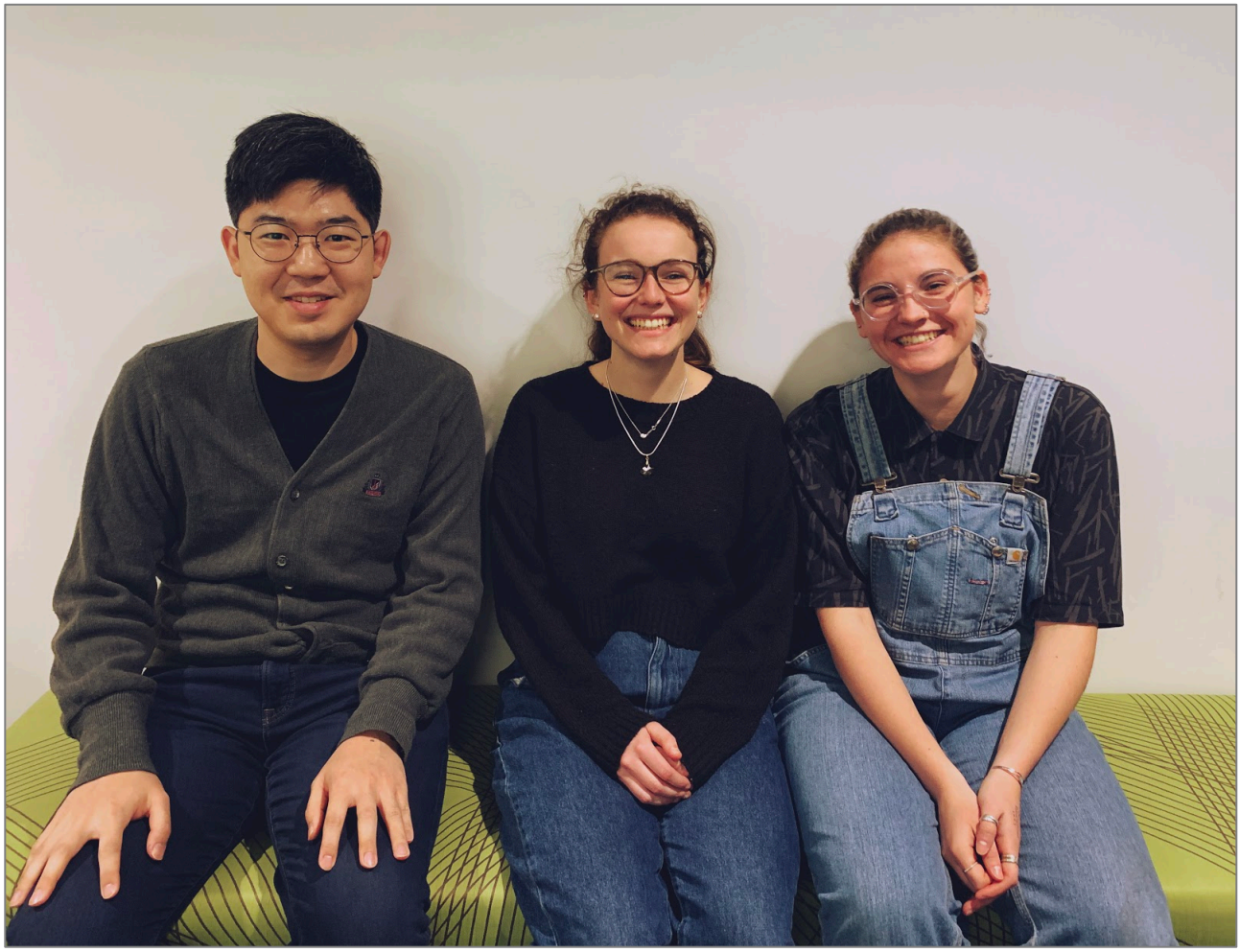
Abby's Laptray

By Team Laprador



Final Report

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ABSTRACT

Our project suggestor Abby is a member of a large community of wheelchair users that uses a power wheelchair. Despite the rising popularity of power wheelchairs, there exist very few accessories available on the market for these wheelchair users including laptrays and tray table attachments. Abby enjoys living a very active and independent lifestyle often including frequent travel, drawing, painting, camping, and being an active member within her community. To support this active lifestyle, Abby would like a laptray that would allow her to more easily perform daily tasks and pursue her hobbies while seated in her WHILL Model M power wheelchair. Most of the laptrays available on the market are tailored for manual wheelchairs, and require attachment onto flat, parallel wheelchair surfaces which Abby's wheelchair does not have. Additionally, trays that are intended to rest on the user's lap are insufficient for Abby as these do not provide her with the stability needed for her to create art and items can easily fall off these trays.

As Team Laprador, our aim for this project is to create a customized laptray for Abby that she can use while seated in her WHILL Model M power wheelchair. Upon completion, Abby should be able to use this tray for eating, holding food and drinks, supporting her laptop, and creating art. This report documents our design process from first meeting Abby, creating and fabricating prototypes, to finally fabricating a functional laptray for Abby to use.

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INTRODUCTION

User and Problem Statement

Abby enjoys a very active and independent lifestyle often involving frequent travel, painting, drawing, camping, and she is an active member in her community. Abby has reduced mobility and balance which requires her to use a powered WHILL Model M wheelchair alongside her service dog Nathan. Abby desires a laptray or tray table that she can use in conjunction with her wheelchair. She hopes to use this tray for eating, supporting her laptop, and creating art outside her home environment.

Figure 1. Abby with her WHILL Model M power wheelchair and service dog Nathan

Abby's WHILL Model M wheelchair (Figure 2) does not come with a tray table attachment and its curved surfaces and various ergonomic controllers make conventional table tray attachments made for manual wheelchairs unsuitable. While seated in this wheelchair, Abby's lap is not completely flat, which makes it difficult to complete tasks such as eating, drawing and using a laptop without items falling off. Additionally, her lap is positioned at an uncomfortable height to complete these tasks.

Design Challenges Imposed by WHILL Model M

Wheelchair controllers – *extruding speed and motion settings prevent a tray table resting of the armrests*

Curved and slanted armrests – *difficult to attach or support a flat tray without it rotating due to minimal point of contact*

Sloping lap angle – *When seated, Abby's lap slopes downwards which provides an unstable surface to support a tray or to complete tasks such as sketching and eating*

Uncomfortable lap height – *Lap height is too low for comfortably completing tasks*

Figure 2. WHILL Model M power wheelchair and its associated design challenges for attaching a laptray

OBJECTIVES

We shaped our project around the following objectives and goals to ensure that we produce a device for Abby that suitably fits her needs and aspirations for this project while also being realistic about the time period and fabrication skills we have to offer.

Fabricate a Prototype that Addresses Abby's Challenges

This objective highlights the need for the device to work and function as a laptray that Abby can use to perform various tasks and meets the design criteria.

Fabricate a Prototype that is both Functional and Attractive

A repeating theme from this course is that assistive technology should not only be functional but also exhibit a "coolness factor," thus we aim to produce a device that Abby finds aesthetically pleasing and also enjoys using.

Use Existing Solutions as Inspiration and Improve Upon them

To create a laptray for Abby, we sought to understand what solutions may already exist for Abby on the market and how we can build upon these designs to fit Abby's needs.

Involve Abby as Much as Possible

Since this product will be used by Abby, it is important that we communicate frequently with her and seek her frequent feedback on our designs and prototypes so that our final prototype can be most functional and attractive for her.

Be Realistic

We recognize we have limited time and resources to produce this prototype. As a result, this objective involves making sure we keep our project well scoped, within budget, and focus on using accessible fabrication processes that our team is comfortable and confident using.

