

Final Design Report

for

Helen and Burton Cook

Engineering for Humanity
Franklin W. Olin College of Engineering
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1. Introduction

Over the past semester, we have chosen to work with community partners Helen and Burton Cook to co-design a solution to a design opportunity they may have. This report will introduce our community partners, describe their needs and values and summarize the design process and key insights gained in the process of developing the final products. Finally, this report will discuss our key learning points in terms of design as well as ageing.

Helen and Burton Cook are a couple who just moved in to Natick 5 months ago after living in Florida for 8 years. They have 3 kids and have been married almost 64 years. Over the course of their lives, they have experienced and accomplished a multitude of things including traveling all over the world, volunteering in the Israeli army and owning and operating 3 furniture stores in Massachusetts. They have also experienced significant trials and tribulations in terms of their health, having both suffered and recovered from cancer.

In the course of getting to know them, we have identified several key needs and values in their lives. These include the following:

1. The desire to be more active
2. The desire to be part of and belong to a community and contributing to it
3. Their strong marriage and relationship
4. Volunteering
5. Physical comfort
6. Having fun and enjoying their lives
7. Pride in their past and what they have experienced, especially internationally
8. Honesty
9. Hospitality and Manners
10. Family, Kids and Grandkids
11. Being independent

2. Overview of Design Opportunity

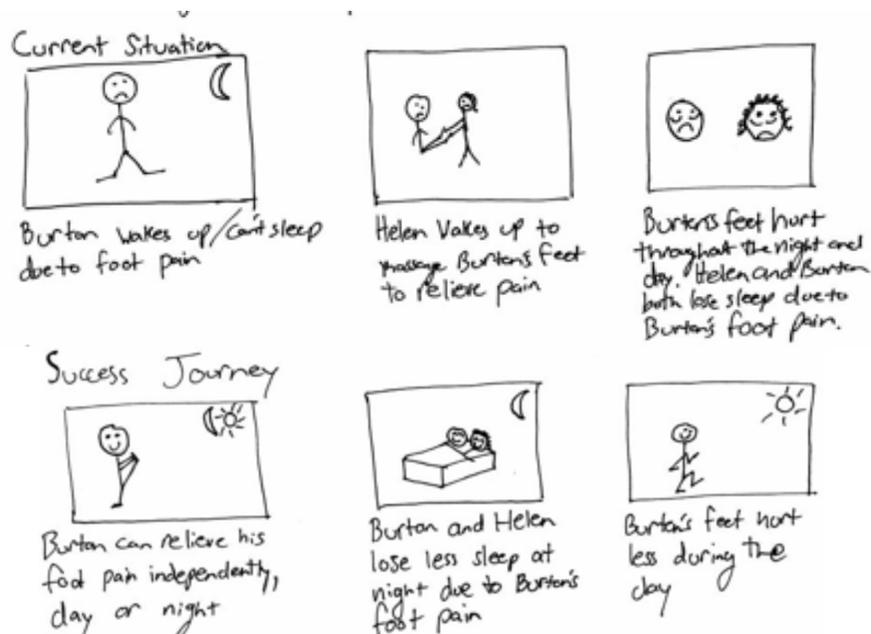
How might we allow Burton Cook to relieve/prevent the pain in his feet independently?

2.1 Problem Statement

Burton needs a way to independently reduce/prevent/relieve the pain in his feet caused by neuropathy.

Burton suffers from neuropathy, a condition in which peripheral nerves (not of the brain or spine) are damaged. This is linked to Burton's diabetes. Burton's neuropathy causes him constant pain in the bottom of his feet and in his toes. Burton's foot pain causes him to stay awake at night and causes him to have trouble doing things during the day. Burton's foot pain is also a reason the couple are lacking in sleep. Helen has recently taken to getting up late at night to rub Burton's feet. Massaging Burton's feet reduces the pain.

2.2 Success Journey



2.3: Criteria & Constraints

The following are the criteria that we as designers set for the solution:

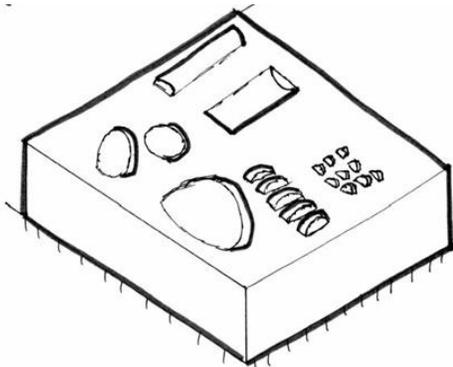
1. Solution should prevent/alleviate the pain in Burton's feet
2. Solution should have some softness in the massaging implements in order to avoid hurting his feet due to the hard surfaces
3. Solution needs to be aesthetically pleasing to leave out in the apartment and to use around others
4. Solution should be something Burton can use independently and without assistance

The following is hence the list of constraints this opportunity faces:

1. Solution should require minimum input effort to use
2. Solution needs to be something his physiotherapist would approve
3. Solution should not have any sharp or rough edges or surfaces that have the potential to harm Burton's feet

3. Initial Design Concepts

We began with four initial sketches, each capturing a broad idea. The ideas are as follows: a handheld massager, a massage board, a vibrating massager and massaging insoles.

