Marshall Playground – Team F4

Final Proposal

December 11, 2017

Abdalaziz Alazmi

Mohammad Alsewaji

Khaled Alenezi

Abdullatif Alenezy

Saad Aldawsari

2017-2018

Project Sponsor: W.L Gore & Associates

Client: Marshall Elementary School

Instructor: Dr. Sarah Oman

Disclaimer

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

Executive Summary

Purpose of this report is to build a design that should be safe, fun, and educated such that it is useful for disable children of ages between 5 to 8 years old. Furthermore, this device should be safe, and the team should consider safety as their number one priority. In addition to safety, it should be easy to use and to set up, as it was one of the clients' requirements for this project. Having education as a part of this project, was the team's and the clients' ideas for the design. Having education as a part of our clients' requirements will force us to mix fun and education together which sometimes might be hard. With all these requirements few designs have been generated that this report will provide in a way that our final design was selected. Pugh chart and decision matrix will be used to help us out in choosing our final design.

The final design that was selected is a portable, fun, safe, and educated cart for children with disabilities in the ages of 5 to 8 years old. This final design was selected and reviewed to both our clients and our staff to get a proof before manufacturing. More than one prototyped designs were provided to our clients and our staff so a selection is to be made. Our clients liked the idea of the cart that will have educated features inside of it, and at the same time fun and safe! This report will provide all the manufacturing procedures, testing procedures, proof of engineering and customer requirements, and some design changes that happened during the period of our first semester of capstone.

Figure 1: Final construction of the design

Table of Contents

1. Background

1.1 Introduction

This project relates to the children in which children will get a source to play around with fun apparatuses and tools. Children with disabilities face a lot of difficulties specifically to move around and try to enjoy at different times. Children with disabilities will have a chance to get a device that they'll have fun with, be safe, and get educated.

Our purpose is to support the children with disabilities and varying needs that require them to be in a classroom that accommodates those specific needs. The majority of students use walkers, gait trainers, and strollers to help them get from place to place in their daily routine. Students are working on academics that are modified to their specific learning needs, as well functional skills and life skills. Some students use a communication device to say their wants and needs, others use sign language, and some have verbal communication skills. So this project will build something that will help those children to have fun playing around and hanging out.

1.2 Project Description

Purpose of this project is to build such a toy that will help children with disabilities to play around with, and through the toy they will be able to spend time all around. This project calls for a fun apparatus for children to play on outside. Basic need is that such a toy or a device that has to be a learning module for them, and it must withstand various weather conditions as it's going to be used in an outdoor areas. It has to be portable, easy to set up and be safe for children to use with a little supervision. Furthermore, this project aims and mainly focus on children with disabilities, and as stated the team will build a device that will help our stakeholders in many ways. This project is designated for Marshall Elementary School located in Flagstaff. Our clients are teacher Eva Herberger and the physical therapist Krista Branch from who work in the classrooms of children with disabilities. This project is fully sponsored by W.L Gore & Associates.

2 Requirements

In this section we are going to discuss about the customer requirements, engineering requirements, testing procedures and house of quality (HoQ)

2.1 Customer Requirements (CRs)

Our design requirements were generated from the given project description in Bblearn. However, all the customer requirements were taken from the meeting with our clients as shown in table 1. We have listed the most important customer requirements that we received from the client so we start building our design. All the customer requirements have helped is a lot in achieving our goals.

Table 1: Design and CRs requirements

Customer Requirements
Portable
Fun Apparatus
Long life
Less cost
Safe
No sharp edges
Material needs to be rubber and soft
Consider different sizes
Sound motivations
Nontoxic material

2.2 Engineering Requirements

The engineering requirements have to be generated from whatever the client gave us in terms of the customer requirements. Therefore, table 2 shows a list of our engineering requirements after evaluating the customer requirements.

Table 2: Engineering Requirements

Engineering Requirements
Device shouldn't weigh more than 30 kg.
Round all sharp edges to 1.375 mm.
Children ages range between 4 to 7 years, accommodation needed for the size of the seat belt
Device needs to at least lasts for 2 years
Size of the crat body will be 1.7 m in length by 1.2 m in width by 0.95 m in height, (Approximately)
Motivation board has the size of 0.4 in length by 0.2 in width (Approximated)

The importance of engineering requirements is to help us focus on the goals and requirements that we generated from the customer requirements that were provided to us by our clients. It was very important that we generated those requirements to force ourselves in implementations and manufacturing plans in setting a goal and requirements so we don't go behind whatever we planned on doing.