Learn Something New

Our team's final objective is to learn something new and valuable from this project whether this be learning a new fabrication skill or learning through Abby and her experiences.

DESIGN CRITERIA

Background research

It is expected that the global electric wheelchair market will surpass US$2.9 billion by the year of 2026 [1], however, the market for customizable accessories for power wheelchairs is almost nonexistent. Therefore, it is hard for power wheelchair users to find accessories such as tray tables that are made specifically for their wheelchairs unless these accessories are made by the same wheelchair manufacturing company. Abby's challenge with finding a simple laptray is exactly that. Since the laptray we intend to make would be customized to specifically fit the WHILL Model M, we do not expect that introducing this laptray would bring a significant impact to the market, however we hope that our general approach to creating a customized design solution for other wheelchair modes could be applied to other models.

Abby's Existing Solutions

When we first met with Abby, she showed us two laptrays that she previously tried as a solution (Figure 3). She found that the first tray (Figure 3a) was unstable over her lap and did not sit flat, which she found uncomfortable after a few uses. In addition, she found that the surface area was limited, and items frequently fell off onto the floor. Despite these drawbacks, she did enjoy the pencil holder feature along the top of the tray which she found helpful for pursuing art. She found the second tray she tried (Figure 3b) was ergonomically uncomfortable and found the shape of the laptray was too wide for her wheelchair. In addition, she found the transparent plastic aesthetic visually unappealing.

Figure 3a. A blue plastic laptray previously used and tested by Abby

Figure 3b. Olivia sitting on Abby's WHILL Model M, testing an acrylic laptray previously used by Abby

Available Products

Although we found a wide range of laptrays available online for manual wheelchair users, we found that there were very few options available for power wheelchair users like Abby. Figure 4 below shows 3 popular wheelchair laptrays that our team found for sale online.

Figure 4a. Sammons Preston Premium Flip-Away Half Lap Tray [2]

Figure 4b. DMI Wheelchair Tray [3]

Figure 4c. Lap Tray for Electric Wheelchair with Joystick Controller Cutout [4]

Team Laprador found that these laptrays were not suitable for Abby for the following reasons:

- **Compatibility with Power Wheelchair** –Most of these laptrays are designed for manual wheelchair users and require flat arm rests or surfaces for attachment. Although the 'Laptray for Electric Wheelchair…' (Figure 4c) is designed for a power wheelchair, it requires attachment onto flat armrests which Abby's WHILL model M does not have. In addition, these trays are not compatible with Abby's power wheelchair controls.
- **Ease of Attachment and Removal** – These laptrays are difficult to attach and remove by the user without assistance, which is unsuitable for Abby's independent and active lifestyle.
- **Difficult to Transport –** Each of these trays is thick and bulky, which would make it difficult for Abby to transport, and these trays are too big to fit in Abby's backpack. In addition, the Sammons Preston Laptray (Figure 4a) requires a permanent installation which makes it difficult to transport and is inconvenient for Abby's active lifestyle.
- **Aesthetic Qualities** – These laptrays are very prominent and visually unappealing, and Abby does not enjoy the materials or aesthetic of these trays.

Interviews with Abby

We met with Abby multiple times to gain a better understanding of her situation and receive frequent feedback on our designs. We first met with Abby at her house to learn more about her background, hobbies, interests and interviewed her on the context in which she hopes to use the tray and what options she has already looked into or tried. Through this initial interview we learned about her physical limitations that we would need to take into account throughout the design process. We enjoyed learning about her active lifestyle and hobbies such as camping, art and her active role and participation within her community. Below we summarize how the limitations she presented to us translate into design considerations.

Abby's Physical Limitations and Resulting Design Specifications

- **Macular degeneration:** Laptray should not be involve a complicated mechanism.
- **Arthritis, multiple back surgeries:** Attach and removal process should be as effortless as possible while seated, and the tray should be at a comfortable height for use.
- **Raynaud's Syndrome:** Materials must not be cold to touch.
- **Allergies to substances such as limonene:** Materials and finishing coatings must not contain any substances or chemicals she is allergic to.

Abby's Active Lifestyle and Related Design Implications

Figure 5. Abby with her board game created for mental hospital units

- **Active community involvement:** Abby is involved in various social activities. For example, she has been helping Gunn High school students who are experiencing psychological problems. This often requires her to eat lunch at the school, and it would be great if she had a laptray that allows her to eat while in her wheelchair. Thus, the laptray should be flat and the material should not be slippery.
- **Drawing and art:** Abby is an artist after all. Currently, she is working on a hand-drawn board game for mental hospital units. Abby wishes to spend time creating her artwork while seated in her wheelchair, so it would be best if our laptray can be designed for this. The surface area of the laptray should be wide enough for her sketchbook and it would be desirable to have indentations that can store pencils and prevent them from rolling off onto the floor.

Design Criteria

From our interviews with Abby, Team Laprador has identified the following criteria that we have determined to be critical for both the functionality and appeal of the laptray.

- Compact enough to store in Abby's backpack
- Wide enough for eating (accommodating the size of her lunch box), her laptop, and drawing materials
- Easy to attach and remove
- Lies flat, with no slippery materials to prevent items from rolling off
- Fabricated from allergy-proof materials and finishing coatings
- Material is light but sturdy (does not bend under the weight of her laptop)
- Curvature will give her space to allow her upper body to rotate easily
- Positioned above her knees to provide comfortable space between her knees and the laptray

Our Aim: Fabricate a laptray for Abby that meets the above design criteria that will allow Abby to complete her daily tasks and pursue her hobbies while on the move or away from home.

METHODS

Brainstormed Design Alternatives

Our team produced multiple sketches to explore potential design directions (Appendix A). We then met with Abby to discuss our designs and spoke with her about ways we could modify and improve them. Based on her feedback, our team selected six design directions to further explore, and fabricated a series of low-resolution prototypes to test and further evaluate with her. These six designs and prototypes are shown below, along with Abby's feedback.

Design 1: Armchair Slot Tray

This design involves a tray with two slots either side that fit over the circular arm rests, and a hinge in the center that allows the tray to be folded and stored inside Abby's backpack.

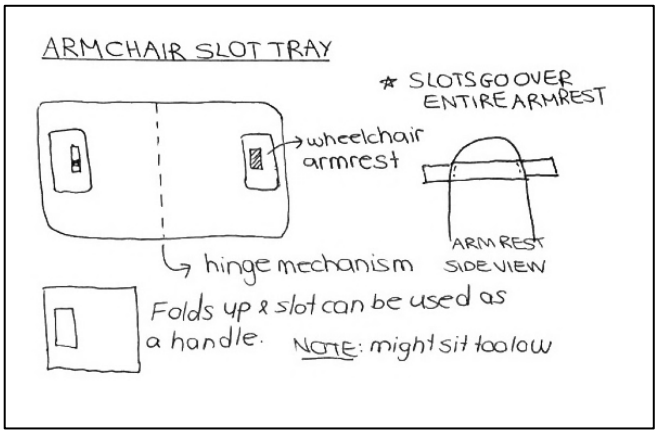


Figure 6a. Initial sketch of armchair slot tray design

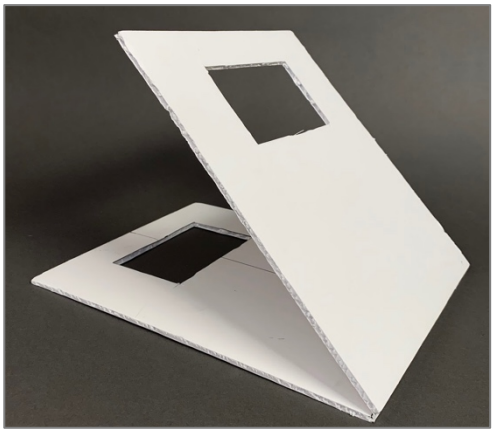


Figure 6b. Initial prototype of armchair slot tray made with foam core

Feedback from Testing:

Figure 6c. Abby testing the armchair slot tray prototype

Figure 6d. Testing the fit of the prototype in Abby's backpack

Abby's Feedback:

+ Fits in backpack
+ Large surface
+ Simple mechanism
- Not flat
- Dips in center
- Sits too low

Design 2: Arched Resting Tray

This design involves a tray with arched sides that folds outward and rest on top of the circular arm rests. This design also features a hinge in the middle so that it can be folded and placed inside Abby's backpack. This design sits at a higher height than our other designs and tries to incorporate the general structure and aesthetic of a small table.

