thus covering the entire surface area of the canvas or stand. The arm support as well as the metal bar can be rotated in any direction.



The bottom of the base contains an oval shaped clamp that acts as a screw to hold on to any surface the client wishes to paint on. The shape as well as the ease of rotation requires less motor skills to screw on than usual clamps keeping the difficulties faced by the client in mind.

Some unique specifics of the design include a 360 degree rotatable support, sliding joint to cover all edges of the canvas, simple clamp that allows the device to be portable and mounted anywhere.

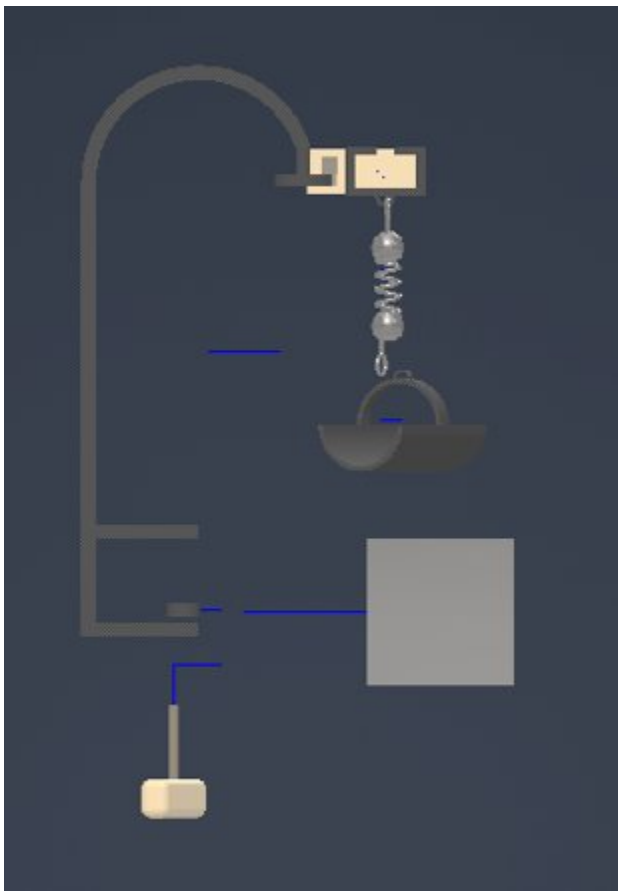
Although not visible in the CAD design, we also plan to have an inner lining made of a comfortable material or a water-filled cushion on the arm support to soften the pressure faced by the forearm.



The design solution implemented the original constraints that we thought of in earlier milestones. These were reiterated using our test plans. Using the various features available on Inventor allowed us to verify them. The total mass of the device was calculated to be 5.90 lbs which can be considered as lightweight and portable for a design solution. We also used the stress analysis to ensure that the arm support could remain stable by using the weight of an average human arm or forearm (1 – 1.5 lbs). Our final test plan included the stretchable spring to ensure easy displacement in the vertical axis. This was done using physical objects and calculations involving the spring constant. The trials conducted output results in the range of 1.4 – 1.7cm of displacement leaving enough gap to allow the client to easily paint on the canvas.

Regarding the materials of the device, many of the components of the “Easel Stable” had CFRP (carbon-fiber reinforced polymer) chosen as the material to be used with the exceptions being the bar and base screw components which are the material polyethylene and the coil components which are made of stainless steel. Stainless steel was chosen for the coil parts as this is simply a common material that springs are made from making these parts easily accessible. CFRP was chosen for many parts of the device because the material has a high Young’s modulus and tensile strength while also being relatively lightweight compared to other materials of its strength and stiffness. This strength, stiffness and lightweight properties of CFRP fulfills the objective of keeping the device durable and the constraint of keeping the device in a below a certain weight. One drawback of CFRP material is its high price. To help lessen the price and further decrease weight of the device, polyethylene was used for parts that did not need the high strength that CFRP provides. For a full breakdown of the costs and materials of each part refer to the “Bill of Materials” in appendix section 3.

The construction of the “Easel Stable” would be simple if it is physically constructed as there are not too many parts to the device. The construction is shown in the figure below where the arm support is connected to the rings on spring, the bar where the spring hangs from can be screwed onto the base, and the clamp at the bottom can be inserted and screwed into the base.



Conclusions

While the “Easel Stable” may have gone through many design changes and refinements, there are still many improvements that could be made to this design to further increase its validity for the client. The obvious next step for this device would be to physically construct it because although the CAD model is a great start, the only way the client could benefit and test the device is by using it when it is constructed. Also, as an improvement a locking system could be added so that the client could prevent the arm support portion of device from moving allowing her to paint without the possibility of a small movement in the device causing a mistake. Unfortunately, because a physical prototype was not made, the comfortability of the device could not be tested. However, if a physical prototype is built the shape of the arm support could be tested to find the optimal shape for the client’s arm to rest on. It was hypothesized that a water-filled cushion on the arm support of the device would be more comfortable for the client, but this would also need to be tested on a physical iteration to test the validity of this claim. Overall, this design offers a reliable solution to the client’s problem of arm fatigue after prolonged periods of painting. This conclusion is supported from the testing of the device where the device was determined to be light enough such that the client can transport it, the device’s arm support was durable enough to withstand the force of the client’s arm, and the device’s spring was flexible enough that the client could be able paint on a canvas rested on both flat on a table or propped up on an easel.

The entire design process of this project offered many challenges, but our team was able to learn important lessons because of these challenges that will help us in our future as engineers. Our team learned to spend plenty of time on the early stages of the design process such as the decision matrix and problem statement as these set a clear goal for the project and laying out ideas this way allowed us to explore many options first instead of focusing on only one possible solution. This knowledge can be applied to any future engineering projects our group members pursue as it is necessary to spend adequate time on the planning and idea exploration stages of the design process so that a solution can be developed properly and address the problem(s) it is designed for. Our team also learned the importance and strength of considering all ideas of others and using critiques to one’s own advantage. Each of us had different ideas as shown in appendix section 2 “Sketches”, and although most of these sketches did not end up as the final design, some of these ideas were combined to create a better design overall. Listening to feedback from both peers, instructors and other students made us recognize flaws and weaknesses in our design which allowed us to properly refine our device to its final version. Considering, comparing, critiquing and implementing team members ideas in an engineering project is crucial for the success of that project. Therefore, these collaboration skills we developed during this project will surely help us in our future engineering projects.

List of Sources

[1] "Give Grip Strength a hand". Harvard Health Publishing, November, 2016. [Online]. Available: https://www.health.harvard.edu/healthy-aging/give-grip-strength-a-hand [Accessed March 13, 2021]

[2] M. Hagen. "Active Hands – Frustrated By The Limitations Caused By Weak Grip Or Poor Hand Function?", Closing The Gap, Mar 31, 2019. [Online] Available: https://www.closingthegap.com/active-hands-frustrated-by-the-limitations-caused-by-weak-grip-or-poor-hand-function/. [Accessed Mar 08, 2021]

[3] Mark C. Doyle, "Adaptive arm support systems and methods for use". US20200038278A1. Enhance Technologies LLC, Jan 18, 2011. Available: https://patents.google.com/patent/US20200038278A1/en?q=arm+support&oq=arm+support [Accessed March 13, 2021]

[4] Steve Golden, Nathaniel Cohen, Ronald Joseph, Marc Safran. "Shoulder immobilizer and fracture stabilization device". US10918513B2. Nov 18, 2009. Available: https://patents.google.com/patent/US10918513B2/en?q=arm+support&oq=arm+support&page=1 [Accessed March 13, 2021]