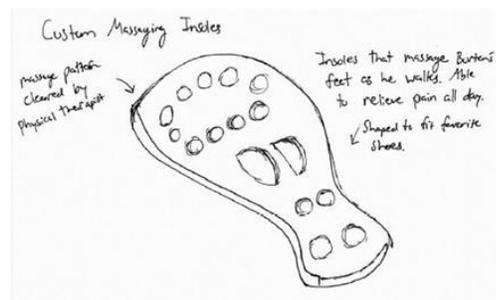
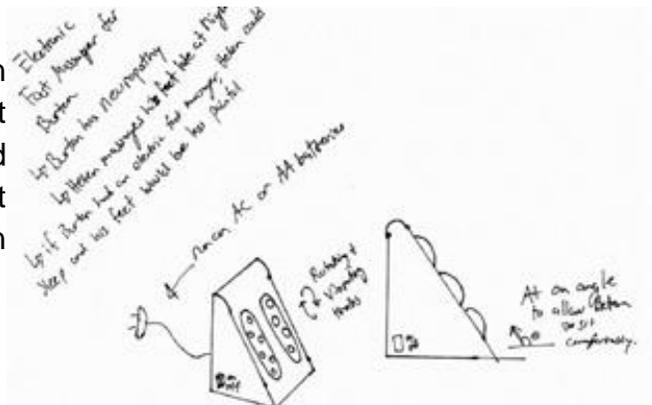


3.1 Massage Board

We wanted to provide him with something that took minimal effort and that he could control in terms of how long his feet are massaged. We chose to pursue the massage board idea. We felt it would provide the most massage options, allowing us to provide Burton with many different massage surfaces in one compact area. We also thought this would take the least amount of effort from Burton, who could sit comfortably and run his feet over the massager.

3.2 Vibrating Massager

We planned to incorporate vibration into this design at some point, but it was not a requirement. We decided we would test vibration separately at first, and design a vibrating element in after.

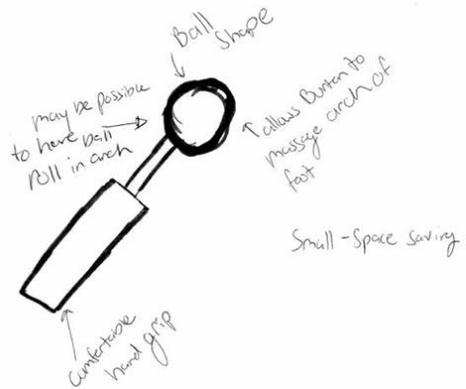


3.3 Massaging Insole

We planned to prototype the massaging insoles by first purchasing insoles that are meant to massage as one walks. We would test these on Burton and find out what elements he found pain relieving and then add custom elements for Burton not provided on the store bought insoles.

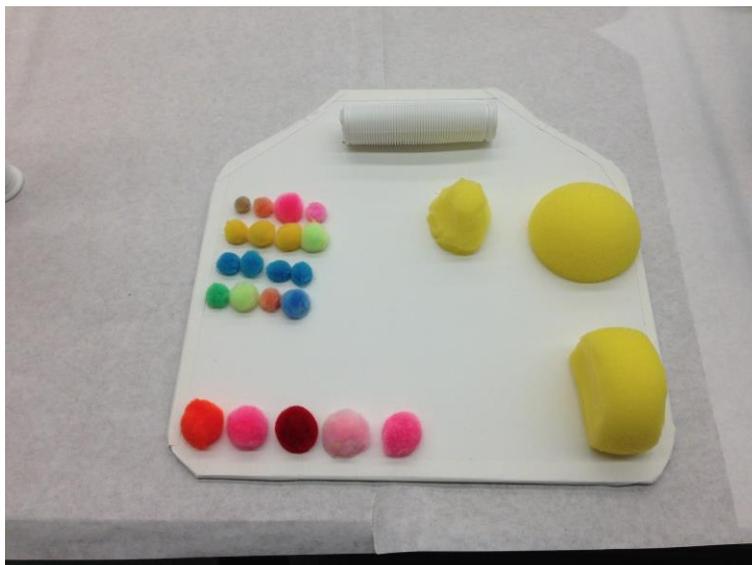
3.4 Handheld Massager

We proposed a handheld massager because we thought it might be easier for him to massage exactly where he wanted if he could use his hands to control the massaging implement instead of his feet. However, we later realized that requiring him to exert strength in his arms would be less beneficial to leveraging his body weight.



3.5 Sketch Modeling

With these sketches in mind, we decided to proceed to sketch model some of these sketches to obtain 3D representations of our ideas. We sketch modeled the massaging board because the type and position of the surfaces was something we wanted to begin testing as soon as possible. We chose not to sketch model the vibrating massager or the massaging insoles because we felt they did not fit Burton's needs and values as well as the massaging board did. At this stage, we also decided to drop the handheld massager idea simply because we felt it was more beneficial to Burton to allow him to leverage his own body weight to help him massage his feet instead of requiring him to exert additional effort with his hands in order to do so.



