

Project Deliverable L: Final Design Report: Assistive Feeding

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0.0 Abstract:

This report covers the entire design process of “Assistive Feeding” project which is to design a system that helps a disabled patient at St-Vincent Hospital to eat independently. We interacted with our client, listed her needs and generated ideas.

After eliminating candidate ideas, we finally chose our “Mechanical Arm Support” as the most beneficial design to our client. We built and tested prototypes, created a business model and analyzed resources and constraints. Finally, we successfully built the final prototype and got prepared for the Design Day.

0.1 Introduction:

We first met our client in early september to discuss her expectation and needs from the Assistive feeding project we were going to design and build for her. We went into this meeting knowing nothing about our client or her condition. However, we knew we would need to gather as much information about her and her condition in order to truly provider her with the best possible solution.

Chapter 1: Need Identification

1.1 About Our Client

Our client is a woman living at St Vincent hospital who has restricted mobility. A wheelchair is the only means for her to get around within the hospital. She has limited strength in her arms and hands to grasp and move objects, which makes it very difficult and exhausting for her to eat as she struggles to hold cutlery and bring it to the mouth.

1.2 Observations of Our Client

- Wheelchair structure
 - She sits in a motor-driven wheelchair with a suck’n blow system to drive the chair
 - A table is attached to the wheelchair and placed in front of her, which is referred to as her ‘life’ as all the items she uses daily are on this tray.

- Movement condition
 - She has negligible movement on the right arm and limited movement on the left: can only reach from the tray (same level as her chest) to her mouth and cannot straighten either arm.
 - She has highly limited finger movement
 - She can only hold a light fork/spoon in a certain way but it is shaky while bringing food to the mouth, which often causes spilling

- She can only scoop, but not stab the food with a fork

1.3 Customer Needs

The needs that were acquired from our interaction with the client (after transcribing) are as follows:

- Relief on the effort required to bring food to the mouth
- Extension of the movement range such that she can reach her mouth with ease and reach across her body

1.4 Problem Statement

Design a system that help our client relieve the effort and extend the range of arm movements

1.5 Benchmarking

- E-Z Eating Assistant



Figure 1.1: Benchmarking product “E-Z Eating Assistant” (2016)

This device was first designed for Jack, a pilot who lost feeling of his arms. This is a simply-structured feeding device. The clamps on top hold the food and the wheel at the bottom moves the food forward or backward.

As we learned from the interview that our client has trouble holding large pieces, this gives an idea to fix that problem.

- iEAT Feeding Robot



Figure 1.2: Benchmarking product “iEAT Feeding Robot”

The iEAT Feeding Robot is a robotic arm that rotates freely on its base and moves a utensil up and down with a stick.

From the video shown on the website, it does have a complete 3-dimensional movement which is formed by two 2-dimensional movements (horizontal and vertical). Furthermore, it detects the user’s arm moves and imitates them, which gives a new perspective on our design of the controlling part.

1.6 Metrics

- cost (in dollars)
- weight of the product (kg)
- dimension of movement (2D/3D)
- range of movement: lateral area covered (cm²)
vertical height (cm)
- material: metal/plastic/wood/nylon etc.
- maximum load: the maximum weight (kg) of the load including the utensil if needed

1.7 Target Specifications

The system we design should:

- Cover the following movement range:

Sideways (x-axis): across our client's body, in other word, from one shoulder to another

Front to back (y-axis): from the far side of the table to our client's chest

Top to bottom (z-axis): from the table surface to our client's mouth

- Have at least one fixed point of connection with the wheelchair or the table

1.8 Reflection of Client Meeting

The first client meeting was successful, as we found out what the client needs and from the results we made the problem statement. Our next step would be to generate the concept of solutions and decide one to go further.

1.9 Conclusion

At this first stage, we have finished the need identification. We obtained knowledge about our client, listed out her needs and did benchmarking and metrics based on our interview with the client. Next up, we are going to make a problem statement and generate ideas.

Chapter 2: Problem Statement and Target Metrics

2.1 Design Criteria

Considering that our client struggles eating since she get fatigued lifting her arm and has limited hand movement our main priority is to find a solution that will replace the motion of lifting her arm up to her mouth. Also, as she can lift her arm up another solution might consist of making a system that will ease the force of lifting or and make it more stable.

Our design criteria will consist of:

- A solution that will truly assist our client eat and live independently
- Safe to use
- Within our capabilities to build
- Within our budget of \$100
- Durable and Strong
- Aesthetically pleasing

2.2 Possible Solutions

Using the above design criteria we brainstormed possible solutions that would help our client. We discussed their function and their advantages and disadvantages to see which solutions proved most promising to our clients needs.

Our proposed solutions Consisted of:

1. Robotic arm: Our first solution is to build a robotic arm (shown in figure 2.1) with a rotating base, 2-3 motor driven joints and necessary sensors for spoon positions, touching, locating plate, and scooping. The robotic arm fully replaces the patient's movements with more complete, stable, and precise movements. This will allow our client to eat on her own without someone else feeding her. To design it requires a combination of complex mechanical and electrical engineering skills and a considerable amount of money.

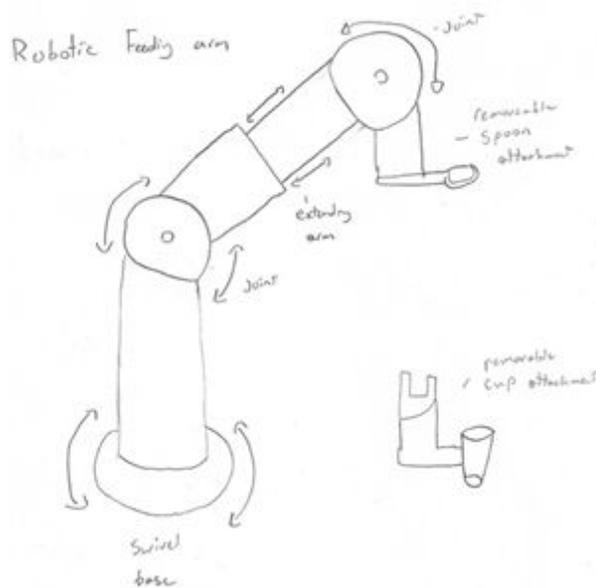


Figure 2.1

2. Self-Leveling Spoon: This solution would work by keeping the spoon head level while the operator eats by using a micro gyro. This device (figure 2.2) would allow the client to eat independently as the concern of spilling your food is drastically reduced granting our client the independence she craves. The downside to this design is keeping it light and perfecting the components to make it tilt successfully and when needed.

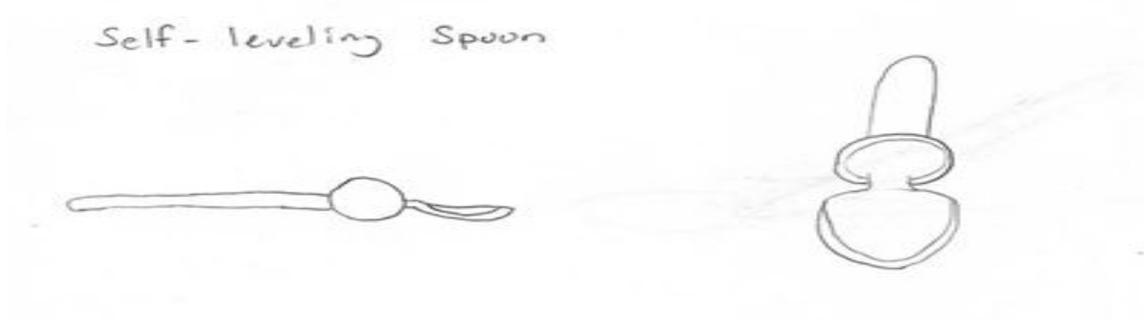


Figure 2.2

3. Plate to Mouth Conveyor belt: The conveyor belt (figure 2.3) would transport food in attached scoops from the plate to the user at rate the user desires (operator controlled). This device will be beneficial to our client as it requires minimal movement on her part to eat, a motion she is struggling with. However, this device will be complex to build with complex subtle details like loading the scoops and getting it to work in a compact manner.