[5] A. Mohammed Rashed, N. Abdel-Wahab, E. M. M. Moussa and N. Hammam. "Association of hand grip strength with disease activity, disability and quality of life in children and adolescents with Juvenile Idiopathic Arthritis", US10918513B2, BMC- Part of Springer Nature, June 28, 2018. Available: https://advancesinrheumatology.biomedcentral.com/articles/10.1186/s42358-018-0012-1 [Accessed Mar 08, 2021]

Appendix Section 1

Patents

US20200038278A1 [3]

US10918513B2 [5]

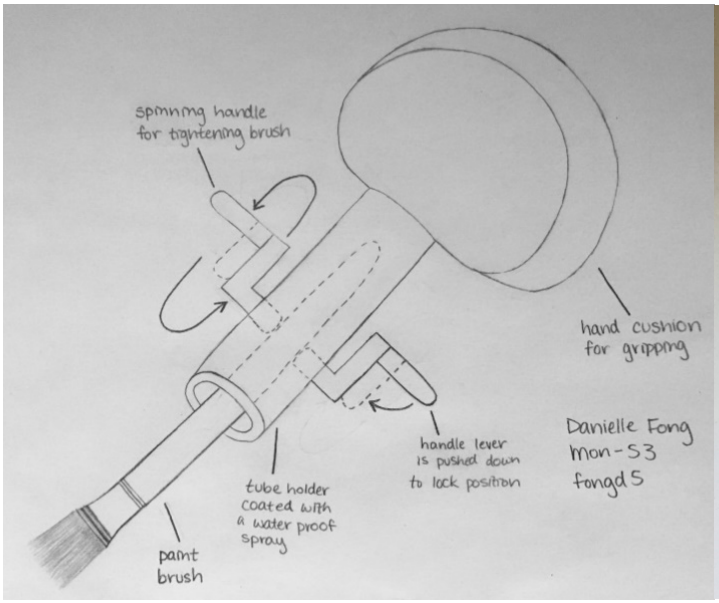
Commercial Products

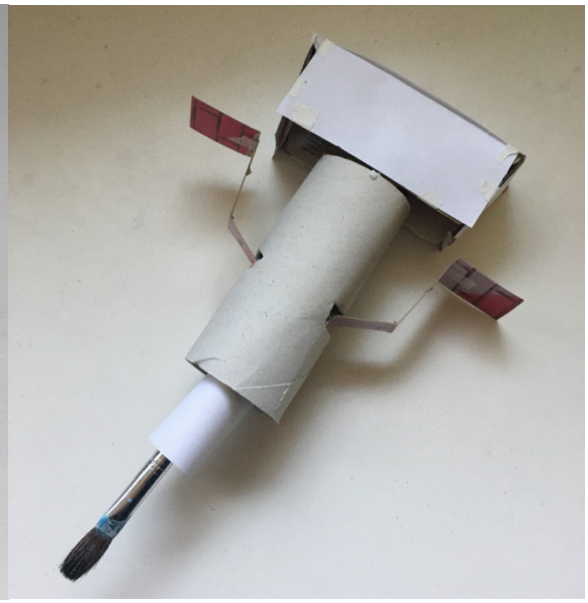
Active Hands designed by Marc Hagen [2]

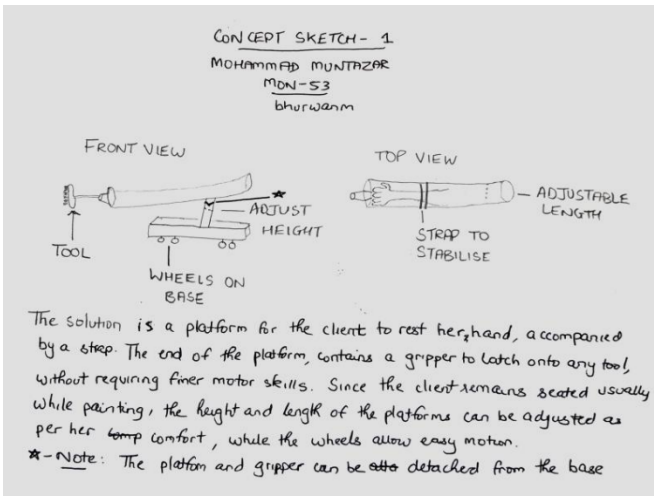
Medical Documents

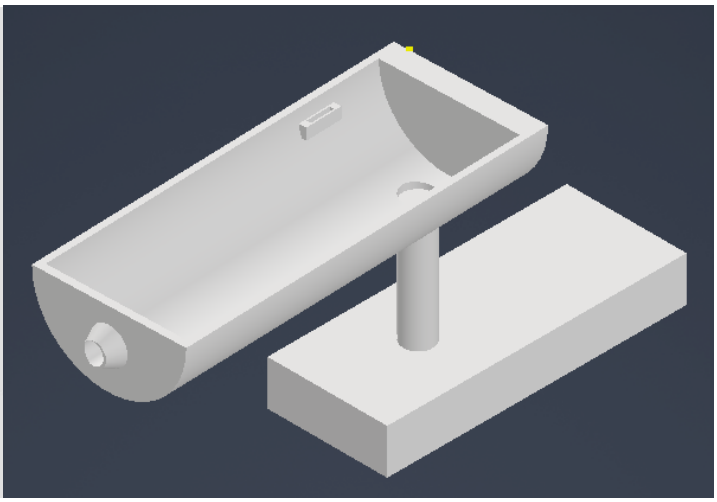
https://www.health.harvard.edu/healthy-aging/give-grip-strength-a-hand [1]

Design Alternatives









Objective Tree or How/Why Ladder

We chose to use the How/Why Ladder instead of the Objective Tree. The How/Why ladder allows us to delve deeper into why we are helping our client, while the Objective Tree does not provide that same functionality. The Objective Tree would help us plan what our solution should accomplish and what constraints that solution must have, but it would not tell us the bigger goal of the project, such as the specific problems we are trying to help the client overcome. The How/Why ladder allows us to focus on the design objectives for our solution using the How side, while also using the Why side to focus on the fact that we are creating this solution for a client's specific goals and needs. The Ladder also allows us to branch out and have multiple thought processes without comprising on any idea.

Client Meeting Notes

- Mobility challenges and pain makes things more difficult (bending at the waist)
- Largest work she has done is the one at the back.
- 5 to 10 pounds is her maximum load.

- Prefer to paint in studio on her own hand.
- Would like to raise plants from seeds.
- Would like to plant flowering plants.
- Range of motion when hands in pain: muscle freezes up and can't hold the brush at all, but range of motion of arm is not affected as much as holding.
- Gripping for a short term of time will make her uncomfortable and painful.
- Wrist dimension: 5- and three-quarter inches
- The client uses variety type of brushes.
- She hasn't tried any painting methods that involved changing her hand placements/ hand positions. She says it may affect her intricate paintings, but that she is adaptable.
- Ankylosing Spondylitis (look up how to spell this), affects the base of her spine, but this does not affect the pain in her hands, no swelling in her hands. The pain is only from nerve damage and sometimes from her other conditions. She also might have arthritis.
- All her activities are more difficult. Bending is one of her huge problems.
- Her max lifting is 5-10 pounds depending on her lymphedema.
- Only likes to paint in her studio, so should focus on helping in this space.
- She would like to plant seeds, but right now only buys pre-planted. Wants more flowering plants.
- When she has muscle spasms in hands she cannot hold a position which obviously affects her paintings.
- May kneel on a meditation cushion and put a canvas on a coffee table to paint. May literally lie on the floor with the canvas on the floor to paint (she has carpet thankfully).
- Her wrist size (right side dominant) 5 and 3 quarters inches at the base. Her left side is the same.
- She uses many brush sizes depending on the message she tries to convey with her art. She does use her fingers to make adjustments in her paintings.
- Bearing the weight of her arms even makes her feel pressure in her lats and back especially when holding things.
- Lying on the ground allows her to conserve her energy.
- Her hand length is (from tip of middle finger to wrist) is 6 and a half inches, and her hand width (where thumb starts to other end) is about 4 inches.
- She is fine with it being portable or non-portable as long as she can use it individually.
- Painting would be her primary target for a solution. It is her way to leave a positive impact on the world. Paintings are an expression of herself. A solution should still allow her to express herself creatively, only enhancing her abilities not changing how she is able to express herself.

