ENGINEERING

McMaster University

Project Four – Power in Community

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial 07

Team Thurs-18

Chengyao Liu (liuc169)

Vaisnavi Shanthamoorthy (shanthav)

Sarah Youssef (youssss6)

Jianhao Wei (weij50)

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Vaisnavi Shanthamoorthy 400319038

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Chengyao Liu 400234569

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Jianhao Wei 400336575

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Sarah Youssef 400313752

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Executive Summary

For this project, our group was tasked with improving the quality of life for a client who is unable to partake in activities due to the roadblocks she encounters because of her autoimmune diseases and mobility restrictions [1]. Our goal as a team was to design a device that would aid her to not be restricted from taking part in these activities. Thus, our proposed design solution is a *Manual Lymph Drainage (MLD) Arm Brace with a Dynamic Arm Rest*. Our device [Figure 1], consists of a dynamic arm rest that can move around with the client's arm while simultaneously providing support by bearing some of the load. This device is a mechanism for manual lymph drainage with a customized MLD roller and is designed to effectively manage the pain encountered from the swollen lymph nodes through use of the rollers applying pressure to manually drain the lymph nodes. The mechanism was designed to be simple, adjustable, and easy to fix.

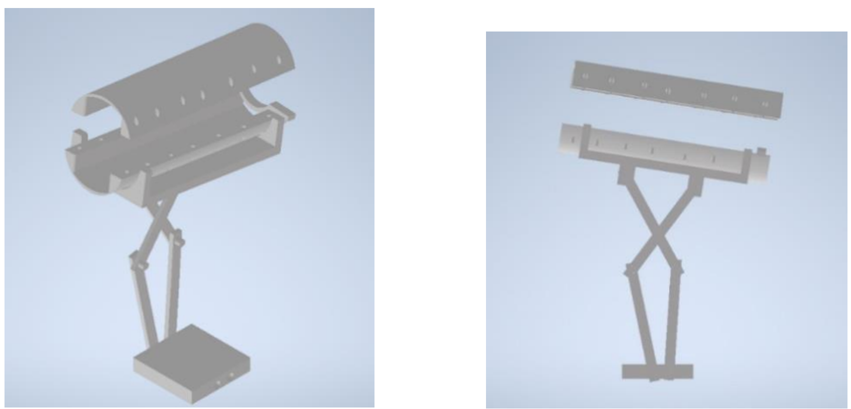

Figure 1: Screenshots of our proposed design solution model

Our design is unique as it explores the intersection of biology and engineering to solve the client's problem using manual lymph drainage. Our device stands out in terms of its multifunctionality of the detachable arm brace on top which allows the arm rest to be used as a stand on its own. Furthermore, to give the client the utmost comfort, a thin line of cotton lining on the inside of the arm brace and holes all throughout the brace avoids the risk of the device agitating the client's skin. Our next steps moving forward consist of a few aspects, if provided with additional time and resources. One further step we would take is to design a more aesthetically pleasing and artistically customizable device as the client has mentioned that numerous of her present devices, as well as all the devices commercially available, lack this component. This aspect would allow the device to represent her creative persona better as well as add a fun aspect of expression to this device. Additionally, we would also like to add a software aspect in the form of a web app that reminds the client to take breaks throughout her day. This would act as an add-on to our parent device and would essentially ensure she is not overworking her body at any time throughout the day. All in all, our proposed design solution effectively

mitigates the roadblocks caused by her lymphedema to effectively allow the client to take part in her daily activities whilst taking care of her body simultaneously.

Main Body:

Introduction

The client we have been tasked to help is someone who has been compelled to adapt to a new situation due to life altering events. She has recently retired from her career as a midwife and is the mother of two children at home [1]. In terms of her medical history, she struggles with numerous autoimmune diseases, one being lymphedema, in addition to being a breast cancer survivor [1]. Lymphedema is characterized by swelling in either your arms and/or legs. [2]. An example of how the swelling can appear on the body can be seen in Appendix A, Section 1, Figure A1. It generally occurs when individuals have undergone cancer treatment that resulted in the damage or removal of their lymph nodes. This causes a build-up of lymphatic fluids blocking regular flow in the lymphatic system [Appendix A, Section 1, Figure A2], which restricts proper draining and ultimately causes swelling of the associated parts [2]. Alanna has mentioned in the client visits that her pain is rooted in her struggles with lymphedema [Appendix A, Section 1, Table 1]. As a team, we decided that we wanted to focus on creating a solution to aid the client in tackling her struggles with lymphedema. Some of the struggles the client has encountered due to this autoimmune disease includes feelings of increased pressure and weight in the associated parts, restricted motion, and in terms of client specific information: it restricts her from being able to do what she loves (painting, sculpting, etc.) [2]. Our goal statement for this project was to design a non-restrictive and comfortable device for the client's arms that manages her pain so that she can continue working on her paintings and sculptures within the comfort of her art studio whilst minimizing her unpredictable periods of pain. The objectives and constraints that were developed for this device were developed by considering what the client had mentioned she liked and disliked about existing products, as well as what we thought would be important for her specific situation. The specific objectives showcased in our objective tree [Appendix A, Section 1, Figure A3], consists of our device being easy to use, portable, safe, durable and adaptable. Ease of use for the client ensures that the client will not have any trouble using the device. Portability ensures that the client can transfer the device, if necessary, without any extra stress added to her body when doing so. As a team we prioritized safety to ensure the client is not at risk while using the device and that it will allow for long term use. Additionally, we understand that many of the current devices have been broken by her children, and so durability is one aspect we focused on, ensuring that our device could withstand a lot of damage. The multifunctionality component of our device brings light to its adaptability and the buckles on the brace give the client the opportunity to adjust the device to her own comfortability - this was another aspect her current devices lacked. In terms of the constraints of our design, it is restricted to be lightweight, specifically within a range of 5-10 lbs (mentioned as the manageable weight to be carried by the client) [3]. We ensured that our device will be within this range through GRANTA by weighing the material and costs of each material used to construct our device and estimating the amount of material needed which determined that the weight was effectively within the range. Another one of our constraints for the device are that it must be able to withstand any damage and is easily adjustable if broken. The device does not require heavy groundwork, as it consists of large components that are easily replaced so that if it were to break, it is an easy fix that can be done in seconds by the client, and it will not cause any extra harm. We prioritized these objectives and constraints as we felt as though they would aid the client the most in overcoming the roadblocks present due to her lymphedema.

When considering existing solutions, we believe our device is unique as we have not previously seen a mechanism that allows the user to manually drain lymph nodes with the use of rollers in this specific manner. However, certain aspects of our device have been inspired by numerous existing devices. For instance, the dynamic arm stand was inspired from a commercial product known as the iFLOAT arm support [Appendix A, Section 1, Figure A4]. With this commercial product, it was a good base idea, but we saw the potential for improvements to be made. For example, the way the linkages were formed in this commercial product provided enough support in our perspective, but it required too complex of a setup to form the device. With our designed solution, the linkages are formed in a manner that requires little manual labour and it provides more support with the added brace on top of the linkages. The dynamic component still exists, as present in the iFLOAT arm support, which allows the rest to move with the arm to allow the client to take part in her daily activities as she pleases. Another commercial product that we were inspired by was the elbow orthosis brace [Appendix A, Section 1, Figure A5] with the Velcro arm straps. We improved the brace by incorporating the Velcro buckles aspect but with a hook and loop for attachment within the holes of the top and bottom of the brace to provide increased comfortability for the client and to allow her to adjust the device so that it is not restrictive. Additionally, our arm brace consists of holes in the top of the brace to allow for ventilation to further allow air flow to the client's arm. In terms of the patents, there were two existing solutions that were similar, which were the Adjustable Brace [Appendix A, Section 1, Figure A6] and the Adaptability Arm Rest System and Application Method [Appendix A, Section 1, Figure A7]. The adjustable brace patent in the United States allows the cross section of the brace to be adjusted to adapt for a swollen limb in the body. This is a similar tactic for our device, but our device utilizes the rollers for manual lymph drainage to aid in the draining of the nodes. We were inspired from this device, and our product initially rooted from this idea of aiding with the swelling by applying a specific pressure with aid from the brace. To make our product unique, we added on the rollers to focus on the clients struggles with lymphedema and how we could mitigate them. In terms of the Adaptability Arm Rest System, the current patent located in Canada was an inspiration for the ability to allow the arm rest to move with the arm. This invention, however, utilized a cradling arm mechanism which we did not view as very beneficial, so we combined aspects of the iFLOAT arm support with its dynamic arm stand and mounting platform components with our unique rollers to produce our device.

Conceptual Design

The ideation phase allowed us, as a team, to explore the design space through using numerous tactics. The concepts and spaces that were initially explored were from the different means developed as a solution to specific functions that were defined in a morphological chart [Appendix A, Section 2, Table 2]. The functions chosen for the morphological chart we developed were defined by the group based on what we collectively thought would be the most important functions of a potential device that could solve the client's specific situation. At this stage in the design process, no completed solutions were defined by any of the group members and this lack of a lock on imagination allowed us to explore the design space more freely. A free flow of ideas procured an extensive list of means for each function that provided a way for the team members to come up with various completed ideas that were demonstrated through initial / rough sketches [Appendix A, Section 2, Figure A8]. We ensured that the initial sketches that each team member produced used entirely different means for each function it hoped to accomplish in order to explore the design space as thoroughly as possible so that the ideas developed would be as diverse as possible.

There were many design alternatives developed for this project that were repeatedly altered and revisited throughout the design process. These alternatives were ones that sufficiently executed the objectives that the team members defined as the most important but were later either ignored or altered in some way due to feedback on the designs as well as the practicality of some of the designs. As shown in the sketches and prototypes, many different types of load bearing mechanisms were explored, as well as entirely different solutions to the client's main problems.

The main decision-making process for this project was when we were choosing the best design between the ones developed by each team member. To aid in this decision-making process, a weighted decision matrix method [Appendix A, Section 2, Table 3] was chosen to choose which design effectively executed each of the project objectives that we defined were the most important for the client's situation. After thorough discussion between the members, a select number of objectives were chosen as the criteria that each design would be evaluated by. The team felt that the best way to evaluate each design was to use a weighted decision matrix because it is a tool that can effectively determine the most important criterion, and then isolate the best design based on the score it was given for that criterion. Through this iteration and decision-making process, we were able to isolate three of the top designs that we wanted to consider as our initial prototype solutions. Though the scores of another design was higher [Appendix A, Section 2, Table 3], we chose to present a lower scored design as an initial prototype because the other design was not viable enough for the constraints of this project due to its complexity that would be hard to recreate as a final solution. As a group, we were able to rationalize that the MLD mechanism would be a better solution overall because it was a smaller and simpler device that could be moved around easily and would be less prone to damage due to its lower number of moving parts.