Figure 2.3

4. Arm Support: This is a device (figure 2.4) that could hold up the patient's arm taking some of the strain away from our client. The benefits is that it would help stop our client's hand from shaking while she eats and ease the force of lifting her arm. A downside is that it would still require her to move her arm to eat still causing fatigue.

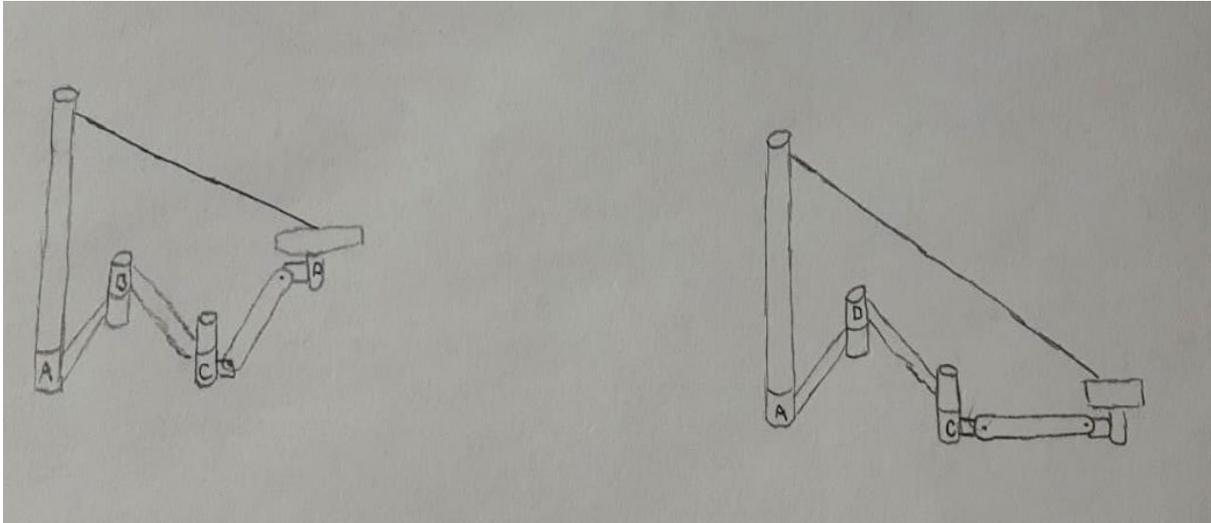


Figure 2.4

5. Rotating Tray: A spinable tray that would be able to turn around so the client can reach every corner of her table/tray. This would help her by removing the need to reach for items on her plate and it would raise up to shrink the distance required for her to reach. The drawbacks are that our client still needs to reach and lift her arm not solving the issue.

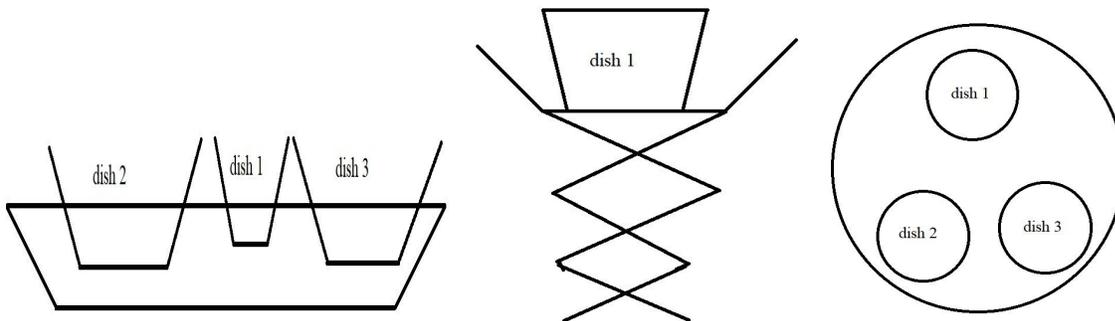


Figure 2.5

2.3 Promising Solutions

Of these solutions we decided the three most promising ones are the Robotic arm, Self-leveling Spoon, and the Arm Support here we will further analysis each solution to tell further which will aid our client the most.

1. The Robotic arm would be useful for our client as it completely eliminates the need for our client to lift a finger. It would work by using position sensors to know where the user is and where the plate is. Another sensor will be used to locate the food on the plate. This will let our client eat without the help of a nurse or volunteer. The downsides to this is our client is not truly feeding herself and may

not be satisfied with the experience. Also the components will be costly to purchase and the robotic arm will be complex to build posing the risk of it being both outside our skills and budget.

2. The Self-leveling Spoon would work by having the spoonhead and the handle independent of each other by having a gyro in the middle. The gyro would keep the spoonhead level regardless of how much the handle tilts. This prevents our client from spilling her food when she brings her spoon to her. However, she still will be required to lift her arm and the spoon will likely be even heavier than a conventional spoon causing further fatigue.
3. The arm support would work by having our client's arm strap into an armrest. There is then a tension band attached to the armrest and a vertical pole (refer to figure 2.4). From the vertical pole would be joints connected by tubes which allow for lateral motion. This will help our client by easing the effort required to lift her arm. The challenges with this design are that the design is still depend on our client lifting her arm and the tension in the band at the rest position might be too strong for her to keep her arm down. Also, the arm support will require a vast knowledge in machining.

2.4 Design Concept and its Functionality

Of the three previously listed designs we decided to further develop is the arm support. We decided to develop the arm support as we believed that considering our skills and budget it would benefit our client the most. This is because it will give her the independence she desires while helping her by reducing the effort of lifting her arm. Also, we felt that the other designs like the robotic were far too complex. The self-leveling spoon was also disqualified as it would not solve our clients mobility problems and probably worsen it by being too heavy. To make the arm support work, we would design it to clamp onto the back of the wheelchair and move in all planes so it does not restrict her movement.

2.5 Conclusion

With our knowledge and creative thinking skills, we generated many concepts and selected three as candidates: the arm support, robotic arm and, self-leveling spoon. Based on our design criteria, we compared pros and cons of each concept and picked out our most promising solution which was the arm support.