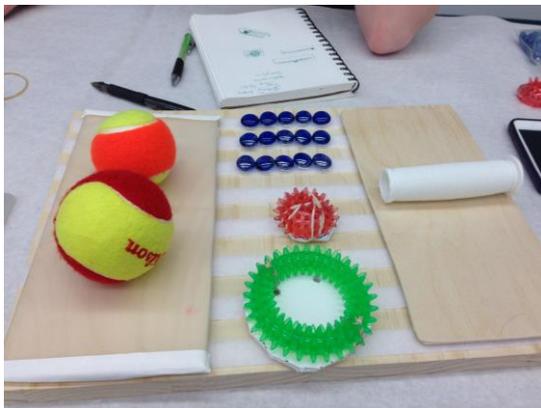
4. Prototyping

After creating our sketch models, we realized that functional prototypes were necessary in order to truly learn what we wanted to about our product because we could only gain insights if Burton could physically apply pressure to and try our prototype. Hence we quickly moved into functional prototypes.

The massage board was our first complete prototype. We started by covering a 12" X 14" X $\frac{3}{4}$ " board of pine wood with Velcro strips. We then gathered different surfaces and covered the backs of them with Velcro as well. This allowed us to move the surfaces around the massage board while testing, which would help us determine the proper placement of all the surfaces on the final board. The surfaces we decided to test included different sized tennis balls, aquarium pebbles, and spiked dog toys. We felt that the tennis balls would be helpful for massaging the inside of Burton's arches and the aquarium pebbles would help him stretch his toes and massage his heels. We tried the spiked dog toys because we wanted to provide Burton with a large range of surfaces and we had yet to give him anything spined. Our goal with this prototype was to find out what surfaces Burton found pleasant.

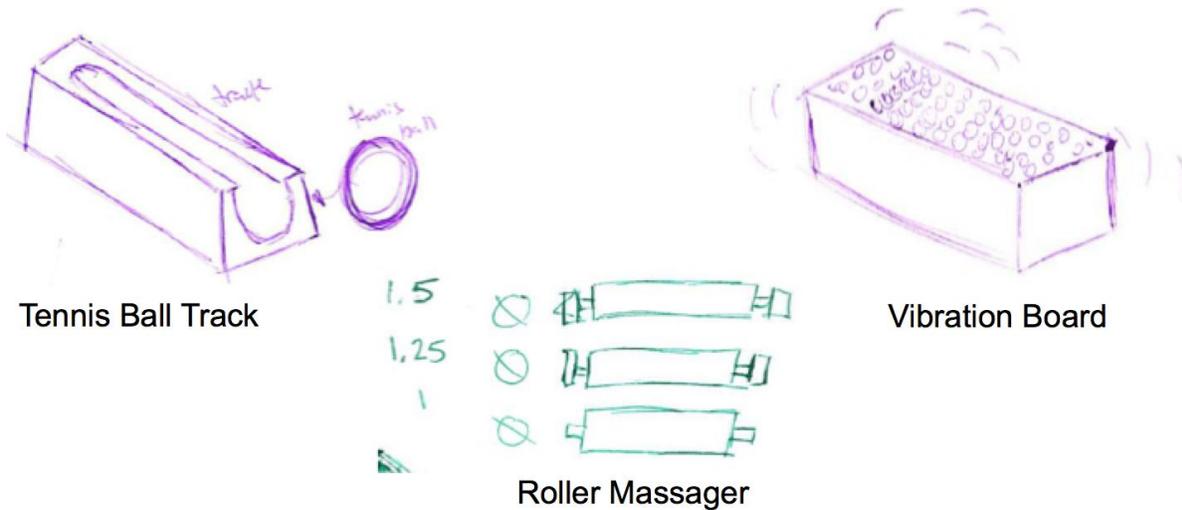
We also decided to prototype a vibrating massager at this stage. We did this by simply placing our phones under a thin sheet of wood (approx. 6" X 12" X $\frac{1}{8}$ ") and setting them to vibrate. We also covered the top with aquarium pebbles. Our goal with this prototype was just to find out if Burton found the massage beneficial.

4.1 Massager Board

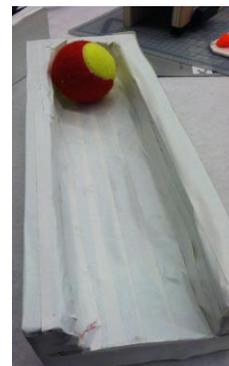
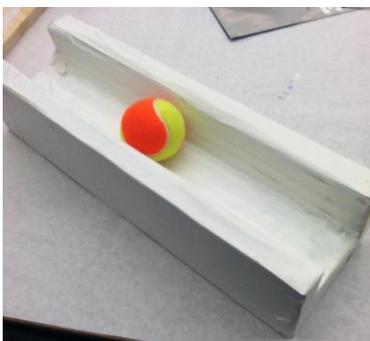


The massage board was our first functional prototype. We mounted half tennis balls and dog chew toys on a wooden board as implements and surfaces on which Burton could use to massage his feet. We also brought whole tennis balls of different sizes for him to try as well as a bicycle grip. These objects comprised our first prototype test.

