Introduction to Product Development and Management

For Engineers

GNG 2101

Final Report

TEAM 7:
Ashley Oraka (8587781)
Daniel Khoo (7788254)
Zach Harbic (300014397)
Danial Ali (300019466)

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Introduction

Everyone knows the feeling of discomfort experienced while sitting for long periods of time. We are able to adjust but wheelchair users like our client Joelle cannot adjust by themselves due to disabilities. Because of this, these users develop blisters (from sweat buildup), and are faced with the massive pain and discomfort felt in the spinal area. Usually they are faced with this pain and aren't able to help themselves like we are - so they constantly need to depend on nurses or family members to help.

Our product helps relieve this pain and make the users less dependable on nurses/family members. Our product - northern comfort - consists of a pressurized air cushion that inflates/deflates into specific areas of the cushion to allow the patient to adjust. This works by having a pump push in air to 2 valves located at either side of the wheelchair. Two switches will control the openings of the valves so that when the user needs adjustment they will hold the switch and allow air to inflate the cells.

Many patients with similar disabilities where they are unable to adjust themselves without the help of a nurse/family member could potentially benefit from this product. As well users who generally feel discomfort while sitting for long periods of time could find this product to be of use as well.

Our team is a highly motivated group of students who have come to understand why a client would want our product. Through our meetings with Joelle we have been able to gain a level of empathy that may not be reached by our competition, leading to our team becoming more capable of designing the right product for the right person.

Design Process

We followed the design process steps that was taught in class. Our design process began with empathization, and coming up with a problem statement based on our client Joelle's needs. These needs were interpreted through our first client meeting. During the meeting she expressed some of her ideas of what the cushion should be able to accomplish. Her main concern was that the cushion should have inflatable air cells to allow her to shift her body weight and relieve pinched nerves in her lower back. Some broader needs were that the cushion should be breathable so that she would get skin rashes from heat and sitting for long periods. We interpreted these needs to create our problem statement: " Our wheelchair bound client needs a cushion that provides adequate support to her lower back to relieve pressure points in her spine. The cushion should be of a material that does not trap heat as the client is sensitive to skin rashes and shear. The cushion should have sections with varying amounts of pressurized substance in each section to ensure pressure redistribution and contour to the client's body for maximum comfort." With our problem statement in mind we started our research of inflatable wheelchair cushions that were already on the market. We found that most

wheelchair cushions were either cheap but too simple or that they were what the client wanted but too expensive. However, we drew inspiration and incorporated our own ideas from them, and decided on a design suitable for Joelle.

Following this we decided on a list of design criteria, metrics, and target specifications that would most suit Joelle.

Design Criteria

Functional Requirements

- Cushion has to fit the client and reduce pressure points
- Cushion has to have vertically moving sections
- Cushion has to be comfortable
- Cushion has to be reliable

Constraint

- Cushion has to be under $100
- Cushion needs to be breathable
- Cushion has to fit in client's wheelchair (47cm x 38cm)

Non-functional Requirement

- Aesthetics of the cushion should be pleasing
- Components of the cushion should be easily replaceable
- The cushion has to fit multiple wheelchairs

Metrics

Metric	Measurement
Length	47 cm
Width	38 cm
Height	18 cm at highest point, 10 cm at lowest point
Weight	less than 1 lbs
Inflation length	1 - 2 inches
Materials	Gel for top covering, foam for base

Target Specifications

- The length must be less than 47 cm because the client feels discomfort if the cushion is larger than the length of the wheelchair seat.
- Width, height and weight are all values which have more leniency since they don't directly affect the comfort of the client.
- Cushion will have a gel covering because it molds to her body and is the most comfortable material - it prevents rashes, sores, etc.
- The cushion will be constructed with a foam/lightweight material base to create a rigid base for the gel covering.
- The cushion shape will be flat to prevent constricted movement.
- It will have 4-6 air pockets that will inflate/deflate by around 2 inches. Surface area for each pocket would be sufficiently large to allow to effective pressure point alleviation when clients exerts weight.
- The target cost is $100
- Must make sure to take safety precautions and produce a reliable product - will be potentially dealing with pressure inflation/deflation or hydraulics as well.