Chapter 3: Project Plan, BOM, and Feasibility Study

3.1 Required Task and Time to Complete Them

- design initial blueprint 2-4 hours
- construct actual sized prototype out of basic material 8 hours
- Purchase supplies needed to build the 2nd prototype 1-3 days
- Manufacture parts for the prototype 2 1-2 weeks
- assemble parts into product 1-2 days
- modify prototype 2 and add components to final product 1-2 weeks

3.2 Sprint Plan

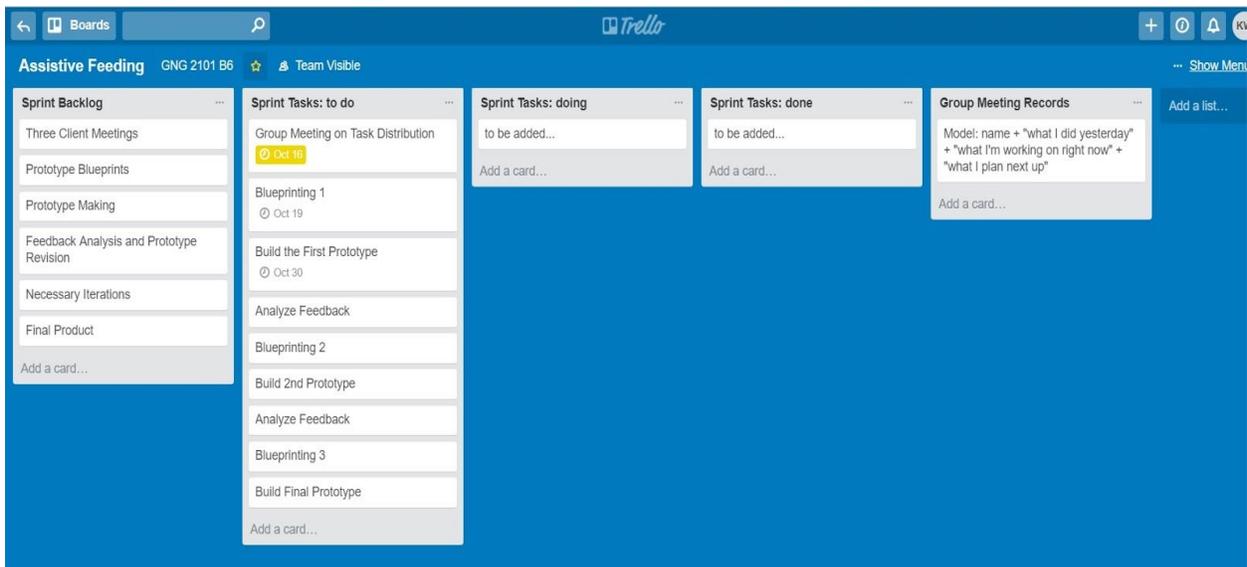


Figure 3.1: screenshot of the Sprint Plan made on Trello

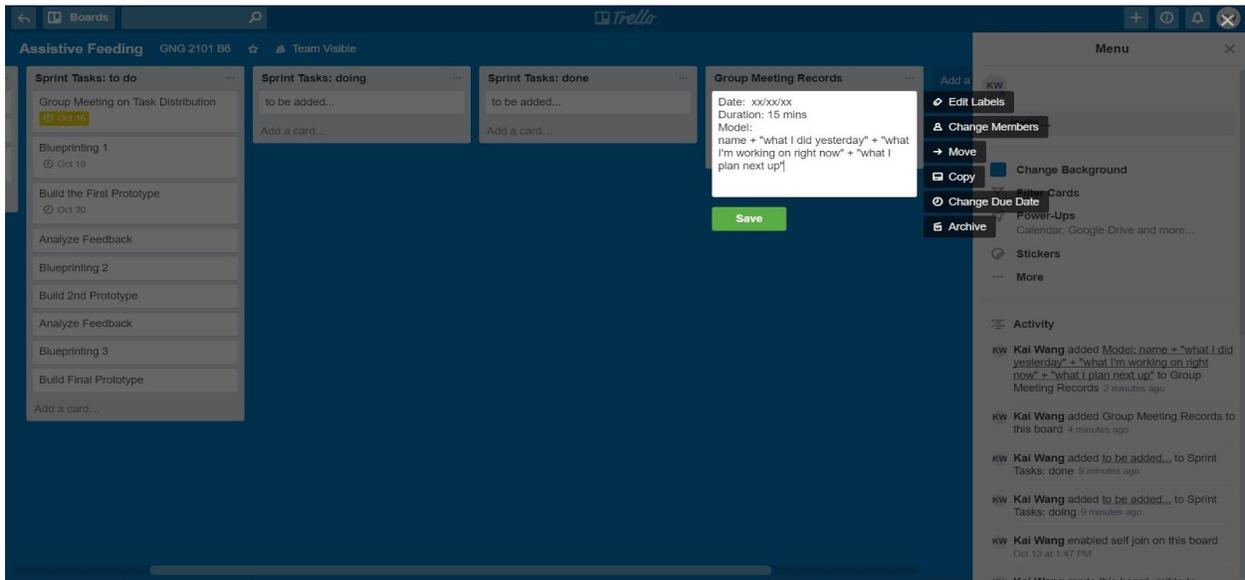


Figure 3.2: the expansion of the group meeting part of our Sprint Plan

3.3.1 Bill of Materials: Prototype I

Prototype I was developed through using household materials we had like a storage shelf we already had, Duct Tape, a tension band, cardboard, and plastic bottles. As the materials were already in our possession they cost us nothing.

3.3.2 Bill of Materials: Prototype II

Our original planned budget consisted of budgeting \$40 for metal parts and tubing \$10 for the hardware as well as \$20 for the armrest. The clamp we will budget \$15 for if we purchase one, if we build one we will add the cost to metal. The 3D printed parts will be free from makerspace and brunfield may supply small metal parts. We kept \$15 unaccounted for in the budget to have funds for any unexpected cost that may arise. In the end we spent \$ 12.26 on hardware, \$7.92 on steel tubing, \$2.88 on the aluminium for the clamp, \$0.16 on steel squares, and \$6.99 on paint. Keepin the product well under budget especially thanks to special pricing from brunfield.

3.4 Cost Justification

These costs are justified as first we will need the tubes to build the frame of the arm support so that it is durable and strong enough to last for years. The armrest is important to ensure comfort while eating as it will prevent the frame of the arm from digging into the operator's arm. Next, investing in the clamp is important so that the arm support is firmly attached to the frame of the wheelchair without wiggling or sliding.

3.6 Uncertainty and Risk

The uncertainty of our design is the optimal range of motion and how the length of our tubing will affect it. This is because we need the tubes to be long enough to provide proper support in all motion but not take up too much space. Also, we will have to run tests to confirm that the tension in the band will truly help lift our client's arm when she eats. Risks we must consider are the stability of the arm support as we do not want it to wiggle and cause an accident when the client is using it. The arm support should also be filed well so that there are no sharp edges posing a risk to anyone who comes into contact with the arm support.

3.7 TELOS Factors

Technical

As a group it will be important to have and develop the necessary skills to build the arm support. This can be done through personal research and applying the skills we learn in our engineering classes. The development and application of our design and manufacturing skills will allow us to build the best product for our client.

Economic

To build the arm support we must budget for the metal and other materials it will take to build it. As we only have \$100 to build the product it will be important to use the money wisely so we can afford all necessary components and supply an effective product for a low price.

Legal

There will be no legal problems like patents when releasing our solution as currently nothing resembling our product is on the market. This means our product abides by all copyrights and laws.

Operational

The largest operational constraint is the manufacturing process of the product as our facility of Brunfield has a limited number of equipment and when it is busy we will have to wait to use certain machines.

Scheduling

There are deadlines posted on brightspace and we have discussed them. We came to the conclusion that even though scheduling around class schedules will be difficult, we if we meet every weekend and discuss regularly we will be able to complete the project on time.

3.8 Conclusion

After analysis of the BOM and feasibility study we have developed an intuitive plan to execute our project in an effective manner and complete it successfully and on time. This is done by reviewing our possible constraints and understanding the cost and resources required to build our product.