2.3 Testing Procedures

Weight of the cart: The weight of the cart will be tested on the choice of materials that it will be made of. The team will test it by doing a research of different materials to see how much each would weight, and therefore, we'll choose the material with the lightest weight found. In that way, we will be able to satisfy this engineering requirements.

Sharp edges: We will test all sharp edges by using Solidworks because this program will help us in seeing how exactly rounding sharp edges would look like. Also, the assumed round off dimension is 1.375 mm for all sharp corners in the body of the cart, however, we'll need to test whether or not this assumed dimension will work or fail.

Age ranges: Age ranges of children will simply be tested by asking the teachers in the classroom, what is the age ranges of children in their classroom. Which was done at the first meeting with the client, and it was found that the ages will range between 4 to 7 years old.

Body of the cart: All what will be needed to test the body of the cart is to know what normally the size of the waists of our stakeholders are. Because testing the body of the cart is dependent on what size will we need to satisfy this engineering requirements.

Motivation board: The team will test this part by looking at how the children will get attracted and motivated. So we'll test many ideas found in industries that might be relative to our ideas and design. The client have also provided us with some information that will help the team in doing a research as a part of testing, such as, said by the physical therapist Krista, "Most children with disabilities get attracted by touching different textures".

2.4 House of Quality (HoQ)

House of quality is a chart which creates the link between engineering requirements, customer requirements and targeted values. House of Quality chart has obtained using the engineering requirements and customer requirements. These requirements have interacted with each other on the basis of client requirements. HOQ tells which engineering requirement is most important for the project and that requirement will be assign the highest weightage. Whereas the one which shows the lowest value of grade got lowest weightage. Table 3 shows the HoQ of our project.

Table 3: HoQ

House of Quality (HoQ)								
Customer Requirement	**Customer Weight**	Device shouldn't weigh more than 30 lbs	Rubber platform needs to be 6X6 ft	Round sharp edges to 1/8"	Sounds at 5 DB	Children ages range between 4 to 9 years	Device size 50X50 inches	9 inches tire radius
1- Portable	4	5	5					3
2- Soft Material	3			5				
3- Safety	5	3	9	9				5
4- No sharp Edges	4	3	9	9				
5- Sound Motivations	3				9			
7- Consider different sizes	3					5		
8- Device size	3	3					3	
9- Picture icons	3							
Total	33	56	74	96	27	15	9	37
Absolute Technical Importance (ATI)		56	74	96	27	15	9	37
Relative Technical Importance (RTI)		3	2	1	5	6	7	4

The percentage and the yellow filled columns and rows represent which are the customer and the weights requirements are important for this project in maximum, and which has the least importance. From the important parts, we can determine which engineering requirements we have to focus on more. For instance, from the HOQ we can see that the device shouldn't weight more than around 30 kg which is quite important for this project. So now we will focus more on these points while building the project.

3 Existing Designs

This chapter will provide how the research has to be done, how the existing designs can be found out, and how the helping of existing designs will provide the team with pictures and ideas of designs that will be related to children with disabilities.

3.1 Design Research

Design research is a process of searching out the related data as the project. As our project is to build such fun apparatus which will help disable children to play around with in the outside environment. For this purpose, we have searched on the internet, and tried to find out different sort of journals, articles, and different websites to see if there are any similar projects or devices close to our design requirements. Therefore, we have found out different designs available with the same requirement, and those are different ideas then the one we will going to implement in this project. From those design problems we have found some issues which will be relevant to our project as well, and those issues are:

1. Size of a project must be sized enough that children can play around easily
2. Portable with easy set up

These two issues are the problem that we will face while building our own project. And there are few opportunities we have identified after research which are:

1. Sound motivation can easily get by putting small speakers
2. Pictures can use for toy shaped icons

So with these opportunities, we will able to fulfill our engineering and customer requirements. From the research, the issues mentioned will now have us focus on our design and finalize it in a proper way. Furthermore, portability is one of our main goals as well, thus, we will keep focusing on our design to make such a design which will not have any portability issues.

3.2 System level

Here are few design ideas that we found which have been built before but these are not similar to the one we are building in this project but their requirements are closely the same as the ones given to us for this project.