From this initial test, we discovered that Burton's feet were far more sensitive than we had anticipated. He disliked the dog toys because he found them too abrasive on his feet. However, to our surprise, he not only liked the tennis balls and bicycle handle but he also preferred to be able to roll his foot over them instead of having them secured to the wooden board. He particularly enjoyed the bicycle grip because it allowed him to dig into the arch of his feet as well as curl his toes around the handle to flex his toes. This was an unexpected learning experience in testing and we used this insight to further develop 3 new and different products: the Tennis Ball Track, the Roller Massager and the Vibration Board. We also decided to drop the massaging board from the list because we felt it did not serve his needs as well as the other items did.



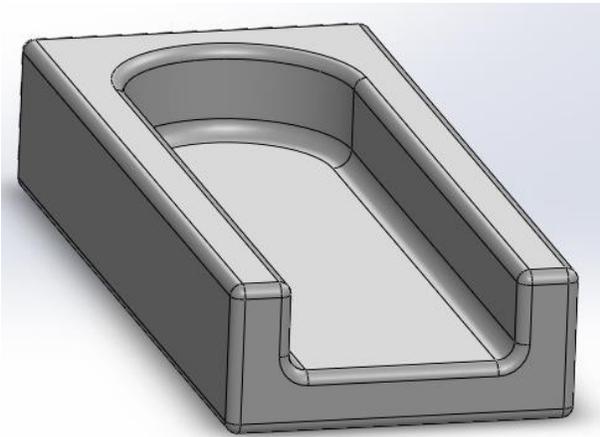
4.2 Tennis Ball Tracks



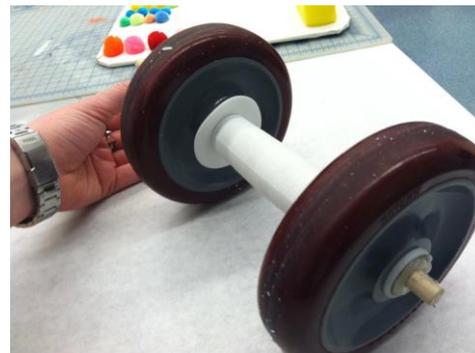
The tennis ball tracks are thus a result of the insight gained from our first round of testing. One of the problems Burton identified at that initial session was that the tennis ball slipped out from under his feet easily and it caused his foot to wobble left and right because it was free-rolling. The solution Burton suggested was to have it on a track in order to keep it in line while still allowing it to roll freely. We pursued this by creating two quick prototypes out of blue foam for different sized tennis balls. We left both ends of the track open for one and one end open for the other. We learned that he liked them a lot because they helped him maintain control of the tennis ball while he used it on his feet. Several further sessions of testing were used to

determine the exact width, length and depth of track that Burton would require to comfortably use the tennis ball in the tracks in a functional manner. We also found that he preferred the smaller ball and the one opened end design. The smaller ball allowed him to stretch the skin in his arch more than the larger ball. He preferred the one open end design because it prevented the ball from leaving the track.

We decided to take what we learned from these two prototypes and start our final product. First, we designed the shape of our final track using Solidworks. The CAD are shown below. Next, we work ordered the design to be made out of machinable yellow foam using a CNC mill. We decided to cover the foam with a layer of fiberglass and several layers of epoxy. After every layer of epoxy, we sanded all irregular surfaces. After the final layer we spray painted two layers of primer, two layers of flat beige to match the Cooks' furniture, and one layer of clear gloss.



4.3 Roller Massager



This product also came from the early insight we gained from our first round of testing. Burton really liked the rubber bicycle grip because it allowed him to roll his foot over it and dig into his arch and also curl his toes around the grip to flex them.

However, he also said that the handle grip rolled left and right as he used it and was not able to keep a steady path. To overcome this, we tried two solutions. The first was simply to remove the flanges on the ends of the grip and leave only the round grip. The second was to design a set of discs that would fit on the ends of the grip in order to guide the grip along a straight path. To quickly prototype this, we used large caster wheels and a wooden dowel as an axle to support the rubber grip when he applied his weight to it.