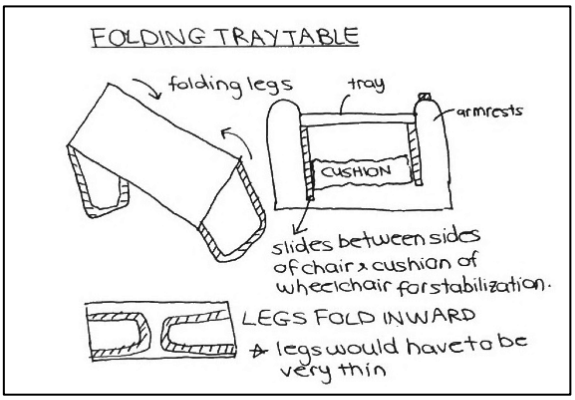


Figure 7a. Initial sketch of arched resting tray

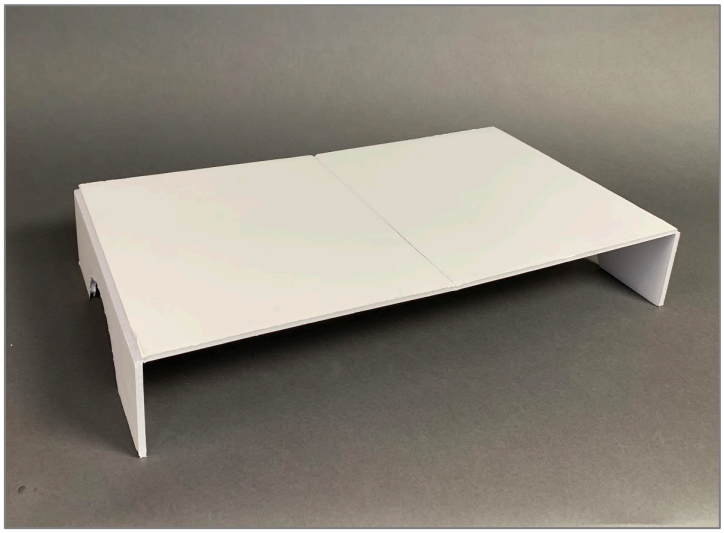


Figure 7b. Initial prototype of arched resting tray made with foam core

Figure 7c. Side view of arched resting tray prototype

Feedback from Testing:

Figure 7d. Abby testing the arched resting tray

Abby's Feedback:

+ Fits in backpack
+ Large surface
- Not flat
- Dips in center
- Sits too high
- Very unstable

Design 3: Sliding Tray (with Armchair Attachments)

This design involves two armchair attachments that fit over the wheelchair controllers, with a sliding tray that is fitted in between and held in position by these armchair attachments. This design was inspired by sliding trays on airplanes and was designed to allow Abby to have more control and flexibility over the positioning of the tray.

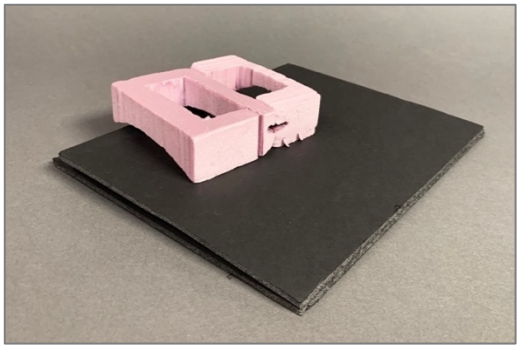


Figure 8a. Prototype of sliding tray and armchair attachments fabricated from foam core and pink foam

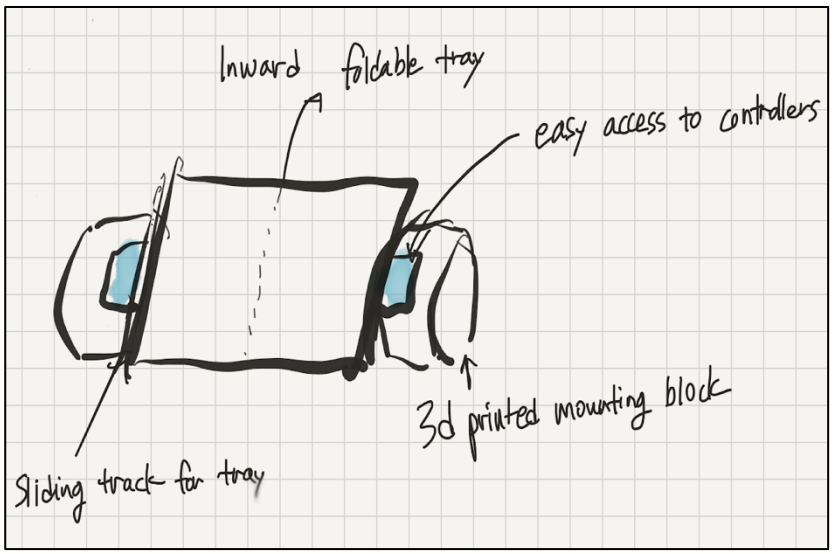


Figure 8b. Initial sketch of sliding tray with armchair attachments

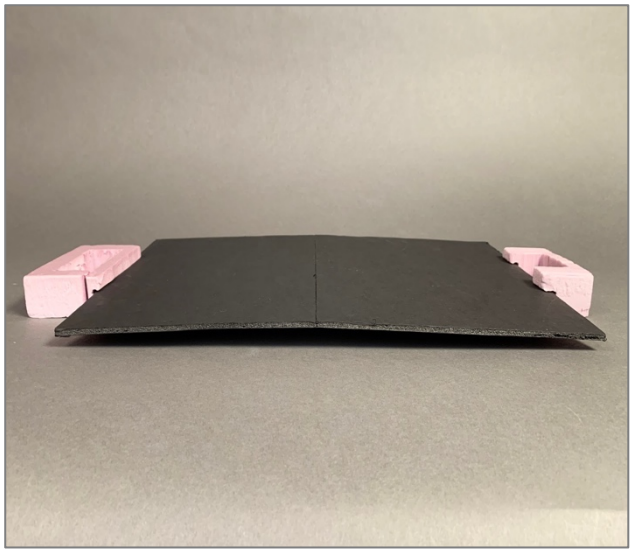


Figure 8c. Assembled prototype of sliding tray with armchair attachments

Feedback from Testing:

Figure 8d. Abby testing the sliding tray with armchair attachments

Abby's Feedback:

+ Abby likes the sliding mechanism
+ Fits in backpack
- Contains multiple components
- Long set up time
- Sliding mechanism is not smooth
- Interferes with function of controllers

Design 4: Folding Tray Table

This design involves a flat tray surface with two thin folding legs. These thin legs slide in between the wheelchair seat cushion and seat sides to support the tray. This design is unique from the other design solutions because it does not rely on the wheelchair armrests which allows for it to be used with the wheelchair armrests in up or down positions.