Benchmarking

To determine what competition our cushion will be up against we researched multiple alternatives to our product. We found similar items, however they were either much too simple or they were much too expensive. For example, we found an inflating cushion that could adjust seating position, however it required manual inflation (displayed below). This product was very inexpensive at only $19.99, however it does not meet the needs of our client as it does not offer a large degree of adjustability. On the other end of the spectrum we found an automatically adjusting cushion that uses pressure sensors to adjust seating position for the user (shown below). The only problem with this cushion is that it is extremely expensive at $3900. This is a very expensive price, and our product can offer a similar degree of adjustability at on $100.

Figure 1: Inflating Insulated Seat Cushion

Cost: 19.99

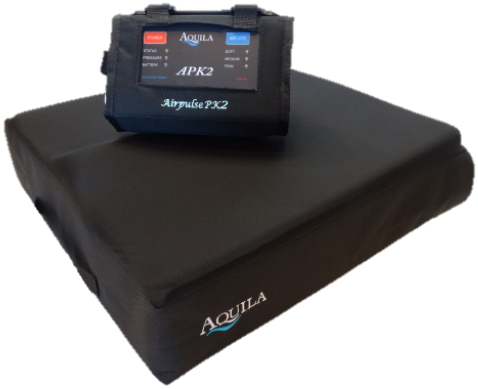
- Designed for users the need moderate to high skin protection
- Pre-contoured foam provides a stable base of support for hips
- conforms to bones to distribute pressure more evenly to reduce peak pressure points

BUT

- Simple Static Cushion
- it is manually inflatable - our client wants an automatic inflation system
- It inflates the whole cushion and not specific points of the cushion
- MANY cushions on the market that help alleviate pain are similar to this one

APK2 Custom Wheelchair Cushion

Cost: $3900

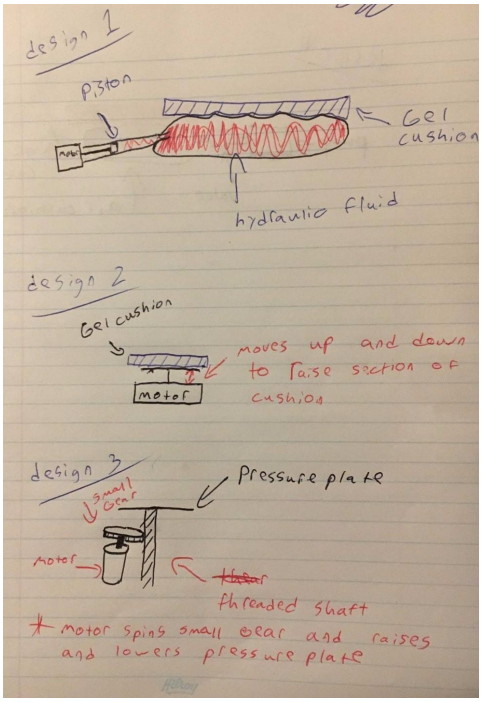


- eliminates constant pressure and automatically inflate and deflate to deliver pressure relief
- Designed for users the need moderate to high skin protection
- Pre-contoured foam provides a stable base of support for hips

BUT

- VERY expensive

Conceptual Designs

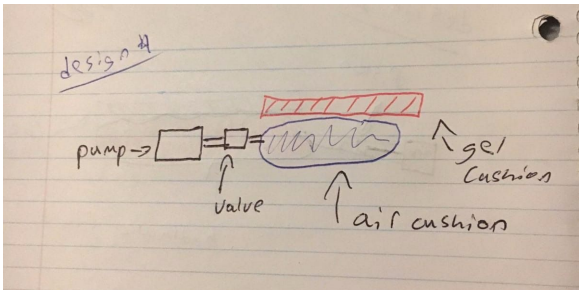


Design 1:

This design illustrates one method with which we could change where the pressure points in our cushion lie. This system utilizes a piston that forces a hydraulic fluid into an expandable section of the cushion, which would in turn change the height at which the cushion contacts the the clients bottom. This expandable sections sits under a gel cushion that offers cushioning and ventilation.

