University of Ottawa

Project Deliverable M: **Final Report**

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GNG 2101A

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Abstract

All the time, users with disabilities and their attendants are discouraged to participate in sport/recreational activities because of the lack of appropriate assistive system and fear of injury, feeling excluded and isolated. The project product was design to arrest their fall before they hit the ice and prevent any kinds of injuries to both the user and the attendant.

This report is a summary of the work of the group A8 for the project “Ice Cube” of GNG 2101 Introduction to Product Development and Management for Engineers and Computer Scientists. During three months, the group worked with a client, David, in order to develop a product for his needs. All the content of the course helped as a tool for create this solution and make it a reality. It contains a detailed description of the project work for this Fall term: Need identification and product specification process, Conceptual designs, Project planning, Analysis, Prototyping, testing and customer validation, Final solution, Final testing results, Business model and Economic analysis. In addition are the User Manual and Design Files, the former to help our client with use of the product and the later for continuous work.

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1.0 Introduction

Kids with disabilities are often sidelined from trying new activities due to lack of sufficient assistive equipment. Products providing more support are often required to allow the user to participate without fear of injury to themselves or their attendant.Our team at Ice Cube believes that anyone with the passion to learn to skate should be given the opportunity to experience the joy of skating.

Our skating aid could be used for anyone new to skating and wants to learn but is specifically designed for those with disabilities or limited motor movement. Uniquely, our design provides support by arresting the fall of the user with the use of an adjustable seat while providing 360° of protection, all of which can be folded and easily transported. In addition, it is adjustable for the use of several different users. Overall, our product provides opportunity to improve physical and mental health for these kids and finally promote inclusion.

2.0 Need Identification and Product Specifications

Our client's son, Liam, has always wanted to skate down the Rideau Canal and his dad has yet to come up with a sufficient solution. Our group's task is to design and build a support that allows Liam to Skate down the Canal with his dad that protects both of them from injury.

After speaking to our client we were able to determine and prioritize some needs of the skating aid. The needs below are listed in priority, 1 being the highest priority.

1. The skating aid is able to catch the user if they fall with the use of an adjustable chair, reducing the risk of concussion and injury to the user or to their attendant.
2. The skating aid is lightweight (<20lbs) and transportable. It is able to fit in the back of their car and David's wife is able to lift the aid by herself.

3. Aspects to make the aid usable for children with disabilities are included such as rounded handles and a keel to keep users from crossing their ankles.
4. The skating aid looks cool and has a cup holder for drinking hot chocolate while skating down the Canal.
5. Adjustable for different users to use the device comfortably.
6. Seat can turn into bench for when the user gets tired or for when they need to tie up their skates.
7. Sides of the skating aid are able to stay upright without fear of falling in on users during setup.

Although in the eyes of David's son, Liam, the cup holder and the cool factor are the most important, for our team, safety is our main priority.

Table 2.1: List of metrics

Metrics	Units	Needs Addressed
Weight	pounds	The client wants a light product so that it is easy to lift and pull around
Sturdiness	pounds	If the user falls the product needs to be able to support their weight
Size	cm	The product needs to be small so that it can fit into a small car
Time	seconds	The product and features should be able to be assembled quickly

Table 2.2: List of Specifications

Specifications	Ideal	Marginally	Reasons
Light	Less than 20 pounds	Within 5 pounds	Easily to be lifted and placed in the car and to move around
Sturdiness	Holds 200 pounds	Within 25 pounds	Able to support his weight as well as the momentum the child has while falling

Small	30in x 30in x 10in	Within 10” per side	Able to fit in a small car
Easy Set Up	60 seconds for setup	Within 2 seconds per feature	Easy set up so anybody can do it without experience. Adjustable for the user

There are currently many different skating aids currently on the market, some specifically designed for those with disabilities that affect motor movement, others simply for beginner skaters.

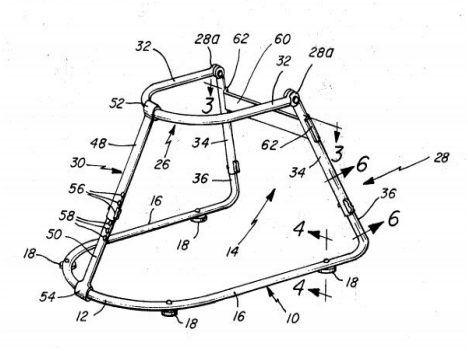


Figure 2.1: Skating aid for beginner skaters (U.S. Patent No. 4021033)

This basic skating aid is made for beginner skaters with handles to hold onto and a backrest to help the user stay upright. This product doesn’t provide sufficient protection for those with disabilities because it doesn’t catch the user if they fall which would help to prevent injuries such as concussions.

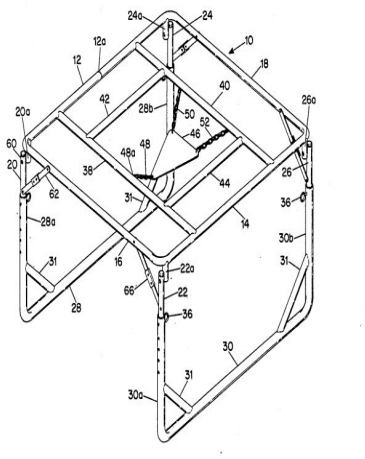


Figure 2.2: Bungee seat skating aid (U.S. Patent No. 5033734.)

This harnessed skating aid a flexible suspended seat able to catch the user if they fall which prevents injury for beginner skaters and those with disabilities. The poles are telescoping to allow for adjustability but it is difficult to get the user into the device to use it. The user must be lifted into the seating area of the aid which could cause injury to both the user and the attendant especially if the user is older or heavier.

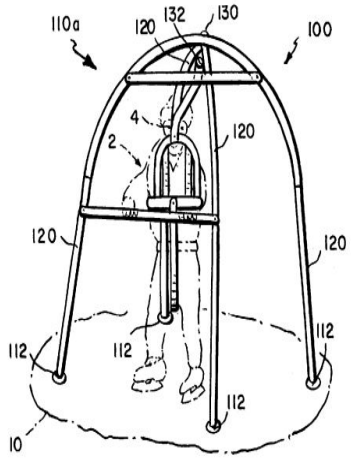


Figure 2.3: Supporting frame skating aid (U.S. Patent No. 6537077 B1)

This skating aid is excellent in that it catches the user if they fall by means of a harness attached to supporting frames. The frame responds to the user's movements allows autonomy for the user as they skate but is difficult to transport due to its large size.

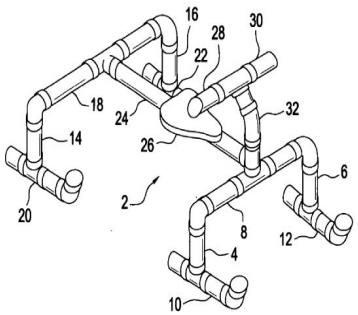


Figure 2.4: Sled style skating aid (U.S. Patent No. 2014/0141940 A1)

This skating aid allows the skater to sit on the seat much like a bike and can be pulled with a rope by an attendant. It is small and easy to transport but doesn't provide the full experience of skating due to the fact that the user is sitting instead of standing.

3.0 Concept Design

Based on our problem statement and our meeting with David, we each up with some criteria and a list of product concepts that we wanted to include in our design. Each of us came up with three ideas:

a. As small as possible (to fit in trunk of car)
b. Gearshift seat
c. Attendant steering device
d. Cup Holder 3D printed
e. Rounded ice wheels for movement in more than one direction
f. Stacked seat method
g. Lightweight and durable material
h. Hanging seat method
i. Skateboard seat method

j. Harness to arrest the fall
k. Adjustable hand and ankle supports
l. 360 degree protection

Table 3.1: Pros and Cons of concept

Idea	Pros	Cons
a	-easy to move -can fit in smaller spaces	-possibly sacrificing strength with a lighter material
b	-easily adjustable -makes the device useable by different people	-cutting slots in the panels takes away strength
c	-the user can take a break while the attendant pushes -if the user loses control it is easy for the attendant to help	-the extra handles will add more weight and require more holes in the panels
d	-the user can have a drink while skating	-this can take up space that is available for the user to catch themselves if they fall.
e	-the product will be able to slide easier. -the device will be able to pivot	-ice wheels can cause the device to spin out of control
f	-the seat with be stronger -makes it easier to make a foldable bench	-this will make the product heavier
g	-the product will move easier -the product will be easy to lift and will still be strong	-a material with these attributes will be more expensive
h	-easy to assemble into a bench	-the hanging piece will be attached with a hinge and this could pinch the user.
i	-if the user falls backwards the seat will catch them	-the seat could be uncomfortable
j	-the harness will catch the user	-it can be hard for the user to get into the harness

k	-the product will be adjustable for more/less developed skaters	Adjustable handles will add slots to the panels which will also give away strength
l	-the user will be protected in any direction they fall	-many components will be needed to provide this such as extra handles. This will cost more money.

After analyzing the list of pros and cons we decided that it would be beneficial if our product was as possible since this will make the user's life much easier when transporting the device. We went with a stacked seat method since this would allow more strength in the seat without it being too wide. A cup holder doesn't affect the user's ability to grab the panel very much so we decided to incorporate that in our design. The rounded ice wheels make it easier for the user to move around so we decided that they should be included in the design. We decided to use a light material to make the product easier to lift. Adjustable hand and ankle supports were included in our design because this allows the product to be accessible by more than one user. We also went with 360 protection because it is important that the user doesn't get injured while using the device.