- She holds her brushes similar to holding her pen and does brush strokes like writing she says. Maybe look into how people who have pain in her hands get help with writing.
- She shakes her hands to sometimes relieve pain, sometimes even she shakes her arms out. Runs her hands under warm water to relieve pain.
- Her floor space is her room is 4 foot by 7 foot, so it is kind of small really.
- Contracting her fingers and holding them in one place can hurt.
- She has a hand stretcher to help with finger strength.
- She prefers silk and cloth fabrics, does not like hard edge fabrics such as Velcro.
- A relaxed grip allows her to feel less pain in her hands. She uses the example that the pen she has she does not need much pressure on paper to write.
- Bigger grip brushes are better for her hands.
- Intricate details would most likely need to be done with the paint brush being held by the hand
- Pain on hands is mainly from nerve damage
- Bending down at the waist is difficult
- Muscle spasms occur when using small paint brushes and limits hand motions or hand loses ability to hold the brush
- Gripping small tools after a short amount of time causes pain and discomfort
- Painting positions are either kneeling/sitting on a floor cushion or lying on the floor to support the body
- A variety of brushes are used and sometimes fingers are used to make fine adjustments
- Pain can either effect the arm first or the fingers first
- Muscles get exhausted easily (arm, torso, back)
- Extending fingers doesn't cause much pain, holding and gripping causes pain
- Measurements
- Wrist size: 5 ¾ in ; Length of hand: 6 ½ in
- Width of hand: 4 in
- Swelling is usually 1 to 2 mm
- Studio dimensions: 4 by 7 ft
- Painting height can go up to 10 feet tall and wide
- Maximum load to lift is 5 to 10 pounds depending on flaring
- Best materials: cotton and silk
- Worst materials: anything with hard edges, velcro, latches
- Allergies: gluten, flower based pre-primed canvases, caution for chemicals

Appendix Section 2

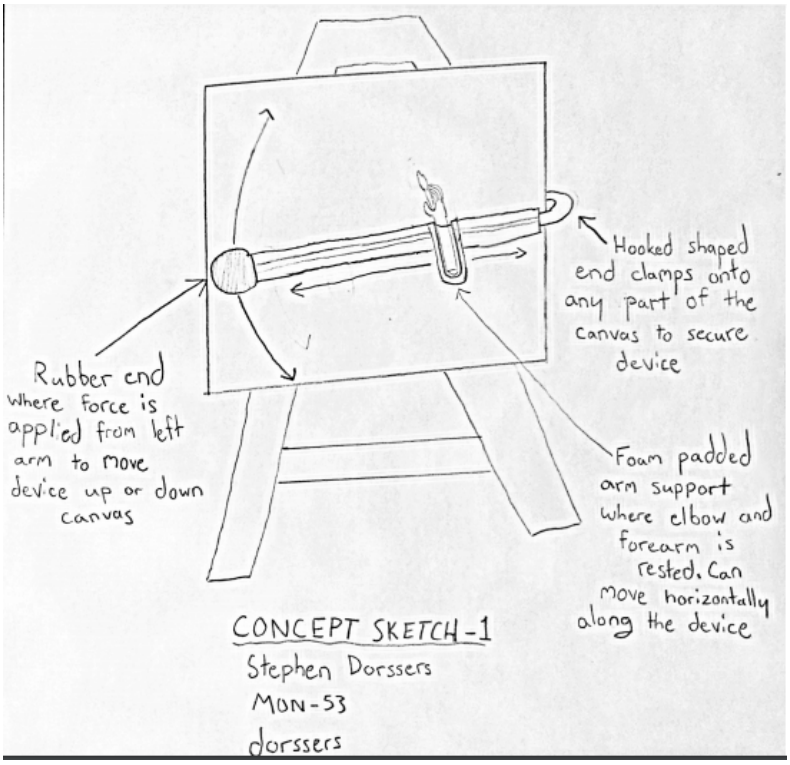
Morph Charts

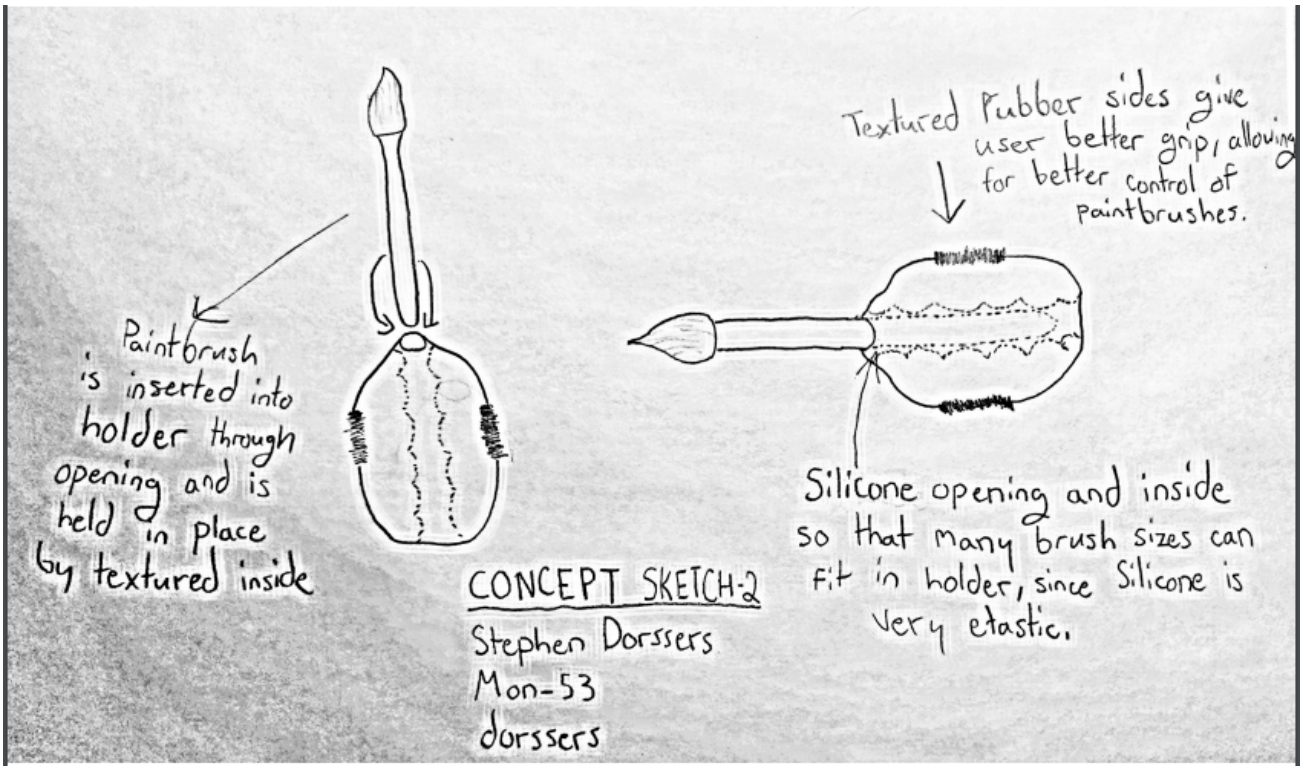
Functions	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5	Mean 6	Mean 7	Mean 8	Mean 9
Allows to hold thin objects	Gripper	Handle	Strap	Magnet	Grooves	Glue	Sandpaper	Straw-like tube	Add a wide handle to object
Support and stabilize arm	Adjustable stand with place to put arm	Table or platform that can be rested on	Shoulder strap arm support	Long bar that arm can be rested on	Hanging strap that user can place arm into	Exoskeleton for arm			
Provide comfort to user	Cotton fabric	Cushion	Feathers	Sponges	Foam	Ergonomic shape	Bean bag	Water filled cushion	
Device can withstand prolonged use	Strong materials (high young's modulus)	Interwoven structure	Waterproof coating spray	Triangular structure	Honeycomb structure	Metal coating			