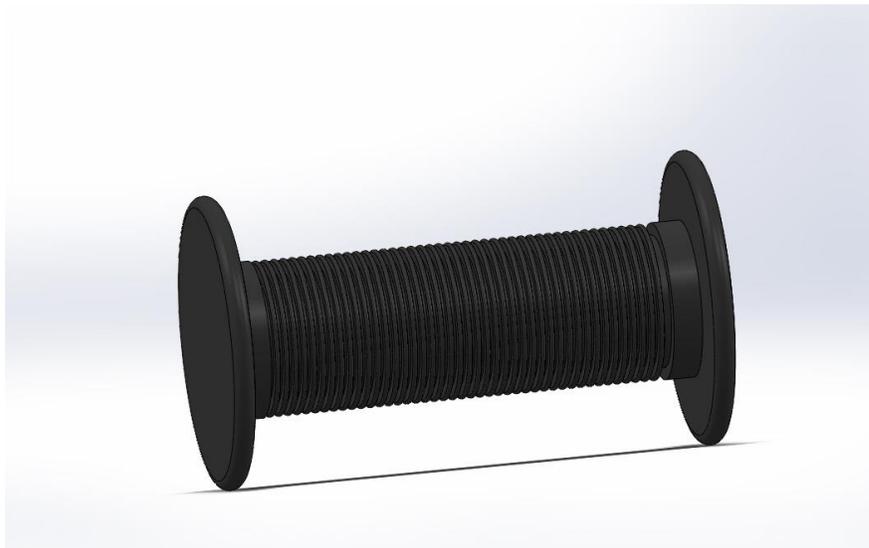
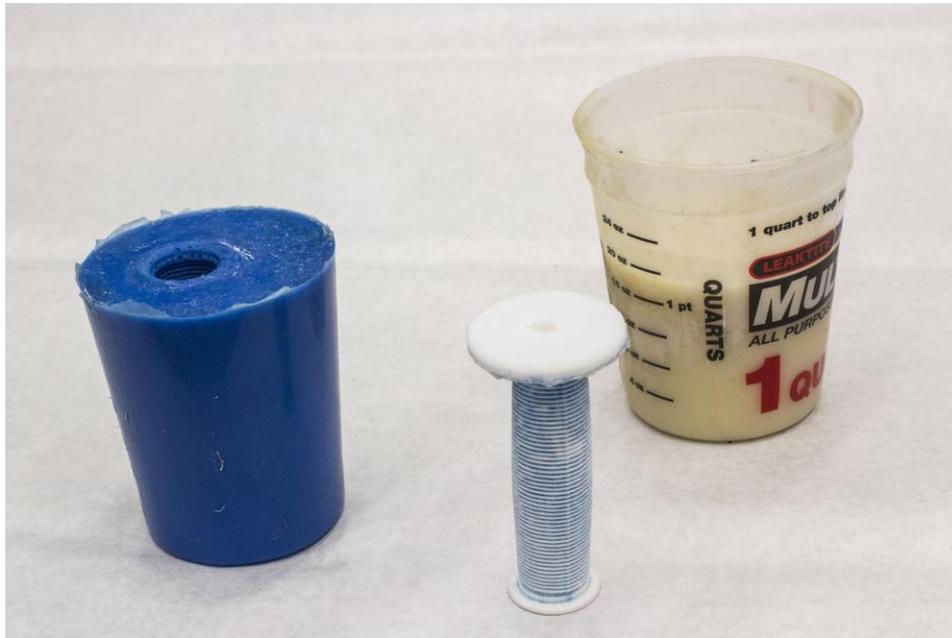
When we brought the product back to Burton for his input, we discovered that this version of the prototype did not allow him to roll his foot back and forth on the roller because the wheels and wooden rod now spun but the rubber grip did not. Burton expressed that this was important for him to be able to roll his foot over the grip as opposed to the grip not rotating at all. Burton also expressed concern that it was too high off the ground because the caster wheels were too large.

With this feedback in mind, we used our next co-design session with Helen and Burton to address the two issues Burton identified. In addition, we wanted to find out if the diameter of the bicycle grip was an important factor in the design. To address the rotation issue, we modified the prototype and secured the grip to the wheels so that it rotated with the wheels. To address the height issue and also test the importance of the diameter, we brought with us short lengths of PVC pipe of different diameters on our next co-design session with Helen and Burton. We used the PVC pipes to simulate bicycle grips and gave him pipes of different diameter to place under his foot to see which he preferred. We also performed quick tests using our hands to hold the pipe at different heights off the ground. This exercise led us to learn that the roller needed to be 1.5" off the floor, which is the level that Burton was comfortable. We also learnt that he preferred the 1.25" diameter because that was the perfect diameter to allow him to work the grip into his arch. At the same session we also unexpectedly learnt that the ability of the grip to flex was important because the flex was what helped to dig into the arch of his feet, which Burton said was something the PVC pipe did not allow him to do.

Armed with these valuable learning points, we then proceeded to produce the final design. In order for the roller to effectively allow him to massage the arches of feet, we knew the roller itself had to be in contact with a reasonably hard surface but the roller itself had to be softer. Hence, we chose to use a track design instead. The roller would now rest on top of a wooden track that would hold it at the specified 1.5" off the ground. Wooden discs on the ends with a diameter of about 2.5" would help to guide the roller along the track. The track now ensured the roller would roll straight while also providing a hard surface that would allow it to massage his foot effectively.

We then proceeded to manufacture the final product. We cut delrin discs to the 2.5" diameter of the wooden discs and glued them to the ends of a bicycle grip to create a model of our final product. We then used Silicone Rubber (Mold Star 30 from Smooth-On) to create a negative copy of the model. Once we demolded the model, we then attached the wooden discs onto the ends of the silicone mold and clamped them in place. We then clamped the mold closed and poured Urethane Rubber (Vytaflex 60 from Smooth-On) in to the mold. Once cured, the rubber

bonded to the wooden discs to create one complete, robust product. We then finished the roller with a coat of paint and clear top coat.