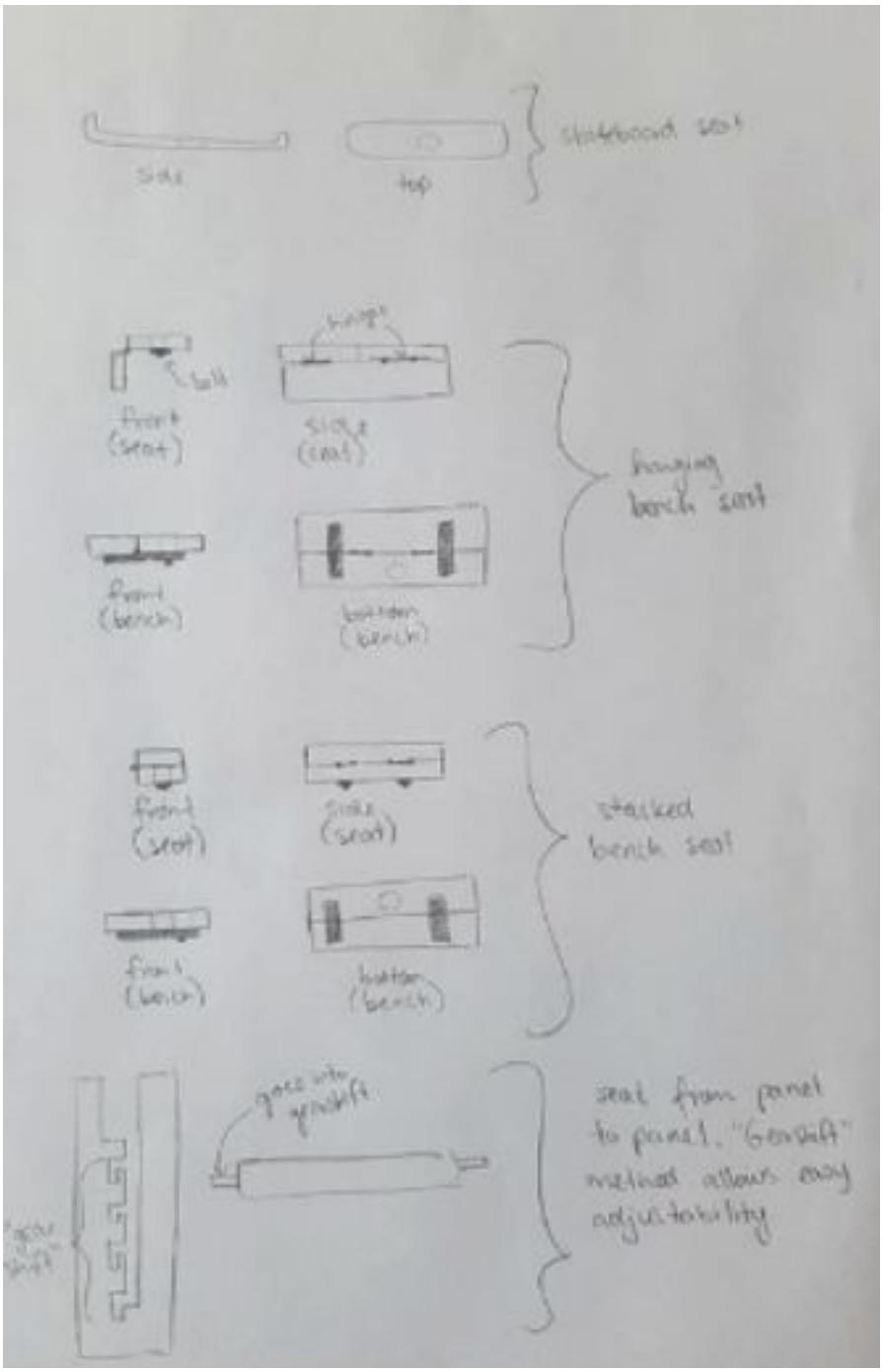


Figure 3.1: Our seat concept designs. Note: designs 1-4 are for a seat standing on a pole from the keel.

We initially chose the skateboard seat concept for strength while keeping simplicity but it was later changed due to results of comfortability tests.

2. In order to incorporate all the product concepts we've come up with, we need to have a plan on how we will design and build all of these concepts

A. In able to make the device as light as possible, we will be dimensioning it as small as possible.
B. An adjustable seat will be attached on top of a pole allowing the seat to move up and down to adjust to the skaters need. We can use either telescoping poles or attachable poles. The telescoping pole could have 4 holes equally spaced around at every height that will allow the skater to sit in four different directions. The height also has to be adjustable to accommodate height differences when Liam grows.
C. The attendant will be able to steer the device using the blades of a hockey stick. The blades are easy to hold onto and contribute towards the cool factor.
D. Liam requests there to be a cool factor on his skating aid, so during our first meeting with David we asked about things Liam likes and we plan to include those in our design. Some solutions for the cool factor include things like flags, colourful head and tail lights, hockey team logos and other things Liam will like.
E. Liam also requests that we include a cup holder in our design. Depending on our design we will either be attaching the holder onto the side, or making it built in.
F. While learning how to skate, kids are still not completely stable and often slip very frequently. To stop their legs from spreading too far, we will be putting two leg guards on either side of the support. Our idea is to attach four guards onto hinges that will be folded down from the top 4 sides of the support.
G. David wants a product that is easy to move. David had included wheels in his prototype but there was a fair bit of friction between the wheels and the floor. If we change the wheels to wheels with minimal friction then it will move a lot easier. This will be useful on the ice and when transporting the product. Our idea is to use semi spheres that will follow the front runners of the support.
H. Lightweight and durable material: David's prototype was made out of wood which is fairly heavy if you use enough of it. David would like a product that will last, and is light enough for his wife to be able to put it in the car with ease. Some materials to consider are aluminium, titanium and plastic (probably delrin).
I. In able to make this device easily usable for kids with disabilities, our handles must be rounded so that they can easily grip and grab a hold of the supports. A skate guard is required for some people with disabilities to ensure that they don't spread their legs too far apart. A keel can also be used to ensure that they don't cross their legs or have them too close together.
J. Options for arresting the fall are to have a seat to catch the user if they fall. A tube with padding that stretches from the front to the back of the device. A harness could also be used to catch the user either from an overhead support or from a support at hip height.

3. Evaluating our solutions involves making charts and giving them ratings.

(5 is the best)

Cool Factor

Criteria	Weight	Lights	Flags	Cup Holder	Hockey Sticks	Hockey Team Logo
Price	60%	3	2	4	1	5
Lightweight	20%	3	2	4	1	5
Safety	10%	4	N/A	N/A	5	N/A
Accessibility	10%	N/A	N/A	N/A	5	N/A

Materials

Criteria	Weight	Wood	Aluminum	Steel	Titanium	Plastic
Price	50%	5	4	2	1	3
Strength	25%	2/3	1	4	5	2/3
Lightweight	25%	2	5	1	4	3

Past Designs

Criteria	Weight	David's Ice Cube	1991 Design (Seat harness) (U.S. Patent No. 5033734.)	2014 Design (Rocking horse) (U.S. Patent No. 2014/0141940 A1)	2003 Design (Over head Support) (U.S. Patent No. 6537077 B1)
Transportability	25%	3	2	4	1
Safety	50%	3	2	1	4
Price	10%	2	4	3	1
Accessibility	15%	3	1	4	2

4. Choosing a promising solution based on our criteria charts

1.) Materials:

Different sections of our design will use different materials based the criteria needed for that specific part. For example for parts that need to support a lot of weight, we will be using materials such as titanium and steel.

First of all the overall structure of the device needs to be very strong, but also considerably light while staying within a decent price point. Therefore according to our chart titanium would be the most ideal material to use for our structure because it is the strongest material, and also considerably light. However it is also quite costly so this adds to the reason why we need to assure our design is small as possible.

Supporting bars such as handhelds and also the stride guard don't need to support so much weight, but instead need to be very light. Also in regards to price, there is a possibility that we are going to use old hockey sticks donated from clubs or stores as the supports, this will add to our cool factor, and help us out with our restraining budget. Therefore composite will be used for the supports.

Our idea for the "Ice wheels" is to use semi-spheres on the bottom that will allow the device to glide across the ice. We will need a material that has little friction with the ice, and is also considerably light. Therefore plastic is the ideal material.

2.) Design:

We are going to use the cubic design. It would be easy to transport in the back of a car as long as we make it foldable with the front and back sides on hinges. We can also attach small wheels for it to be wheeled to and from the house, car and rink much like a hockey bag. Although the overhead harness has the highest ranking for safety, our client would not be able to transport it easily and it is expensive to manufacture. The seat of the ice cube will be successful to arrest the fall and easy for Liam and other people with disabilities to use. Although the 2014 design is the most accessible for people with disabilities, there's not as much support to keep the user from falling while trying to skate with it.

3.) Cool Factor:

To make our device cool, we'll be using things like flags, head and tail lights, laser cut hockey team logos, cup holders, and hockey sticks to make our design look cool. We need to make sure that Liam thnks the things we are using are cool.

4.) Adjustability

We will use telescoping pin joint poles to make the device adjustable, that way the adjusting will be quick and easy, and our clients won't be required to carry more pole parts with them to the rink.

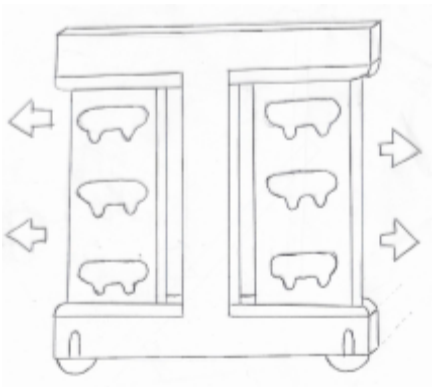
Our design is in the shape of a cube with a nearly identical front and back. The main structure of the design including the front, back, keel and seat support will be made of steel for strength.

There will be movable handles from the front to the back of the aid allowing for the height and distance to be adjusted according to the user's needs. The handles will be made of hockey sticks with a stopper at one end and the blade of the stick will be at the back of the device for the attendant to use as handles.