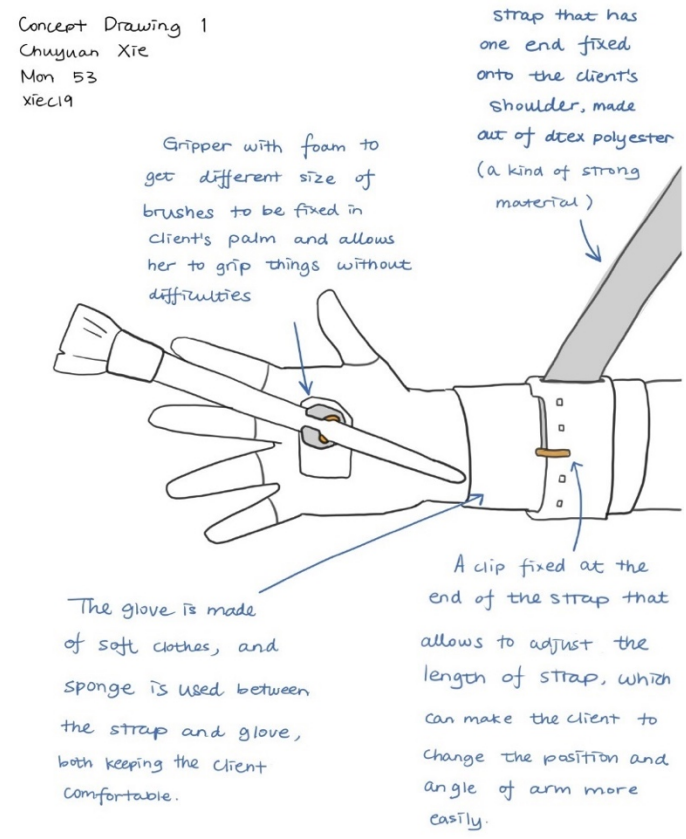
Decision Matrices

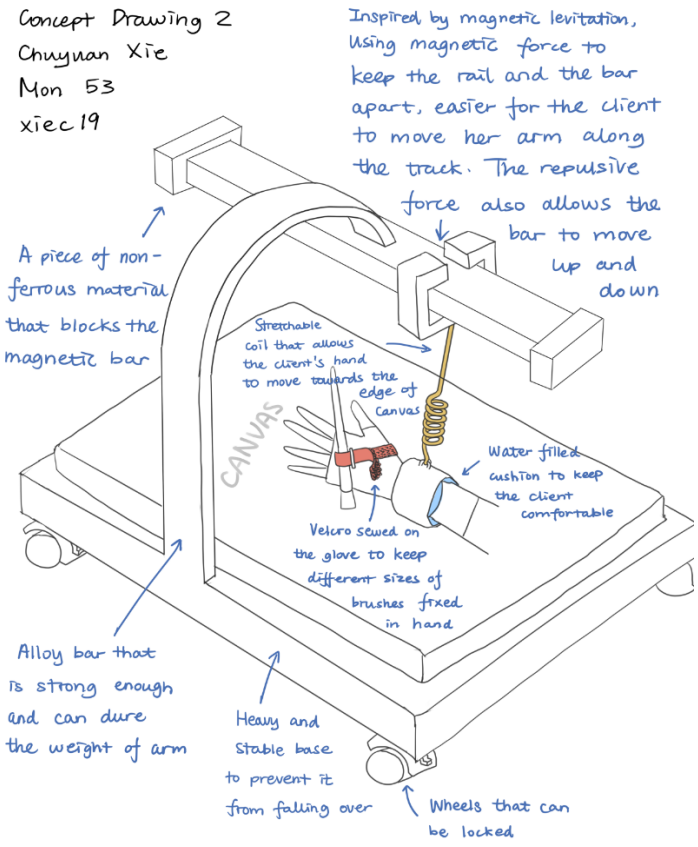
Design Objectives, Functions, Constraints	**Priority (5 = most important)**	**Moveable arm support attached to canvas.**	**Hand gripper to hold various paint brush sizes**	**Magnetic levitation bar with water-filled cushion**	**Arm support with gripper.**
(C)Less than 5-10 lbs needs to be lifted	2	3 (multiply score by priority and add to get total)	3	3*2 = 6	2*2 = 4
(O)Comfortable gripping of paintbrush	3	0	3	2*3 = 6	1.5*3 = 4.5
(O)Stabilize arm	5	3	0	3*5 = 15	3*5 = 15
(O) Portability	1	2	3	2*1 = 2	1*1 = 1
(O)Durable and can be used for a long period of time	4	3	3	3* 4 = 12	2*4 = 8
Total		**35**	**30**	**41**	**32.5**