Design 2:

This design utilizes a mechanical system to change the pressure points of our cushion. A small electric motor pushes a platform up and raises the height of the cushion. 4 of these motors would be used to raise and lower different sections of the cushion to alleviate pressure points.



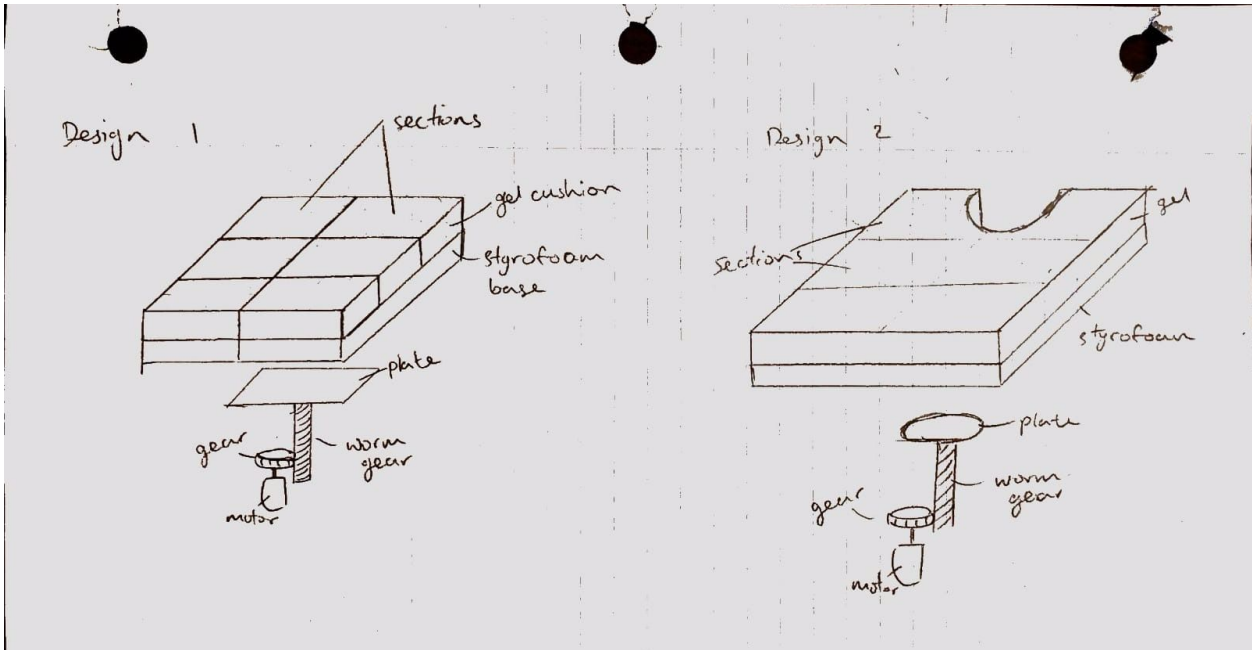
Design 3:

This design shows how the electric motor from design 2 would change the height of the cushion. The electric motors spins a small gear which in turn spins a worm gear mounted to a pressure plate which raises and changes the height of a section of cushion.

Design 4:

This design uses a pneumatic system to compress air in the cushion to alter the pressure point experienced by the client. The design consists of a pneumatic pump to compress the air, a valve to control how much air is pumped into the system, an air cushion to fill with compressed air, and a gel cushion to provide comfort.