Chapter 4: Prototype I and client meeting preparation

4.1 Second Client Meeting:

In our second meeting with our client we explained our conceptual design to her. Our client was very interested in our design and gave us a few points of feedback. First, she requested that the arm support be made to help her reach her head and not just her mouth as originally planned. Also, she asked if we could make the support system help her reach across her body a task she struggles with also. One way we can use this feedback to help our client reach higher is to lengthen the frame of the support system so it can cover the extra distance so she can reach higher. For helping her reach across her body we can mount the tension band on the inside of the support system giving it a x component to help pull our client's arm shown in figure 4.1. This will ease the effort she has to use to reach across her body.

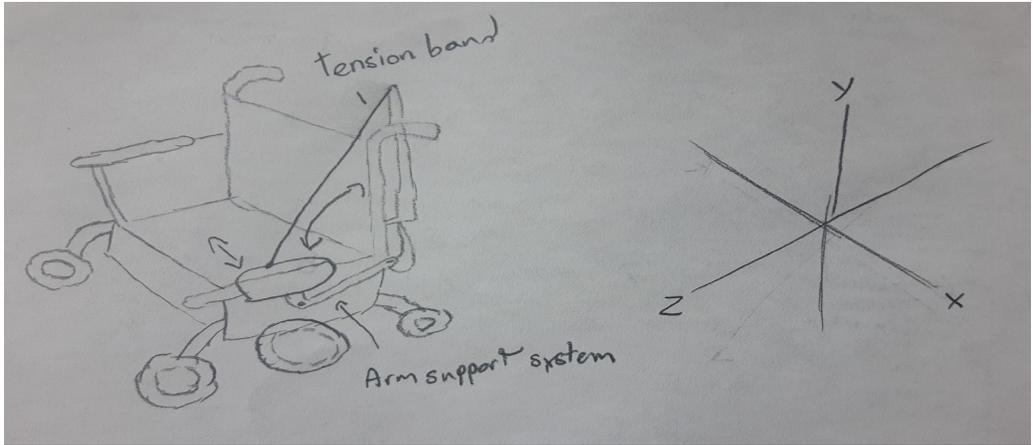


Figure 4.1

4.2 Objective of Prototype

Our first prototype shown in figure 4.2 is a proof of concept of our design to show our client that the tension bands will prove affecting in supporting her arm and allowing her to reach above her head. The prototype design consist of an armrest attached to a pole with a joint at each end allowing it to move up and down. At the armrest there is a tension band stretching to a pole where it gives the arm support system a resting height past were the arm will rest when in normal sitting position (so when in use the tension is their to pull your arm when you raise it, shown in figure 4.3).

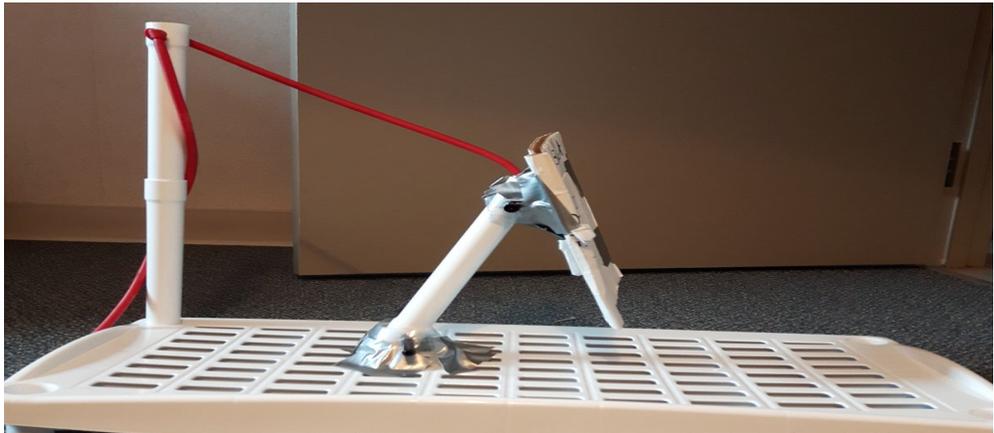


Figure 4.2



Figure 4.3

Also we are going to present our client with a similar clamp to the one we are going to make to attach the support system to the client's wheelchair. The clamp shown in figure 4.4 is what is used to hold your bike lock to the bike while you ride it and attaches to the frame. Hence, we are going to follow its proven design for our product.



Figure 4.4

4.3 Testing Prototype:

We can test our product by using weights and a suitcase scale (figure 4.5).



Figure 4.5

First weigh the weights by themselves with the scale to see the value of their mass (should be equal to their weight). Next place the weights on the arm support system armrest and repeat the previous step. With the addition of the vertical component of tension from the band it should reduce the mass indicated on the scale. If this is the case the test will prove successful and assist our client in raising her arm. Also, for the clamp we can test its ability to remain securely attached to a pole without having a moment occur at the point of contact with the pole. By adding force especially at a distance from where it attaches (like that it will experienced from the arm support system) we can test if the clamp is capable of remaining securely fastened.

4.4 Results of Testing

After testing our prototypes they both passed and proved our hypothesis' from section 4.3 correct. Something we can learn from our testing is that the arm support may require modification so it can reach up to your head in a comfortable range of motion. This could range from a rail system to more joints with further analysis required.

4.5 Outline for Next Meeting

At our next meeting we will present our prototypes to our client and explain to her how it works and will assist her with eating. Next, we will explain the testing we put the prototypes through and why the results previously stated will prove positive for the design being successful.

4.6 Conclusion

By constructing our first assistive feeding prototype it allowed us to get an idea of the challenges we will face in the future like restricted movement caused by the support system. By realizing these possible problems now it gives us time to plan a solution in advance. Also, by reviewing our clients feedback it allows us to design the product for more than just eating as it can now be used for daily tasks our client struggles with that are taken for granted. Overall, our prototype shows promising results in allowing our client live a more independent lifestyle.