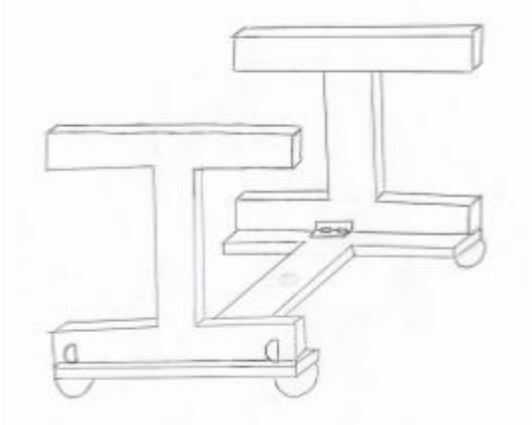
A pole with a seat will be able to screw into the centre of the keel (tapped) and the height of where the back folds in will be flush with the height of the keel. The front will be offset with respect to the back so that they can fold in and lie flat (hinged). The pole will be telescopic for the seat height to be adjustable. The seat will be shaped similar to the shape of a skateboard (an oval with upright edges).

Semi spheres will be used as wheels on the ice to be able to move in all directions and they will be on the sides for easy transportation off of the ice.

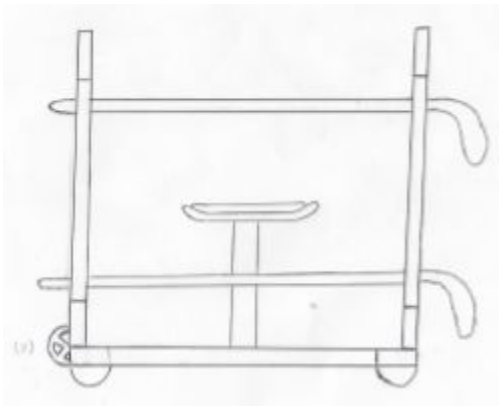
5.) Sketches of our group concept:



Front View



Orthographic View



Side View

6.) Core Functionality

The main focus of our design is to assure that Liam and other kids using the device will not get hurt while skating. Therefore our design will arrest their fall before they hit the ice and prevent any kinds of injuries.Our target specs explain that we want a small, lightweight design, but also a strong material that will be used to construct our design. We believe that our design has many beneficial factors that will satisfy our customers wants. This will take a long time to plan and actually build, therefore we must stick to our agenda and plan that we have created to get this project done on time.

4.0 Project Plan and Feasibility Study

It was developed a plan for completing preliminary and detailed prototypes that the team present to the client and also, it was created a BOM of the materials and parts required to complete these prototypes. A feasibility study to verify the viability of your proposed solution was also provided.

Here is an initial list of all the tasks which need to be completed, an estimated duration for each task, as well as who is responsible for each task and any task dependencies:

Task	**Estimated Time**	**Who**	**Dependencies**
Order materials	2 weeks (to come in)	Heidi	Design blueprints
3D Model Design	1 week	Stephen & Carolina	List of ordered materials
Cut Hockey sticks	1 week	Jackson	Design Blueprints
Test Ice Wheels	2 days	Carolina & Heidi	Built Base/ordered materials
Build Two Front Supports	2 weeks	Heidi & Stephen	Ordered materials
Attach front supports to base	0.5 week	Stephen & Jackson	Completed Base and front supports
Assembly Seat and keel	2 week	Heidi & Stephen	Attached Base and front support

Build base (with runner and Ice wheels)	1 week	Jackson & Carolina	
Finishing touches/ Tests	1 weeks	Everyone (C as test subject)	Functioning design
Test W fold	2 days	Jackson & Carolina	

For this project, we followed a specific calendar that was given to us that will help ensure that we finish our project in time. We followed this list very closely and making sure that we put out our best work at each deliverable due date. Our milestones were:

October 14th: Prototype 1

It will be very difficult and almost not possible with the budget that we're working within to be able to make a whole separate prototype that we would end up discarding for the main project. So instead we will be making individual parts that will all come together at the end to make our final product. Parts like the base with the 4 spherical orbs will be made by this date.

October 21st - October 28th: Business

These dates have deliverables that deal with the business side of things for our project. For now we do not know to many details about these deliverables because we have not learned the content needed for it yet. Therefore to prepare for the worst, we will be making sure that we set more than enough time aside to be able to work on these deliverables in case they turn out to need a lot of time dedicated towards them.

November 18th: Prototype 2

On this date, our group will be visiting David for the final time before our design day to present our final prototype. We must be finished if not very close to be finished our prototype at this time, as it is the last time David will be seeing it before design day and we need to ensure that he likes all aspects of it. David has been great about sharing his ideas and feedback whether good or bad on all the ideas we've proposed about the project.

November 28th: Design Day

On this date, all modifications and builds to our design must be finished and will be presented to our judges and clients. What we have done with our design by this day, is what we have to hand in as our final product, so we must be sure that we will finish by this time. Following our project plan and Gantt chart is crucial and will help us succeed by this date.

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1		3D Design	5 days	Mon 10/8/18	Fri 10/12/18		Stephen
2		Prototype 1	0 days	Sun 10/14/18	Sun 10/14/18	1	
3		Presentation preparation	2 days	Sat 10/13/18	Mon	1	Heidi,Carolina,Jack
4		Project Progress	0 days	Wed	Wed	3	
5		Business Model	3 days	Thu 10/18/18	Sat 10/20/18	3	Heidi,Carolina,Jack
6		Business Model	0 days	Sun 10/21/18	Sun 10/21/18	5	
7		Economics Report	0 days	Sun 10/28/18	Sun 10/28/18		
8		Order materials	6 days	Mon 10/15/18	Sun 10/21/18		Heidi
9		Client Meeting 3	0 days	Wed 10/31/18	Wed 10/31/18		
10		Build base	6 days	Mon 10/29/18	Sun 11/4/18	8	Carolina,Jackson
11		Build seat	6 days	Mon 10/29/18	Sun 11/4/18	8	Heidi,Stephen
12		Assemble/test seat & keel	1 day	Mon 11/5/18	Mon 11/5/18	10,11	Carolina,Jackson
13		Build front & back	6 days	Mon 11/5/18	Sun 11/11/18	8	Heidi,Stephen
14		Attach wheels to base	1 day	Tue 11/6/18	Tue 11/6/18	10	Carolina,Jackson
15		Test wheels	2 days	Wed 11/7/18	Thu 11/8/18	14	Carolina,Jackson
16		Prototype 2	0 days	Sun 11/18/18	Sun 11/18/18		
17		Attach front & back to	2 days	Mon	Tue 11/13/18	10,13	Jackson,Stephen
18		Cut hockey sticks	2 days	Fri 11/9/18	Sat 11/10/18		Carolina,Jackson
19		Assemble/test side	3 days	Wed	Fri 11/16/18	18,17	Carolina,Heidi
20		Test fold	1 day	Mon 11/19/18	Mon 11/19/18	19	Carolina,Jackson,H
21		Finishing touches	5 days	Tue 11/20/18	Sun 11/25/18	20	Carolina,Heidi,Jack
22		Presentation/Poster	0 days	Sun 11/25/18	Sun 11/25/18		
23		Design Day	0 days	Wed 11/28/18	Wed 11/28/18		
24		Intellectual Property	0 days	Sun 12/2/18	Sun 12/2/18		
25		Final Project Presentation	0 days	Mon 12/3/18	Mon 12/3/18		
26		Final Project Report	0 days	Mon 12/10/18	Mon 12/10/18		