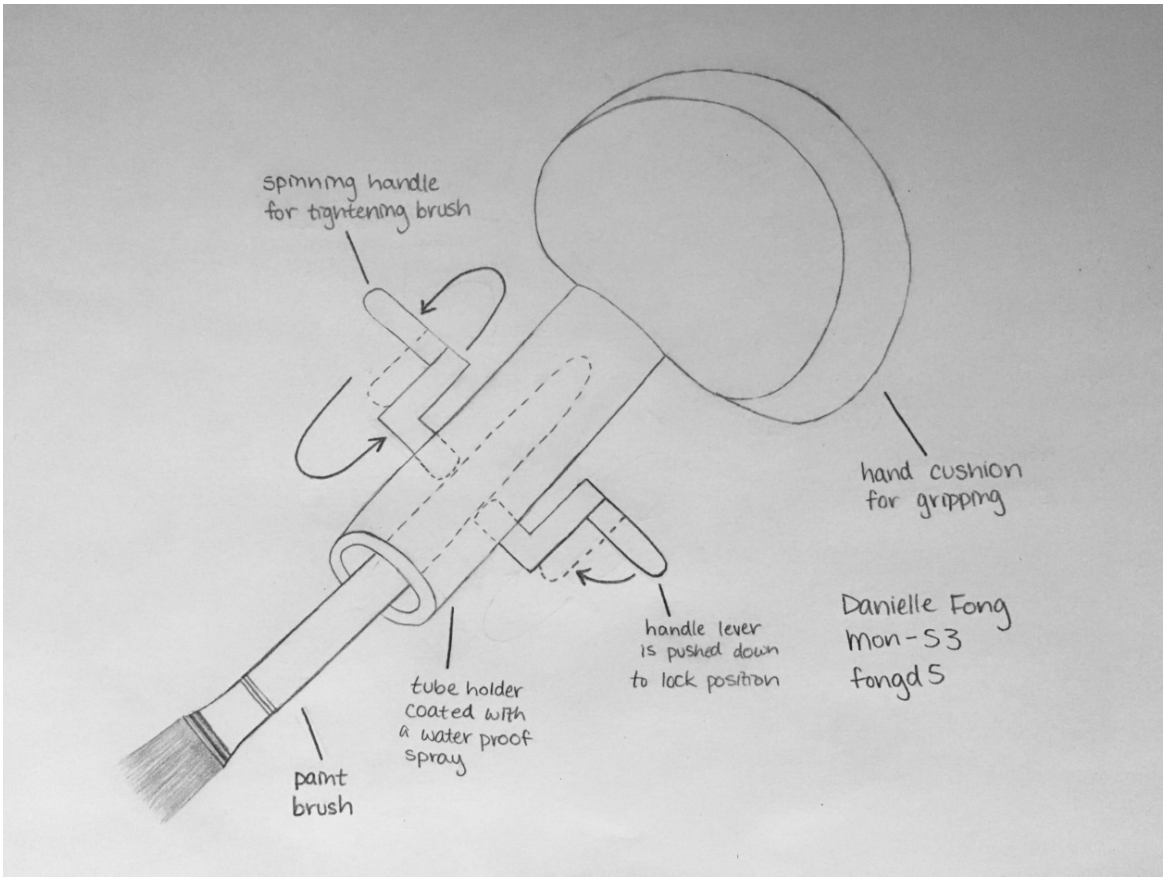
Sketches

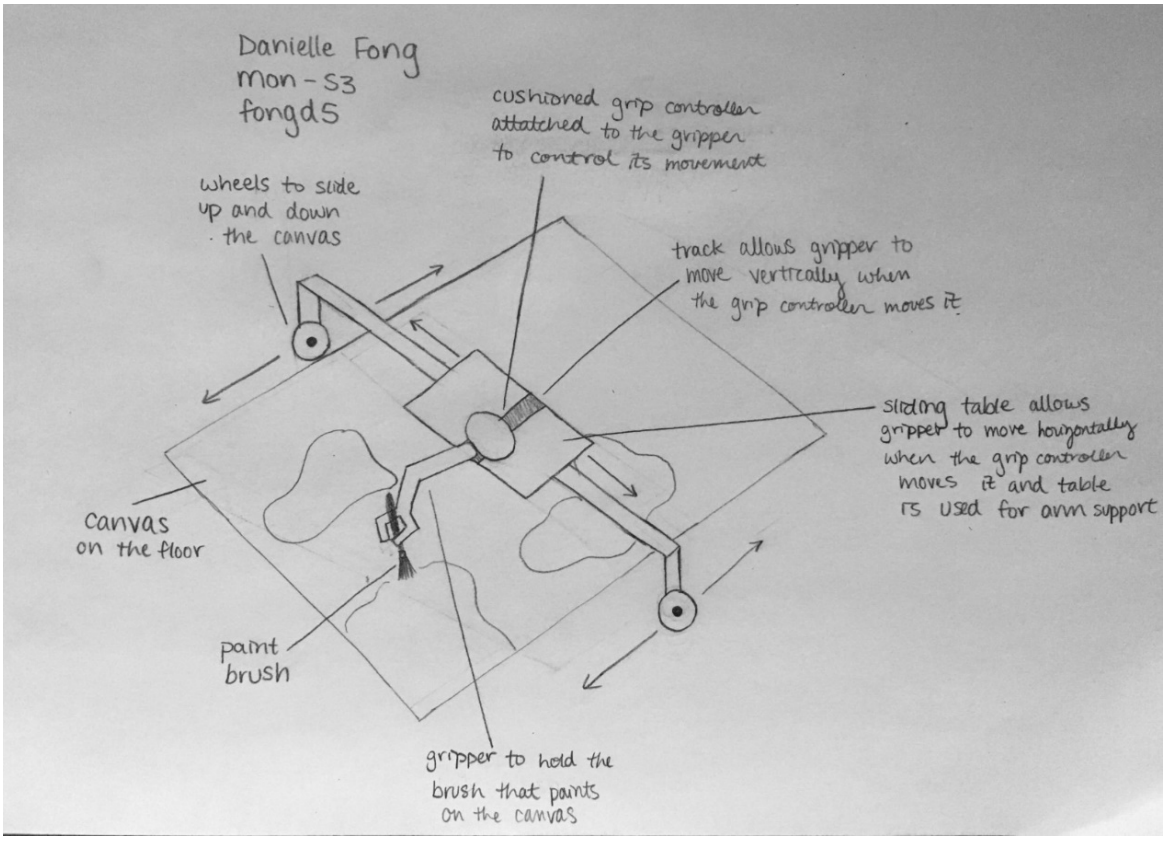

Hooked shaped end clamps onto any part of the canvas to secure device
Rubber end where force is applied from left arm to move device up or down canvas
Foam padded arm support where elbow and forearm is rested. Can move horizontally along the device
CONCEPT SKETCH-1
Stephen Dorssers
MON-53
dorssers


Textured Rubber sides give user better grip, allowing for better control of paintbrushes.
Paintbrush is inserted into holder through opening and is held in place by textured inside
Silicone opening and inside so that many brush sizes can fit in holder, since Silicone is very elastic.
CONCEPT SKETCH-2
Stephen Dorssers
Mon-53
dorssers


Concept Drawing 1
Chuyuan Xie
Mon 53
xiec19
Strap that has one end fixed onto the client's shoulder, made out of dtex polyester (a kind of strong material)
Gripper with foam to get different size of brushes to be fixed in client's palm and allows her to grip things without difficulties
The glove is made of soft clothes, and sponge is used between the strap and glove, both keeping the client comfortable.
A clip fixed at the end of the strap that allows to adjust the length of strap, which can make the client to change the position and angle of arm more easily.


Concept Drawing 2
Chuyuan Xie
Mon 53
xiec19
Inspired by magnetic levitation, using magnetic force to keep the rail and the bar apart, easier for the client to move her arm along the track. The repulsive force also allows the bar to move up and down
A piece of non-ferrous material that blocks the magnetic bar
Stretchable coil that allows the client's hand to move towards the edge of canvas
CANVAS
Water filled cushion to keep the client comfortable
Velcro sewed on the glove to keep different sizes of brushes fixed in hand
Alloy bar that is strong enough and can dure the weight of arm
Heavy and stable base to prevent it from falling over
Wheels that can be locked


spinning handle for tightening brush
hand cushion for gripping
Danielle Fong
Mon-S3
fongd5
handle lever is pushed down to lock position
tube holder coated with a water proof spray
paint brush

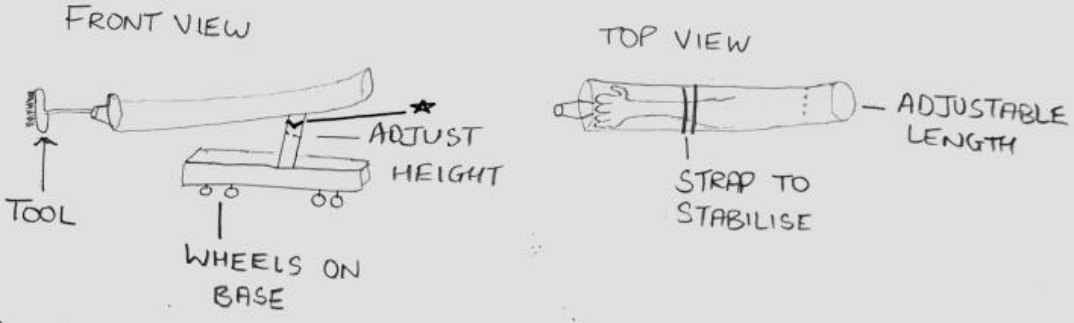

Danielle Fong
Mon-S3
fongd5
cushioned grip controller attatched to the gripper to control its movement
wheels to slide up and down the canvas
track allows gripper to move vertically when the grip controller moves it
sliding table allows gripper to move horizontally when the grip controller moves it and table is used for arm support
canvas on the floor
paint brush
gripper to hold the brush that paints on the canvas