Chapter 5: Business Model and Validation

5.1 Business Model:

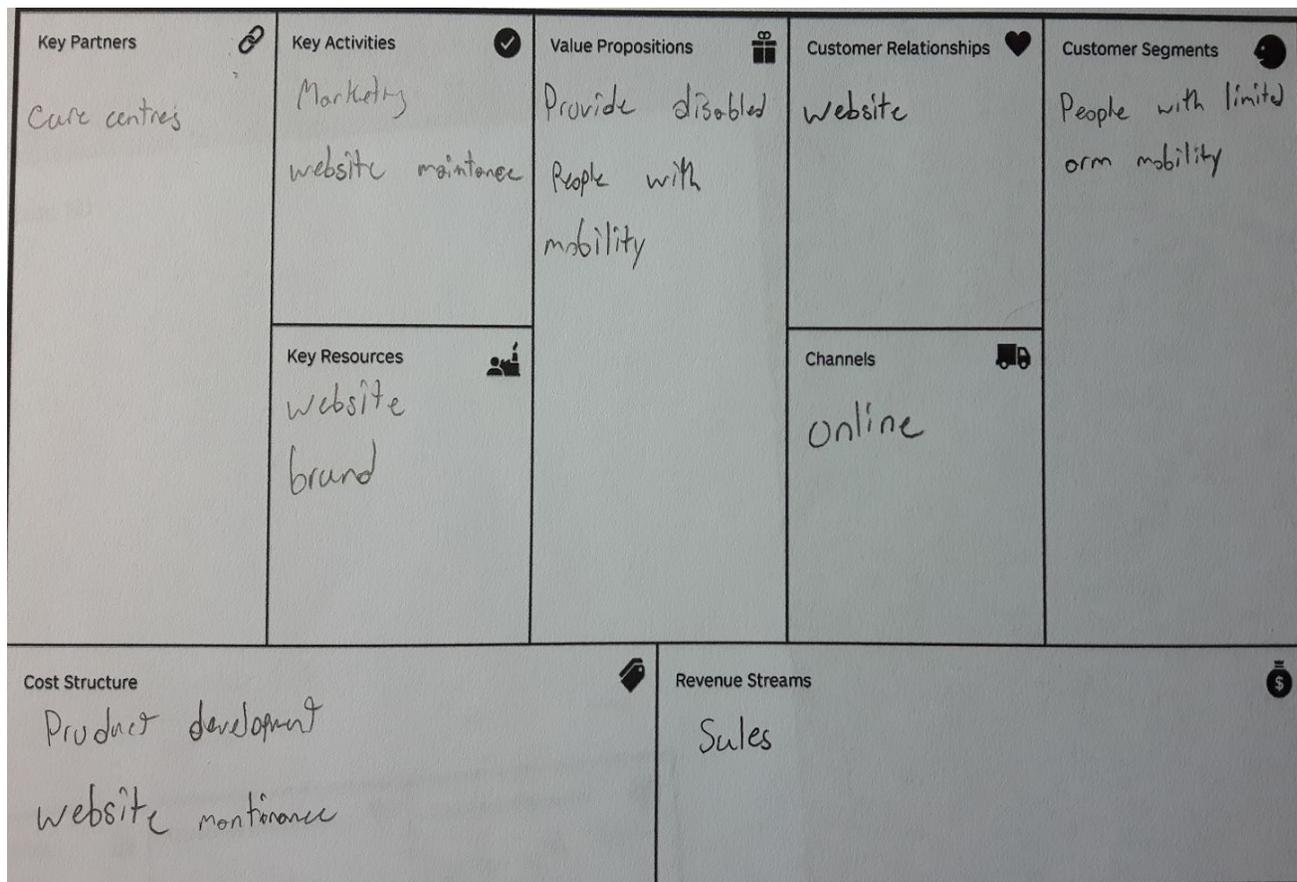


Figure 5.1: first proposed business model

Our first proposed business model shown above, focuses on providing those who have limited arm mobility with a system to regain independence like feeding themselves. Having spoken with an interested person with mobility issues about the product we can see a demand for it within the market. We would sell our product on the website we designed as well as have a customer support section on the site. Our revenue would come from the sales generated by our product. To maintain growth and productivity we will have to hold our key resources of website and brand to the highest possible standard to ensure quality. To do this we will need to market our product and keep the website up to date and ensure it is user friendly. Our main cost will come from product development and website maintenance. We can increase our market penetration by partnering with care centres to ensure our product gets into the hands of those who need it.

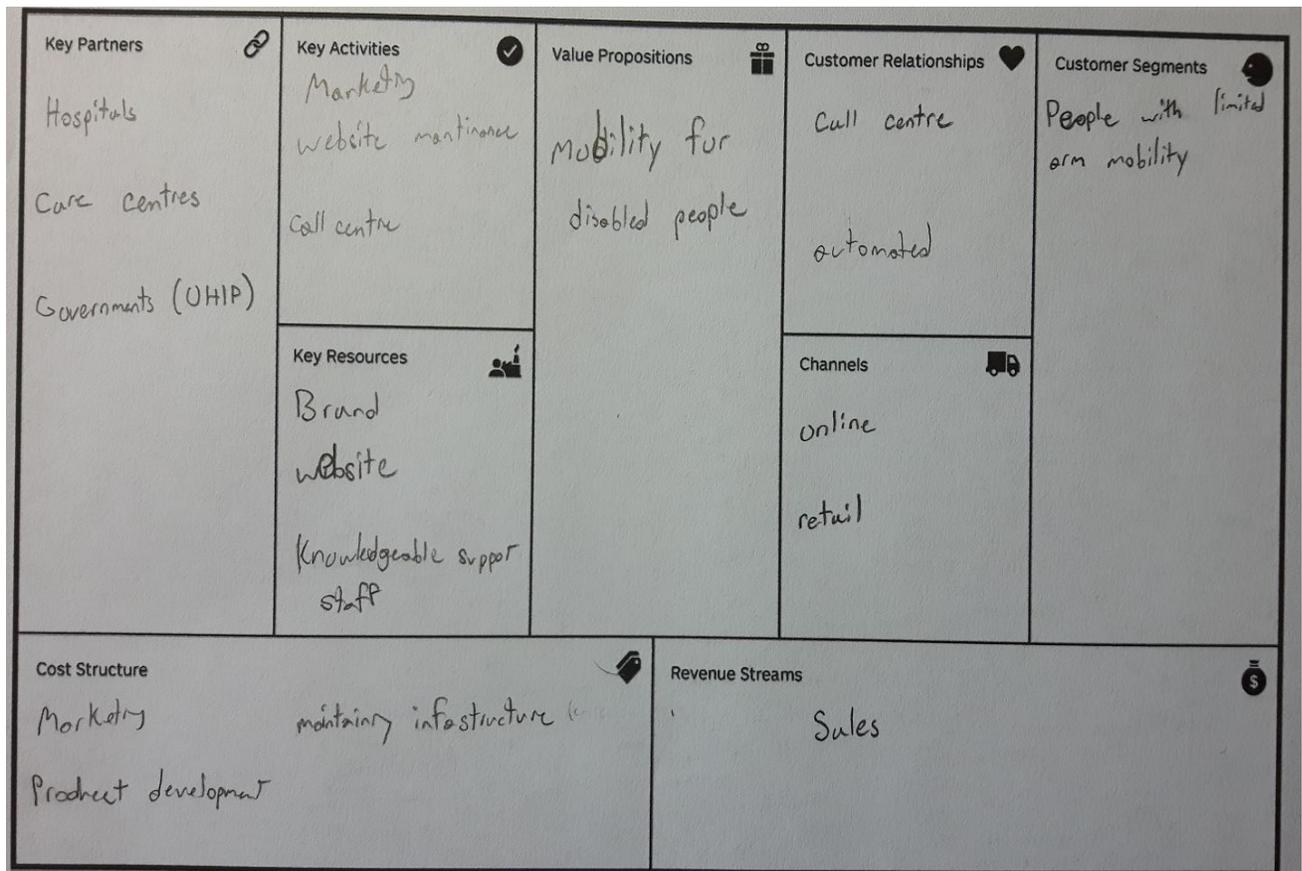


Figure 5.2: second proposed business model

Our second business model focuses again on giving mobility to those who like strength to move their arms in regular task. We will product revenue through the sales of our product through online and retail locations. Realizing that many people from older generations who would use the product do not always trust purchasing items online. Also our customer relations will extend to a website and call centre making answering customer questions fast and easy. To make this happen we will need a strong brand, website, and a collection of knowledgeable staff to interact with customers. Key activities for this will be marketing, web maintenance, and call centre maintenance to ensure all aspects of the company run efficiently. Our main cost will be marketing, product development, and maintaining the web and company infrastructure. We can boost penetration into the market by partnering with hospitals, care centres, and

government programs like OHIP to ensure our product is known and accessible to all who will need

5.2 Assumptions of Business Model:

Of these two models the second is the most viable. This is the case based off the assumptions that first, by partnering with hospitals and care centres our product reaches the hands of those who need it. Also, by partnering with government programs like OHIP it provides consumers access to the product if they otherwise could not have afforded it. Also, by being accessible through phone, it provides our customers with a human experience to answer their questions and provide assistance. This is convenient for customers as many will be from an older demographic who struggle with technology and navigating websites. By selling the product in retail stores it will also increase market penetration as many people do not trust purchasing products online. Also, it gives them a chance to test the product and see how it will improve their life.