Chosen Designs:



Design 1:

Cushion uses a gel top and will simply be separated into six sections. It will be strengthened by using hard styrofoam as the base of the cushion and attached using velcro. Sections of the cushion will rise using a mechanical system with a worm gear and a motor.

Reasoning:

A mechanical system is chosen as it seems to be the simplest to implement. The cushion shape is designed similar to what was observed at the client meet. A gel top will be used as the client specifically mentioned that she prefers a gel cushion over other types of cushion. The styrofoam at the bottom will provide a stable bottom for the cushion to rest on and a stable top for the plate to push.

Design 2:

Cushion is similar to the first design except that it has a cut out at the back where the spine is expect to rest on. It will use the same mechanism as the first design except for round pressure plates instead of rectangular ones.

Reasoning:

The cushion has a cut out as it will make the cushion more breathable and prevent pinching on the nerves in the client's spine. Similarly to design's 1 reasoning the cushion will use a styrofoam base and similar mechanism but with round plates instead of rectangular plates.

Analysis (design 1 and 2): (3 is Best, 1 is Worst):

	Design 1	Design 2
Fit the client	2	3
Fit the wheelchair	3	3
Moving sections	2	3
Breathability	1	3
Reliable	2	2
Size	2	3
Weight	2	3
Cost	2	2
Aesthetics	1	2
Parts Replicability	1	1
Fit multiple wheelchairs	1	1
Total	44	59

*Total is found by applying different priority levels established in the beginning.

Final Concept: Design 2 with modified cushion cut out.
Based on this analysis, it can be seen that the second design chosen will be closest to achieving Joelle's goal of creating a comfortable wheelchair. The mechanical system will be implemented for inflation/deflation, and the cushion will have 6 sections as well. This design is made more breathable and provides more support to the client because of the cut out at the back. The moving sections will be composed of round pressure plates which we believe will feel more comfortable for the client instead of the flat rectangular ones. While this design is very similar to the first one with the same dimensions and general target specifications - the core functionality of this concept achieves all the goals of creating a comfortable cushion.

Prototype Testing and Customer Validation

Prototype I

Our 1st prototype focused on the layout of the air cells within the cushion. We made a couple of assumptions after meeting Joelle during the 2nd client meeting: 1) Client experiences multiple pressure points within the area shown above. 2 large sections might be inadequate hence, we need to change the middle placement. 2) Clients needs to be able to activate individual cells when she experiences discomfort. Interconnecting all cells would lead to combine inflation and deflation which does not satisfy clients needs. In addition, we wanted the cushion to be inflated by a hand pump as that would lower the cost.

Therefore, we made a test plan for the first prototype

Prototype I Test Plan

- Testing for number of sections in the middle: Initially we created 6 cells within our model with 2 major cells in the middle. We noticed it covered a very small surface area. Using our clients measurement and wheelchair measurements we noticed we needed to increase the width of the cushion to ensure all pressure points within that area were addressed. Increasing the width was not an option as we had designed a cushion using the maximum width possible. We decided to play with the sections by moving them and creating more compartments.By doing this, we concluded the number of sections in the middle would range between 6-8 to ensure all pressure points are targeted.
- Testing for connections between cells to the pump: By creating this model we noticed we could pass individual pipes from each cell to the pumping system. This way the client can individually select what area she needs to be inflated/deflated. We also realised we didn't need multiple pumps as we suggested in the previous deliverable.

From our first prototype, our client stressed on the need to alleviate all pressure points therefore, we decided we needed to increase the number of air pockets in the middle portion of the cushion. In addition, our client also stressed on the need for automation. She needed a system that operates without additional assistance.

With the client's feedback we decided that our original idea of inflating the cushion manually was not going to work and we had to automate the cushion with an air compressor.