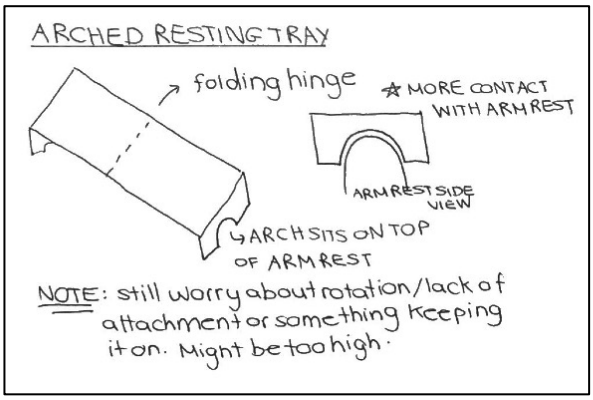


Figure 9a. Initial sketch of folding tray table

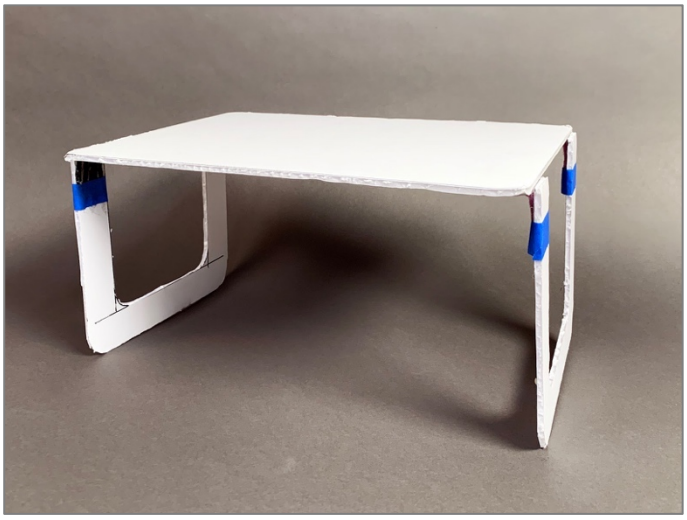


Figure 9b. Initial prototype of folding tray table made with foam core

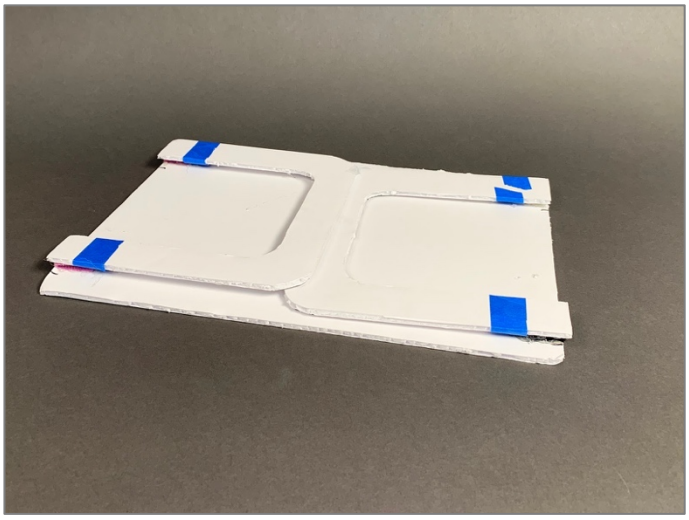


Figure 9c. Folding tray table with legs folded inwards

Feedback from Testing:

Figure 9d. Abby testing the folding tray table

Figure 9e. Testing the fit of the prototype in Abby's backpack

Abby's Feedback:

+ Fits in backpack
+ No interference with controllers
+ Can use with armchairs up or down
+ Flat surface
- Limited surface area
- Difficult to set up from seated position
- Doesn't sit flat

Design 5: Velcro Attached Slot Tray

This design involves a tray with two slots either side that fit over the wheelchair controllers, and Velcro straps that wrap around the circular wheelchair armrests for additional support. This design also incorporates a hinge in the middle that allows the tray to be folded and placed inside Abby's backpack.

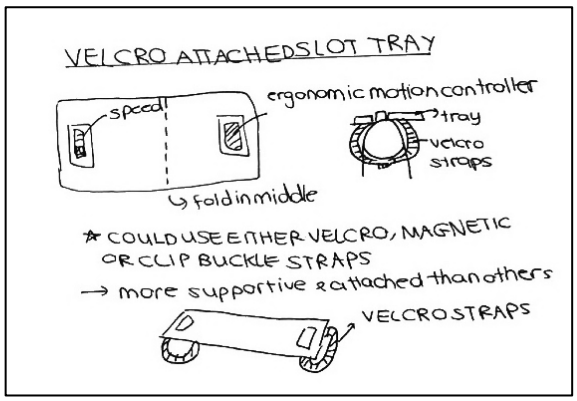


Figure 10a. Initial sketch of Velcro attached slot tray

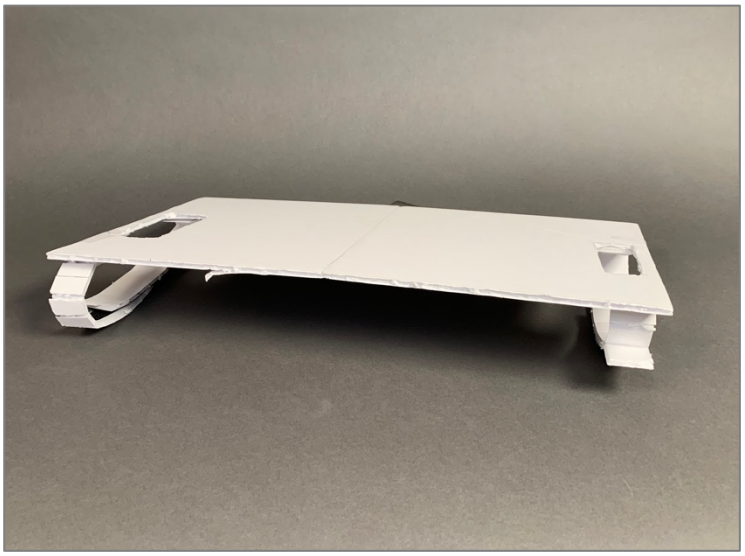


Figure 10b. Initial prototype of Velcro attached slot tray made with foam core

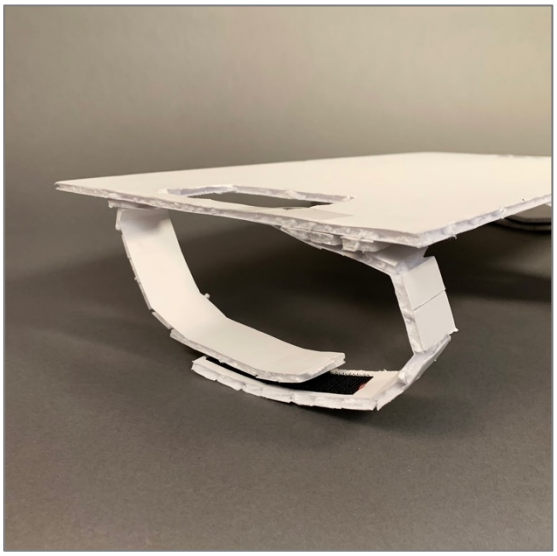


Figure 10c. View of Velcro support attachment

Feedback from Testing:

Figure 10d. Abby testing the Velcro attached slot tray

Abby's Feedback:

+ Fits in backpack
+ Stable and secure
+ Attaching and removal process is simple
+ Sits at comfortable height
- Dips in center
- Concerns about durability of straps

Design 6: Curved Controller Slot Tray

This design involves a flat surface that rests on top of the wheelchair armrests with slots either side that fit over the wheelchair controllers. The part of the tray closest to the user is curved to allow for greater upper body freedom and flexibility.