CONCEPT SKETCH- 1

MOHAMMAD MUNTAZAR

MON-53

bhurwanm



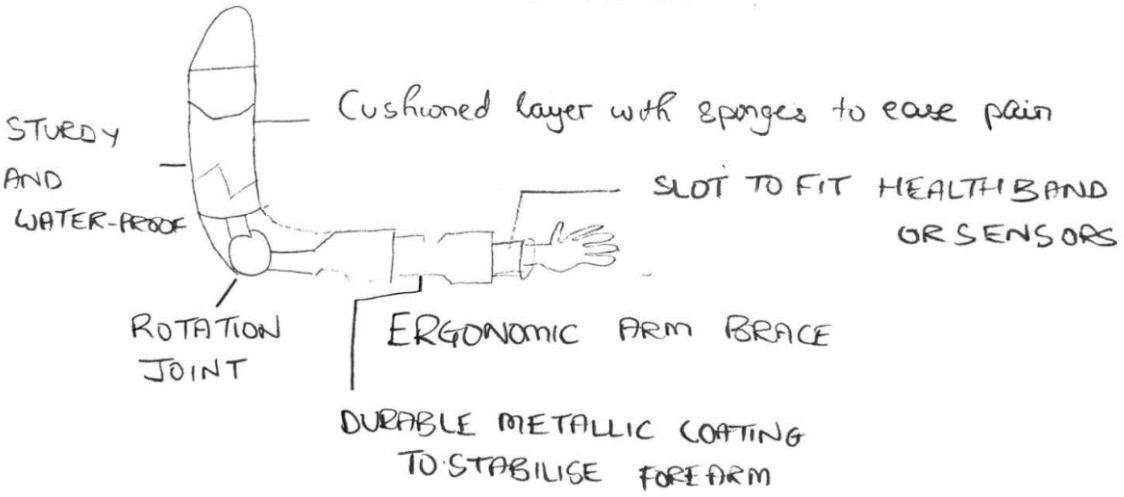
The solution is a platform for the client to rest her hand, accompanied by a strap. The end of the platform, contains a gripper to latch onto any tool, without requiring finer motor skills. Since the client remains seated usually while painting, the height and length of the platforms can be adjusted as per her ~~comp~~ comfort, while the wheels allow easy motion.

*-Note: The platfom and gripper can be ~~atta~~ detached from the base

CONCEPT SKETCH-2 MON-53

MOHAMMAD MUNTAZAR BHURWANI

bhurwanm

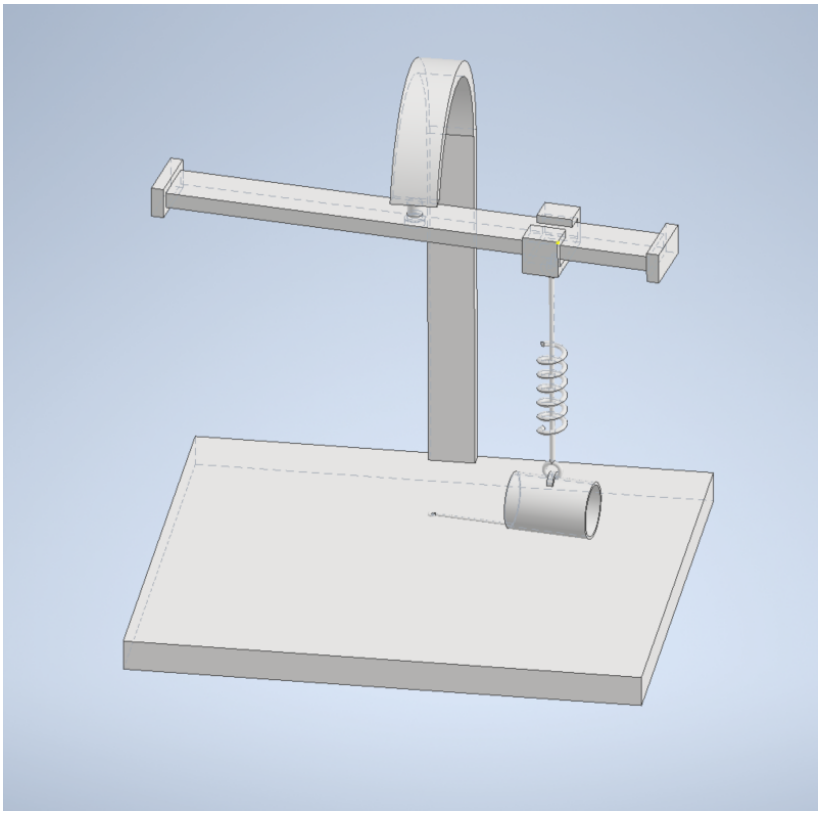


Design Review Notes

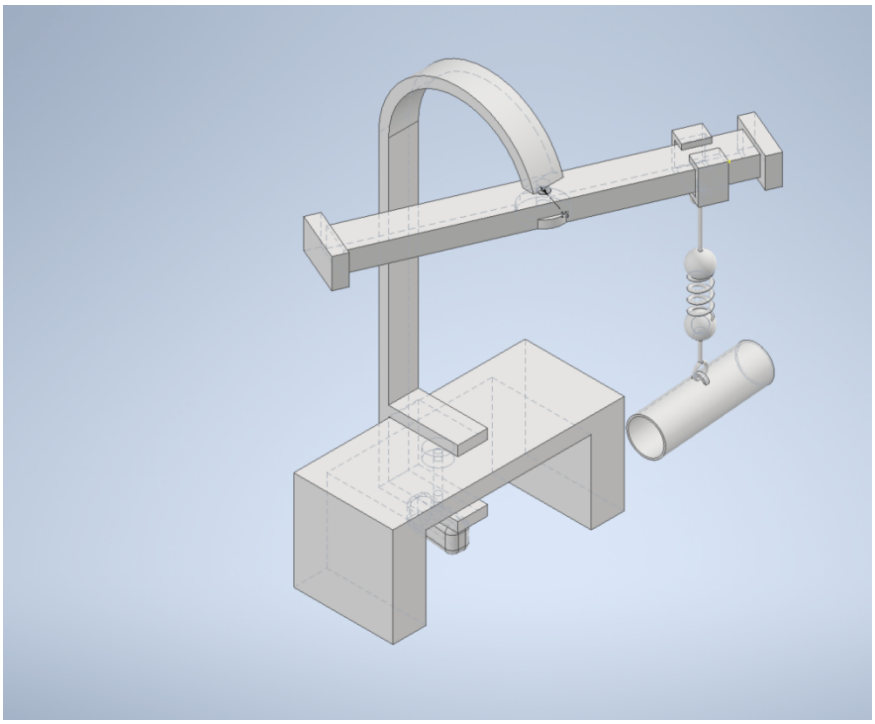
Include feedback from peers in this row. *Design 1: (Moveable arm support attached to canvas):* • *Find a better way to clip the device onto the canvas, maybe by attaching it to both sides.* • *Find a way to allow the device to move up and down a canvas.* • *Being able to lock arm stabilizer in place.* *Design 2: (Magnetic levitation bar with water-filled cushion)* • *Instead of Velcro, design a stretchable strap that fits her hand and brushes.* • *Increase the length of the bar* • *Prevent the rail from moving freely while painting* • *Use a smaller base that can attach to the table*
Include feedback from science students in this row. *Design 1 (Moveable arm support attached to canvas):* • *Unique design* • *Make sure that the handle can rotate to reach all the degrees of freedom* • *Potentially add another handle to be placed on another part of the canvas to reach more degrees of freedom* • *Not to limit the location of the handle so it can be used on different parts of the canvas* *Design 2:(Magnetic levitation bar with water-filled cushion)* • *Good idea* • *Ensure that the part around the wrist is waterproof or washable* • *Make sure the rail at the top can reach all positions of the canvas*