Figure 4.1: Project plan part 1

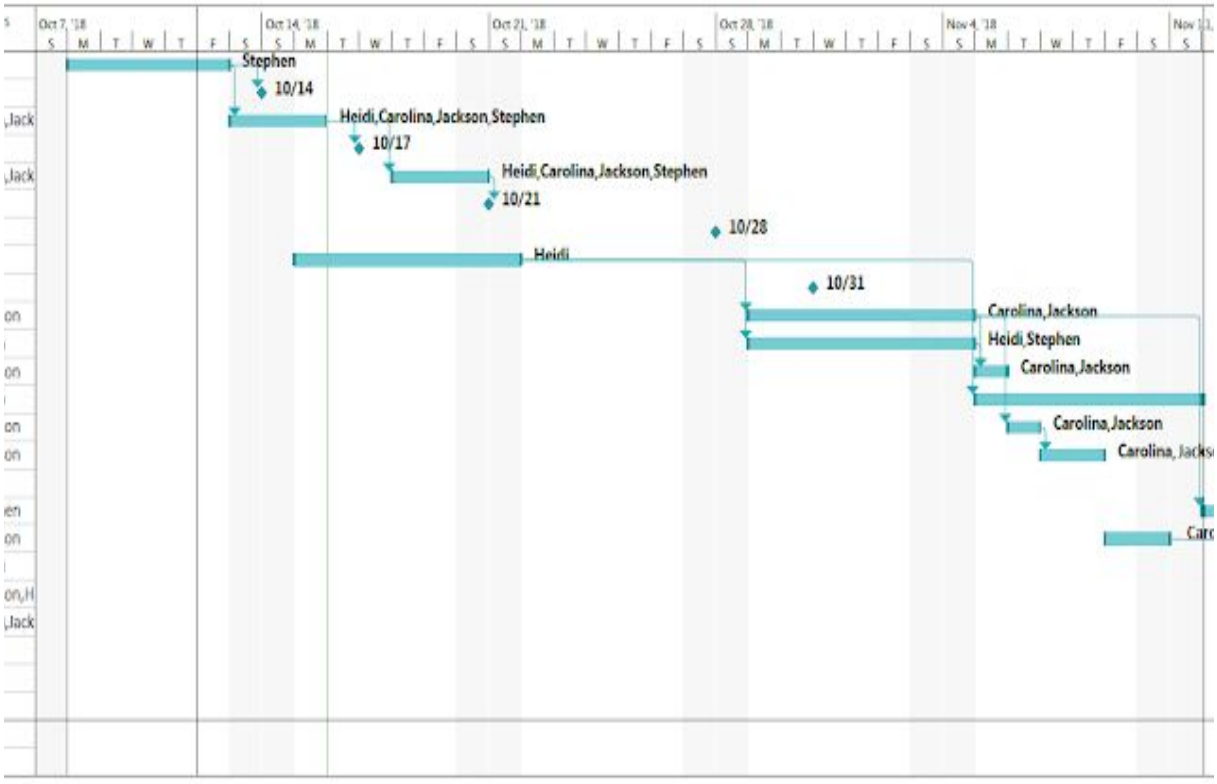


Figure 4.2: Project plan part 2

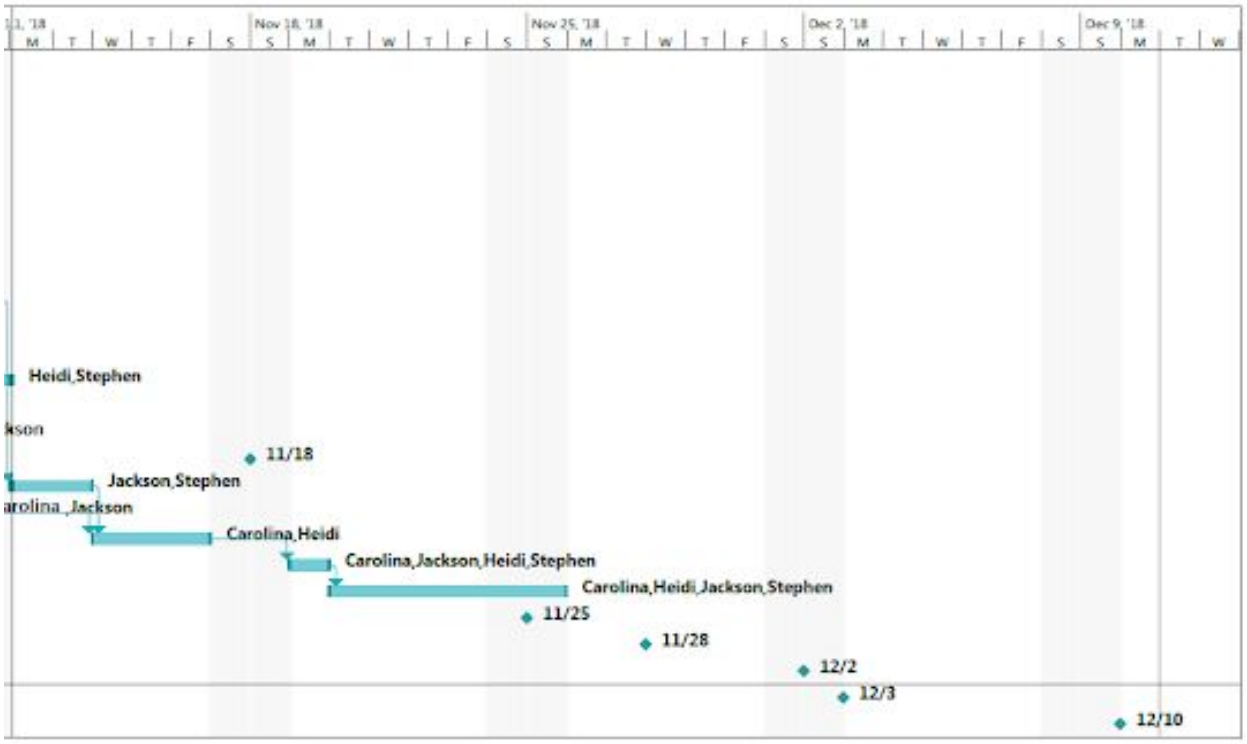


Figure 4.3: Project plan part 3

Table 4.1: Bill of Materials

Item Number	Part Name	Description	Quantity	Unit Cost ($)	Extended Cost ($)
1	Hinges	Everbilt 3-inch Satin Nickel 5/8rd Door Hinge (for seat to bench)	2	4.47	8.94
2	Hockey Sticks	Composite used hockey sticks	4	- (donated)	-
3	MFD panels	Hardboard	2		
4	Ice Wheels	1 ½ inch diameter acrylic rod	1	15.82	15.82
6	2” ABS Telescoping pole	Outer telescoping pole	1	7.98	7.98

7	1 ½” ABS telescoping pole	Inner telescoping pole	1	5.48	5.48
8	Caster wheels (For transportation on snow)	2in diameter caster wheels	2	3.87	7.74
9	Cup Holder	Made to fit any size hot chocolate cup	1	-	-
10	Support holder	Part is 3D printed one half at a time	24	-	-
11	First half side support	For holding ankle guard sticks	12	-	-
12	Second half side support	For holding ankle guard sticks	12	-	-
13	Clevis pin	½” diameter x 3” for telescoping poles	2	4.79	9.58
14	Hairpin cotter pin	To keep clevis pin in telescoping poles	1 (2 in one pack)	4.79	4.79
15	Transverse bar	For panels to rotate around during folding	4	-	-
16	Side support slot	Attached to ends of hockey sticks to fit into slots	8	-	-
17	Styrofoam	For support in between panels of MDF	1 (cut to two pieces)	-	-

18	Pipe insulators	1½" diameter. Border around MDF and styrofoam layer	9	0.79	7.11
19	Base	Wood for base	1	18.79	18.79
20	PVC coupling	Seat Support	2	0.62	1.24
21	Spray Paint	Colour plastic prints	1	8.47	8.47
Total				79.65	91.95

With taxes the total is 103.90.

For the Feasibility study, the five TELOS factors were discussed.

1. **Technical: Does your team have enough expertise and technical resources?**

Our team definitely has enough expertise. We all know how to use a drill press, mill, and lathe, and members in the group have experience in welding and the use of power tools. We also have the skills to make necessary calculations such as calculating the angle the hinge needs to be placed at in order for the part to fit on the product.

We have plenty of resources available to us. We have the Brunsfield Centre that has drill presses, mills, lathes, and power tools. So we are able to surface faces of small parts, drill and bore holes, face small parts, and screw parts together/make necessary cuts to the materials. We also have a spot in the maker lab where we can weld some of our parts together. There are many suppliers we can use to get materials such as Amazon, Carr, Spaenaur, and McMaster.

For anything that we're not familiar with, we have many people that can help us along the way. First of all, David helps us to understand the lives of children with disabilities which helps us with the planning of our project. At our second meet, we showed him many of our ideas, some of which he loved and some of which he helped us understand how they might not be the best solution for people with disabilities for various reasons. Our TA, Jay, has been very helpful in coming up with ideas and checking on if they're feasible. We don't have as much expertise with different kinds of materials but he helps us to understand what materials are available to us and what pros and cons they all have.

2. **Economic:**

The cost of the product can be reasonable. Our bill of materials is just over $100. Luckily, some materials were free as they were leftover from other projects. We were able to avoid additional shipping fees by buying locally.

Although we have a $100 budget, another reason to try to keep expenses low was for David's patent. He has spoken to us about the possibility of selling the product (or a later version) and he wants the aid to be affordable for any family who may have a child with disabilities. He doesn't want to deprive children in need of the product of the ability to skate just because of financial issues, so we tried to keep the cost to a minimum.

3. **Legal:**

While David was building his prototypes, he researched many patents for skating aids. He analysed their strengths and weaknesses if used by his son and built his prototypes from there. We have viewed the patents and one of our challenges while coming up with designs for the skating aid was not making our design too similar to any of those patents. We discussed the advantages and disadvantages of many aspects of the designs and tried to incorporate some of the general ideas into our own design. Overall, we had to be aware of the patents so that we didn't copy them and to learn from them, but they have not caused legal problems for us. David has a pending patent for his own design so we wanted to try to incorporate his previous prototypes to our design so that he could still use it for his patent.

4. **Operational:**

A main factor that could prevent our success is time. Three of our team members are taking six courses this semester and our last team member is also taking GNG1103 which has a big time commitment for a project as well. Trying to set aside time to work on this project (especially is we want to all get together) and to work on other courses is sometimes difficult to do. We have split tasks up to complete deliverables separately and on time but for decision making that needs to be done, we want the whole group together and present, which isn't always possible.

5. Scheduling:

Deliverable	Deadline
Prototype 1	October 14th
Project Progress Presentation	October 17th
Business Models	October 21st
Economics Report	October 28th
Client Meeting 3	October 31th
Prototype 2	November 18th
Presentation/Poster	November 25th
Design Day	November 29th
Intellectual Property Search	December 2nd
Final Project Presentation	December 3rd
Final Project Report	December 10th

The deadlines were provided by our professor and teacher assistant, and they were reasonable because they considered the duration of the course. They helped keep us on track in order to be able to complete the project and give a product of quality to David.