3.2.1 Existing Design # 1: “Punch A Bunch” toy

This is a toy formed apparatus which is portable and will not affect by the weather conditions. Also it is long lasting as all of the material used in it is plastic. There are pictures of fruits of large size made on the board and their mouths have cut. So children can play by putting things in their mouths [1].

Figure 2: Board with holes [1]

3.2.2 Existing Design # 2: A baby's laptop

A laptop in small size with the keyboard where kids can play with sound and some alphabets which can be useful and fun for children with disabilities. This might be an idea to implement the our dashboard design or the featured dashboard design [1].

Figure 3: Baby's laptop [2]

3.2.3 Existing Design # 3: A small running Train

This is also a fun playing apparatus. It is a train which moves around with a battery backup and it doesn't need the track as well so with such design with no track this design and toys ideas are beautiful and attractive to children to children with disabilities [2].

Figure 4: Small running train [3]

3.3 Functional Decomposition

Functional decomposition is basically a way to describe the project in details. First of all, there will be a black box model which describe the top level of the system by just telling the inputs and outputs of the system. Then there is hypothesized model which is also known as hierarchy model in which the detailed functions of the inside elements of the product will be explained in details. Here is the black box model section. It is very significant that we do our black box and functional decomposed models because they help us in examining the design we'll consider. As the subsystem of our project contains a cart and displaying board.

3.3.1 Black Box Model

Black Box model is quite important for any project because it tells the input and output of the system. It doesn't depend on the working on inside model, it just tells what inputs will take by the system and what outputs generates by the system. Black Box model of this system is showing below as

Figure 5: Black Box Model

3.3.2 Functional Model

Functional model basically shows the steps used by the system from an input to an output. It also demonstrates what are the things happening inside the system to generate the outputs. All the processes though which the input goes, shown in the functional model are interlink between inputs and outputs in the model. Here is the functional model for our project.

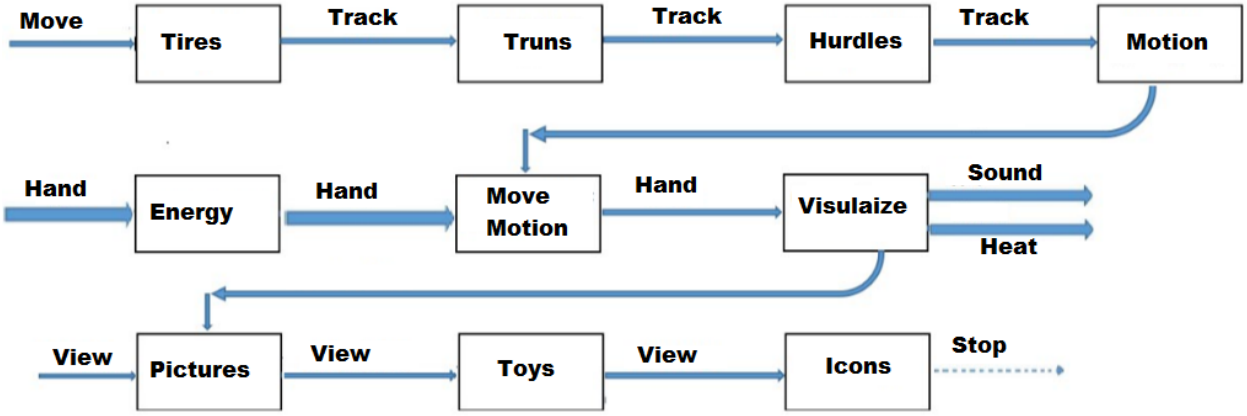


Figure 6: Functional Model

This functional model will help us in building the project as we now knows what are the processes we have to perform in the project in order to develop the project. So it gave us the basic knowledge about our project so we got to know about project in details for the processing.

3.4 Subsystem Level

In this section we are going to discuss our three sub systems for the project.

3.4.1 Subsystem # 1: Track

The product will move on some sort of track that could be either in a ground or any track like a train system track. So the cart will easily move over the track. This is really important for our project as it will provide a moving platform so it will be easy and a good fun device for the children.

3.4.1.1 Existing Design # 1: Tracking System

Tracking system is a track similar to the train on which trains moves only in the direction where the tracks heading. Train cannot move other than the track system that's why this design could be useful for our project. For children when they want to move the apparatus, it will move only in a specific direction and it will be easy for them. And this track can be placed at any location and move the cart.