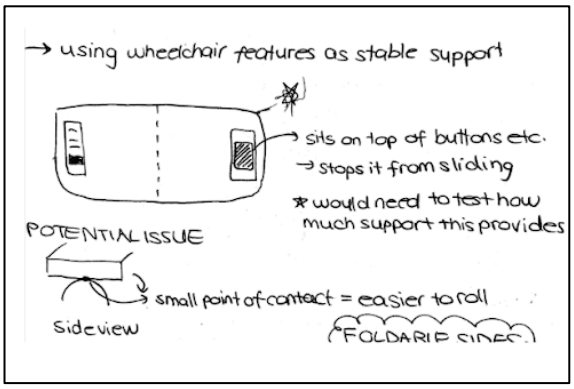


Figure 11a. Initial sketch of curved controller slot tray

Figure 11b. Initial prototype of curved controller slot tray made with laser-cut Duron

Figure 11c. Close up of laser-cut controller slot

Feedback from Testing:

Figure 11d. Abby testing the curved controller slot tray

Figure 11e. Testing the fit of the prototype in Abby's backpack

Abby's Feedback:

+ Fits in backpack (even without hinge)
+ Flat and sturdy
+ Abby loves the curve shape
+ Sits at comfortable height
+ Enjoys the simplicity
+ Easy to attach and remove
- Sits at slight angle (good for art but problematic for eating and drinking)
- Rotates slightly

Evaluation of Designs

Team Laprador used the following table (Figure 12) to identify the best design to move forward with. The designs were evaluated based on Abby's feedback, and ease of fabricating a high-fidelity prototype given our skills, time, and cost constraints.

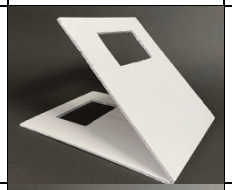
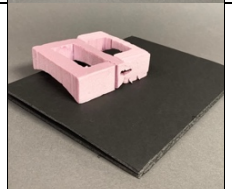
Design	Prototype	Ease of Fabrication	Abby's Feedback
Armchair Slot Tray		+ Could simply fabricate with laser cutter - Team has no experience with hinges and it will be difficult to get this flat and stable	+ Fits in backpack, large surface, simple - Not flat, dips in center, sits too low
Arched Resting Tray		- Difficult to get arch geometry - Difficulty with perfecting hinge component for center and folding side hinges	+ Fits in backpack, large surface - Not flat, dips in center, sits too high, unstable
Sliding Tray		+ Easy to fabricate flat tray + Could 3D print attachments - Will be difficult to fit armrest attachments/ensure they stay on	+ Fits in backpack, likes sliding mechanism - Multiple components, long set up time, sliding not smooth, interferes with controllers
Folding Tray Table		+ Could quite easily laser cut legs - Hinges will be difficult	+ Fits in backpack, no controller interference, can use with armchairs up or down, flat surface - Limited surface area, not flat, difficult to set up
Velcro Attached Slot Tray		+ Could laser cut tray component - Will be difficult to attach Velcro/ rubber straps to tray	+ Fits in backpack, stable, secure, easy to attach and remove, sits at comfortable height - Dips in center, concerns about strap durability
Curved Controller Slot Tray		+ Easy to laser cut tray shape + Illustrator file already created	+ Fits in backpack, flat and sturdy, loves curved shape, comfortable height, enjoys simplicity, easy to attach and remove - Rotates slightly, sits at angle

Figure 12. Table evaluating design alternatives 1-6 based upon criteria of Ease of Fabrication and Abby's Feedback

Refined Prototypes of the Curved Controller Slot Tray

After the evaluation of our designs, our team chose to move forward with the Curved Controller Slot Tray as it received the most positive feedback from Abby. We also believed the fabrication of this prototype was within our skill sets and cost/time restraints. To improve this design, we worked on trying to increase the stability and incline of this tray. After receiving feedback from Abby that she preferred a flat tray for eating and an angled tray for doing art, we came up with a rotating clip mechanism which allows for both a flat and tilted setting to be achieved. To further increase the stability of the laptray, we designed two front supports that attach under the front of the tray, which match the curvature of the circular armrests and increase the point of contact between the tray and armrests. The CAD assembly model is shown in Figure 13a, and the models for the clips and front supports are found in Appendix C.

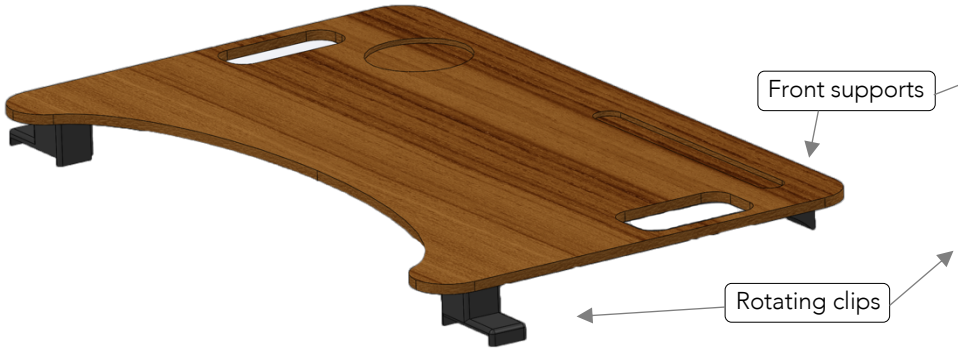


Figure 13a. CAD assembly model of curved controller slot tray with rotating clips and front support attachments

Figure 13b. First prototype of laptray with 3D printed clip mechanism (prototyped with magnets)

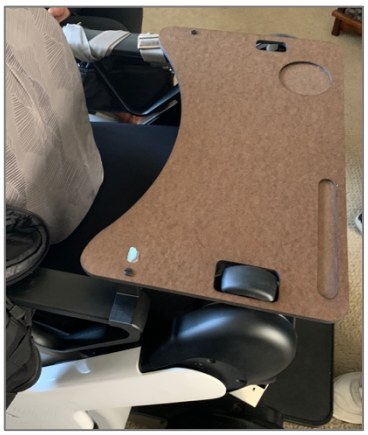


Figure 14. Prototype of laptray with refined clips and controller

To refine this prototype and ensure a perfect fit for the clips, we met with Abby 6 times over 3 weeks. We worked closely with Abby to refine the shape of the tray surface to ensure a tight fight around the controllers, and also worked on refining the overall shape and dimensions of the front supports and clips. This process proved to be challenging as the curved components of her wheelchair were difficult to measure accurately. To solve this problem, we first reached out to her power wheelchair manufacturer WHILL Inc. requesting these dimensions, however they were reluctant to release technical information. We then tried using modelling clay to create a mold of the curved armrest surface which we were able to 3D scan and import as a CAD file (Figure 15).

This scan was helpful for forming the shapes of our front supports, but we found that this scan was difficult to calculate absolute dimensions from. To find the perfect fit for the clips, we ended up using a trial and error process which involved 3D printing over 10 sets of low-quality clips which we tested on Abby's wheelchair during each of our visits (Figure 16).