Include feedback from peers in this row. *Instead of an arm support that surrounds the whole forearm, one that only covers a half can reduce the tightness, increase flexibility, and save the material. It will also have a soft and removable lining to make it washable and comfortable enough. The spring can also be shortened so the arm support can start at a higher point and can be stretched down using the spring.*
Include feedback from science students in this row. *-It looks like it could be difficult to move it to a different spot or stand for the client* *-It might be difficult for her to paint in different positions* *-Would it be possible to clamp it to a canvas so that it can be painted vertically* *-The bar could be shorter so that it can spin 360 degrees and it could be dangerous for her to have a longer bar and this bar could* *-It might be hard for the client to screw in the clamp to the base. Look into other ways to clamp the device to the base such as push/pull* *-The design is good and innovative*
If applicable, include feedback from the client in this row.

Initial Prototype

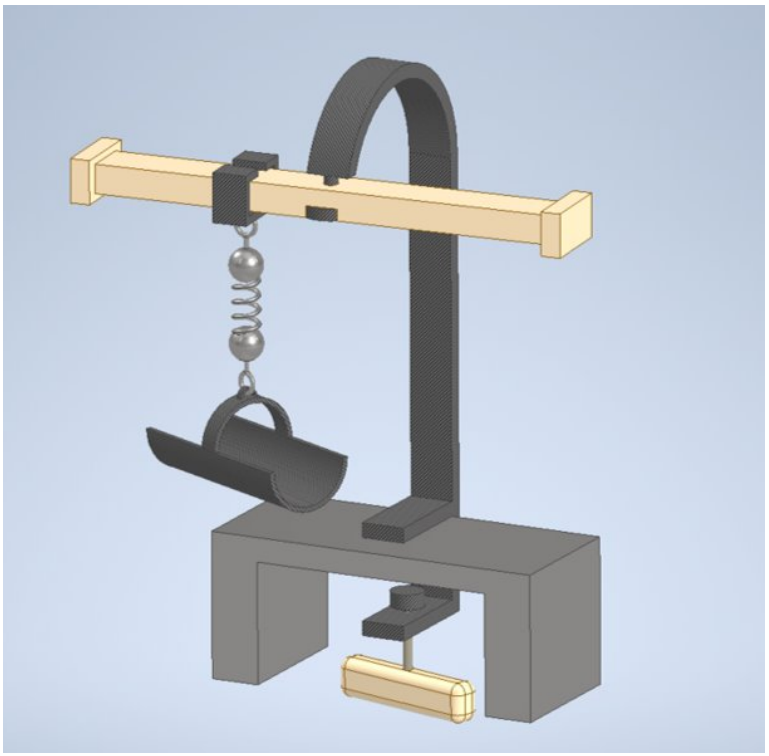


Refined Prototype

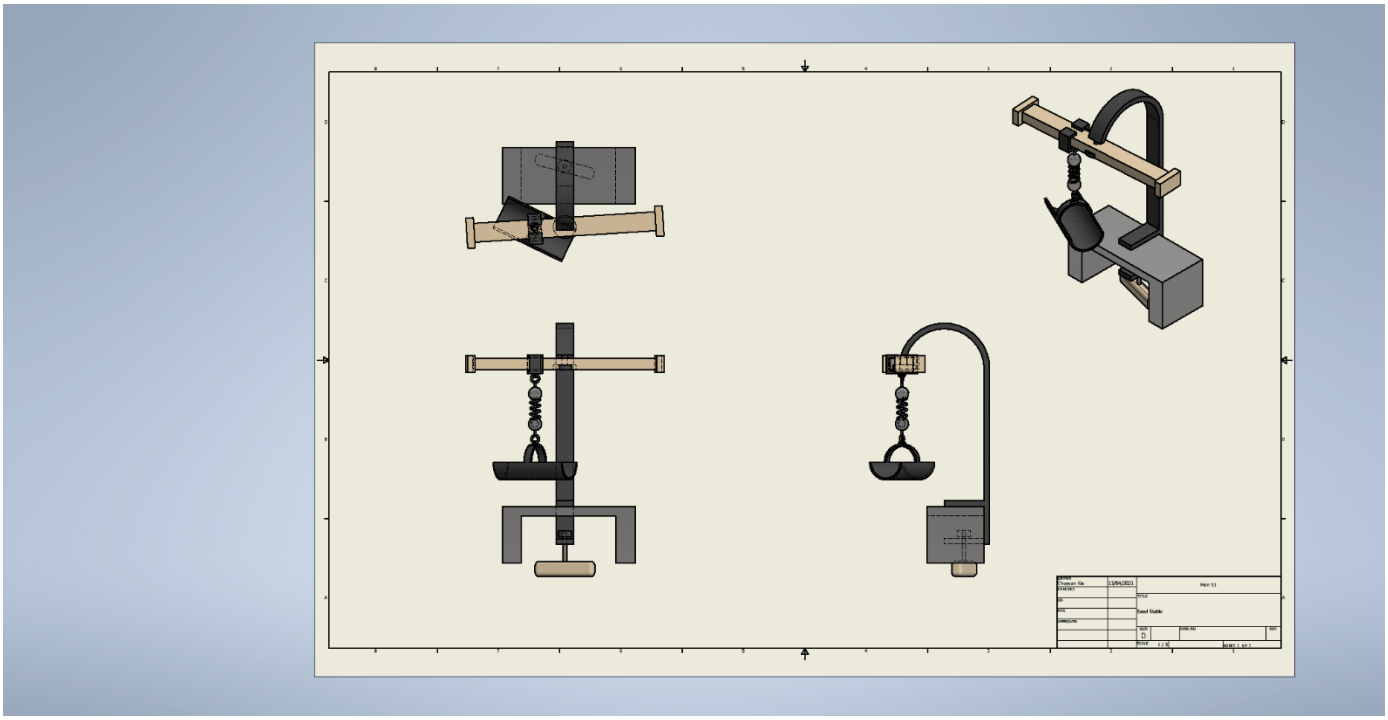


Appendix Section 3

Final Prototypes



Final Drawings

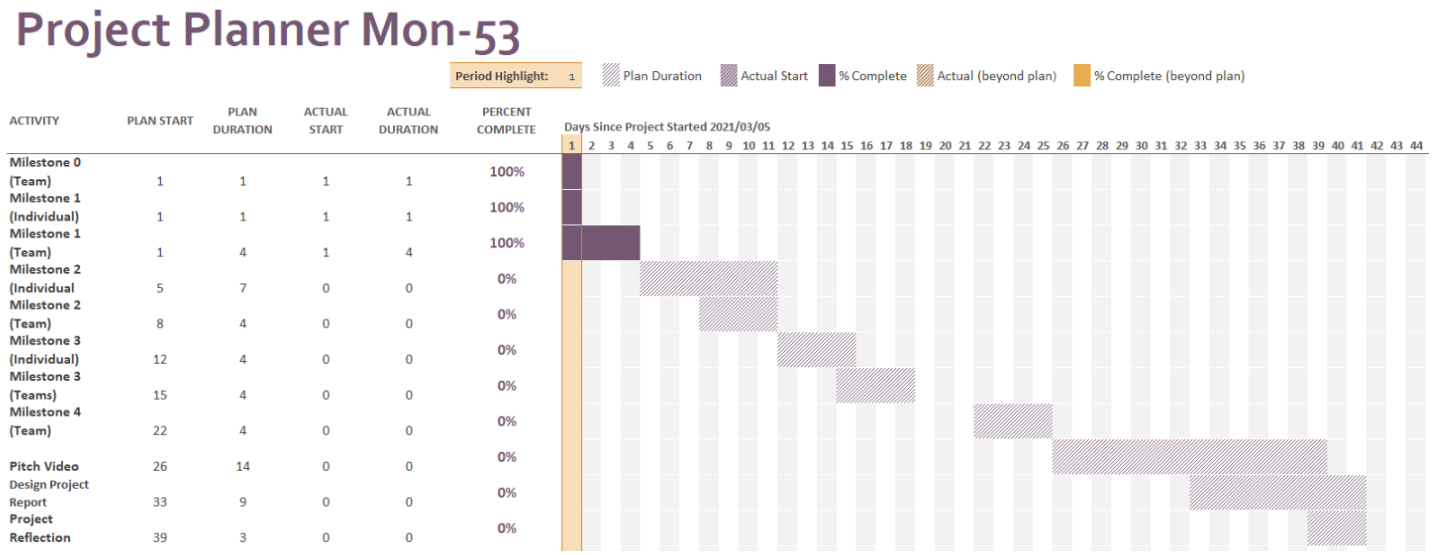


Bill of Materials

Parts	Quantity	Price of Each Part ($)	Cost of Parts ($)
Base (CFRP)	1	20.47 (1.011 kg)	20.47
Bar (Polyethylene)	1	2.13 (0.790 kg)	2.13
Connector (Polyethylene)	1	1.72 (0.085 kg)	1.72
Arm Support (CFRP)	1	4.52 (0.223 kg)	4.52
Base Screw (Polyethylene)	1	0.46 (0.171 kg)	0.46
Base Bottom (CFRP)	1	0.41 (0.020 kg)	0.41
Bottom of Coil (Stainless Steel)	1	2.50 (0.042 kg)	2.50
Top of Coil (Stainless Steel)	1	4.00 (0.363 kg)	4.00
		Total Cost	36.21

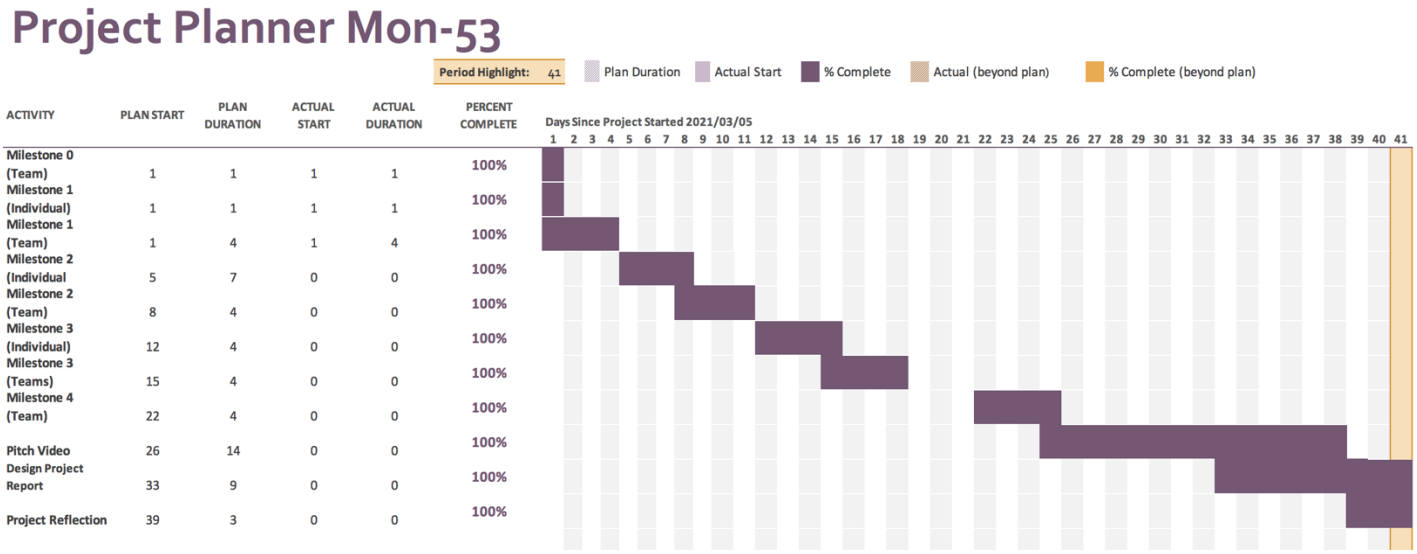
Appendix Section 4

Preliminary Gantt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (Team)	1	1	1	1	100%
Milestone 1 (Individual)	1	1	1	1	100%