Prototype II

Prototype II Test Plan

- Our biggest concern is whether the cushion will have the ability to lift the client. We will test the prototype on ourselves by putting the cushion in a wheelchair and testing to see if the cushion will be able to lift one of us. Additionally, we want to take note of the noise level made from the air pump and take note of the time it takes to fill the air cells.
- We will also test the cushion for breathability by sitting on the cushion for a long period of time, observing if there is any discomfort experienced during the test. To make this test more legitimate, we are not allowed to shift about in the chair when we are sitting as this

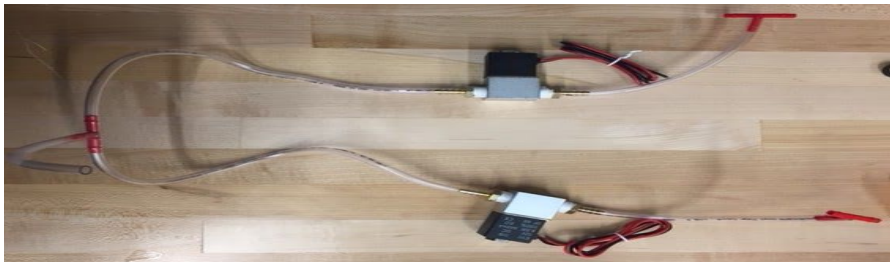
will simulate a more realistic result of what our client feels and the discomfort she experiences. This test will also allow us to observe if the material of the cushion causes heat rash in lower regions of the thighs.

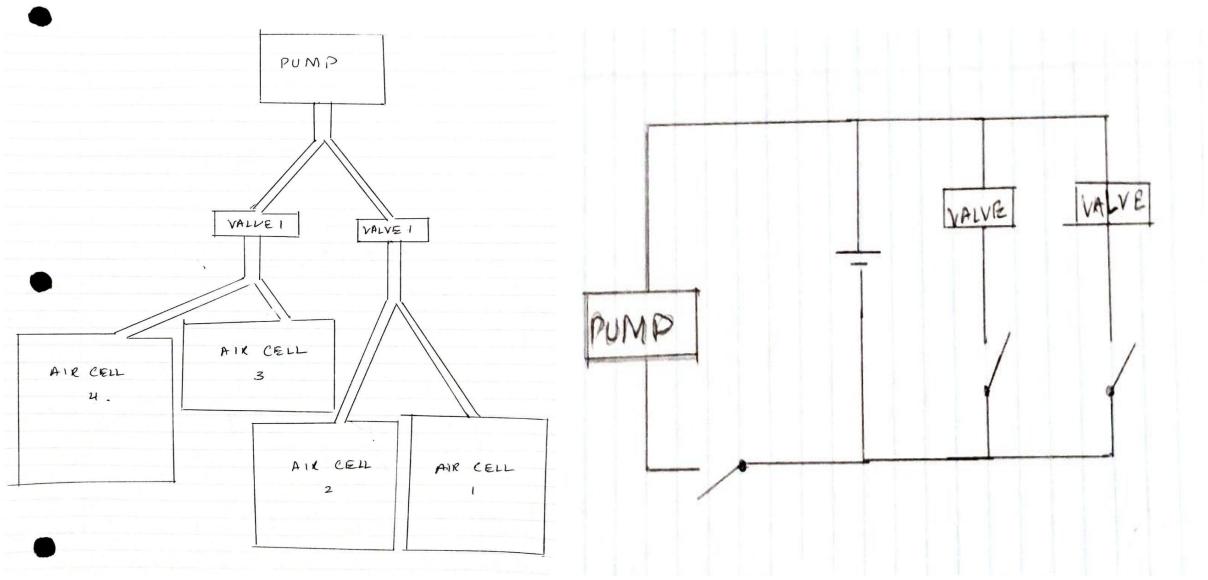
- Lastly, we will test if the inflation and deflation of the air cells will relieve us of pressure points felt in ourselves. This will be done by sitting on the cushion for a long period of time and we will inflate or deflate the cushion when we feel any discomfort. This test will allow us to know if the cushion will solve the client's need to shift when she feels nerve pinching in her back and legs. This test will also allow us to test if the number of air cells in the cushion is adequate, originally the client mentioned that splitting the cushion into a minimum of 4 sections, but we think that more sections will allow more movement and would better solve the client's needs. Additionally, we will perform this test with a gel cushion on top of the air cells to test if our hypothesis of the gel cushion making the air cells redundant is right.