3.4.1.2 Existing Design # 2: Ground level

This is an option of ground level, which means the simple ground with small grass or no grass can be used for the track to move the apparatus. This is a very common idea as everything with tires can move over the ground. In the same way we can use this system in our design and use the simple ground as a track so the children will not need to put any defined track and can move towards each side.

3.4.1.3 Existing Design # 3: Carpet road

This design is basically the roads we have available in our surrounding. This is a good track as well and useful for the plan ride and movement. This option is also useful for our design because we can move our apparatus over the carpeted surface.

3.4.2 Subsystem # 2: Tires

This subsystem will play an important role in our project for moving the apparatus all around. Tries is the only best way to move things around without carrying them. That's why it plays an important role children apparatus with which they are playing and can take it around without any problem.

3.4.2.1 Existing Design # 1: Plastic Tires

Plastic is good material to use and there are hundreds of tires available in plastic materials. These are smooth, don't have any hard edge, and long life as well. We can use this type of tires in our project and that's why this existing design is useful for our project.

Figure 7: Plastic Tires [3]

3.4.2.2 Existing Design # 2: Iron Tires

These tires are also available in different sort of materials. Irons tires is an existing design and we can use this design for our project because for any tracking method iron tires can work and move all around.

Figure 8: Iron tires [4]

3.4.2.3 Existing Design # 3: Rubber Tires

Rubber tires design is available and this type of tires are soft and have the capability to cover up some sort of jerks because of their elastic nature. This design is useful for our project especially if we use ground track or carpet road track.

Figure 9: Rubber Tires [5]

3.4.3 Subsystem # 3: Visualizing Board

This is another important part of our project, as visual boards will be used for the matters of having fun and enjoying such boards that could have different toys and textures that the children can be attracted to and get educated at the same time.

3.4.3.1 Existing Design # 1: Wooden Board

Wooden board is an existing design and useful for holding kneels in them and placing pictures, toys, icons etc. on the board. This is useful for our project because if we use wooden board, we can place any sort of items over it, and it they can be attached.

Figure 10: Wooden Board [6]

3.4.3.2 Existing Design # 2: Iron Board

Iron boards are not very common but it is an existing design. It is useful for our project in a way that we can put the icons over the board and put the displaying pictures, for instance.

Figure 11: Iron Board

3.4.3.3 Existing Design # 2: Plastic Board

Plastic boards is another existing design which is useful for displaying features over it. Writing techniques can be implemented in a plastic board. Thus, this is a good option to use.

Figure 12: Plastic Board

4 Designs Considered

As the purpose of this project is to build fun apparatus for children with disabilities, multiple designs have been considered for to fulfill the design requirements. This chapter will show the designs generated by the team.

4.1 Design # 1: Cart moving on rail track with display board

This is a cart design with 4 tires which moves over the rail track as shown in Figure 13. The cart has a dashboard attached to it that has different tools, textures and toys. This design though, would have advantages and disadvantages.

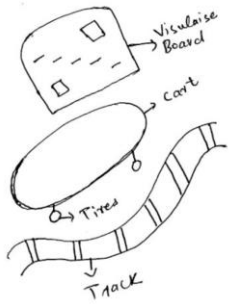


Figure 13: Rail track and cart system

Advantages	Disadvantages
• No sharp edges of cart and board • Sound Motivations • Picture Icons • Safe • No toxic Material • Portable • Easy to Set Up	• May be little longer in size • Track could be difficult to manage

4.2 Design # 2: Portable Wall

This is a portable wall with tires and a holding platform which most importantly is safe. The wall can be useful for displaying items like pictures, icons and toys and there are speakers attached to the wall which produce sound for enjoyment and attractions for the children. It is also portable as it can be folded back and easily stored after getting done using it.

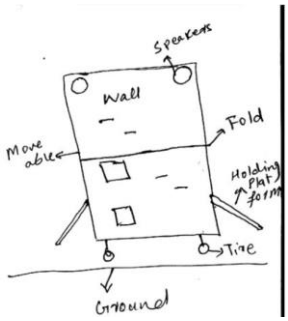


Figure 14: Portable Wall

Advantages	Disadvantages
• Safe • No sharp cuts • Sound • Moveable • Portable • Easy to set up	• Big in size • Difficult to stand up the big wall with tires and slit

4.3 Design # 3: Moving Stairs

This is a design of moving stairs. A stairs made up of wood with the tires under them. These stair can move around and two children can play with it. One children can sit over the stairs and second children will push the stairs. Other than this, it has a displaying part on which pictures and icons can use for display. Another option is that a child can put the ball over the top and it will flow down towards the end where the ball catcher will catch it. Following figure is showing the design.