4.4 Vibration Board



During our initial testing, we asked Burton if something with vibration would be beneficial. The thinking behind this was that it might be useful if we could also incorporate something that he did not have to physically move to get a massage. We created a quick prototype by placing our cell phones under a thin plank of wood, covered the surface with aquarium stones and set our phones to a mode of continuous vibration. He thoroughly enjoyed the initial prototype and this led us to develop a vibration board.

We began by making a stand to mount a motor under the board with an offset weight, which creates vibration. To do this, we nailed a thin piece of wood (approx. 6" X 12" X $\frac{1}{8}$ ") to two 2" X 4" planks of wood. Using a motor in the supply stock room, we cut a small piece of metal, and mounted the metal to the output shaft off center. This created the vibration. We then mounted the motor on the underside of the stand.

Next, we covered the stand and aquarium beads with Velcro. This allowed us to lay the beads on the platform in any configuration without having them move around while the board was in use. We wired the motor to run off of two AA batteries and provided an on/off switch, both mounted to one side of the board.

When we took this prototype to Burton, our first big surprise was that he enjoyed it tremendously. He initially told us that the vibration was sufficient, but after a week of using the vibration board he decided that the vibration could be stronger. Over the course of several testing sessions, we also discovered that we assumed he would need a specialized pattern to conform to the contours of his foot. Contrary to that, he preferred the pebbles tightly but equally spaced across the platform. We also assumed that he would like to move the pebbles around in different patterns as he felt necessary. Over the 1 week of testing, we learnt and realized that he had no idea what to change it to even though the product offered him that flexibility. Hence, Burton felt that if we could cover the top surface with a material such as plastic that could be easily wiped clean, it would benefit him more than the ability to move the pebbles. Finally, we assumed he would want control over the strength of the vibration. This again proved to be false as he said he liked the strength of the vibration as it was and thought it was unlikely he would ever change it.

We also showed the product to Burton's Physical Therapist (PT), who explained to us that the purpose of any massage for Burton was to improve flexibility in the soles of his feet because they were stiff as a result of his neuropathy. Hence, when he walked, the stretching of the stiff soles would cause him pain that massaging would be able to help minimize. Burton's PT also told us that massaging helped with blood circulation but did not do anything for the neuropathy itself. She approved of our vibration board prototype, saying it was not a danger to Burton. She liked the massage it provided as well, both for Burton and herself.

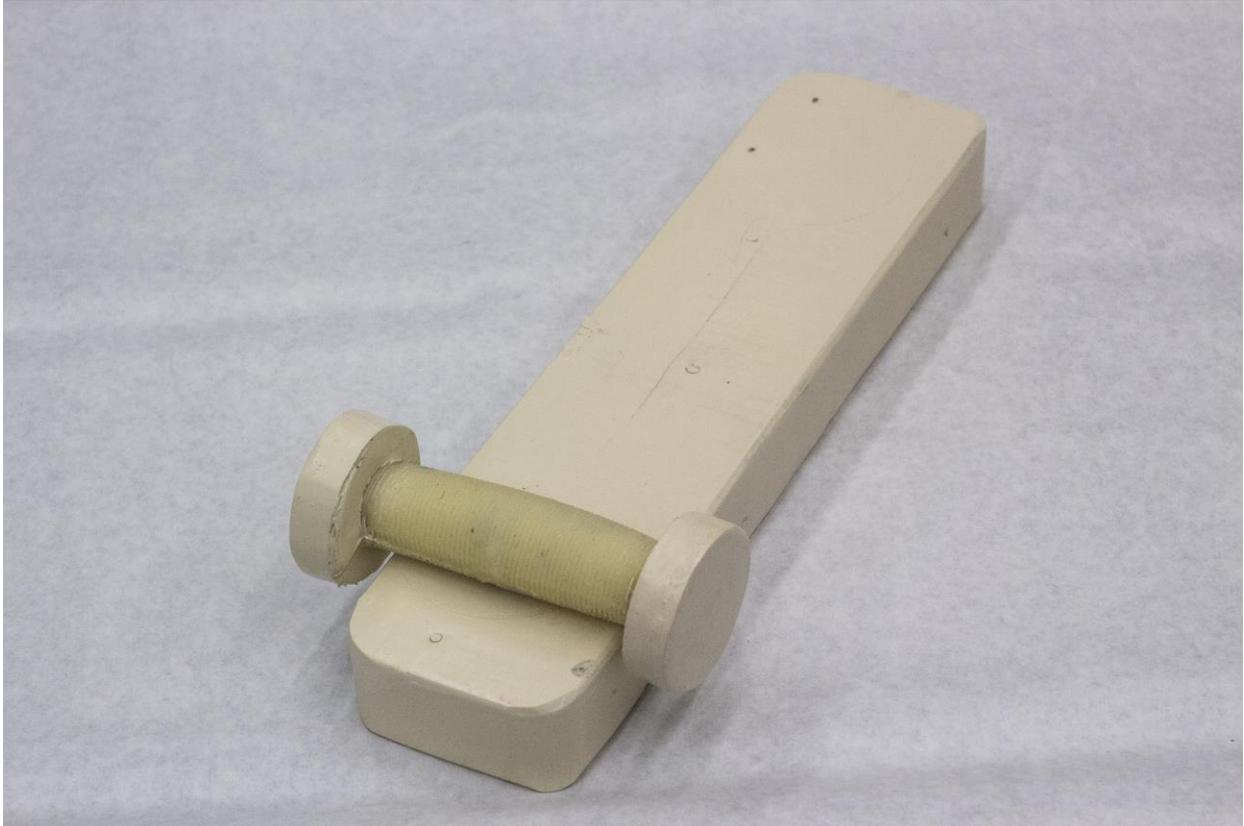
We decided to create a final product with what we learned from this round of prototype/test. The CAD of the final stand is provided below. We decided that closing all sides of the final product stand would be necessary for safety reasons. We did not want Burton to hurt himself with the motor. We began in a similar way, making a stand out of wood. We used an approximately 11" X 6" X $\frac{3}{4}$ " plank for the top piece. We used the same $\frac{3}{4}$ " pieces to lift the board off the ground approximately 4". We closed the front and back sides with thinner wood, approximately $\frac{1}{8}$ " thick. These thinner sheets were just for safety and did not need to withstand stress from Burton's foot. Again, we mounted a motor with an off center weight on the underside of the stand. This time both the motor and weight were larger, providing a larger vibration. We then began to really think of where to mount the on/off switch. We knew we wanted it facing upwards at the level of the stones, but we weren't sure how to mount it. At first, we created a small box out of fiberglass that we thought we could epoxy to the side of the board. The box we created turned out to be aesthetically displeasing and unable to bear weight. After a talk with Ela, we decided to mount the switch in the top surface of the board, above all the aquarium stones. This would allow Burton to turn the board off with his toes rather than bending down.