Table 1: The Validation Board

Core Assumptions	Customers	Problems	Solutions
1	People with only arm movements	Need extension in arm movements; arm support able to install on one certain type of wheelchair	Keep original arm support design
2	People with full leg movements (i.e. able to walk) but limited arm movements	Need extension in arm movements; arm support able to install on any type of chairs, and is removable	Keep original arm support design and redesign the base to be adjustable to fit for different type of chair arms

3	People with temporary arm disability (e.g. injuries) and need full arm movements during the recovery period	Need extension in arm movements; need the mobility;	Stronger and more versatile structure; the rest is the same as the second customer group
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Table 5.1

Assumption testing:

Among all the assumptions we have made, we pick the third group “people with temporary arm disabilities” as our riskiest one. To test it, we will first: develop a prototype with a stronger structure and wider range of motion, and call on volunteers who recently had an arm injury like falling off a bike, or from a high place etc. Second: We ask them to try out our prototype and then have them to answer a questionnaire which consists of three main questions: “What are the occasions that you find yourself in urgent need of full arm movement?” “What are the differences when you do something with and without the arm support? Give examples.” and “Do you think the cost of our product is reasonable as a temporary assistive equipment?” Third: We collect and analyze the answers: if we find that the occasions they need our product are very few, there is no big difference with or without our product or the cost is not considered worthwhile and we cannot cut them down anymore, we should probably drop this assumption. That’s the invalidation part of our business. The first two groups are what we consider the promising ones, and the validation process will be similar, but we expect positive answers in this case.

By working with possible customers we can learn where they would struggle and design the help centre around the lessons learned their allowing it to run as efficiently as possible. Approaching retailers will also be important as to see if they are interested in the product and want to carry it in their stores. By showing them the prototype we can test their interest in carrying our product.

5.3 Risks of our Business Model:

In order for our business to succeed, these core assumptions must prove correct. Without our partners our brand will struggle to get recognition and be known to consumers. Also running a call centre is expensive as it requires an office, staff, and

training for the staff. All of these factors are costly and if the centre is not used sufficiently by customers it will be a burden the company cannot afford. Selling the product in retail is also a key assumption as by selling it wholesale we make less profits however we assume that it will allow us to sell more volume and hence have a greater profit margin.

5.4 Conclusion:

Overall, our business model is meant to allow our Assistive feeding/arm support system to reach as many people as possible through partnering with health care centres, hospitals, government agencies, and retail outlets. Getting these entities to see the value in our product will be the largest task to overcome and will determine if the product is successful or not. With our product our customers will gain the ability to eat on their own, scratch their face and head, and reach objects all activities which we take for granted in everyday life that they struggle with. If we can get these organizations to see the value our product brings to people's lives by allowing them to live more independently we will achieve success.

Chapter 6: Customer Validation and Next Step Presentation

6.1 Considerations of Design

While designing our arm support system to assist our client eat we have been struggling to plan the layout of joints and the most beneficial length of tube to attach them which will allow for the most fluid and comfortable movement. This is an important consideration as our client has limited mobility and we could worsen it by making the arm support to rigid or uncomfortable. Another important issue we must consider is that our clients wheelchair is at its maximum width and therefore we must keep our design as narrow and skinny as possible. Also, as our client's wheelchair is electric it is not the same layout and frame as the ones provided to us by St Vincent's so we will have to take detailed measurements in our client meeting and rely on them to produce our product.

6.2 Client Feedback

Having met with our client we were delighted to hear she likes the initial prototype and looks forward to seeing what the final product will look like. She said she

felt the tension helping her lift her arm, even with the tension less than that of the final product. While speaking with her we learned it is best to have her forearm rest on the assistive feeding arm support as we assumed to optimize her movement. Also, she stated the height of the arm support should be about 8 inches to allow her to easily get food to her mouth.

In our meeting we clarified several key factors including whether or not designing a 360 degree swivel at the armrest joint or to assume our clients elbow will compensate this motion. After discussing with our client we agreed it was an unnecessary feature which does not need to be prioritized. Also, we will have to determine the exact width we will have to work within knowing our clients wheelchair is approaching the maximum width. In the meeting we learned we cannot exceed the width of the wheelchair as it will prevent her from easily moving through doors and narrow places. Also the height at which the support system will max out at must be determined to balance both comfort and allow for maximum reach. In the meeting we learned the current height of the prototype of about eight inches would be sufficient for her required movement.

6.3 Plan For Future Development

Currently, our action plan is to construct the arm support system allowing it to move freely in all directions comfortably. We plan on doing this by dividing the arm support system into smaller sections and fabricating these sections one at a time. Allowing us to problem solve one issue at a time and ensure each part functions properly. We have begun fabrication of the first few joints coming off of the main vertical pole and hope to have an operational prototype within the coming weeks. Once this is complete we will test its efficiency and present it to our client. Having performed test and met with the client we will modify any aspects that do not work and apply them to a final product.

Chapter 7: Economics Report

7.1 Cost Associated With Arm Support System:

Variable cost: The variable cost would be the materials used to build the arm support. As production increases the cost of material will decrease as our company will have stronger buying power and can negotiate a lower price due to placing larger orders. With the lower price from the supplier our cost will decrease and increase profits.

Fixed cost: The fixed cost of the business will be the rent, salaries, property tax, insurance, interest and utility delivery fee.

Direct Cost: Direct cost include labour, material, and expense cost

Indirect Cost: Indirect cost will include office supplies, office hardware (eg, printers, computers), depreciation, and utility usage.

7.2 Three-Year Income Statement:

	Year 1	Year 2	Year 3
Sales Revenue \$750/unit	500 units sold \$375000	600 units sold \$450000	750 units sold \$562500
Cost of Goods Sold \$150/unit	500 units \$75000	600 units \$90000	750 units \$112500
Gross Profit	\$300000	\$360000	\$450000
Operating Expenses	Rent \$100000 Utilities \$5000 Wages \$50000/worker (4 workers) = \$200000 Insurance \$11250 Total expenses: \$316250	Rent \$100000 Utilities \$6500 wages \$50000/worker (5 workers) = \$250000 Insurance \$11250 Total Expenses: \$367750	Rent \$100000 Utilities \$7500 Wages 50000/worker (6 workers) = \$300000 Insurance \$11250 Total Expenses: \$418750
Operating Income	-\$16250	-\$7750	\$31250

Table 7.1

7.3 NPV of Breakeven Point:

Year One: In the first year of operation the business will have a loss of \$16250 meaning in order for us to break even we must sell an additional 27 units. $\frac{\$316250}{\$600/unit} = 527.08$ units this equation shows that to break even 527.08 units must be sold whereas we only sold 500 showing we were 27 units short and loss \$16250 in revenue.