Milestone 1 (Team)	1	4	1	4	100%
Milestone 2 (Individual	5	7	0	0	0%
Milestone 2 (Team)	8	4	0	0	0%
Milestone 3 (Individual)	12	4	0	0	0%
Milestone 3 (Teams)	15	4	0	0	0%
Milestone 4 (Team)	22	4	0	0	0%
Pitch Video	26	14	0	0	0%
Design Project Report	33	9	0	0	0%
Project Reflection	39	3	0	0	0%

Final Gantt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 (Team)	1	1	1	1	100%
Milestone 1 (Individual)	1	1	1	1	100%
Milestone 1 (Team)	1	4	1	4	100%
Milestone 2 (Individual	5	7	0	0	100%
Milestone 2 (Team)	8	4	0	0	100%
Milestone 3 (Individual)	12	4	0	0	100%
Milestone 3 (Teams)	15	4	0	0	100%
Milestone 4 (Team)	22	4	0	0	100%
Pitch Video	26	14	0	0	100%
Design Project Report	33	9	0	0	100%
Project Reflection	39	3	0	0	100%

Logbook of Additional Meetings and Discussions

WEEK	DATE	DURATION	MILESTONE	SUBJECT MATTER
9	March 19, 2021	1 hour	Milestone 3	- Presented our designs to each others - Created a decision matrix to choose the top two designs
10	March 25, 2021	40 min	Milestone 4	- We split up the work and each worked on refining the prototype
10	March 25, 2021	1 hour	Milestone 4	- Worked on worksheet of milestone 4
10	March 26, 2021	1 hour	Milestone 4	- Talk about the problem we had when working on refined prototype. - Assembled the refined prototype.
10	April 1, 2021	1 hour 20 min	Milestone 4	- We discussed about the final prototype and made changes in the length of spring, the gripper and supporter
11	April 5, 2021	20 min	Final Presentation	- We split up work on test plans and talked about difficulties when working on them
11	April 8, 2021	50 min	Final Presentation	- Discussed about the format of the slides
11	April 9, 2021	30 min	Final Report	- Split up work on final report

Appendix Section 5

[1] "Give Grip Strength a hand". Harvard Health Publishing, November, 2016. [Online]. Available: https://www.health.harvard.edu/healthy-aging/give-grip-strength-a-hand [Accessed March 13, 2021]

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