We then spray painted the stand to match the color of the Cooks' walls and furniture; we used the same beige we used to paint the tennis ball tracks. We sprayed two layers of primer, two layers of beige, and one layer of clear gloss. We then picked a pattern of stones (having different colors of blue) to give the board personality. We created a C shape for Cook in the stones. We glued the stones down and spread a layer of epoxy over the entire board. This secured the stones, gave it a glossy smooth finish, and made it simple to clean. We mounted the battery case on the inside of the stand to avoid it being accidentally knocked off. We mounted the box such that Burton or Helen could easily turn the stand upside down, slide open the battery case, and replace the batteries. Finally, we covered the motor using a board of foam core press fit on the underside of the stand.

5. Solution

At the end of the design process, we presented Burton with what we called “The Massage Kit”. It consisted of the three pieces of massage equipment, each that massaged his feet in a different way.

5.1 Roller Massager



Key Features:

- 1 Rubber handle for softness
- 2 Wooden wheels to guide the roller to roll straight on the track
- 3 Able to flex around his feet

How it benefits him

- Stretches skin in the soles of Burton's feet
- Allows Burton to wrap toes around, stretching them and allowing for circulation

5.2 Tennis Ball Track



Key Features

- 1 Fibreglass is hard so that it doesn't compress under his feet
- 2 Guides the ball such that it won't slip out from under his feet
- 3 Fits his feet within the groove for comfort

How it benefits him

- Stretches the soles and arches of Burton's feet

Vibration Board



Key Features:

- 1 Resin coated top for easier cleaning
- 2 Power switch can be activated by his foot
- 3 Stones on the top are arranged in a 'C' for aesthetics

How it benefits him

- Provides a moderate vibration to massage Burton's toes, arches, soles, and heels without requiring him to exert extra effort

6. Conclusion

Revisiting our design criteria and constraints, we feel the tennis ball track satisfies most, if not all of them. The track helps prevent pain in Burton's feet by allowing him to easier stretch the skin in his arches on a tennis ball. This helps prevent pain while Burton walks. The implement, a tennis ball, he uses with the track is soft and not harmful. The track is made to be used independently. The purpose of the track is to make it easier for Burton to roll a tennis ball under his feet. The main idea is for it to require minimal effort, which it does successfully. We had Burton's physical therapist approve the track. All edges of the track are rounded. We have checked it for any sharp edges or potentially harmful surfaces.

The one goal we feel we did not fully satisfy is the aesthetics of the track. The faces are not as smooth as we would have liked and there are several places where the epoxy and spray paint coagulated to form drips that we unfortunately could not sand down.

In terms of the initial criteria and constraints that we set for this project, the Roller Massager meets most of them well. It helps to alleviate the pain in his feet and we have validated this both with some medical knowledge as well as Burton's own testimony. It also has some softness in the rubber used to mold the round grip, which ensures that his feet will not be hurt by the roller. It is also something Burton can use without any additional assistance and thus meets the criteria that it can be used independently. In addition, the roller massager requires minimum effort to use, although it does require Burton to apply some pressure to push his foot down. His physical therapist did see the product and give her approval on it and the roller is round and the wood has been finely sanded to avoid sharp or rough edges that may harm Burton's feet.