5.0 Analysis

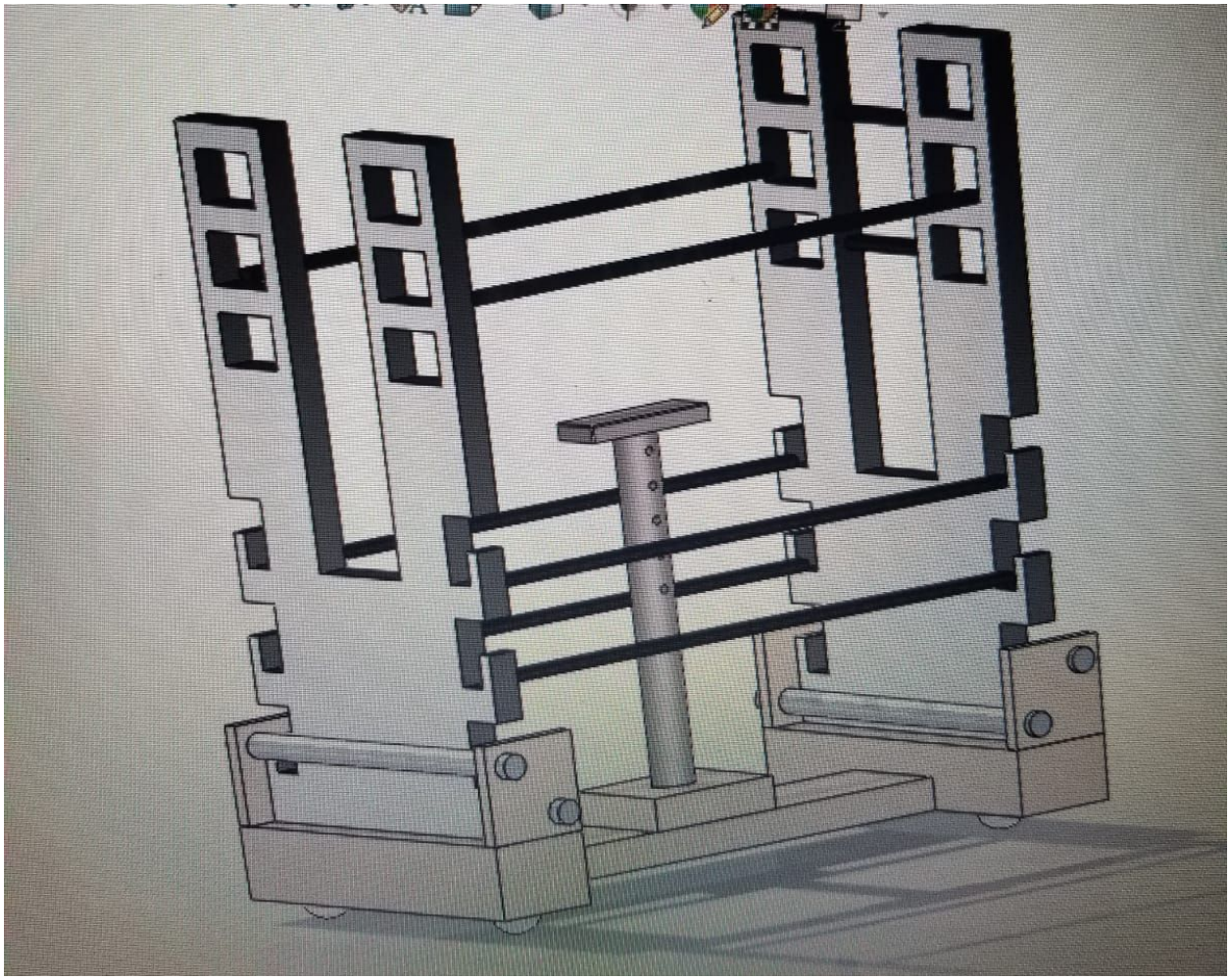
One of the requirements for our product was that it was able to fit in a small car. In order to insure we met this requirement, we took the measurements of a Saturn Ion as this car has a small trunk. We measured the dimensions to be 18 inches high by 41 inches wide and 35 inches deep. We took this into account and made sure that our product was smaller than these dimensions. Our final dimensions folded were 14 inches high, 26 inches wide and 34 inches deep. Our product is built for users between the ages of roughly 4-15, so we want our seat to be able to hold 180 lbs (81.6kg) when falling. To calculate this we will have to calculate the force of

the user falling on the seat. The acceleration due to gravity is 9.81m/s^2. So the force of someone that is 81.6kg falling on the seat can be calculated by multiplying the mass (kg) by the acceleration due to gravity (m/s^2). This gives us a force of 800.5N. This is the amount of force our seat needs to be able to take. This force is dispersed to the hinges, telescoping poles, and the metal supports underneath the bench. The hinges are not strong enough and cannot withstand much of a load which is why the steel supports were added. Steel has a yield strength of 370 MPa. The supports have a perpendicular area to the load of 4800mm^2 (120mm x 40mm) the maximum force that each steel support can withstand is calculated by multiplying the yield strength by the perpendicular area to the load. This gives you a value of 1776000N. This shows that the two bars are more than enough to support a load of 800.5N.

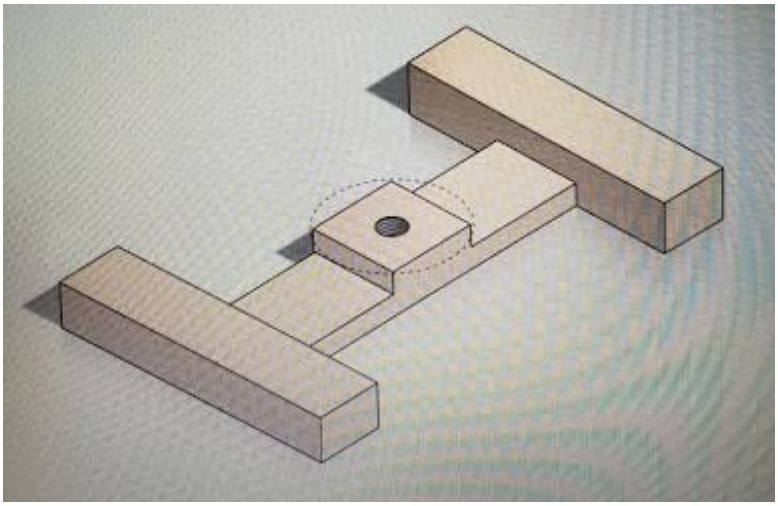
6.0 Prototyping and Testing

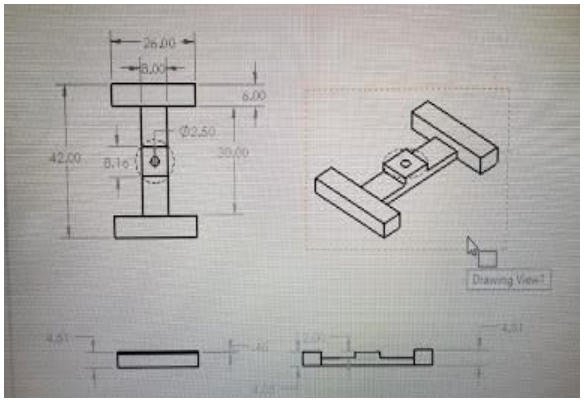
We decided that our first prototype would be a 3D CAD instead of a physical prototype. We decided this because as we learned in class from our professor, first prototypes are meant to be very cheap if not cost any money at all, through using very cheap and recycled materials. However we thought that since our design relies heavily on supporting weight and weight distribution, that it would be a waste of time to build something that wouldn't be able to demonstrate how it would support a user. Therefore instead we modelled a 3D CAD with specific coordinates and measurements, that would make building our final prototype much easier.

SolidWorks Prototype #1



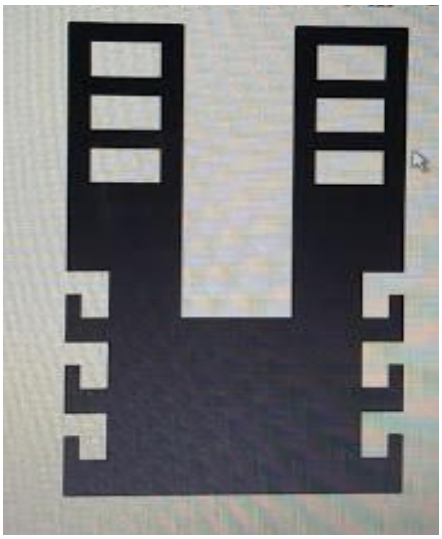
Base

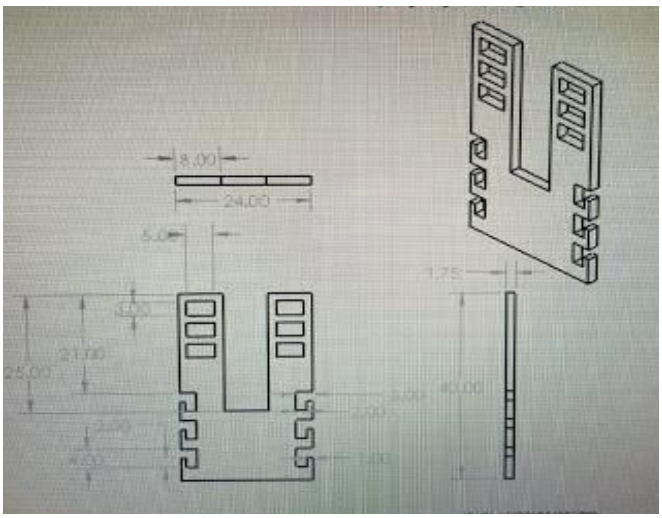




The product features include a base with a unique centre keel that prevents crossed ankles for some users with disabilities. The open base permits normal lateral skating stride, but can be closed to limit lateral stride if it's necessary using the side supports in the front/back supports panels.

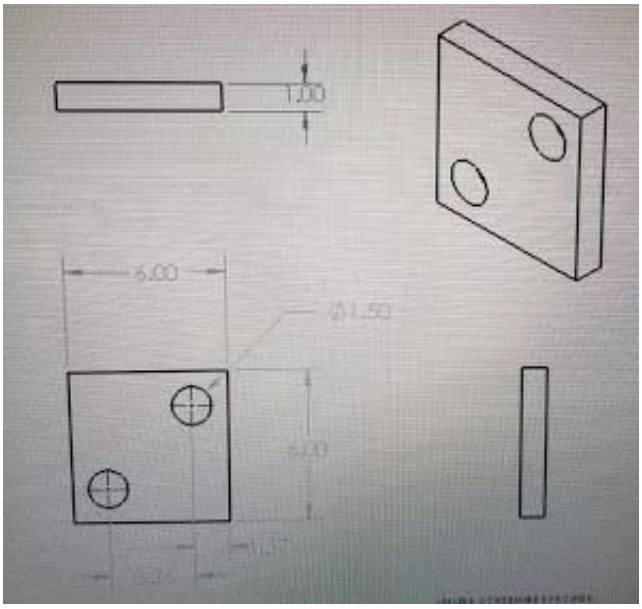
Front/Back Supports





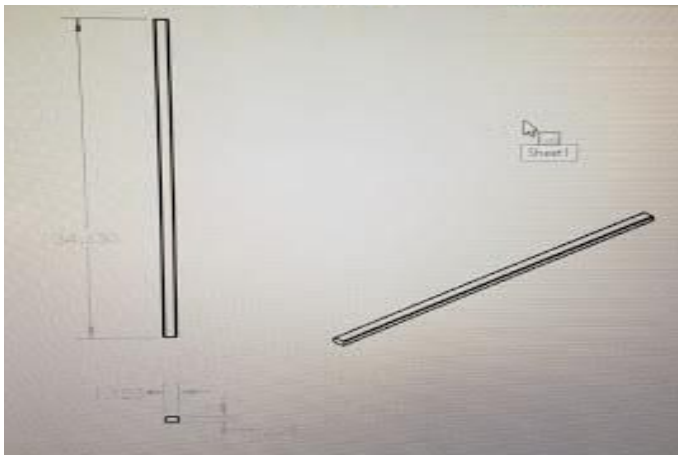
These panels with configurable side rails will permit adjust to multiple height and width settings. They surround the disabled skater protecting him from falls and collisions, and stabilize the user and attendant at the same time.