Figure 15. 3D scan of clay mold of wheelchair armrest

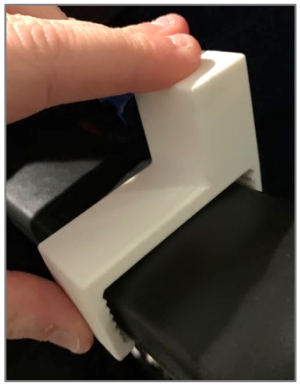


Figure 16. Testing out the fit and dimensions of the clip

Laptray Fabrication: Woodworking

Figure 17. Alessandra sanding the edge-glued wood panels

After presenting different material options to Abby for the final prototype, we collectively decided to go with a thin and light wood option. Our team worked closely with Abby to try and understand the colors and aesthetic she would like for her tray, and then took a trip to Woodcraft in San Carlos to purchase wooden panels. In the PRL Wood Shop, we edge-glued these wood panels using wood glue, clamps, and weights to form a larger wooden panel with a dark and light pattern. We sanded this panel until it was smooth with no noticeable incline between the different wood types.

To avoid the burn marks and smell typically produced by laser cutting, we decided to manually craft the table outline and controller slots using a router (based advice given by the PRL CA's). Since our team had no experience using a router, we booked an introductory session in the Wood Shop with a PRL CA where we practiced making this shape and determined which of Team Laprador's members should make the final cut. To make the final cut, we used our most recently refined Duron prototype as a stencil guide to follow and used the table router to trim down the panel to the desired shape (Figure 18). We then used the remaining scrap wood to test out different wood stains and coatings to bring to Abby so she could choose her desired finish.

Figure 18. Jinho using the table router and Duron guide to shape the laptray

RESULTS

Our final prototype builds upon the Curved Controller Slot Tray design. This prototype features a hand-crafted wooden tray made of Cherry and Walnut Fig woods (Figure 19), with two 3D printed dual-setting clips and two front supports. The wooden tray rests on the front circular armrests of the WHILL Model M (with the slots placed over the controllers), and the 3D printed clips attach to the thin back armrests for support. The clips switch between two settings, which allow for the tray to switch between a flat mode for eating and using a laptop, and an inclined mode which is more convenient for creating art. The rotating clip mechanism has a brass pin connection with magnets embedded into the clips and tray. The clips easily snap into the desired setting, allowing the mechanism to be operated by someone with limited hand dexterity.

Figure 19. Team Laprador's final fabricated functional laptray, handcrafted from wood

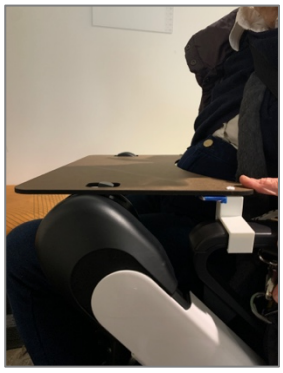


Figure 20a. Rotating clip positioned in the flat setting, with Abby exhibiting the laptray in this setting

Figure 20b. Rotating clip positioned in the slanted setting, with Abby exhibiting the tray in this setting

Figure 21. Abby practicing changing the settings on our laptray prototype

The clips fit tightly around the back armchair to support the tray and stop it rotating forward when a heavy object is placed at the front of the tray. We worked hard to create a tight and secure fit between the clips and the armchair, while also making sure these clips are still easy to apply and remove by Abby. The final design for these clips features a jagged inner surface with angled sides that wrap around the back armrest in the flat position. For safety, the edges of the clip are all filleted and smoothened to ensure that these are not sharp.

To test this clip, we placed Abby's water bottle at different positions on the tray to ensure that it didn't cause the tray to rotate forward or detach. The prototypes of our clips were printed on an Ultimaker with tough PLA (Figure 22). This allowed us to quickly prototype changes in our designs using a cheap material, however the tough and inflexible nature of this material made it hard for Abby to attach and remove the clips. For our final prototype, we hope to print these clips using a more flexible and durable material called FormFlex, which would allow the clip to be more easily attached and removed. (Unfortunately, the PRL closed due to COVID-19 mid-way through our 3D print set up)

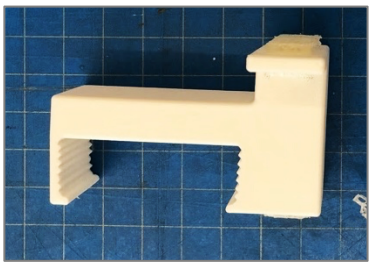


Figure 22. Final 3D printed prototype of clip design using tough PLA

The tray fits into Abby's backpack without the need for a folding mechanism or hinge in the middle, which ensures a level flat surface with no dip or extruding line in the center. The curved edge of the laptray is designed to fit the curvature of Abby's upper body to make this more comfortable for her.

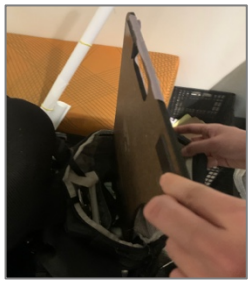


Figure 23. Olivia sliding the tray into Abby's backpack

Team Laprador worked hard to make this project aesthetically pleasing and beautiful for Abby. We worked closely with Abby to identify woods, colors, and styles that she liked and made decisions with her preferences in mind to ensure that the final prototype was something that she would enjoy using. We used a combination of Cherry and Walnut Fig woods for the laptray surface, shiny brass hardware, and a beautiful Cherry finishing stain chosen by Abby. In addition, we chose to print the clips out of a black matte material to complement her wheelchair armrests and make the clip components more subtle. When choosing materials and stains, we made sure to check their associated Material Safety Data Sheets to insure these did not contain anything Abby was allergic to.

Figure 24. Stain testing between cherry (center) and maple (right) wood stains

Our prototyping costs have been low due to our use of low-cost materials such as foam core, Duron, and PLA. Our most notable costs came from purchasing the natural wood panels ($31) and 3D printing with FormFlex material ($54). If this product were to be manufactured in bulk, costs of 3D printing would be reduced significantly, and material substitutions could be made for the wood (such as Duron) to provide a lower cost alternative.

DISCUSSION

Challenges and Solutions

Team Laprador's biggest challenge was securely attaching the tray to Abby's wheelchair, while also achieving the dual incline setting. We really hoped to include the dual incline setting to encourage Abby to pursue art, however it was difficult to design a clip method to attach the tray to the wheelchair in both settings without the design becoming too bulky. Our solution was to prioritize the clip attachment of the tray in the flat mode. In this mode Abby is more likely to store more heavy items on the tray which makes this mode more vulnerable to tipping forward when items are placed on it. When Abby interacted with the tray in the inclined mode, we noticed that while drawing, she rested her forearms on the points of contact between the back armchair and the table keeping the tray stable. For this reason, we decided that a clip attachment would not be necessary for the inclined mode and instead chose to allow the tray to rest on the armchair in this setting, prioritizing our clip design for the flat setting (Figure 25).

Figure 25. Prototype with clip resting on armchair during inclined position

Figure 26. Clip contact with armchair obstructing the inclined mode

In addition, we experienced challenges with designing and perfecting the clips as it was difficult to accurately measure the required dimensions. In result, our prototype iterations relied significantly on frequent testing with Abby. Our team also ran into challenges with the clip colliding with the armchair when changing incline settings (Figure 26). In the end it took 16 prototypes of clips to achieve a successful and functional mechanism (shown in Appendix B).

For the tray surface, the thickness of the natural wood (0.25 inches) posed challenges with warping. We learned that wood this thin has a high chance of warping, and traditional woodworking practices to combat warping (such as joining and planing) do not apply to materials of this thickness. As a result, we took precautionary steps to minimize warping, including thorough flattening of the wood using weights while it was being glued together (Figure 27).