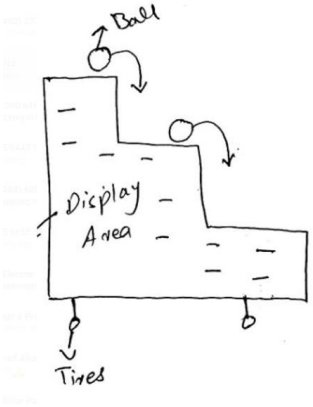


Figure 15: Moving Stairs

Advantages	Disadvantages
• Easy to use • Moveable • Portable	• Sharp edges • Difficult to control because of the weight

4.4 Design # 4: Motor car with play cards

This design consists of motor car which has play cards in it. Play cards will move up and down and keep changing their logo. And there is a color ball attached at the back side that has multi colors light in it. As the car move those lights starts blinking in different colors. This is a motor car so it operates on batteries and can move with any pushing by hands.

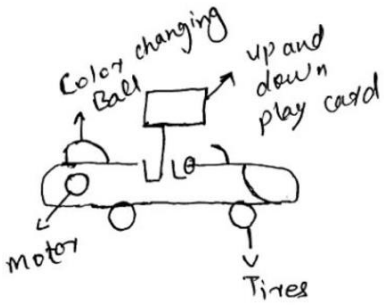


Figure 16: Motor Car

Advantages	Disadvantages
• Moveable • Safe • No toxic material	• Motor can cause trouble for running the car by children • Battery need to replace after some time of interval

4.5 Design # 5: Sliding Mobile

This is a sliding mobile design which is a mobile screen with a keypad over it. It has tires and a stand which the mobile will move and children will press the button and different pictures and themes will appear on the screen. It has a sound motivations that can attract the children.

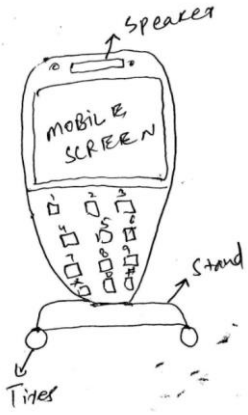


Figure 17: Sliding Mobile

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Mobile holder is a sensitive thing • Mobile can drop

4.6 Design # 6: Bubble Ball

This is like a gun machine in which a ball is inserted through from the top and then moves in different directions and come out of the gun from three different points, and the gun thereafter has the capability to get moved around with the help of tires so any children can move the gun.

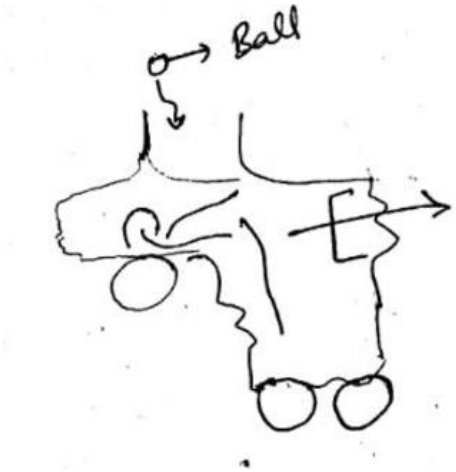


Figure 18: Bubble Ball

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Ball is sensitive to hit

4.7 Design # 7: Push wall with baby walker

Children can sit in the walker and then push the wall in a way that it feels like some door is moving out of the way as shown in Figure 19.

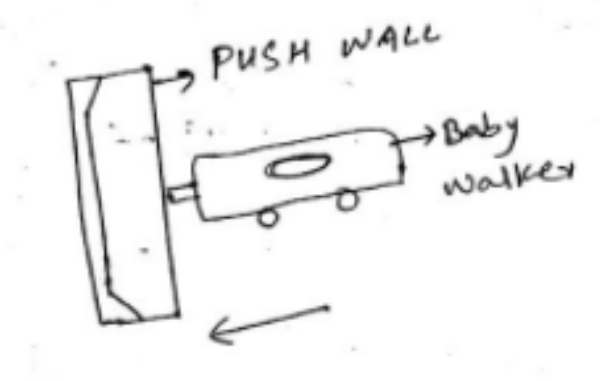


Figure 19: Push Wall with Baby Walker

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Not Safe

4.8 Design # 8: Baby Car

Children who cannot walk around have a good apparatus that they will drive which is a car that they can use with ability of going everywhere. This is an electric car which has all the controls.