Final Product









Schematic of pneumatic and electrical systems

Our final product has a total of four air cells, and two switches which controls the two front and two back cells.

Our product works by using an air compressor that is powered using an AC to DC converter drawing power from a wall outlet to the compressor. There are two solenoid valves which are wired to the switches on the user's handle. These switches allow for the user to adjust the pressure in the air pockets. Both solenoid valves and switches are powered by a 9V battery. The battery and switches are placed together in a 3d printed holder.

The compressor is connected, by clear tubing, to four air cells in the cushion. The air cells are repurposed water wings and fills up completely in approximately ten seconds. Since the air cells are made from water wings, the max weight limit for the cushion has not been tested. This is a design feature that we hope to improve in future iterations of the cushion.

The material of the cushion originated from a pillow. This ensures that the cushion is soft, breathable, and comfortable for the user. Using a pillow also allows the air cells within the cushion to work efficiently and as intended since there isn't another cushion on top of the air cells to hinder performance.

Business Model

Business Model Canvas : Manufacturing Business Model

<table>
<tr>
<td rowspan="2">Key Partners

-U of Ottawa (Will be providing financial support

- Canadian Tire (Distributor where key components will be bought)

- Amazon (Distributor where key components will be bought)

-LIFE(Organization that is helping our client, where meetings and decisions are made)

-Joel (the client who we are creating the product for.)</td>
<td>Key Activities

- Find Distributor for key components of product (Air pump, styrofoam base, valves, etc.)

- Refine Design (Current designs always being improved)

-Build prototypes(Crucial for client to be able to see visual representation of product)

-Testing (important for spotting inconsistencies, and improving design)</td>
<td rowspan="2">Value Proposition

- provide comfortable and effective product to reduce pain experienced by customer

- Are able ensure client receives support and relief for spine and back

- Target Wheelchair users, hospitals, office workers, people who sit for extended periods of time</td>
<td>Customer Relationships

- Ensure design is comfortable for customer

-Dedicated Personal Assistance:

We want to establish an intimate and hands on relationship with the customer to be able to better understand the pain they are going through and provide a better solution.</td>
<td rowspan="2">Customer Segments

- Niche market for wheelchair users (Based on specialized needs and characteristics if the client - each one has different set of problems)

- Mass market for office workers who sit for extended periods (This market displays wide view of potential clients)</td>
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<td>Key Resources

- Relationship with hospitals

-Technical(intellectual) expertise of our engineering /design of the product

-financial support from university

-physical</td>
<td>Channels

- Email, client meeting, meeting with LIFE staff

-Want to reach clients through storefront to be able to gauge their specific needs/problems</td>
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	prototypes and designs			
Cost Structure - Fixed cost: materials, Labour - Variable: custom cushion for different wheelchairs (different dimensions) - Cost driven business (focus on best priced value proposition and low cost structure)		**Revenue Streams** - One time initial purchase price for product - Maintenance fees -fixed cost for product but varies somewhat for custom designs for specific wheelchairs		

Economical Analysis

Northern Comfort

INCOME STATEMENT

Year ending [DEC 31st 2019, DEC 31st 2020 & DEC 31st 2021]