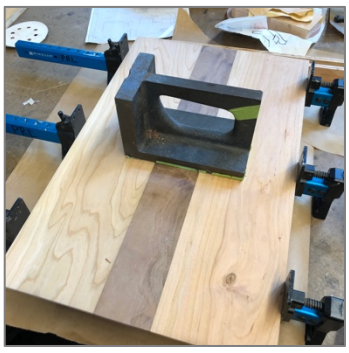


Figure 27. Team Laprador's material warping prevention measures

NEXT STEPS

Due to the closure of the PRL for COVID-19, our team was unable to finish the final prototype. When the PRL reopens, we plan to enroll in Directed Study with Dave Jaffe to complete our final steps: printing the clips out of FormFlex material, drilling and embedding magnets into the laptray, applying the Cherry stain and waterproof coating, and attaching the clips to the laptray by installing the brass pins. Once these steps are complete, we hope to give the prototype to Abby and celebrate our finished protype with her.

If our team choose to continue this project as directed study, we would like to include some additions to the design. Given the time restraints, we were unable to successfully master the hand router for creating indentations on the tray for Abby's water bottle and pencils (Figure 28). We hope that with more time we could add these features, so that Abby can get the most out of her tray. We would also like to make a spare set of clips, to allow for Abby to switch the clips out in case the original clips get lost or broken.

Figure 28. Olivia practicing making indentations for Abby's water bottle and pencils using a hand router.

Through directed study, our team would also like to explore how we can bring this laptray to more users to make our design more universal. Team Labrador's design is specifically made for the WHILL Model M, thus we hope to reach out to WHILL Inc. about a potential collaboration. If granted an opportunity to work with them, we would like to explore how we can make our design more universal across different models of their power wheelchairs by modifying our basic clip and tray files.

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We would like to thank our project suggestor and friend Abby for all her excellent and honest feedback and for her kindness in welcoming us into her home.

We would also like to thank Dave Jaffe for all his continuous feedback and support throughout the course and for his kindness and flexibility particularly towards the end of the course.

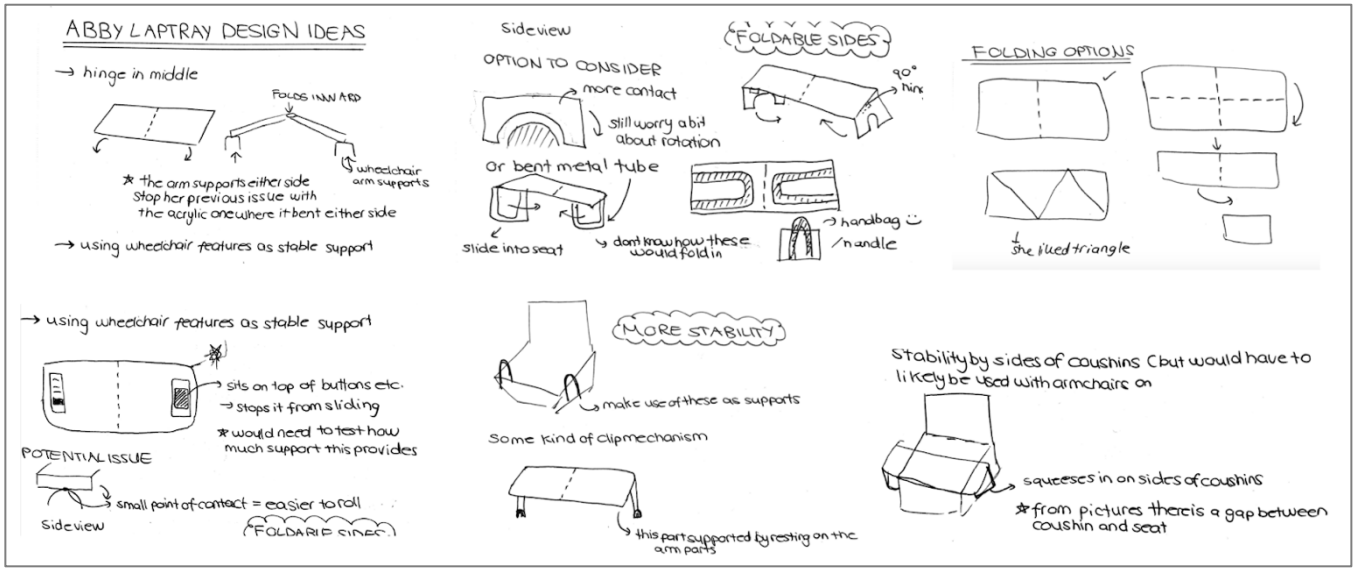
We would also like to thank the PRL CA staff, in particular Manu Garzaron for his help and patience in teaching us how to use the table and hand routers and making this a fun experience.

Finally, we would like to thank Nathan for inspiring our team name and logo, for showing us his tricks with picking up coins, and for welcoming us into his home!

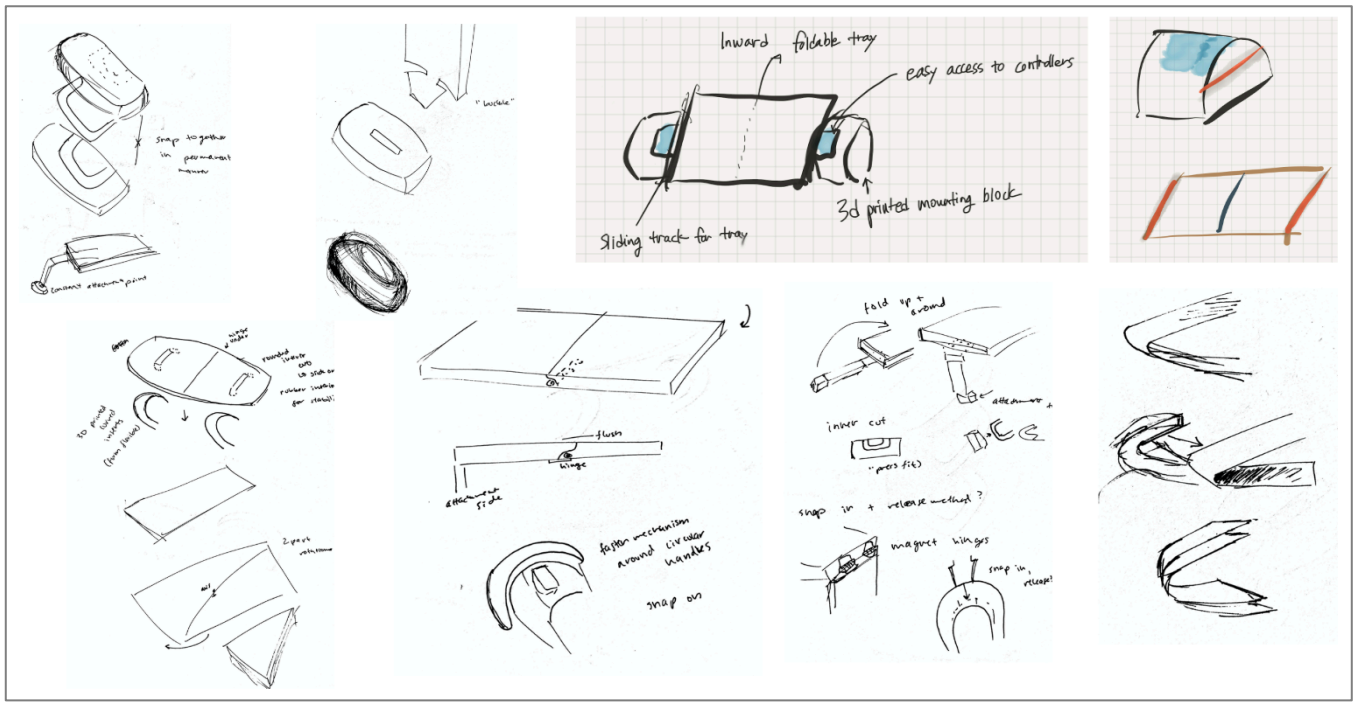
APPENDIX

Appendix A: Initial Brainstorming Sketches

The following pictures show Team Laprador's initial sketches exploring different laptray designs and ways in which the laptray could be attached to Abby's wheelchair. These designs formed and inspired the six design alternatives presented to Abby.