The design process was heavily influenced by all feedback from many people involved in the design process, throughout all stages. The design feedback from both design reviews can be found in Appendix A, Section 2, Figure A9. An initial prototype that involved a complex dynamic arm brace [Appendix A, Section 2, Figure A10], was later refined and altered to match the feedback given that it was too impractical of a design solution for this project's application. Early in the initial MLD prototype's development, feedback [Appendix A, Section 2, Figure A9(a)] indicated that the MLD mechanism was a strong idea, but it needed to be altered somewhat in order to include some aspect of load bearing for the client while also having a pain management aspect through the MLD. This led our team to include the MLD concept as one of the main ideas for our final design; as well as induced discussion about what type of load bearing aspect we would like to include. In later stages of the project, newer feedback from the science students [Appendix A, Section 2, Figure A9(b)] allowed us to narrow down which types of material we would like to use as well as adding any final details to the final design. One of the final most revisions to the design was reducing the roller from two attached rollers to only one roller that can simply slide in and out of the arm brace if needed. This decision was made after considering the feedback that the device should be completely safe for the client, and it was determined that having single roller would make it easier to control its movement, thus making it a safer device.

Final Proposed Design

Our final design is a device known as the Manual Lymph Drainage Arm Brace with a Dynamic Arm Rest [Appendix A, Section 3, Figure A11]. This device offers a new path to independence for the client as it consists of a dynamic arm rest that can move around with the client's arm while providing support. Moreover, this device is a mechanism for manual lymph drainage with a customized MLD roller. The device works by using a dynamic roller in an arm rest to apply pressure to drain the client's lymph nodes. The roller in the arm brace can move back and forth in the arm brace with a handle attached to the roller; this allows its movement to be controlled by the user so that they are able to apply manual pressure in the direction of lymph drainage whenever needed. The adjustable Velcro attachments allow for proper customizability and comfort of the design. The MLD mechanism (roller) is also detachable to further allow our device to be multifunctional and exist solely as a dynamic arm rest. Additionally, to mitigate any chance of a flare from occurring, we also designed the arm brace with small holes to allow for proper ventilation for the client's arm.

In terms of the specifications of our design, the dimensions can be seen in the engineering drawings for each of our subassemblies [Appendix A, Section 3, Figure A12]. Moreover, our design features a very flexible mechanism that allows the client to effectively take part in her favourite hobbies without worrying about overworking her body. The design ensures utmost comfortability for the client with both the adjustable buckles and the inner cotton lining sheet. The device is made with durable materials which allow our product to last for a long time. In addition, as mentioned the device consists of holes in its brace setting it apart from many braces currently in the market and allows for clear ventilation for the client's arm. In Appendix A, Section 3, Figures A12 and A13, both our engineering drawings as well as our exploded assembly are included, respectively. In the numerous drawings, you can see the intricate aspects of our design as it is broken down and, in the assembly, you can see how each part is assembled in a manner for the final proposed design solution to effectively work as one.

The criteria used to evaluate our design was based heavily on the objectives defined in previous milestones as these objectives would be the best to define if the mechanisms were efficient enough for the client's situation or not. Some criteria were based off specific requests of the client (i.e.. visually appealing) so these were included as criteria as well. All our objectives mentioned initially are present in the final proposed design as they still felt of great value and each served their own respective role in our final design in tackling the client's problem. Our key objectives were ease of use, portability, safety, durability, and adaptability. To ensure our device was easy to use, through both a motional demonstration in Inventor [Appendix A, Section 3, Figure A14] and a test with a "fake" client with a physical prototype, we scaled our metric based on the ability to secure the device around the user's dominant arm using their own non-dominant hand. This was on a scale of 1 to 5, with 5 being that the device was properly secured, defining it to be easy to use, and 1 being the device was unable to be secured, and thus defining it to be the hardest to use respectively. The objective was defined to be a 4 on the scale, relatively easy to use for the client as it did not take long to set up and secure the device. Portability was tested in terms of how lightweight design was specifically if it was within the range of 5 to 10 lbs, since this the range the client can lift without harming themselves. The objective was not able to be scaled properly in Inventor and was based on the weight of materials through GRANTA, thus as of right now it meets the objectives but for further improvement, we would need to be able to scale the entire device. There also exists limitations because there is no physical prototype that exists with the proper materials, which means it can only be theorized and estimated how much the device would weigh, as physically finding the true weight is impossible in this environment. Safety was tested through counting the number of sharp edges on the design, 5 being over 5 sharp edges and 1 being none, and because all edges are designed to be blunt and rounded, it received a 1, indicating the design is safe for client use. Durability was deemed to be not viable since we could not find a proper metric to test it in a virtualized manner, so no conclusions were concluded for this objective. Adaptability was measured in terms of being able to adjust to the clients arm if need be, and on a scale of 1 to 5, 5 being able to adjust to any position easily, and 1 being not able to adjust to any position easily, the device is design with buckles so when testing our dummy hand in Inventor or our initial prototype in real life, the device is easily able to adjust to the client's utmost comfortability, thus resulting in us giving it a 5. This metric is again limited due to its virtual nature, as only simulations can be run on the device, and the physical device might not function exactly as how the model does. The device designed by this team effectively meets the objectives that were defined and hoped to achieve, thus making it an effective solution for the client.

For the physical construction of the device, the most suitable option with the correct time and resources would be to build the physical model of the device through 3D printing for the main structure using the materials mentioned in the bill of materials [Appendix A, Section 3, Table 4]. For some additional aspects of the device, such as the crystal MLD roller, 3D printing might not be available, so this aspect would be manually carved to customize it so that it is well accustomed to the client's situation. In terms of why we used certain materials, for the arm stand, we decided that aluminium alloy was the best material to select, as seen in the MPI plot of density vs. price [Appendix A, Section 3, Figure A15], it is one of the materials located in the upmost left corner and furthermore it is the lightest one and cheaper than the other alloys located beside it, indicating it would be the best material selection given the relationships between price and density. In terms of the material selection for the arm brace, we chose to use hard fibre sheets made from chemically treated lightweight cotton because the material is lightweight, yet still hard enough so that it can apply enough pressure on the lymph nodes as the roller moves through the arm brace. The material was also used due to its high capability of withstanding extreme temperatures, which means the client will be able to use the device in any weather or environment. In terms of the buckles on the brace, we chose to use Velcro (which is made of nylon), and an adhesive hook and loop to loop it through the brace holes, to further enhance the adaptability of the device. Finally, we decided to use a customized stone/crystal tool for the main MLD mechanism because the MLD rollers that exist commercially are not physically suited to the arm rest that was designed by our team, so the material would have to be customized in its shape. The edges would also have to be blunted to best suit our client's conditions. Crystal was the material chosen for the rollers as it is what is traditionally used for manual lymph drainage in professional fields, as it is what best applies the proper pressure without harming the user.

Conclusions

If given more time to improve our device, some of our next steps would consist of improving the brace and linkages in the arm rest to make the entire device easier to control with increased flexibility to allow for the client to be able to take part in any daily activity she desires whilst using our device. Thus, we will first try to redesign the parts that need improvement in the form of sketches, then use Autodesk Inventor to model them, and finally make prototypes through 3D printing for testing. As a team, we learned a lot throughout this entire design process. With the numerous iterations of sketching and prototyping, it allowed us to make mistakes regularly and learn from those mistakes. For instance, our initial prototype consisted of upper and lower boards that were connected by some straps and enclosed outside the forearm. However, during testing we found that this was not strong enough which led to a decrease in support. Later, we adopted a design that merged two semicircles to form a brace, which not only ensured stability but also made it easier to wear. Our final prototype passed numerous of the testing stages mentioned in the report above, indicating to us that this design was successful in terms of meeting the objectives and constraints we revised throughout the design process. After coming to the end of our design process, we have realized a few key aspects. Firstly, we need to ensure that we understand the client's problem fully to design a practical solution. Initially, we had a few prototypes that were not practical or feasible in any manner for the task given to us, but the design reviews aided us to review these options and alter them so that they were more feasible for the project we were doing. From the design process, we have come to learn and appreciate how much of a role feedback and iteration in the engineering design process plays and how big of an impact it makes. By seriously considering the feedback and criticisms given during the design reviews, we were able to immensely improve our ideas which resulted in the development of our final design idea. In terms of our team dynamic, we knew that everyone had their strengths in certain areas over others. This allowed us to at times, play to each other's strengths, but also switch up roles to ensure that everyone was learning and building upon their skillset by having new experiences. We worked very well together - everyone was willing to help, and regardless of the huge time difference internationally between the team members, we were always able to find time to work on the task in an efficient manner. As mentioned above, throughout the project, it is very important for a team to discuss key product objectives before proposing design ideas, which we struggled with at the start of this project. Thus, if we were to restructure our design process, we would consider having a more in-depth interview with the client to try and better understand their struggles and thus better understand the main problem. The sole thing we would improve upon for our team dynamic is to communicate and brainstorm more collaboratively, which we learned after our first incident during our initial design review. Instead of our usual routine of individual brainstorming, and regrouping after some time, if working together again, we would have a timed schedule to meet back as a group and share our ideas to mitigate the risk of misunderstanding the task at hand. This would allow us to consider more comprehensively and allow the final solution to be the utmost best it can possibly be for the client.

List of Sources

[1] "ENGINEER 1P13 – Project Four: Power in Community," class note for ENGINEER 1P13, Faculty of Engineering, McMaster University, Winter, 2021.

[2] "Lymphedema – Symptoms and causes," Mayo Clinic [Online]. Available: https://www.mayoclinic,org/diseases-conditions/lymphedma/symptoms-causes/syc-20374682. [Accessed: April 10, 2021].