	2019	2020	2021
REVENUE			
Sales revenue	$ 18,750.00	$ 75,000.00	$ 150,000.00
Cost of goods sold (C.O.G)	$ 1,365.00	$ 5,460.00	$ 10,500.00
Service Revenue			
Interest Revenue			
Other revenue			$ 60.00
Gross Profit	$ 17,385.00	$ 69,540.00	$ 139,560.00
OPERATING COSTS			
Marketing Costs	$ 250.00	$ 15,000.00	$ 10,000.00
General & Administrative Costs	$ 200.00	$ 2,000.00	$ 2,000.00
Equipment Rental	$ 5,000.00	$ 10,000.00	
Depriciation costs			$ 1,000.00
Research and development		$ 700.00	$ 1,000.00
Rent	$ 10,000.00	$ 10,000.00	$ 10,000.00
Salaries and Wages	$ 3,500.00	$ 30,000.00	$ 35,000.00
Software		$ 1,000.00	$ 500.00
Travel		$ 240.00	$ 300.00
Transportation	$ 300.00	$ 500.00	$ 500.00
Website hosting	$ 100.00	$ 100.00	$ 100.00
Total Operating cost	$ 19,350.00	$ 69,540.00	$ 60,400.00
Operating Income	$ (1,965.00)	$ -	$ 79,160.00
Interest expenses			
Total Expenses	$ (1,965.00)	$ -	$ 79,160.00
Net income before taxes		$ -	$ 79,160.00
Income Tax 25%		$ -	$ 19,790.00
Net income	$ -	$ -	$ 59,370.00

User Manual

Set Up:

1. Place cushion on seat (Figure 1)
2. Attach airlines to inlet
3. Attach controls and pump to arm rests (Figures 2,3)
4. Plug pump into wall

Functions and Operation:

1. Turn pump on
2. Press and hold front button to raise front cushions for **max of 10 seconds**
3. Press and hold rear button to raise rear cushions for **max of 10 seconds**
4. Release switch once done
5. Turn pump off
6. Press front button to deflate front cushions
7. Press rear button to deflate rear cushions
8. Repeat as necessary

Troubleshooting:

Cushions wont inflate

- Check that airlines are not crimped
- Insure pump is on
- Insure pump is connected
- Insure battery for controller has power
- Insure air pockets have not burst

Pump will not turn on

- Insure pump is plugged into wall

Maintenance:

- The only maintenance necessary is to replace the battery that powers the buttons. Simply remove the old battery and place the new battery in the holder

Safety:

- Do not operate in wet conditions
- Do not over inflate the air pockets
- Do not run pump excessively

Conclusion

Through the development of our product we have learned many new skills and concepts. This project has shown us exactly how we can improve the lives of others using the skills we have learned in class. We have learned to apply the design lessons that have been taught to us as well as the technical skills taught in the lab. For example, our product required the use of a soldering iron to wire our controller. Additionally we employed our new knowledge of 3D Printing to construct parts for our product. These new skills will translate well into the workplace in a technical setting. We also employed design criteria to determine the most effective way to solve our problem statement. This will translate well into the business and development aspects of the professional world.

Though we finished our project and it completes most of our design criteria, there is still room for improvement. To ensure our product meets all of the needs of our client we must continue developing our product. The first task would be to replace our power source with a battery to improve mobility. We are currently drawing power from the wall to actuate our pump, which will be an inconvenience to our client. Additionally, our pump is extremely loud and it may be embarrassing or difficult for our client to use our product in public. To fix this issue we would construct a compartment to isolate and insulate the noise created by our pump. Our third issue is that our cushion could easily offer more adjustability with a minor increase in price. This would result in a more effective product that would aid our client with relieving pressure points. Finally, we do not know the weight limit of our product, so we will have to test this at some point to inform the user of our products limitations

Throughout the length of this class we have learned ways to improve our future projects. For instance, we have learned that it is always best to attempt to employ the simplest solution to a problem where applicable. This would have alleviated headaches throughout the length of our project. Additionally, we have learned to truly listen to our client. We discovered new information once we went back for our second client meeting. This information would have made our initial stages of design much easier had we fully understood what our client had initially wanted.

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