Year Two: In the second year the business we need to sell 613 units to break even where we only sold 600 units. This shows we were 13 units off of breaking even and loss revenue of \$7750.

$$\frac{\$367750}{\$600/unit} = 612.92 \text{ units.}$$

Year Three: In the third year of operation 698 units are required to break even. In this year our company sold 750 units allowing us to have a profit of \$31250 by selling 52 units past the break even point. $\frac{\$418750}{\$600/unit} = 697.92$ units

7.4 Assumptions:

In this report several assumptions had to be made. First we assumed that the cost of producing the product would remain constant and not fluctuate with production levels. This Assumption is valid as it is difficult to determine the adjusted pricing we will receive from suppliers as production increases and we begin to develop a relationship with our supplier and order more material. Next, we had to assume the values of our business expenses, cost and revenues. These values were assumed based off of averages in ontario for example wage and the cost of rent and the general process of how a business develops over its first three years of operation. For example very few businesses are profitable within their first year and in their second year are often around the break even point. The Utility cost are assumed to increase over time as the production ramps up since more energy will be required to product more inventory. We also had to assume that insurance would remain constant over time. This assumption was made as insurance companies often will keep monthly rates constant, but it is possible for the cost to increase as the value of the business increases. However, it is difficult to determine by how much with each insurance company being different as well as the perceived value of the business.

7.5 Conclusion

In order to turn our product's business model into a successful company it is important to understand the cost of operating the business and how to maximize our profit. This will allow us to see where we can try to be more efficient like finding a cheaper place to rent or manufacturing overseas where labour and rent will be cheaper. Without considering these factors could result in a poor business plan and the company failing due to lost revenue caused by lack of profits and too many expenses.

Chapter 8: Prototype II and Client Meeting Preparation

8.1 Feedback From Third Client Meeting:

At our third client meeting we displayed our first prototype (figure 1) to our client as a proof of concept that the tension bands will in fact help our client lift her arm. Our client was impressed by the prototype and even wanted to try it out where she confirmed that she felt the tension helping her. In this meeting we were told to not have the arm support extend past the width of the wheelchair as it is at the maximum width. Also, we learned the tube that moves vertically should be about 8 inches like the approximate length of the first prototype. Our client also asked if we could design it to help her reach across her body as that is a movement she also struggles with.

8.2 Design Goal of Prototype II:

The goal of our design is to create an arm support that will assist our client with eating as well as other task that involve lifting your arm. We will achieve this by having a series of joints connected together by tubes allowing for motion in all planes. A tension band will provide lift from a pole and attaches to the arm rest. The design should be simple and versatile so anyone can set it up and use it easily regardless of their seating position and chair.

8.3 Design Day Outline

1. A Complete Final Prototype

First of all, a well-assembled, functioning prototype of the arm support should be built, and it should be successfully and firmly attached to the wheelchair before the design day.

Verification: Before or during the preparation time on the Design day, we will have our team members taking turns to sit on the wheelchair and try out the function and the tension of the band; we will also exert some force on the arm support from different directions to test if it's firmly attached.

2. The Proper Function of the Prototype

The proper function of the prototype consists of some important aspects like: the tension of the band and its adjustability, the range of arm movement on the armrest, the flexibility around the joints, the solidity of the entire structure.

Verification: We verify the functions by observing the functioning of the product and asking the feeling from testers.

3.The Design Process of our Final Prototype

The entire design process of our prototype, from generating the problem statement to testing the final prototype should be presented.

Verification: we make a presentation board with the explanation of each part and their corresponding figures; we proof the board before presentation to make sure we do not miss any important phase of the design process.

8.4 Purpose and Function of Design:

The Purpose of our prototype is to display the capabilities of our product. Our Prototype performed successfully in the way we intended as it was able to move in all planes and ease the effort associated with lifting your arm. We intend to thoroughly test the functionality of this prototype and determine where improvements need to be made to increase its functionality. The improvements that arises from testing the product include adding a strap to the armrest to secure your arm into it giving better control, shortening the pole length to test if it provides more control in motion and so it takes up less room at a table, creating an adjustable clamp so the support can attach to any wheelchair frame, finally we intend to create an easy twist adjuster for the tension band to it can easily be changed according to client's needs.



Figure 8.1

Figure 8.2 below shows the range of motion the arm support will have due to its four joints labeled A-D which will allow our client to move in any horizontal plane of motion she desires.

This is important as she already has restricted motion and we do not want to restrict it further by making the arm support too rigid. Also this design allows the arm support to move in flush with the chair so it can squeeze through narrow areas.

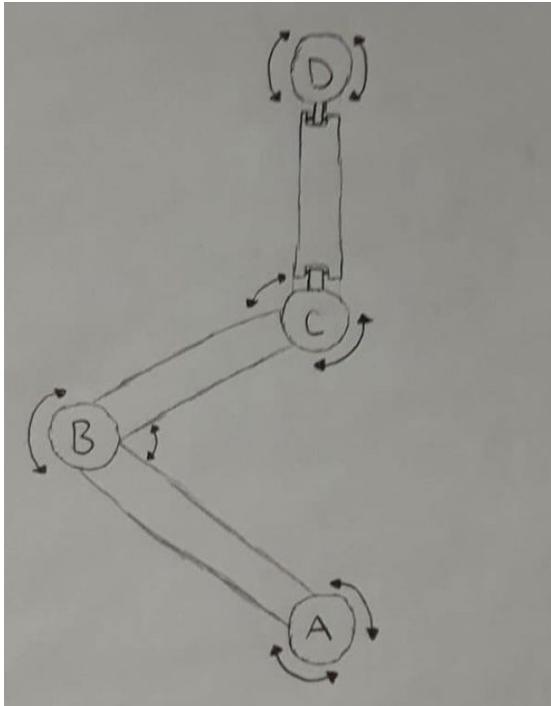


Figure 8.2: Layout of joints

Figure 8.3 displays the pins in the tube between joint C and D which will allow the arm support to move vertically the motion that will help our client the most.

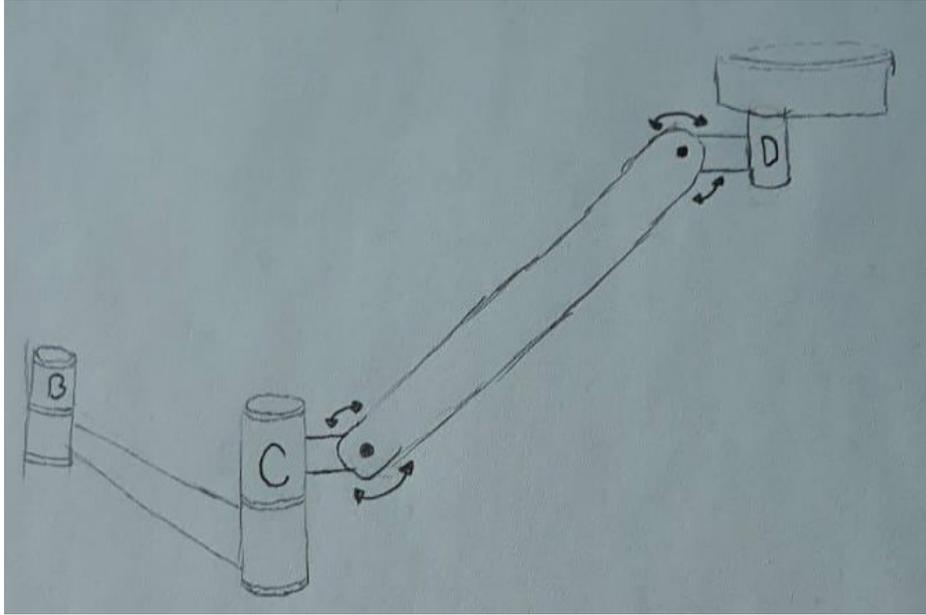


Figure 8.3: Layout of pins that allow for vertical motion

Figure 8.4 displays how the clamp will attach to the wheelchair and how it will work by having four bolts screw into the holes attaching the two clamping pieces together. The semi-circle notches is where the back mounting bar on the chair will sit so that it securely in between both pieces.