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[6] Adjustable Brace, by S. Summit, K. B. Trauner. (2019, Mar. 6). Patent US10238520. Accessed on: Mar. 12, 2021. [Online]. Available: https://patents.google.com/patent/US10238520B2/en?q=arm+brace&oq=arm+brace

[7] Adaptive arm support systems and methods for use, by M. C. Doyle. (2013, Dec. 10). Patent CA2893555A1. Accessed on: Mar. 12, 2021. [Online]. Available: https://patents.google.com/patent/CA2893555A1/en?q=dynamic+support+arm+rest&oq=dynamic+support+arm+rest

Appendices

Appendix A

Section 1:

Medical Documents:

Figure A1: Swelling caused by swollen lymph nodes

Source: Adapted from [2]

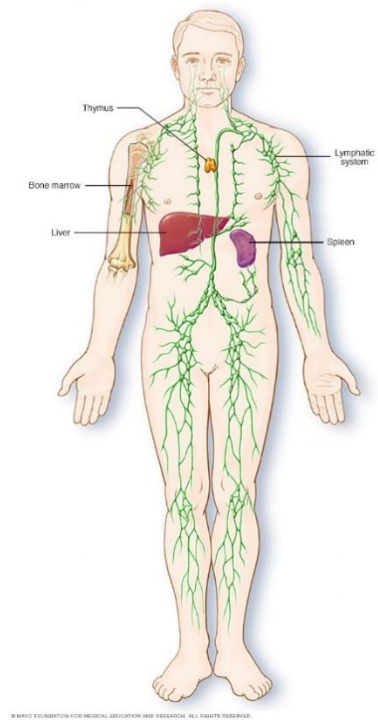


Figure A2: Image of a Lymphatic System

Source: Adapted from [2]

Client Meeting Notes:

Table 1: Client Meeting Notes

Client Visits
• likes working with very big canvases (needs to be quite mobile in order to work on these) • flares cause heightened sensitivities • easier to grip larger brushes (wide grips of any kind are easier) • struggles with the grip on smaller brushes • can bear about 5 to 10 pounds

- believes was given a wrong instruction to stop weight bearing
- large flat objects easiest to grip
- stairs are sometimes hard
- pliers could be good

- Current assistive device aiding with the client's grip
  - What aspect does and doesn't work?
    - Grabbing device was made of a lot of plastic components & then her children turned it into a weapon, so she didn't use it anymore
      - Devices that she uses her kids also have access to, so it is important to ensure it is not easily breakable
    - lymphedema garment is not made holistically
      - It is difficult for her to wear it in all situations as it does not consider her other conditions.
      - It is important to note that we should take this into account to essentially provide the client with a device that is not solely specified towards targeting one condition but is also not aiding the client in a manner where this device is creating further complications in terms of another one of her conditions

What size canvas do you prefer?
- Prefer giant canvases (would need to increase mobility in order to work around the large canvas)
- Also works with smaller canvases likes working with square canvases
- If working with smaller

Only uses left hand to support right hand when painting, cannot paint with left hand at all
- Focus on relieving the pain from her right side so she does not need to bear it with her left

Allergies/sensitivities to certain fabrics/materials
- Fibromyalgia (when it is active) what is against her skin feels comfortable
  - Soft and seamless is ideal for when it is active

What kinds of things that are easier to grip?
- Certain brushes with wide grip → helps it to be easier to use
- Working with brushes with fine tip but wider handle

Where does pain rooted from?
- When fibromyalgia flares and feels like fire and predominantly in upper torso and arms
- Also is where lymphedema from vasectomy
  - With everything Alanna has mentioned, in order to provide a solution that accounts for her fibromyalgia flares, we could potentially create a device that has larger areas of contact with skin over smaller points of contact

Height: 5 foot one and a half

Large flat objects are better (paintbrushes)
- Since they allow her to have a better grip due to the wideness of the surface available

Knowing when to stop
- Constant learning process
- When Alanna mentioned this, it really showed to us how much of a fighter she is, she has overcome so many roadblocks and we are hoping to provide her with a

device that will allow her to be able to continue to take part in her daily activities in a comfortable manner Lives in a three-story home • Stairs are hard at times, rails on one side, utilizes cane Bears weight on stool to create stability She is right handed, which small hand and small finger She likes large flat brushes rather than round brushes She is not allergic to fibre She can't drive car, because it makes her very painful She rather like round-tip handles

Objective Tree:

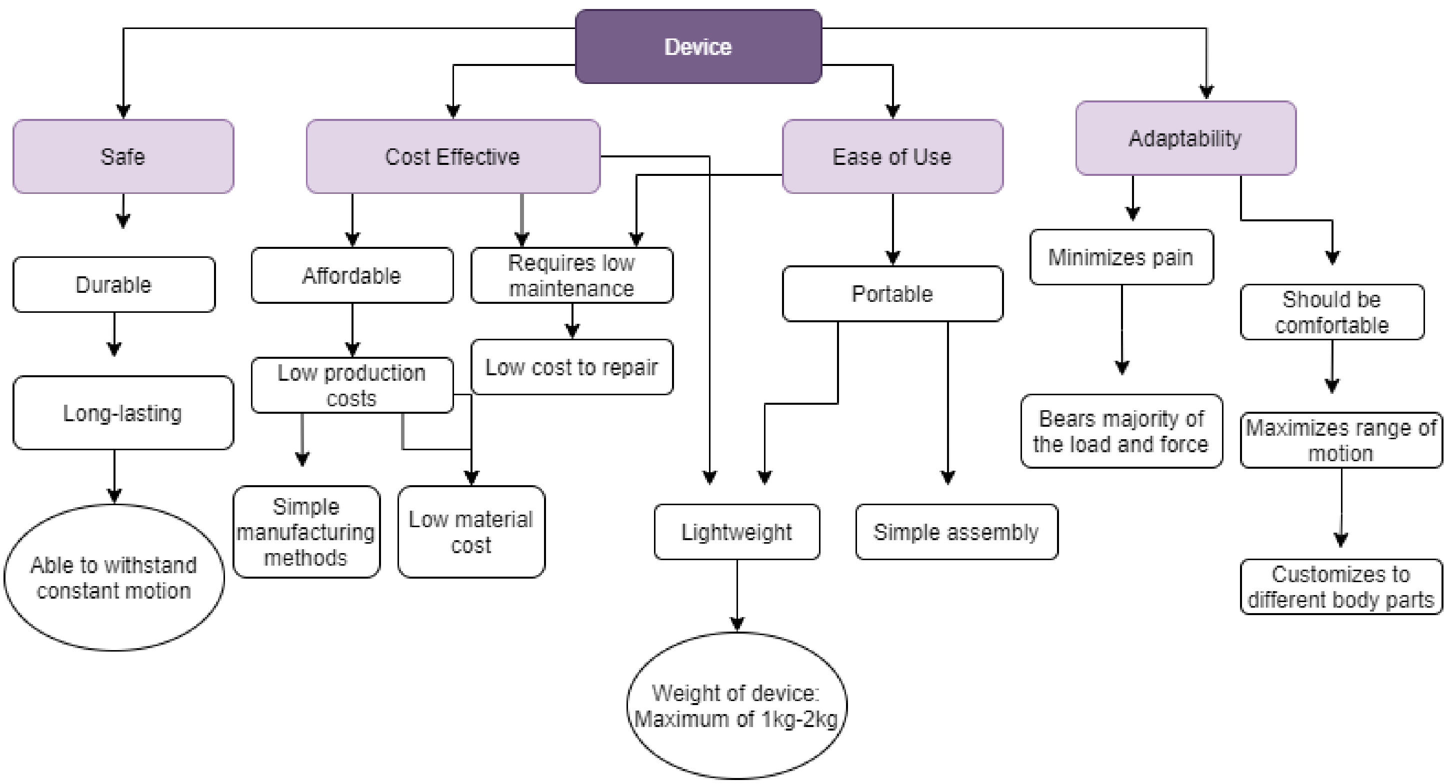


Figure A3: Objective Tree

Commercial Products:

Figure A4: iFLOAT Arm Support

Source: Adapted from [4]

Figure A5: Elbow Orthosis Brace

Source: Adapted from [5]

Patents:

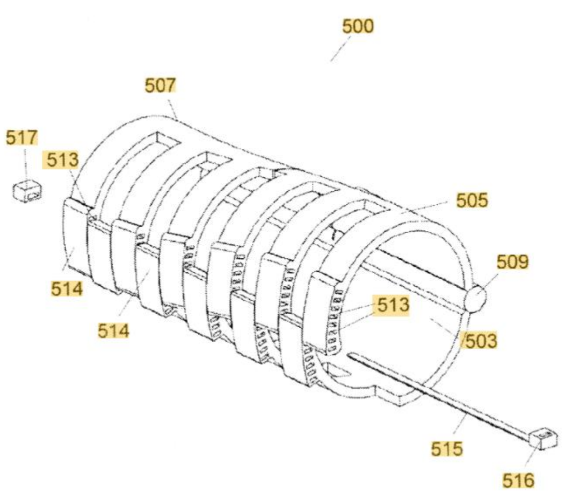


Figure A6: Adjustable Brace

Source: Adapted from [6]

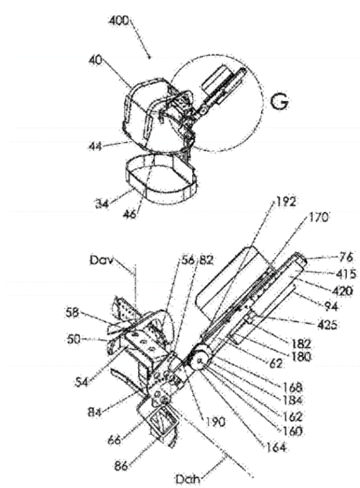


Figure A7: Adaptability Arm Rest System

Source: Adapted from [7]

Section 2:

Morph Chart:

Table 2: Morphological Chart

Functions	Means				
Bears Load off Joint	Lever	Wheelchair	Using a custom brace	Rollers that conduct manual lymph drainage	Cane/Walker
Easy to Grip	Flat, wide handle	Gauntlet that wraps around hand	Flexible handle that fits around hand	Custom gripper that fits around objects	Gripper glove
Provides support for dominant arm	Moving arm rest/stand	Flexible arm sling	Portable dynamic connecting arm brace that mounts to any surface	Soft, heating wrist splint	Vest with arm support structure
Reminds Client to Take Breaks	Coded timer	Pressure sensor in body	Coded reminder app	Coded app to create a schedule to avoid overworking your body	Coded tracker app (in terms of fitness or activities)

Decision Matrices:

Table 3: (a) Weighting for Criteria (b) Weighted Decision Matrix

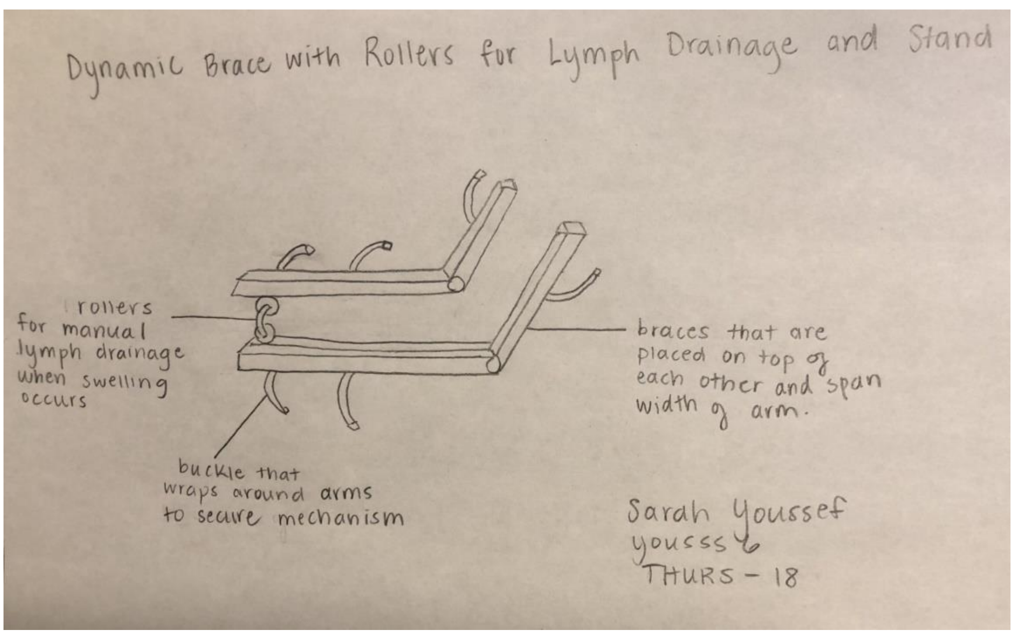
Weighting for Criteria

	Lightweight	*Cheap to produce / manufacture*	*Durable*	*Aesthetically Pleasing*	*Adjustable*	*Bears Load off Arm*	***Score***
Lightweight	*1*	*1*	*1*	*0*	*0*	*0*	***3***
Cheap to produce / manufacture	*0*	*1*	*0*	*1*	*0*	*0*	***2***
Durable	*0*	*1*	*1*	*1*	*0*	*1*	***4***
Aesthetically Pleasing	*1*	*0*	*0*	*1*	*0*	*0*	***2***
Adjustable	*1*	*1*	*1*	*1*	*1*	*0*	***5***
Bears load off arm	*1*	*1*	*0*	*1*	*1*	*1*	***5***

Weighted Decision Matrix

	Weight	*Manual Lymph Drainage Arm Brace*		*RemindMe! App*		*Forearm Lifter*		*Dynamic Arm Brace*	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Lightweight	3	5	**15**	3	**9**	4	**15**	1	**3**
Cheap to produce / manufacture	2	4	**8**	3	**6**	5	**10**	2	**4**
Durable	4	2	**8**	2	**8**	3	**12**	3	**12**
Aesthetically Pleasing	2	3	**6**	5	**10**	1	**2**	1	**2**
Adjustable	5	4	**20**	1	**5**	2	**10**	4	**20**
Bears load off arm	5	1	**5**	1	**5**	4	**20**	5	**25**
TOTAL			**62**		**43**		**69**		**66**

Sketches:



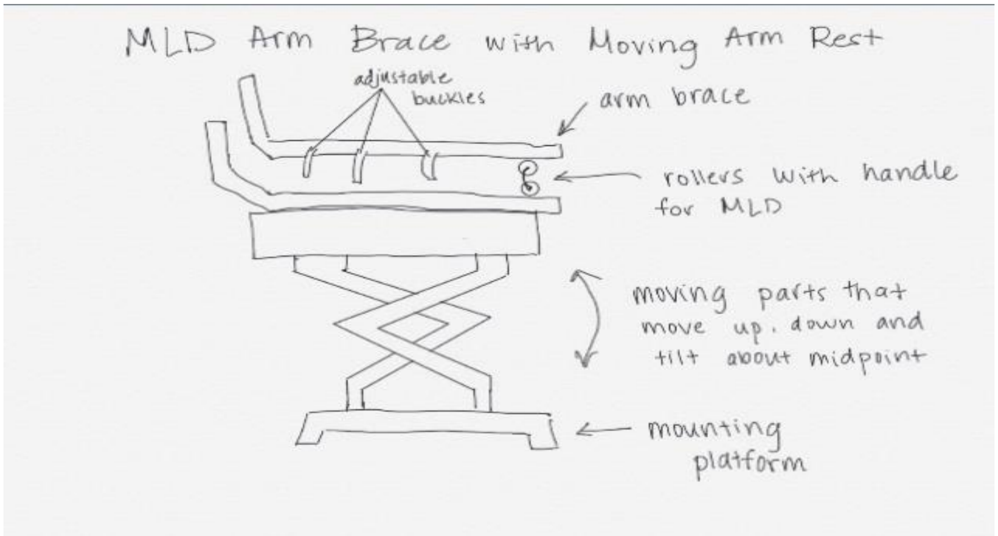


Figure A8: (a) Initial sketch for manual lymph drainage arm brace (b) Initial sketch of final proposed design solution

Design Review Notes:

Include feedback from peers in this row.

- *Ensure that material is lightweight --> choose one that is adaptable for this case.*
- *Interesting concept with the roller idea aspect for the manual lymph drainage arm brace concept*

Include feedback from science students in this row.

- *Mentioned that if we were to go with an arm brace, the client mentioned in a client session that all the arm braces present in the market are solely black --> potentially make it visually appealing to the client and offer different colours.*
- *Ensure that all of aspects of your design are something you can build if we were to be in person.*
  - *Think about the practicality of your designs.*
- *Possibly come up with an idea to combine both the brace and rollers concept.*
- *Ensure that the brace is not tightly fit and that since it is designed specifically towards the client, that if the client were to lose or gain weight, it should be adaptable in that sense.*
  - *We have buckles but we could potentially think of another solution for this.*
- *We suggested using cotton lining for our manual lymph drainage arm brace concept --> they said that would that be a great idea.*
- *Ensure that for your concept, it is easy to remove around the arm so that the client will not struggle with that aspect of it.*

Include feedback from peers in this row. *N/A*
Include feedback from science students in this row. - *Possibly consider the possibility of making the device multifunctional, and if it could be used solely as an arm stand as well.* - *Ensure that there no room for bacteria buildup, possibly could create holes to increase air flow in arm brace.* - *Ensure no sharp edges as it could lead to flares for the client since the client suffers from several autoimmune diseases.* - *Ensure device is portable (not too large)*
If applicable, include feedback from the client in this row. *N/A*

Figure A9: (a) Design Review #1 Notes (b) Design Review #2 Notes

Initial Prototype/Prototype Iteration Pictures:

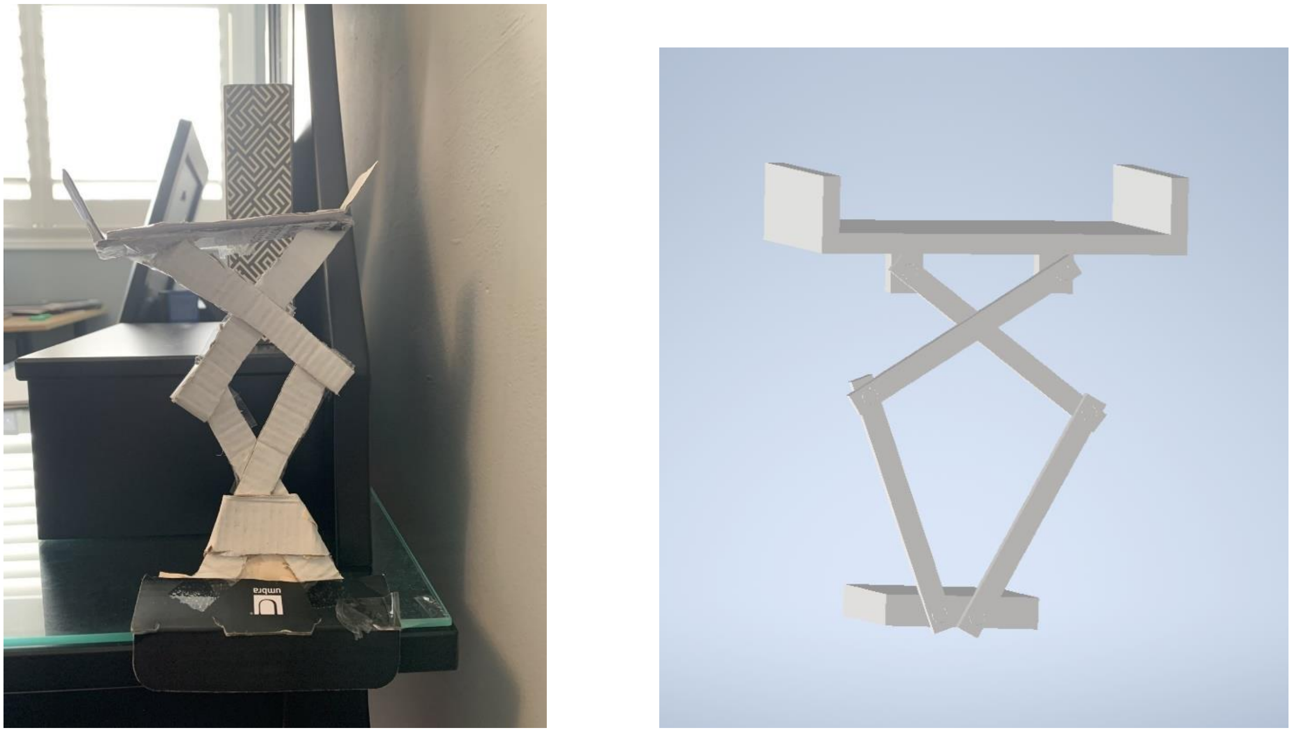


Figure A10: Initial Prototype Iteration Pictures

Section 3:

Final Prototype:

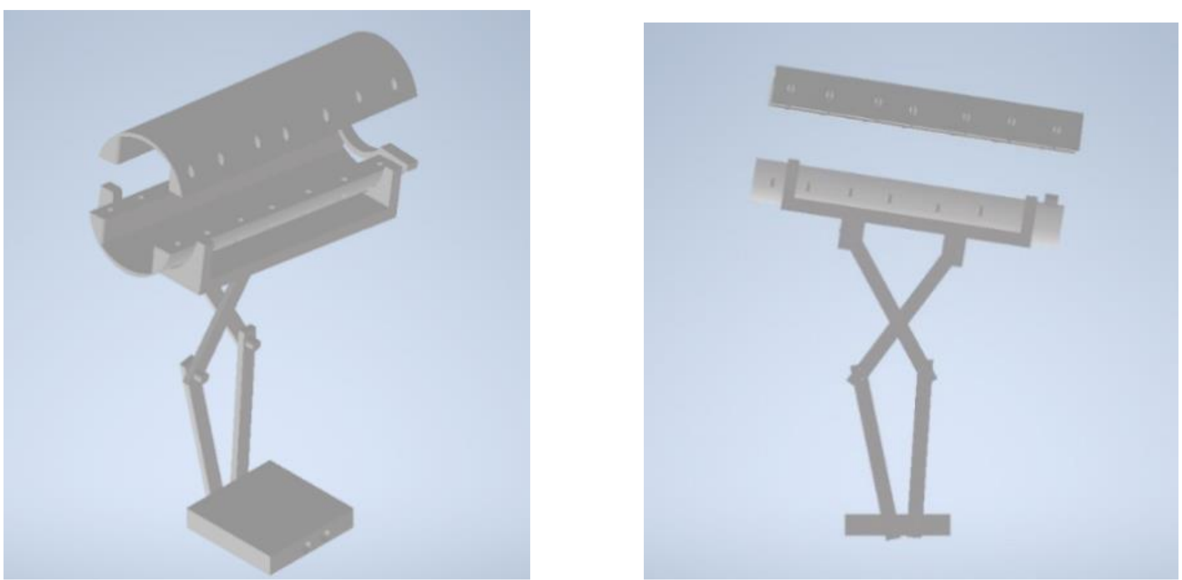
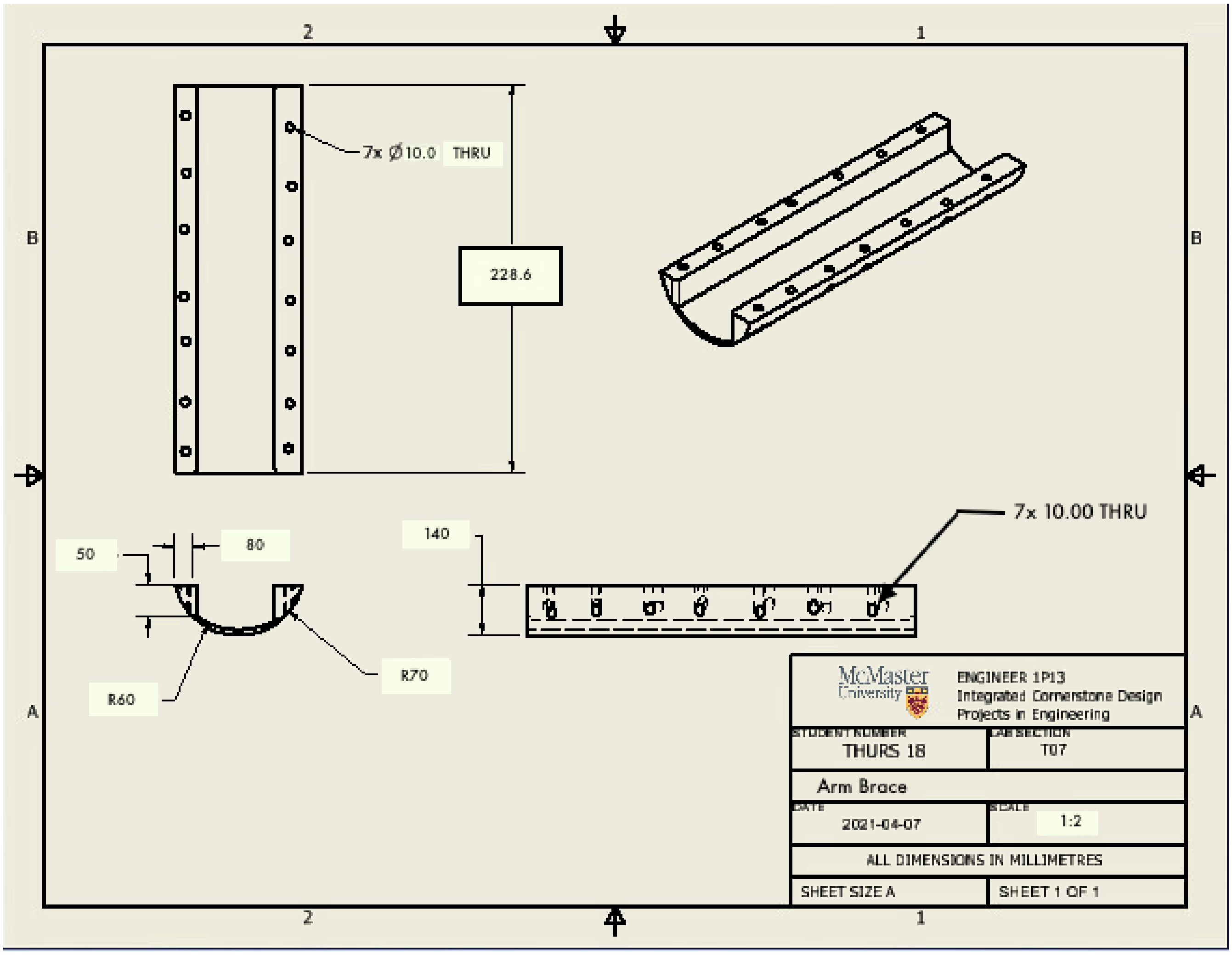
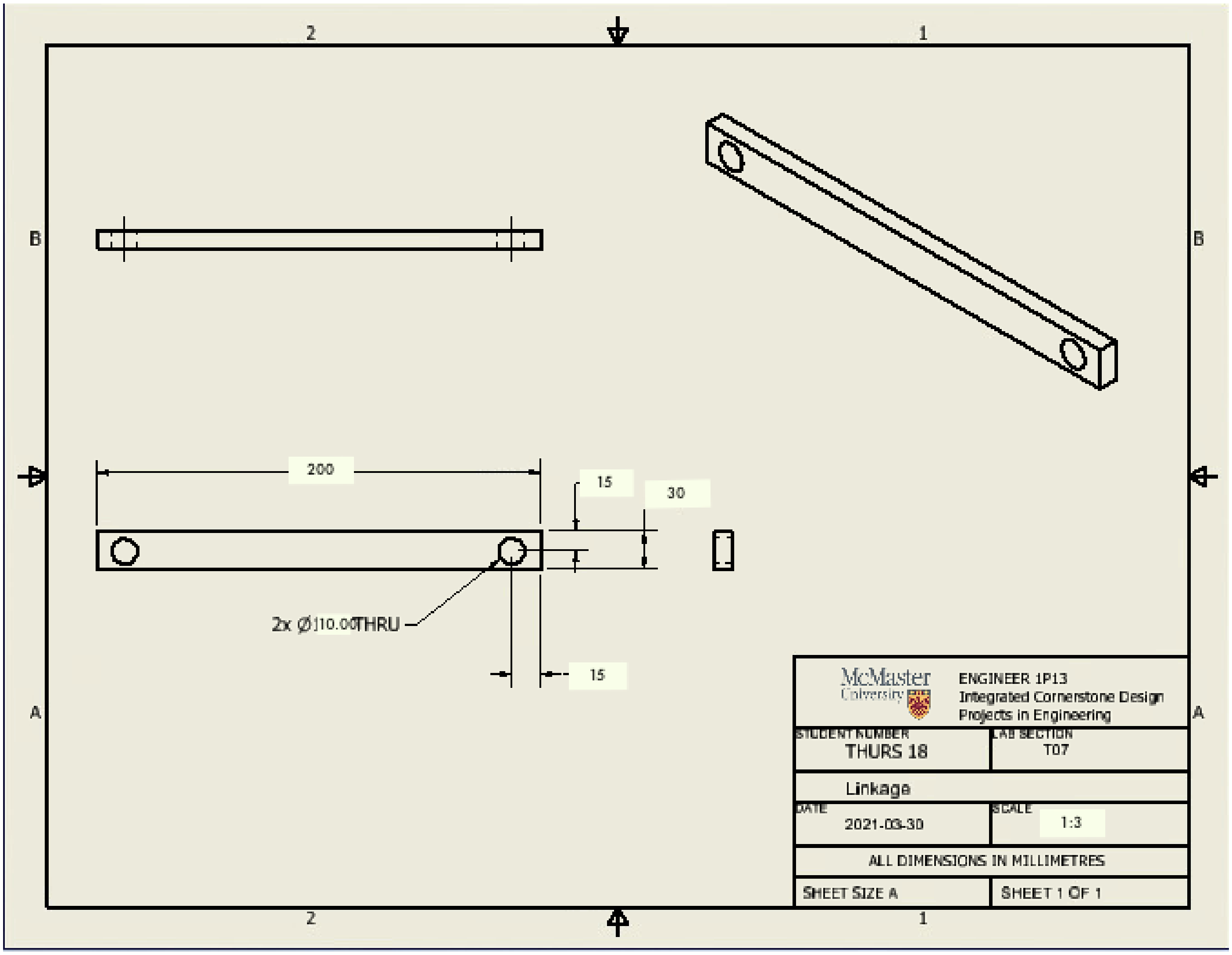


Figure A11: Screenshots of our Final Proposed Design Solution

Final Drawings:

Engineering Drawing of Final Model

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Integrated Cornerstone Design
Projects in Engineering
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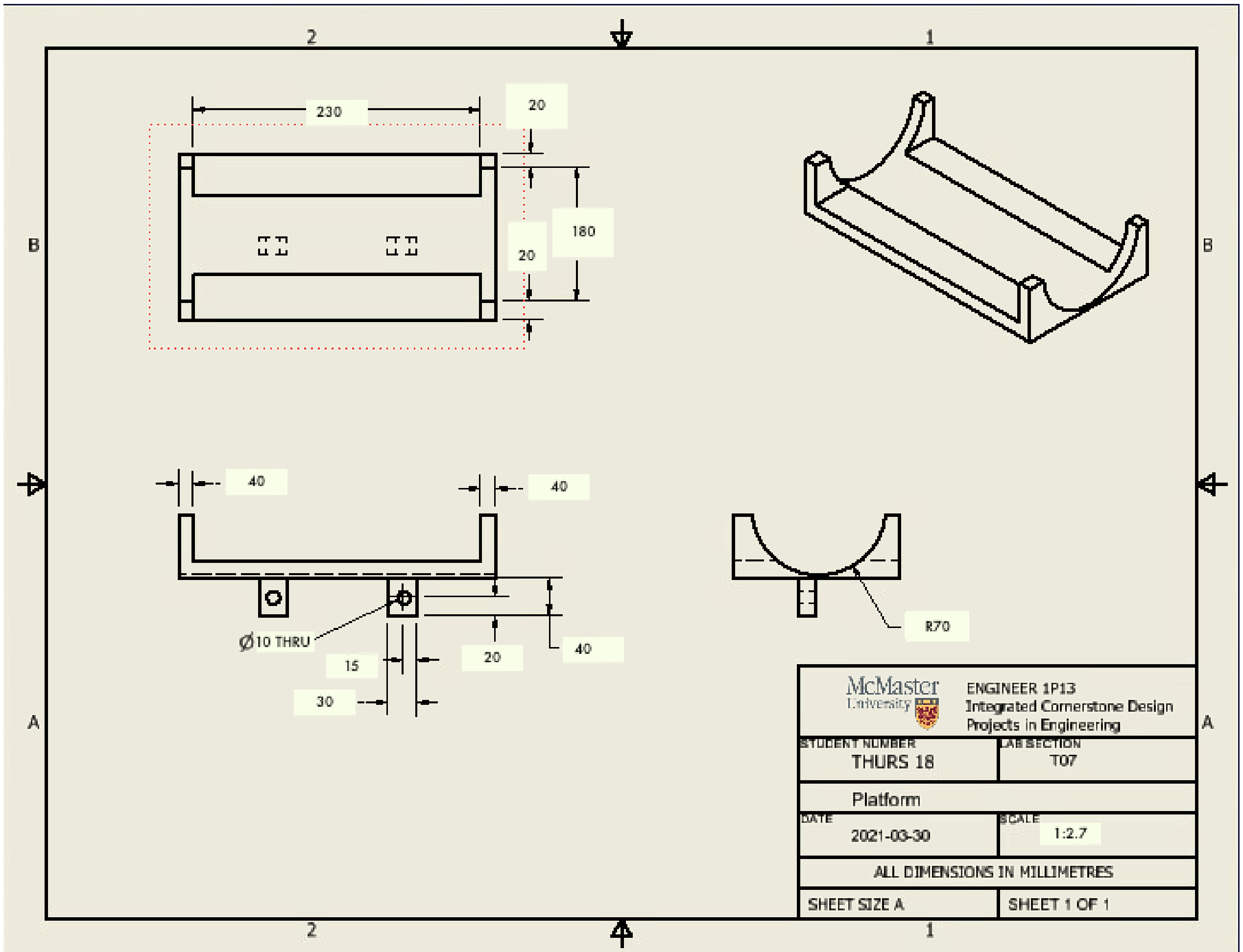

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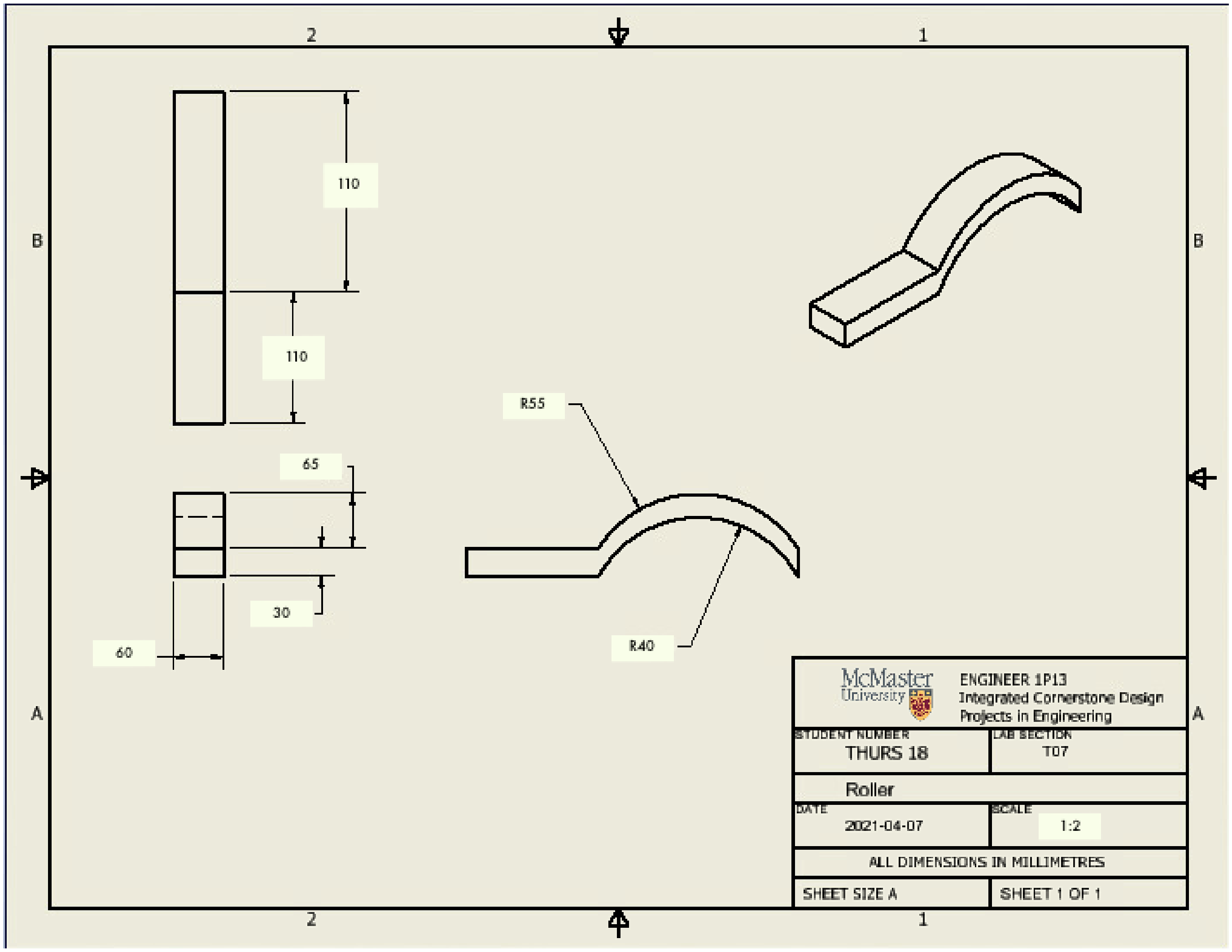
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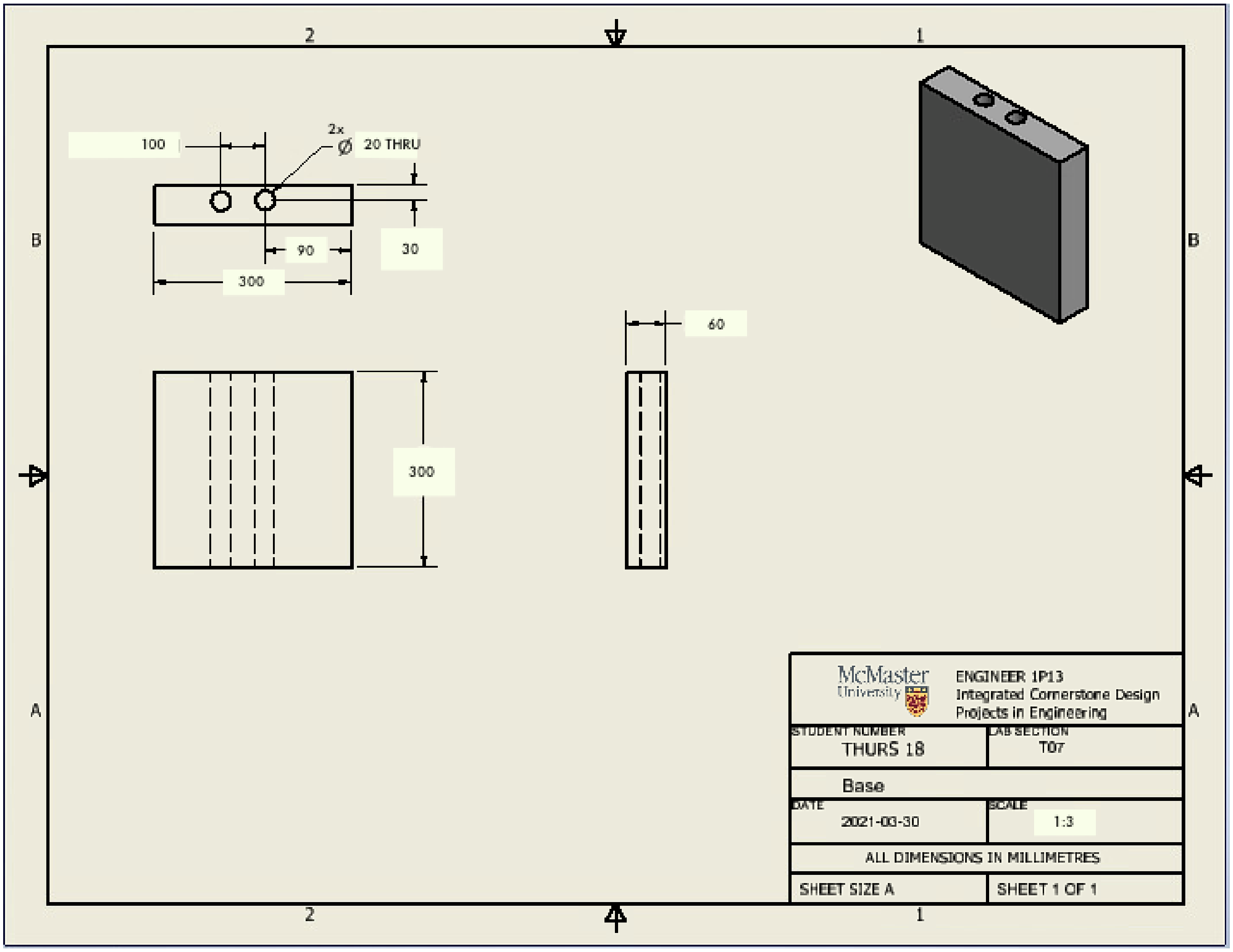
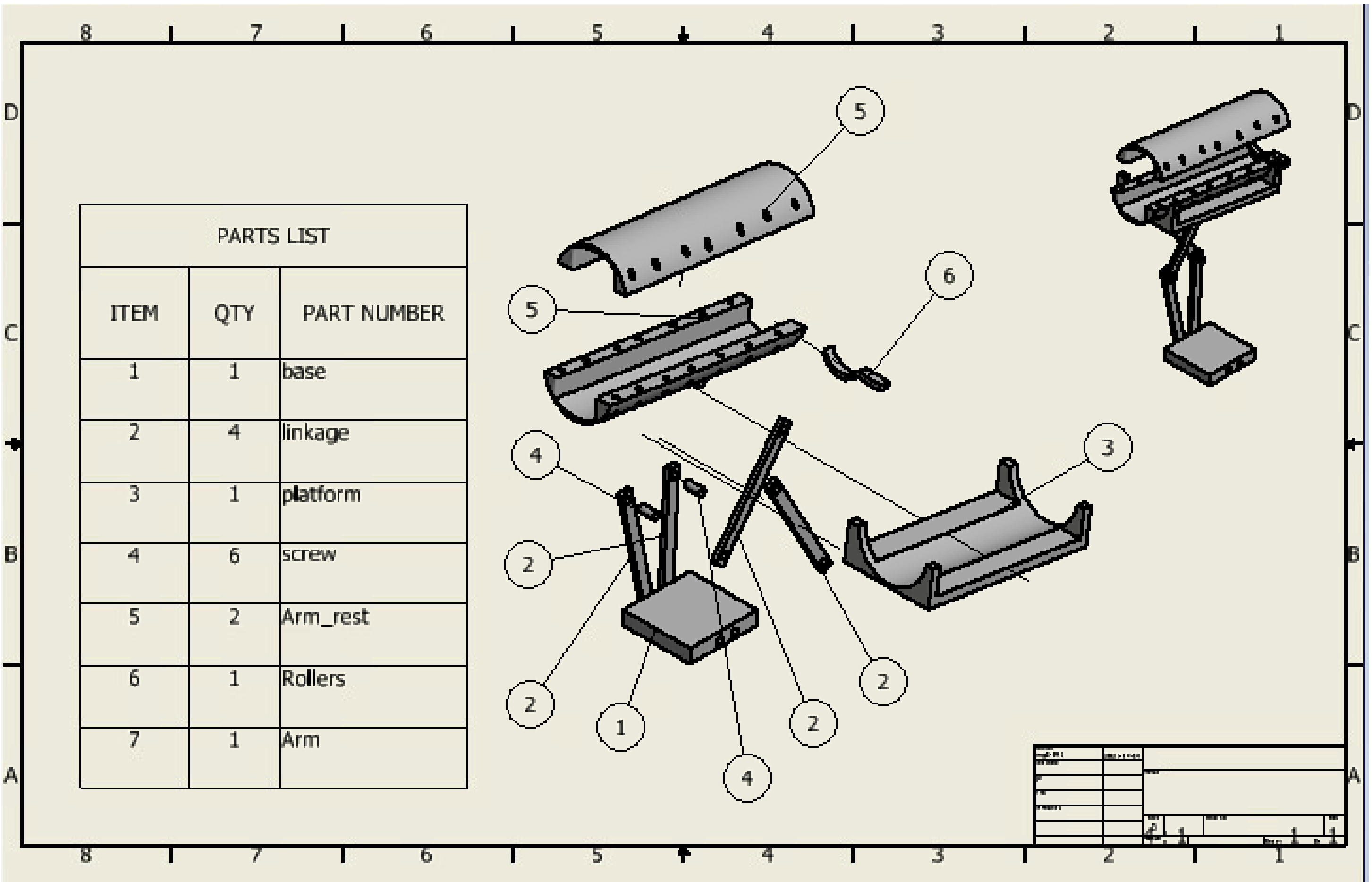