Initial sketches brainstorming possible laptray design solutions by Olivia Lancaster

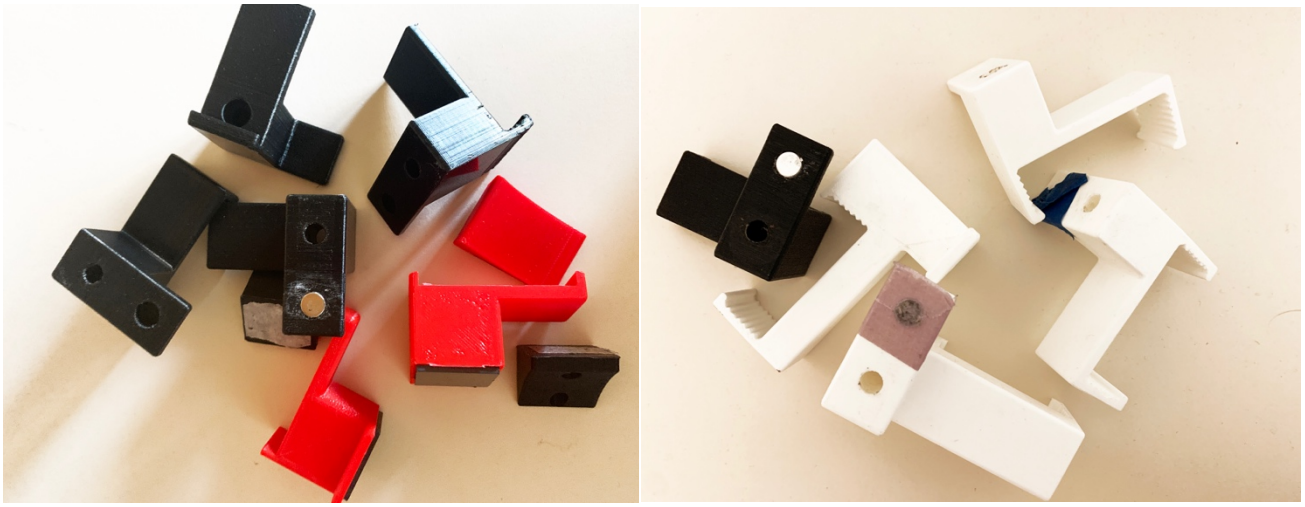


Initial sketches brainstorming possible laptray design solutions by Alessandra Diaz and Jinho Chung

Appendix B: Additional Photos of Prototype Iterations

The following photos further illustrate the multitude of prototypes Team Laprador fabricated before reaching our final functional laptray for Abby. These prototypes were crucial in determining the correct fit of the clip attachments, front supports, and the dimensions of the tray surface and controller slots.

Clip Prototypes



3D printed prototypes of clips with different designs and dimensions, which played a crucial role in fabricating our clip mechanism.

Front Support Prototypes

3D printed prototypes of the front supports of the laptray designed to increase the overall stability of the laptray.

Laptray Surface Prototypes

Fabrication of our layered 3/8inch Duron prototype with indentations for Abby's water bottle and pencils.

Using duct tape to mask the controller slots to allow us to easily measure and alter the dimensions of the controllers.

Team Laprador's seventh and final Duron prototype with the correct dimensions for the controller slots and indentations

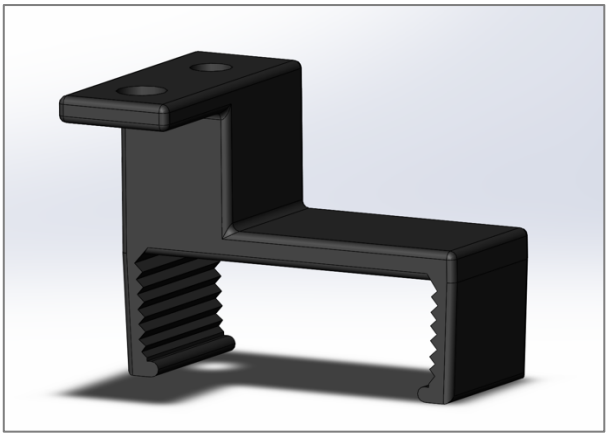
Alessandra fabricating our first hand-crafted natural wood prototype on scrap plywood with the help of CA Manu Garzaron.

Appendix B: Screenshots of CAD Models

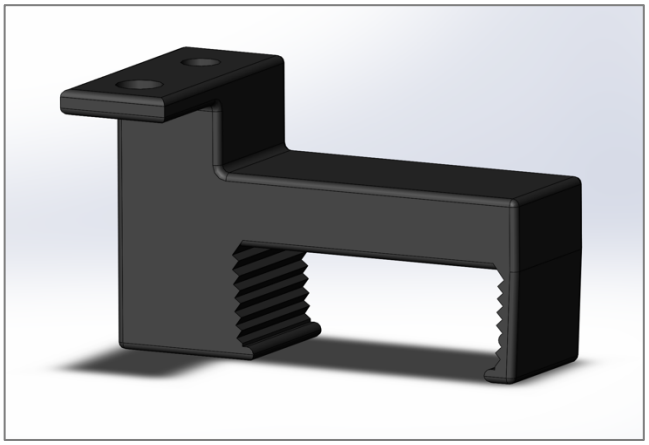
The following exhibit the CAD models designed for the tray surface, clip mechanism, and front supports. These CAD models were crucial to the fabrication and development of our prototypes and the clip and front support designs were used for our 3D prints.

CAD model of top view of laptray with clip mechanism and visible water bottle and pencil indentations

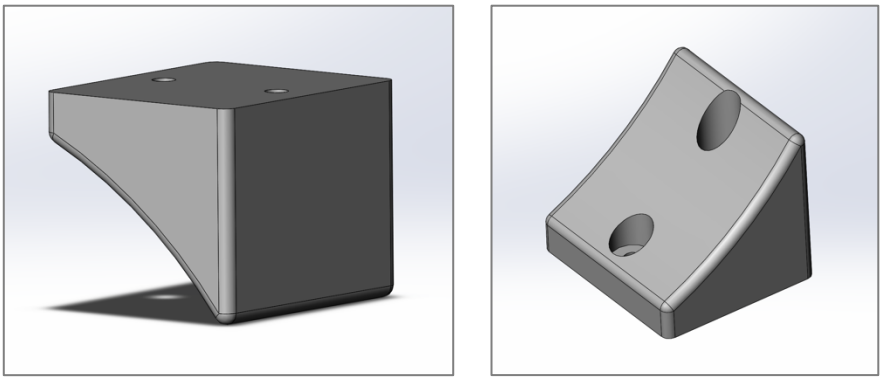
CAD model of the bottom view (underneath) of laptray with clip mechanism and front supports



CAD model of initial rotating clip design with embedded magnet holes



CAD model of final rotating clip design with embedded magnet holes



CAD model of front supports with holes for screws