Panel Pole Supports



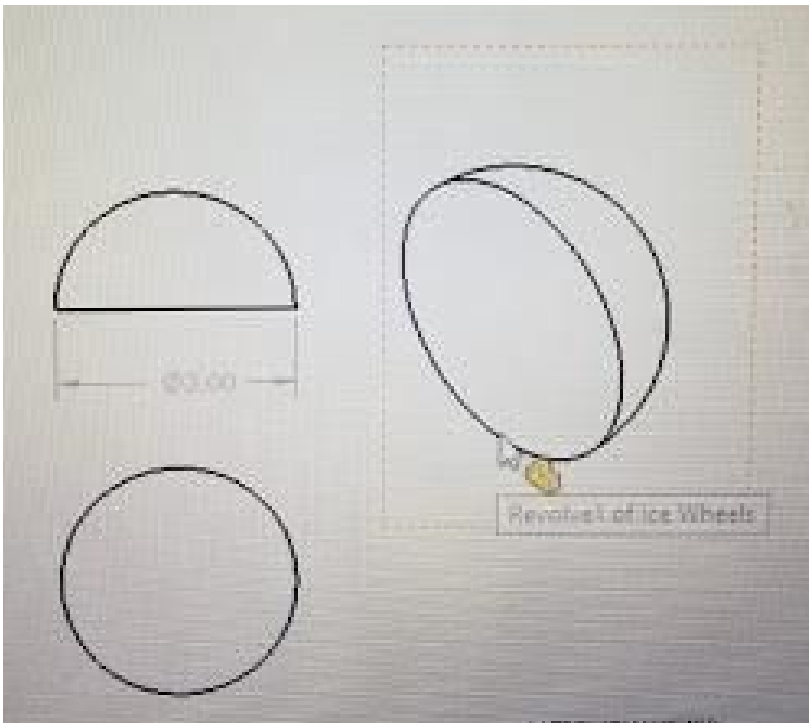
The panel pole supports are designed to support the front/back panels and allow them to rotate. Poles are inserted in it for this.

Side and Front Supports



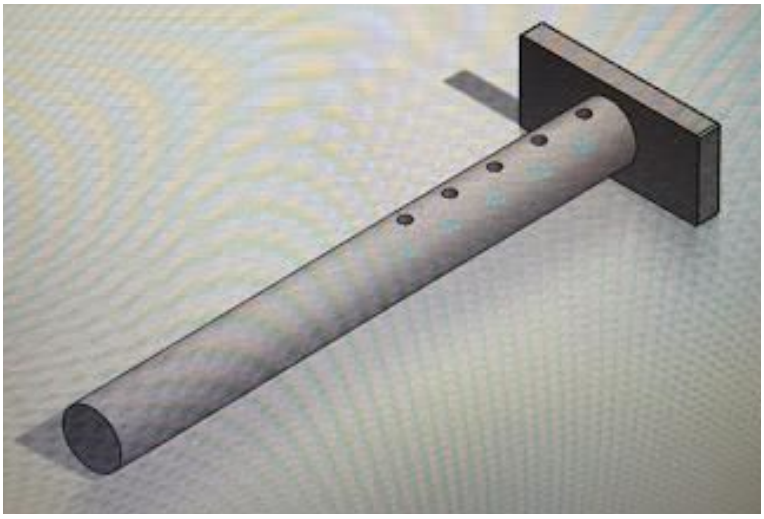
The configurable side rails let the user hand holds with the Side and Front Supports, that in our product will be hockey sticks. Hockey sticks are part of our cool factor and we tested that they are easier to grab than the poles in David's prototype, because these poles rotate too much and that decrease the support and stability of the user. They can be inserted in different side rails in order to adjust to the user height and width.

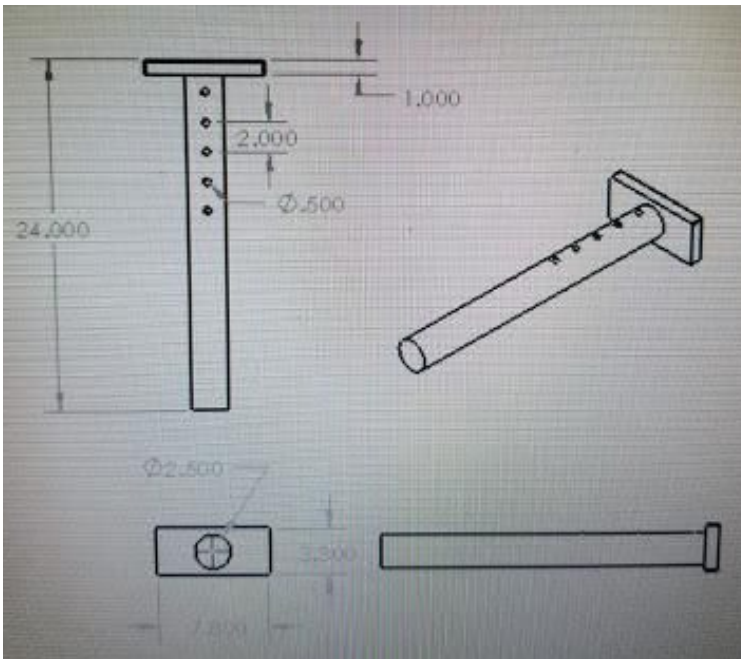
Ice Wheels



The wheels will be spherical to create a smooth movement for the product and allow to follow any direction, independently of the side of the ice cube.

Seat





Which functions are arrest falls, prevent injury to skater or attendant and convert into a bench to rest or change footwear. Also, takes physical load off attendant.

We had plenty of ideas to go off of already with David's two prototypes. David's ideas are useful and we incorporated them into our design but we also had our own ideas to improve the project. We presented our ideas and he gave us a lot of critical feedback that we will use to improve our design. From our Solidworks prototype, we plan to build and test our second prototype as we go. We have many tests set in place for our design and have alternate design plans set it place if our components don't meet our testing standards. We're looking forward to building our second prototype and eventually being able to watch Liam skate on the ice using it.

7.0 Final Prototyping and Testing

Our final prototype consisted of a base keel with lightweight panels attached and able to rotate along a pole for foldability. Protruding from that keel are detachable poles a seat attaches to in order to be able to catch the user if they fall. As the user gets tired, they can flip the seat into its bench mode and comfortably sit on the bench as the attendant continues to skate and push the aid. From panel to panel reaches hockey sticks as adjustable handles for the user to place into whichever slot is the most comfortable for them as they skate. In addition to handle hockey sticks, there are also ankle guard hockey sticks meant to restrict the motion of overextension of the user's legs. This is especially important for beginner users of the device who would have the ankle guard in the lowest placement providing the most restriction. As the user continues to skate and improve their mobility, they can move the ankle guards up to the next level continuously and eventually remove them altogether if they desire more freedom in their stride. In contact with the ice while using the device are four acrylic "ice wheels" that allow for movement in any direction while on the aid. The skating aid also includes a cup holder to carry any desired beverages of the user or attendant such as hot chocolate, tea, coffee or water.

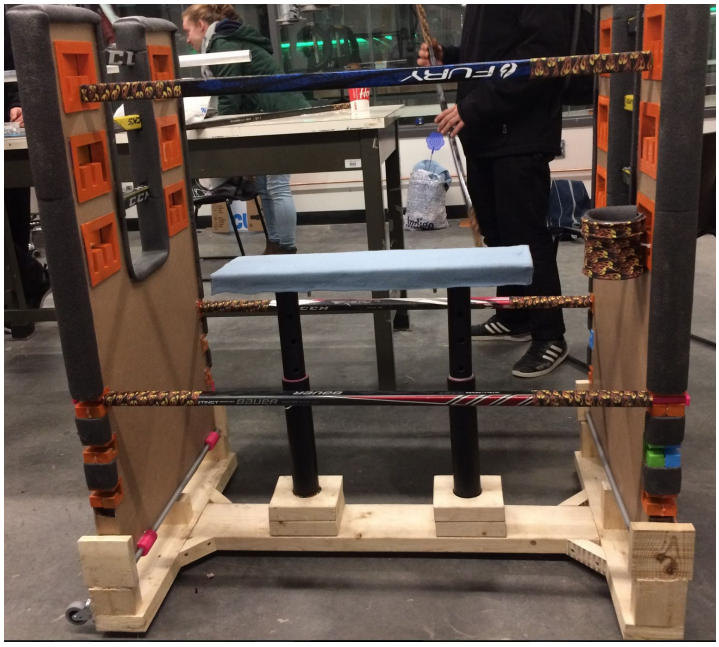


Figure 7.1: Ice Cube assembled with the seat converted to bench mode

Figure 7.2: Ice Cube assemble with user in position for skating

The final prototype was tested in many aspects to ensure that it has met our standards. We tested our seat as we went along, initially trying the hanging bench seat. This was chosen after scraping the skateboard seat idea due to its ability to change to a bench with comfort and for aesthetic reasons as a seat. We modified our initial design of the hanging bench seat to incorporate two poles as we made the seat longer. We tested the seat as we made it, testing the comfortability of the seat (which it passed) and its strength as a bench (which it scored much lower). Due to the positioning of the hinges, the additional bench piece had a tendency to lower when force was applied. Quickly we decided that this must be resolved and we changed the position of the hinges to the top of the seat instead to change to the stacked bench seat design. This worked much better because even as the bench piece wanted to lower with the force applied, the seat piece of wood was there to inhibit it.