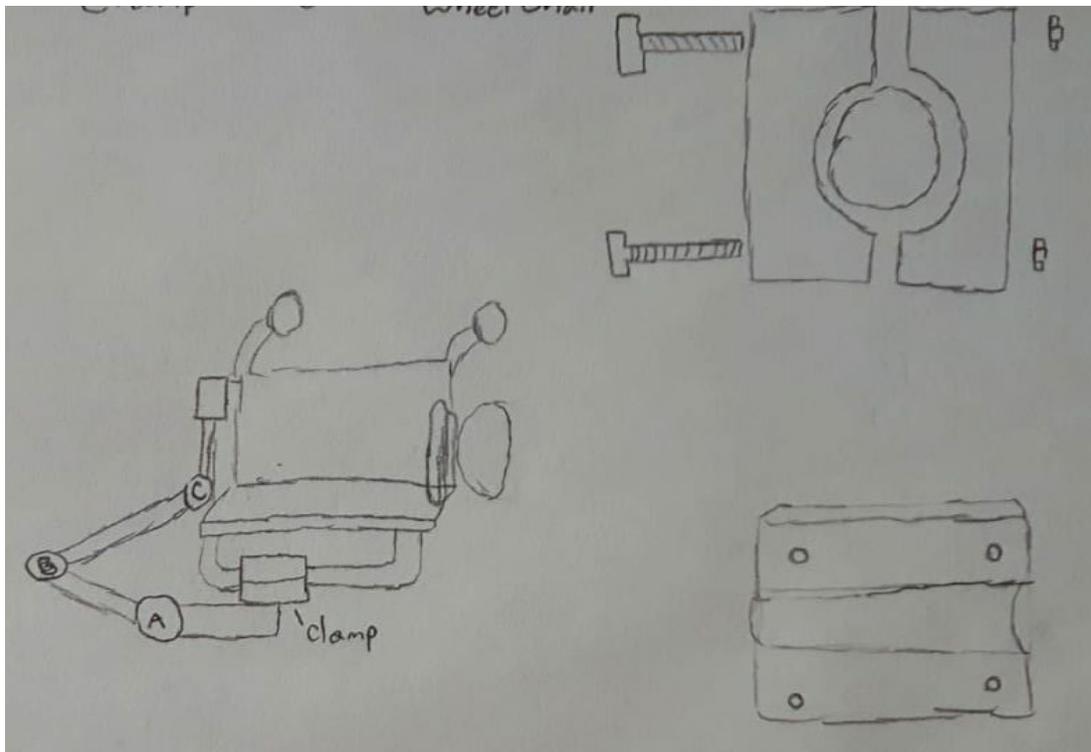


Figure 8.4: clamp of how the arm-support will attach to the wheelchair

Figure 8.5 displays how the tension band will operate. When the armrest is not in use the tension in the band pulls the armrest up to the height of your mouth well seated in the chair. When you place your arm in the armrest the weight pushes it down so that when you have to lift your arm the tension is there to pull it up. This will result in less effort to lift your arm and make eating easier for our client and many others.

8.5 Conclusion:

Overall, the prototype we produced followed its intended design and met all the requirements placed before it. It assisted with the effort required to lift your arm and could move within all planes of motion. At design day we displayed this prototype to possibly to a panel of judges and received valuable feedback to improve the design and make it more efficient. We then tested this prototype and used the feedback we received and found key areas which should be improved so the arm support works to its highest potential.

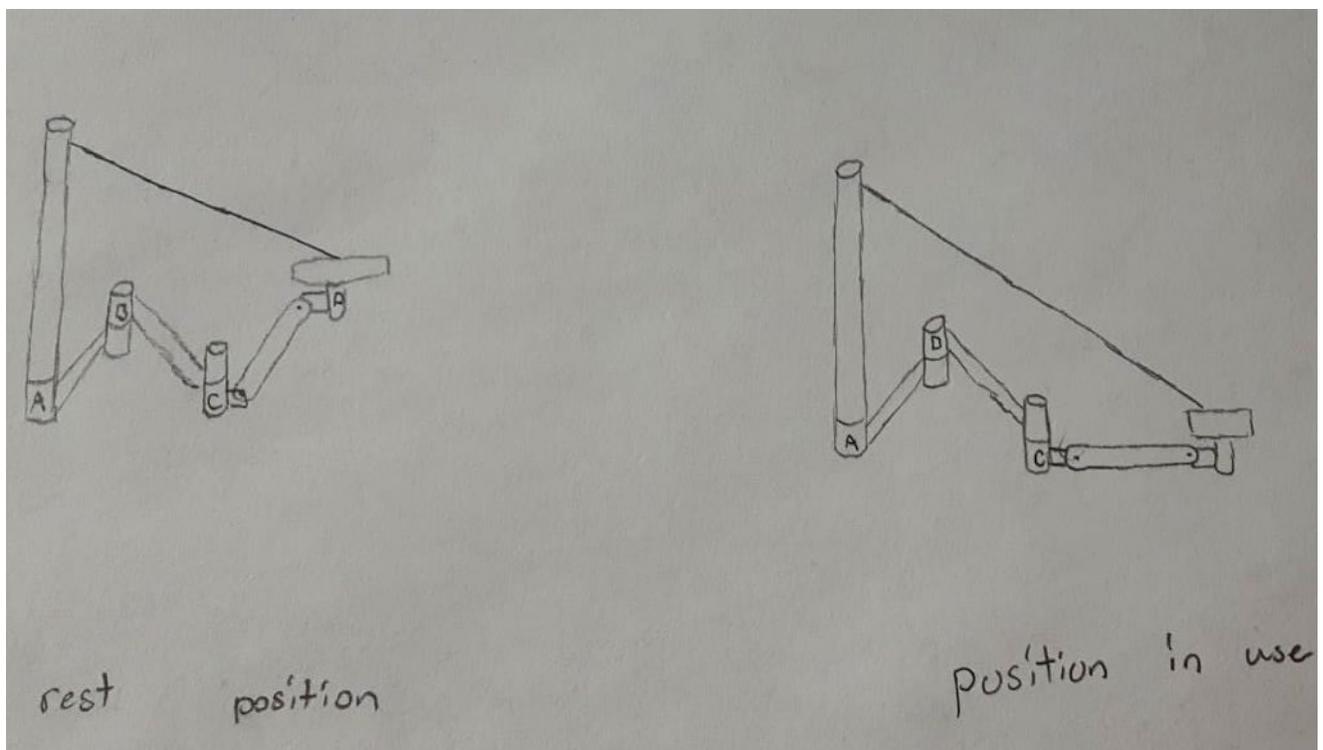


Figure 8.5: Display how tension system will work

0.2 Conclusion and Future Work

Overall, we produced a high fidelity prototype of our product to present to our client following the design process learned in class. Our product was fully operational and assisted our client in the process of lifting her arm. For future work we plan on shortening the tubing between joints so the arm support is more compact. Also we plan in testing with different tension bands at different heights and to develop a easy adjusting notch. Finally we plan on adding an arm strap to allow for better control of the product.

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