The one criteria the roller did not fully meet is aesthetically pleasing. It is the same color as the other items in their home and is able to be stored when not in use. However, while we tried our best to manufacture the final product to the best standard, we still fell short of making it look like a professional product.

For the vibration board, again we feel most criteria and constraints have been satisfied. The vibration of the board helps circulate blood to Burton's heels, arches, and toes. The board is covered in gorgeous stones and even has a 'C' shape in it to represent Cook. The stand is spray painted beige to match the walls and furniture of the Cooks' apartment. We consider the board quite aesthetically appealing. The board is made to be used independently. The board only requires Burton to turn it on with his foot and for him to sit comfortably, resting his foot on the stand surface. This is considered minimal effort. Burton's physical therapist approved of the massager and even wanted to buy one for herself. We sanded the stand to have smooth edges that are not a harm to Burton.

7. Lessons Learned

Through this design process, we learnt many lessons about design and co-design. The first lesson we learnt was that there is great value in both quantity and quality of sketches and ideas. Gathering all the ideas that you possibly can and asking for input from others can sometimes yield ideas the designers themselves may not have thought of. Many minds are better than one. Overall, one should not limit oneself by what one thinks is buildable when brainstorming.

The second lesson is that ideas should be taken into 3-D sketch models quickly. The third dimension is ridiculously valuable, particularly if one is unsure about some aspect of a design such as the size, shape, feel, smell, look and emotional involvement.

The third lesson is one that Ela and Caitrin have emphasized a lot throughout this class: Testing! Testing a prototype as soon as possible can yield a lot of useful insight, even if objects are simply taped together. If we were to redo this project again, we would have prototyped and brought the massage board to Burton quicker because we learnt that he preferred other massagers compared to the massage board and this changed the whole direction of the project. If we learned this earlier, we could have made better final products.

Fourthly, listening carefully to what a user says or the feedback they give is extremely valuable. Sometimes, the best ideas and opportunities are found in the slightest passing remark someone might make

Finally, asking questions frequently is extremely important because it is only through these questions that one learns about people and this course is ABOUT LEARNING ABOUT PEOPLE! Asking people why they do, say, eat, feel, carry, etc certain things tells you a lot about a person. You will have a much easier time identifying a problem statement and working out solutions if you ask questions.

8. Future Work

8.1 Tennis Ball Track

If we were to continue work with the tennis ball track, we would most likely test using a track that was not covered in fiberglass. We would like to recut a piece of yellow foam in the same design as our current final product and cover it in several layers of epoxy. We are curious to see if the track could actually withstand wear without the fiberglass. If it is durable enough to withstand daily use, using solely the yellow foam is more desirable for aesthetic purposes.

8.2 Roller Massager

We feel that it would be beneficial to remold the roller in the future because we made several mistakes due to our inexperience with rubber molding. Firstly, the roller was held at a slant when the silicone rubber was poured in. This resulted in a negative that was slightly skewed. Consequently, the roller we molded out of Urethane Rubber was also slightly skewed. In addition, when we clamped down the wooden discs, we did not find the exact of the disc. Consequently, the rubber discs were joined off-center. Lastly, when we molded the Silicone Rubber negative, we did it in a round container.

Consequently, when we clamped that mold together to pour in the Urethane Rubber, it deformed the mold enough that the final product was slightly elliptical instead of being a perfect circle. We believe if we had done the molding in a rectangular container, we would be able to avoid deforming the mold during clamping.

8.3 Vibration Board

We feel that the vibration board could provide a stronger vibration. If we were to continue working, we would mount a larger motor with a larger off center weight to the underside of the board.

9. Aging Insights

Another big surprise was how much sleep was a problem in general but in particular for Helen and Burton. Over the course of this class, we have had multiple people tell us about either a relative or friend or even themselves having trouble sleeping. In the case of Helen and Burton, their problems sleeping are the result of a multitude of physical and emotional factors, including pain, worry and anxiety. This class really taught us how

much these emotions can be amplified through ageing and the impact they can have on people's lives.

This project went beyond teaching us about design. We became very close to two wonderful people. We learned what aging can mean for someone physically and socially. It can mean not being able to physically do all the things one is used to doing. The emotional impact of this can be huge. It can isolate people and make them feel alone. The elderly can also be isolated regardless of health conditions. Social stigmas around the elderly can keep companionship out of reach for many of our elders.

Through looking for design opportunities, we realized how much of the world is not made for the elderly. Closets, bathtubs, chairs, counters, cabinets, stairs, all these things, of which are usually in a person's home, can be a danger and a challenge for the elderly. Much of what is manufactured and sold today is marketed to those without physical challenges. We learned just how limited an elder's world can become just by their surroundings.

Another big surprise was how much worries about health and family impact the lives of the senior citizens we met. In particular, health worries seemed to be a dominant worry for many people in some shape or form.