We simulated the attendant falling onto the the aid in various directions and found the seat to be successful in keeping the attendant from falling. We tested the strength of the attachments of the

hockey sticks at different infills to see which was strong enough to help keep a falling user up. We found that the attachments with our lower infill to fail under the force of the user falling but our higher infill of 80% was was successful. From there, we printed the remainder of our hockey stick attachments with 80% infill.

When the product was assembled, we tested rolling it around in its folded state to see how easy it was to transport on land. It was rolled around inside and outside with a small layer of snow and we were able to roll it although the snow made it more difficult as it would sometimes build up on the side of the aid. We decided that the wheels would have to be moved to a lower position to allow for snow clearance during transportation outdoors.

Figure 7.3: Folded Ice Cube being transported indoors

Although having a device that you are able to disassemble allows it to be transportable, if it is too difficult or time-consuming to assemble, the latter outweighs the former. We found that consistently, one person was able to set up the aid in less than 60 seconds. Although the test

could be biased since the person being observed knew that they were being tested for speed, the results still indicate that the aid can be set up within a one minute time frame.

8.0 Business Model

The Bricks and Clicks business model would work well to commercialize our skating aid. Having a physical store where potential clients could actually see and feel the aid would help them to test out its strength and comfortability for themselves. Before purchasing, the user needs to feel confident about the product and a store with skating aids to test out would help them do so. In addition, there will be opportunities to test out the aid via skating development programs that we hope to partner with. Those who have seen the product used or tested it there can go online to our website and purchase their own. Having an online connection is important for us because although there are a lot of families with a person with disabilities, our demographic is small in comparison to the entire population. In order to reach every family, we would have to have a lot of stores throughout the country. Instead, we can have a few stores in more densely populated areas and have the online purchase as a backup so that your address doesn't prevent you from being able to purchase the product and learning to skate.

What

Value Propositions: We will be giving accessibility to people with disabilities that is both safe for the user and the attendant. We will provide users with a means to be integrated into equal participation with their peers.

Who

Customer segments: We are creating value for people with disabilities who want to learn to skate without fear of injury. We are also creating value for companies or organizations that could use our product such as hospitals and hockey teams for people with developmental disabilities (Capital City Condors).

Customer Relationship: We will build customer relationships by providing tutorials for people to learn to skate with their skating aid and opportunities to test out the aids. We will also form a community by sharing stories through social media.

Channels: We will be distributing our product to customers in multiple ways to assure that we target every customer possible who would be interested in our product. First we will have our product in local retail stores to target everyday shoppers, as well as an online store that will help adapt to the mass increase of online shoppers. Also to contribute to our social image that will eventually help us gain more sales, we will be donating units to multiple charities or ice rink facilities that will use our product and help advertise for us.

How

Key Partners: In order for our business to function, we will have to create relationships and partner with organizations that will help in manufacturing, supplying components and advertising our product. Advertising companies such as online and TV commercial companies will allow potential customers to see our product for the first time at a quick glance that will catch their eye and hopefully lead them to visiting a store and buying our product. We will also partner with clubs for people with disabilities and Non-Profit organizations who can use our product and spread the word. The University of Ottawa men's hockey team was kind enough to donate hockey sticks and in the future they would be a key partner to continue to supply sticks and for their involvement in advertising.

Key Activities: Our business needs to manufacture the product on a consistent basis while others are working on sales, customer service and delivery. We will also have tutorials for new customers and trial sessions going on in communities for potential customers to try the aid themselves.

Key Resources: Resources that will be key for our business to function, are material suppliers that are able to keep up with our constant demand for materials to produce our product. We would need a physical location to produce and sell our product as well as a great team of engineers, technicians, sales associates and marketers to ensure that our business is a success.

Online platforms will be able to advertise our product will need to be maintained daily and kept at a sufficient quality.

How Much

Cost Structure: With manufacturing and producing our product comes many expenses that will have to be taken into account when we set our pricing for the product. Independent of how many products we sell, we will still need to pay some fixed costs such as building rental, machinery, patent fees and delivery of the final product. We will also have to pay indirect costs such as insurance, utilities, website fees, internet, marketing and accounting expenses. Depending on how many products we sell, we will pay a variable cost for materials such as wood, styrofoam, aluminum and PLA plastic and on wages as well as packaging, all of which directly used for our product. In order to make profit, there will have to be considerable gaps between manufacturing costs, wholesale price, and customer pricing. In our case, we have spent $102 to build our final product (which would lower due to buying parts in bulk and increase due to spare parts that were of no cost to us).

Revenue Streams: Customers are currently paying up to $1000 for a viable skating aid. Our goal is to be able to sell the product for a price between $300 and $600. Ideally we would like to do direct sales but if needed, at the current price of $102, if we wholesale to companies at a price of $200 who will sell our product at $300-$600, this will allow us to make almost $100 profit on every unit sold.

9.0 Economic Analysis

When creating a new product, it's important to consider all of the associated costs as you're starting a business. We will cover all of the costs associated with turning Ice Cube into a business as well as a 3 year income statement with expenses and profit. We will also find our break-even point with the help of NPV analysis.

1.)

Cost Type	Cost

Variable	Wood materials 2x8x12 Millstead SPF - $16.25*100=$162.50 Metal materials 24x48x0.25 aluminum - $39.00*200=$7800.00 3D printing materials - $20/kg 24x96x1.5 styrofoam - $27*100=$2700 Wages - $14/hr Hydro - $0.94/kWh Water - $1.50/m^3
Fixed	Building Rental - $500/month Patent fees - $2000 Transportation of final product - $700/month
Direct	Machinery - $1500 (flat fee) Packaging - %9 of Variable Costs. = 0.09*10682 = $961.43
Indirect	Website fees - $5/month Internet for building - $50/month Marketing - $300/month

Figure 9.1: Variations of costs

2.)

Information for the balance sheets:

- Units sold in year 1: 100
- Units sold in year 2: 250
- Units sold in year 3: 500
- Selling price of one unit: $300
- Calculation of sales revenue: sales revenue = units sold x selling price of one unit

	Year 1	
Sales		$30000
Cost of Goods Sold		10682.5
Gross Profit on Sales		$19317.5
Operating Expenses		
Marketing Expenses	3600	
General & Admin Expenses	3121.43	
Total Operating Expense		$6721.43
Operating Income		12596.07

Interest Expense	180	
Earnings Before Tax		12416.07
Income Tax		3104.02
Net Income		9312.05

Year 2

Sales		$75000
Cost of Goods Sold		26706.25
Gross Profit on Sales		$48293.75
Operating Expenses:		
Marketing Expense	3600	
General & Admin Expenses	3063.56	
Depreciation	150	
Total Operating Expense		$6513.56
Operating Income		$41780.19
Interest Expense	120	
Earnings Before Tax		41660.19
Income Tax		10415.05
Net Income		31245.14

Year 3

Sales		$150000
Cost of Goods Sold		$53412.5
Gross Profit on Sales		$96587.5
Operating Expenses:		
Marketing Expense	3600	
General & Admin Expenses	4807.13	
Depreciation	135	
Total Operating Expense		$8272.13
Operating Income		88315.37
Interest Expense	60	
Earnings Before Tax		88255.37
Income Tax		22063.84
Net Income		66191.53

3.

Break Even Point: $\frac{\text{Fixed costs}}{\text{Sales price/unit - Variable cost/unit}}$

$\frac{16\ 400}{113.99 - 102.25}$

1397

We will break even at 1397 units sold

Discount Rate: 10%
Discount Factor: 1/(1+r)^n

Year	Cash Flow	Present Value
0	-33 000	-33 000
1	-3 000	-2 727
2	72 272	59 728
3	209 728	157 571

We will break even the second year of business.

4. Developing our economic report came with many assumptions.

We assumed that the value of the machinery depreciated by 10% each year. The value of machinery continually decreases so you can't have a fixed value because the machinery is always going to be worth something, so 10% is a reasonable amount to assume.

We assumed a constant income tax of 25%. Although income tax percent increases as the income of the business increases, we are unsure of at what values it will change so for our calculations we assumed a constant income tax of 25%.

We also assumed that the cost of production per unit would be $102.25 while in reality partnerships and continuous customers could allow for potential deals that would decrease the cost of materials.

The interest rate was assumed to be 2% compounded annually. When we borrow money from the bank they will charge interest based on the amount of money borrowed.

We are assuming that we borrowed $9000 from the bank and we pay back the interest plus $3000 each year. This is because none of us have full time jobs, and we need money to purchase machinery, materials, etc.

Monthly fees were also assumed to remain constant when in reality they could fluctuate and impact the costs associated with the business.

After laying out all of the costs associated with the production of Ice Cube and the business, we have realized the true cost of a business. We have discovered the importance of looking at indirect costs that aren't as obvious as the direct materials and machinery to physically make the product. We realized that taxes and interest can make a significant impact on a net income, and that there is more to a business than total sales. We found that our break even point is when 1397 units are sold during our second year of business. With the help of our video pitch, we would expect to have interest in our product and be able to grow a business with the costs and sales provided.

Ice Cube

User Guide

Version 1.0 • 10 December 2018

Ice Cube • 75 Laurier Avenue, University of Ottawa

TABLE OF CONTENTS

1. Introduction

Ice cube is designed to provide the joy of skating while preventing injury. This device will help increase the participation of kids with disabilities while ensuring safety and comfort.

All the time, users with disabilities and their attendants are discouraged to participate in sport/recreational activities because of the lack of appropriate assistive system and fear of injury, feeling excluded and isolated. We want to change that, helping kids with disabilities to be able to experience the joy of skating.