Figure A12: Engineering Drawings of Sub-Assemblies

Exploded Assembly of Final Model



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	base
2	4	linkage
3	1	platform
4	6	screw
5	2	Arm_rest
6	1	Rollers
7	1	Arm

Figure A13: Exploded Assembly of our Final Proposed Design Solution

Motion Demonstration of Final Proposed Design Solution:

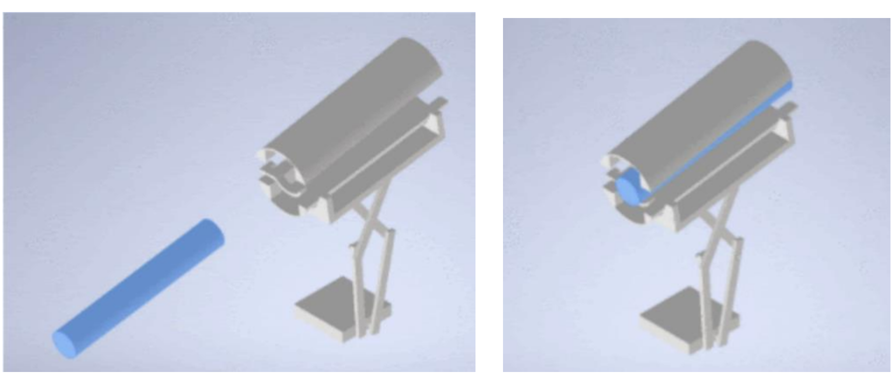


Figure A14: Screenshots of stages of motion demonstration

Bill of Materials

Table 4: Bill of Materials

Parts	Quantity	Price of Each Part ($)	Cost for Parts ($)
Base	1	10.20	10.20
Linkage	4	2.90 (1 kg)	8.12
Platform	1	2.90 (1 kg)	2.90
Screw	6	3.25	19.50
Arm rest	2	63.69	127.37
Roller	1	20.00	20.00
Buckles	1	11.64	11.64

Material Selection Plot:

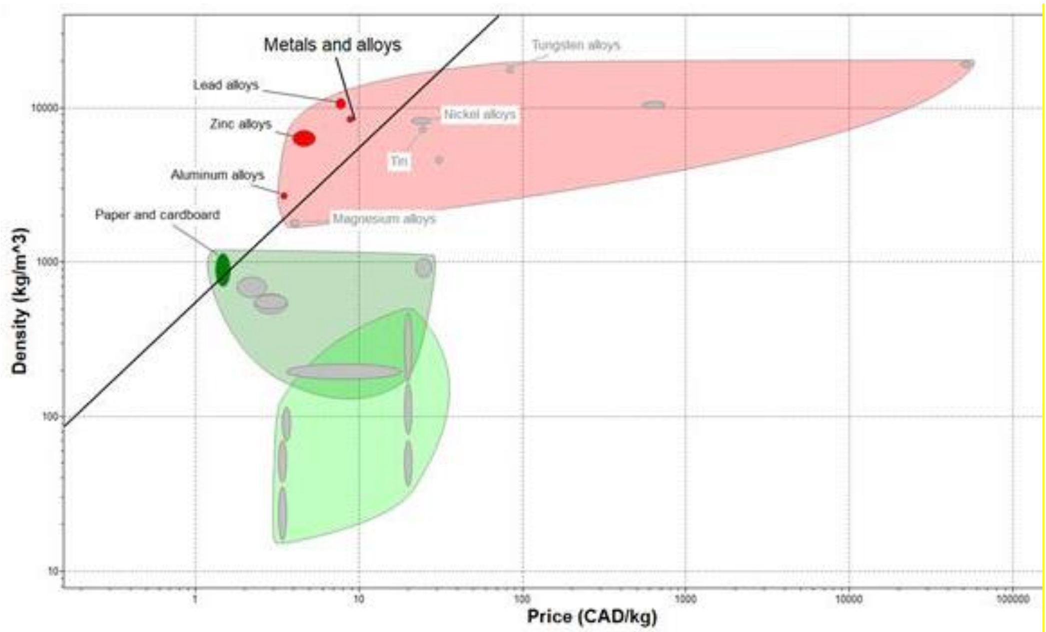


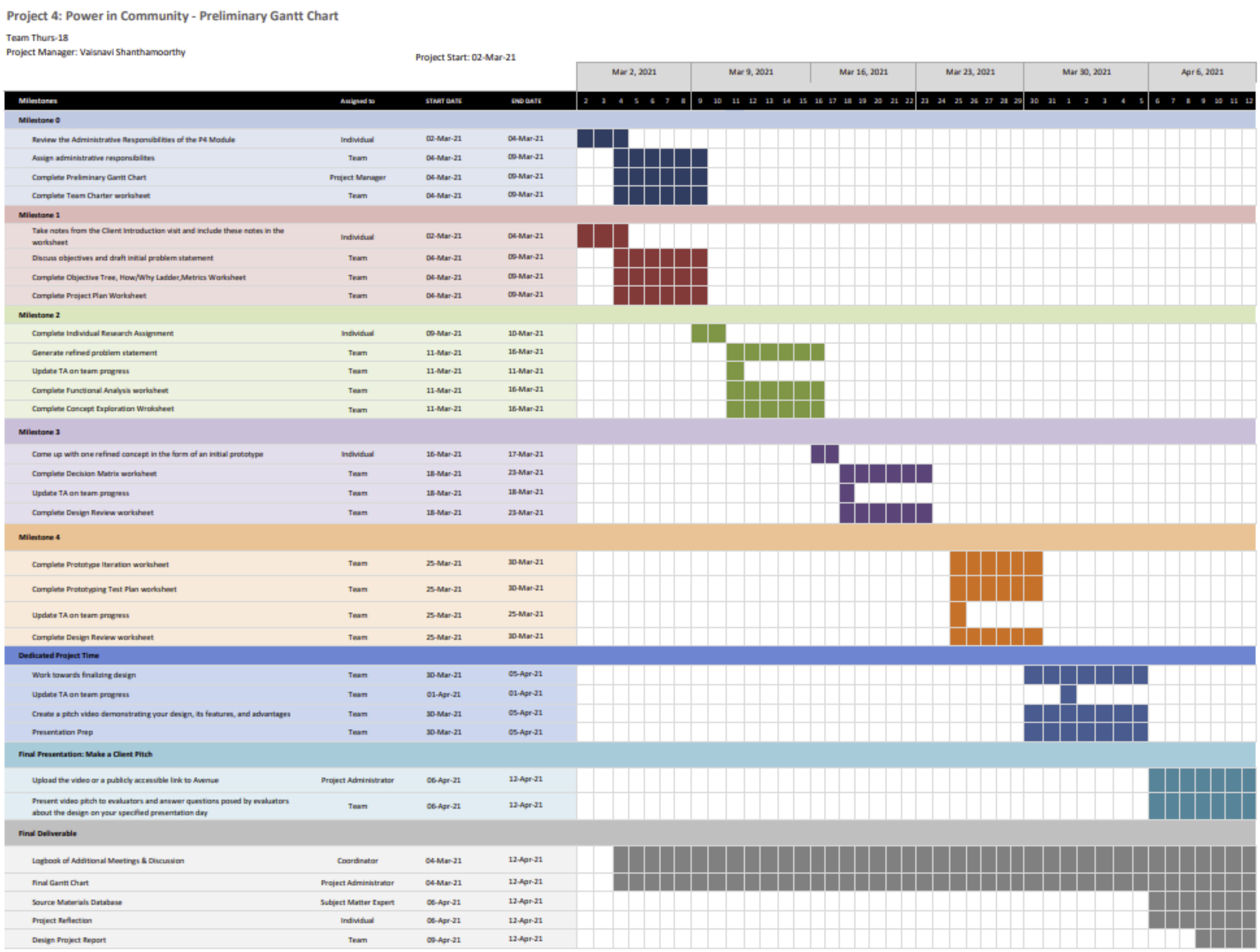
Figure A15: MPI Plot for Material Selection of the arm rest

Source: Adapted from [20]

Appendix B

Section 4:

Preliminary Gantt Chart:



Project 4: Power in Community - Preliminary Gantt Chart

Team Thurs-18

Project Manager: Vaisnavi Shanthamoorthy

Project Start: 02-Mar-21

Milestones	Assigned to	START DATE	END DATE
Milestone 0			
Review the Administrative Responsibilities of the P4 Module	Individual	02-Mar-21	04-Mar-21
Assign administrative responsibilites	Team	04-Mar-21	09-Mar-21
Complete Preliminary Gantt Chart	Project Manager	04-Mar-21	09-Mar-21
Complete Team Charter worksheet	Team	04-Mar-21	09-Mar-21
Milestone 1			
Take notes from the Client Introduction visit and include these notes in the worksheet	Individual	02-Mar-21	04-Mar-21
Discuss objectives and draft initial problem statement	Team	04-Mar-21	09-Mar-21
Complete Objective Tree, How/Why Ladder,Metrics Worksheet	Team	04-Mar-21	09-Mar-21
Complete Project Plan Worksheet	Team	04-Mar-21	09-Mar-21
Milestone 2			
Complete Individual Research Assignment	Individual	09-Mar-21	10-Mar-21
Generate refined problem statement	Team	11-Mar-21	16-Mar-21
Update TA on team progress	Team	11-Mar-21	11-Mar-21
Complete Functional Analysis worksheet	Team	11-Mar-21	16-Mar-21
Complete Concept Exploration Wroksheet	Team	11-Mar-21	16-Mar-21
Milestone 3			
Come up with one refined concept in the form of an initial prototype	Individual	16-Mar-21	17-Mar-21
Complete Decision Matrix worksheet	Team	18-Mar-21	23-Mar-21
Update TA on team progress	Team	18-Mar-21	18-Mar-21
Complete Design Review worksheet	Team	18-Mar-21	23-Mar-21
Milestone 4			
Complete Prototype Iteration worksheet	Team	25-Mar-21	30-Mar-21
Complete Prototyping Test Plan worksheet	Team	25-Mar-21	30-Mar-21
Update TA on team progress	Team	25-Mar-21	25-Mar-21
Complete Design Review worksheet	Team	25-Mar-21	30-Mar-21
Dedicated Project Time			
Work towards finalizing design	Team	30-Mar-21	05-Apr-21
Update TA on team progress	Team	01-Apr-21	01-Apr-21
Create a pitch video demonstrating your design, its features, and advantages	Team	30-Mar-21	05-Apr-21
Presentation Prep	Team	30-Mar-21	05-Apr-21
Final Presentation: Make a Client Pitch			
Upload the video or a publicly accessible link to Avenue	Project Administrator	06-Apr-21	12-Apr-21
Present video pitch to evaluators and answer questions posed by evaluators about the design on your specified presentation day	Team	06-Apr-21	12-Apr-21
Final Deliverable			
Logbook of Additional Meetings & Discussion	Coordinator	04-Mar-21	12-Apr-21
Final Gantt Chart	Project Administrator	04-Mar-21	12-Apr-21
Source Materials Database	Subject Matter Expert	06-Apr-21	12-Apr-21
Project Reflection	Individual	06-Apr-21	12-Apr-21
Design Project Report	Team	09-Apr-21	12-Apr-21

Final Gantt Chart:

Project 4: Power in Community - Final Gantt Chart

Team Thurs-18

Project Start: 02-Mar-21

Mar 2, 2021 | Mar 9, 2021 | Mar 16, 2021 | Mar 23, 2021 | Mar 30, 2021 | Apr 6, 2021

Milestones	Assigned to	START DATE	END DATE
Milestone 0			
Review the Administrative Responsibilities of the P4 Module	Individual	2-Mar-21	4-Mar-21
Assign administrative responsibilites	Team	4-Mar-21	9-Mar-21
Complete Preliminary Gantt Chart	Project Manager	4-Mar-21	9-Mar-21
Complete Team Charter worksheet	Team	4-Mar-21	9-Mar-21
Milestone 1			
Take notes from the Client Introduction visit and include these notes in the worksheet	Individual	2-Mar-21	4-Mar-21
Discuss objectives and draft initial problem statement	Team	4-Mar-21	9-Mar-21
Complete Objective Tree, How/Why Ladder, Metrics Worksheet	Team	4-Mar-21	9-Mar-21
Complete Project Plan Worksheet	Team	4-Mar-21	9-Mar-21
Milestone 2			
Complete Individual Research Assignment	Individual	9-Mar-21	10-Mar-21
Generate refined problem statement	Team	11-Mar-21	16-Mar-21
Update TA on team progress	Team	11-Mar-21	11-Mar-21
Complete Functional Analysis worksheet	Team	11-Mar-21	16-Mar-21
Complete Concept Exploration Wroksheet	Team	11-Mar-21	16-Mar-21
Milestone 3			
Come up with one refined concept in the form of an initi	Individual	16-Mar-21	17-Mar-21
Complete Decision Matrix worksheet	Team	18-Mar-21	23-Mar-21
Update TA on team progress	Team	18-Mar-21	18-Mar-21
Complete Design Review worksheet	Team	18-Mar-21	23-Mar-21
Milestone 4			
Complete Prototype Iteration worksheet	Team	25-Mar-21	30-Mar-21
Complete Prototyping Test Plan worksheet	Team	25-Mar-21	30-Mar-21
Update TA on team progress	Team	25-Mar-21	25-Mar-21
Complete Design Review worksheet	Team	25-Mar-21	30-Mar-21
Dedicated Project Time			
Work towards finalizing design	Team	30-Mar-21	5-Apr-21
Update TA on team progress	Team	1-Apr-21	1-Apr-21
Create a pitch video demonstrating your design, its features, and advantages	Team	30-Mar-21	5-Apr-21
Presentation Prep	Team	30-Mar-21	5-Apr-21
Final Presentation: Make a Client Pitch			
Upload the video or a publicly accessible link to Avenue	Project Administrator	6-Apr-21	12-Apr-21
Present video pitch to evaluators and answer questions posed by evaluators about the design on your specified presentation day	Team	6-Apr-21	12-Apr-21
Final Deliverable			
Logbook of Additional Meetings & Discussion	Coordinator	4-Mar-21	12-Apr-21
Final Gantt Chart	Project Administrator	4-Mar-21	12-Apr-21
Source Materials Database	Subject Matter Expert	6-Apr-21	12-Apr-21
Project Reflection	Individual	6-Apr-21	12-Apr-21
Design Project Report	Team	9-Apr-21	12-Apr-21
Learning Portfolio Entry	Individual	9-Apr-21	12-Apr-21
Self and Peer Evaluation	Individual	9-Apr-21	12-Apr-21

Logbook of Additional Meetings and Discussions:

1. **March 8, 2021 (All members present)**
    a. All the members met during this time to finish unfinished details on the Milestone 1 work and successfully completed the work during this time.
2. **March 15, 2021 (All members present)**
    a. All the members met during this time to discuss the different means in the means chart to ensure that each mean chosen for the members were diverse enough and explored enough of the design space.
3. **March 22, 2021 (All members present)**
    a. Members met to complete the design matrix before submission. The members discussed which objectives should be put on the weighted decision matrix, weighed them by importance and evaluated each design in the decision matrix.
4. **April 8, 2021 (All members present)**
    a. Members met to complete the final presentation PowerPoint. After this was complete, the members met on a separate call to record the pitch video, edit and submit it.

Section 5:

Source Materials Database:

[1] "ENGINEER 1P13 – Project Four: Power in Community," class notes for ENGINEER 1P13, Faculty of Engineering, McMaster University, Winter, 2021.

[2] "Feb. 24th Client Visit Q&A," class notes from ENGINEER 1P13, Faculty of Engineering, Mcmaster University, Winter, 2021.

[3] "Mar. 10th Client Visit Q&A," class notes from ENGINEER 1P13, Faculty of Engineering, Mcmaster University, Winter, 2021.

[4] "Lymphedema – Symptoms and causes," Mayo Clinic [Online]. Available: https://www.mayoclinic,org/diseases-conditions/lymphedma/symptoms-causes/syc-20374682. [Accessed: April 10, 2021].

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[8] "Fibromyalgia Pictures: Flare Ups, Rash, Trigger Points, and More." https://www.webmd.com/fibromyalgia/ss/slideshow-fibromyalgia-overview (accessed Mar. 10, 2021).

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[11] "Avacen receives Health Canada nod for fibromyalgia pain relief device | Medical Design and Outsourcing." https://www.medicaldesignandoutsourcing.com/avacen-health-canada-nod-fibromyalgia-pain-relief-device/ (accessed Mar. 10, 2021).

[12] Stephanie Watson, "Autoimmune Diseases: Types, Symptoms, Causes, and More," Healthline, 26 March, 2019. [Online]. Available: https://www.healthline.com/health/autoimmune-disorders#treatment [Accessed: Mar. 15, 2021].

[13] "How autoimmune diseases impact patient experience," Health Europa, 25 March, 2020. [Online]. Available: https://www.healtheuropa.eu/how-autoimmune-diseases-impact-patient-experience/98882/ [Accessed: Mar. 15, 2021].

[14] "What's the deal with autoimmune disease?", Havard Health Publishing, Havard Medical School, May, 2018. [Online] Available: https://www.health.harvard.edu/diseases-and-conditions/whats-the-deal-with-autoimmune-disease [Accessed: Mar. 15,2021].

[15] "Autoimmune diseases", Office on Women's Health, U.S. Department of Health and Huamn Services. [Online] Available: https://www.womenshealth.gov/a-z-topics/autoimmune-diseases [Accessed: Mar. 15, 2021].

[16] "Artists overcoming disabilities", Making A Mark, 2013. [Online]. Available: https://makingamark.blogspot.com/2013/02/artists-overcoming-disabilities.html [March 10th 2021].

[17] "5 World-Famous Artists That Had Disabilities", PASSIONATE PEOPLE. [Online]. Available: https://www.passionatepeople.invacare.eu.com/5-world-famous-artists-disabilities/ [March 10th 2021].

[18] "French Tattoo Artist Gets World's 1st Prosthetic Arm That Doubles as a Tattoo Machine", abcNEWS, Avianne Tan, 15 June 2016. [Online]. Available: https://abcnews.go.com/International/french-tattoo-artist-worlds-1st-prosthetic-arm-doubles/story?id=39844337 [March 16th 2021].

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