Skating may not be an essential life skill but there are many kids who have a passion to learn how to skate but never get the chance. For kids and people with disabilities, the fear of injury can often sideline them from trying something new. We want to ensure that anyone with the passion to skate is able to do so without fear of injury to themselves or those around them. In addition, people with disabilities often feel excluded from daily activities, such as skating during the wintertime, due to a lack of sufficient equipment. By creating a skating aid specifically for people with disabilities, they will get the equal chance to know the joy of skating.

2. Overview

Our product is design to arrest their fall before they hit the ice and prevent any kinds of injuries to both the user and the attendant. With a lightweight but strong design, it provides 360-degree protection, safety and comfort. Overall, it is an opportunity to improve physical and mental health for these kids and finally yet importantly, promote inclusion.

2.1 Cautions and Warnings

While Ice Cube is meant to act as a skating aid that provides support to users while skating, users must be aware of the risks that come along with using the device. Potential cuts, scrapes, wounds or further injury may occur while using the device. Any action you take upon the information provided in this guide is strictly at your own risk, and we will not be liable for any injury inflicted while using the device.

Anyone with any of the following health issues or concerns are advised to not use Ice Cube until properly treated from their condition:

- Pregnancy
- Neck, Back, or Bone Ailments
- Recent Surgery or Illness
- Heart Conditions
- High Blood Pressure
- Under the influence of Drugs or Alcohol



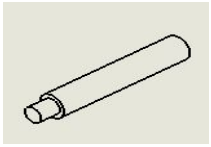
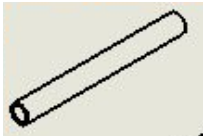
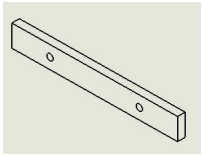
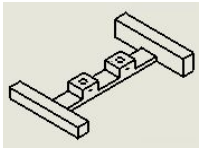


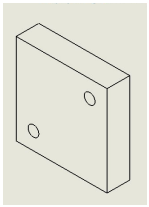
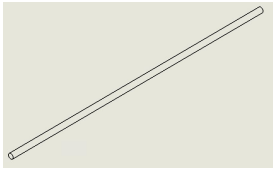
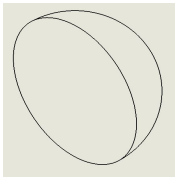
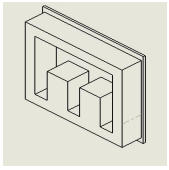
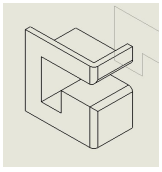
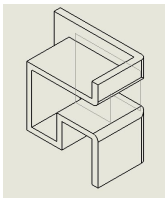
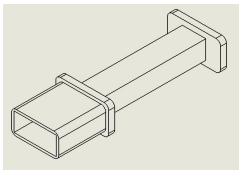
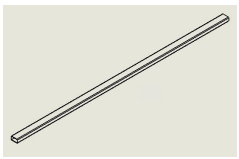
3. Getting Started

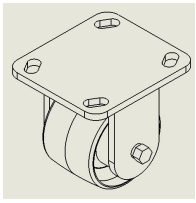
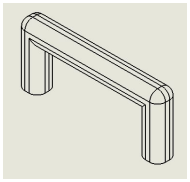
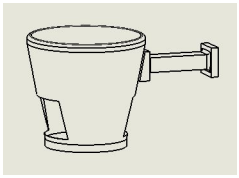
Our design is different from the rest because it provided 360 degree protection for the user that includes handles at the front and sides of the product in case the user loses his balance or falls forward, and a seat that will catch the user if they fall backwards. Other devices with protection are difficult to transport but our product is foldable so that it is easy to store and carry around. The product is light so that it can easily be carried on and off the ice. In order for the product to be useable for many different people, the seat adjusts with the use of telescoping poles to accommodate the heights of different users. There are also different slots for handles so that the user can adjust them to their comfort. In addition, the seat turns into a bench for the user to sit once they are tired and for when they would like to tie up their skates.

3.1 Product Features

A complete list of product accessories are included with every Ice Cube purchase.

Accessory	# of pieces	Picture
Inner Telescoping pole	2	
Outer Telescoping pole	2	
Seat	1	
Base	1	

Transverse Bar Holder	4	
Transverse Bar	4	
Ice Wheel	4	
Half 3D Printed Support Holder	24	
1st Half Side Support Slot	12	
2nd Half Side Support Slot	12	
Side Support Slot	8	
Side Support	4	

Caster Wheel	2	
Handle	1	
Cup Holder	1	

3.2 Set up Instructions

1.) Set the support down on the ground lying flat on the ice wheels.
2.) Unfold the first panel so that it is perpendicular to the base, and set down the friction tab holder.
3.) Unfold the second panel perpendicular to the base, insert a side support, and fold up the friction tab holder.
4.) Insert both outer telescoping poles into their slots in the base and secure them in place.
5.) Insert the inner telescoping poles into the outer poles to a desired height, and secure the height using the pin provided.
6.) Place the seat on top of the poles so that the holes in the seat are concentric with those of the inner poles, and secure the seat in place.
7.) Set other ankle guards and side supports to desired heights/widths and assure the support is stable.
8.) Ready to Skate!

3.3 User Accommodations

Ice Cube is specifically designed to accommodate for all heights, weights, shapes and sizes of users using the support. No matter how big or small, Ice Cube can fit them all!

First, each panel front and back, have a total of 18 different configurable options for that the side supports can be inserted to, giving you a tremendously large variety of adaptable options. Similarly, the ankle guard slots on each panel are set at three different height, to adopt for the developing stride of different users on the support. Also the two poles that support the seat are telescoping and therefore able to increase or decrease in height depending on the length of the users lengths.

Ice Cube understands that a large number of the support users have disabilities in their legs, that causes them to have a lack of endurance when skating for longer durations of time. Therefore instead of having the user sit out early on skating sessions with their friends in family, the seat easily converts into a bench for the user to sit on while an attendant navigates from behind, in only three simple steps.

1. Unfold the metal slabs that are located underneath the seat into a position perpendicular to the seat.
2. Tighten the nut and bolt securely onto the bottom of the seat.
3. Unfold the seat so that the second seat panel rests on top of the metal slabs.

3.4 Transportability Instructions

To transport the device,

1. Remove the seat from around the telescoping poles, and place it into the transportable tote bag. Assure that the seat is folded into its skinniest form when placed in the bag.
2. Remove both the pins from inside each telescoping pole system and insert the four poles along with the pins into the tote bag.
3. Remove all but one side support and place them into the tote bag.
4. While removing the fourth side support, flip the friction tab up onto the first panel and place the fourth side support into the tote bag.
5. Flip the friction tab back down from the panel and fold one panel on top of the other, each horizontal to the base of the support.
6. Grab the handle on the end of the base and angle the device so that the caster wheels come in contact with the ground, allowing the device to be transported on land.

4. Using the Device

4.1 Skating

After properly setting up the device with the seat in the skinny position and with only one side support assembled, step into the device with one leg on either side of the seat. This position allows the user to propel themselves forward by skating with a chosen option of stride allowance. After the user is comfortably set in their skating position, set the second side support into position to lock them into the device.

4.2 Sitting

After setting up the seat in the bench position, move the second side support underneath the first to add extra support behind the user sitting on the bench. From this position, the attendant can comfortably propel the user in any direction with ease.

4.3 Attendant

Whether the user is skating or sat down on the device, the attendant is to be behind the device guiding/steering the user in the correct direction. The attendant is responsible for the chosen path the user will take, and also must be aware of surroundings at all times.

5. Maintenance

5.1 Troubleshooting

If ever the device is not functioning properly, do not try and use the device in this defective state. The first step into repairing a broken support, is to locate the missing or damaged feature that is causing the fault. In the case where piece is missing, extra parts such as screws, clips, tabs, bolts, nuts and washers are including in your Ice Cube package. Make sure to store these spare parts in a safe location such as the Ice Cube tote bag.

5.2 Support

In the event where your Ice Cube support has broke and you are not able to identify the problem, contact the Ice Cube team at (xxx) xxx-xxxx. The team is able to travel right to your door to fix your device, and guarantee same day repairs upon request.

11.0 Design Files

Our group will continue to work on our present design to further satisfy our client's needs. We also welcome other groups who would be interested to help improve our design, and encourage them to use our current design as a building block to start with. The following files are copies of our 3D CAD prototype. Along with this we also will supply our class presentation slideshow that helps generalise the problem and our solution. (See Submission folder) Our Makerepo description and video can be found at https://makerepo.com/project_proposals/34 and https://makerepo.com/itscaroortiz/gng2101a8ice-cube

12.0 Conclusions and Recommendations

We have gained a lot of knowledge from completing this project. We learned about design methods that helped us excel and deliver our product on time for design day. We learned to use many tools thanks to the help of the workers in the Manufacturing Training Centre, Brunsfield and Richard L'Abbé Makerspace. We learned the importance of having one team leader to guide and organize tasks, and make all final decisions so that they are made on time to stay on track with our Gantt chart because building takes more time than you think it will. Working with our client David was phenomenal, and gave us unique real life experience that no classroom lecture can provide. Working with an actual client provided a different kind of motivation instead of simply wanting to do well to get a good mark. Our client was very knowledgeable and was able to help us understand kids with disabilities as well as what often works for them and what doesn't. We were always able to get expertise advice from our Project Manager, for example, what materials or machines we would have to use to make our visions a reality. Working on this project not only taught us new skills and knowledge we did not previously know, but also helped reinforce the theory we learn in our classroom.

Some recommendations that we have for other teams that choose to take on a product development project includes developing a realistic project plan and following through. With anticipation and organization, all the tasks can be complete in a short amount of time. Also ensure to make a group with different backgrounds because everybody will have something unique and different that will help in the design process and will make the experience richer. Finally, don't be afraid of changing your original conceptual design, sometimes taking risks is needed and it actually may work.

13.0 References

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