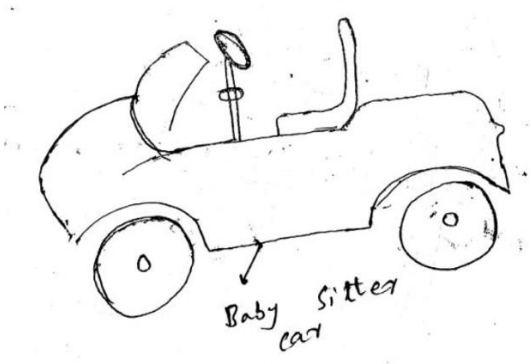


Figure 20: Baby Car

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Need to put baby in it • Control is difficult for child

4.9 Design # 9: Electro Mechanical Hand

This is a hand with electro mechanical movement in it and it can control the hand whereas it has a pencil at the end so children with disabilities can use it, and get help in writing. Being a fun apparatus the main thing is to handle the hand and write correctly as showing below.

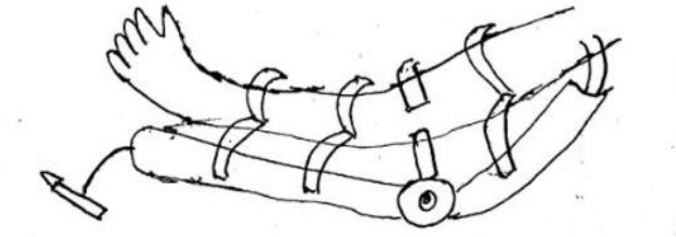


Figure 21: Electro Mechanical Hand

Advantages	Disadvantages
• Easy to use • Sound motivations • Portable	• Pencil control is difficult

4.10 Design # 10: Moving baby cart over the railroad

A specific track will carry the child sitting in the cart to some other place and it will be a fun travelling in the cart as showing below

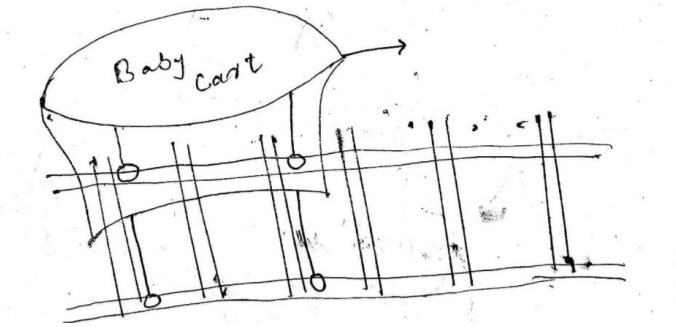


Figure 22: Moving Baby Cart

Advantages	Disadvantages
• Easy to use • Sound motivations	• Not safe

5 Design Selected

In this chapter, the team planned on developing the designs generated in the previous chapter. Furthermore, different techniques were used in this chapter to help us get to our final solution of the design, and select the implementation and the manufacturing plans.

5.1 Rationale for Design Selection

Purpose of this project is to build such an apparatus which provides fun and education to the children with disabilities. Therefore, few designs have presented for selecting the design. This selecting procedure will be finalized by using two different methods. One is the Pugh chart and the other is the decision matrix.

Table 4: Pugh chart

5 Designs for Fun Apparatus	Weightage	Moving Stairs	Moving Wall	Moving Cart	Motor Car	Sliding Mobile	Bubble Ball	Push Wall Baby Walker	Baby Car	Electro Mechanical Hand	Moving Baby Cart
Fun Apparatus	8	+	+	+	+	D	-	-	+	+	-
Play on outside	7	S	S	+	-	D	S	+	+	+	+
Withstand in weather conditions	6	-	+	+	+	D	-	S	+	-	-
Portable	5	+	+	+	+	D	S	-	-	-	S
Easy to set up	4	+	S	+	S	D	+	-	-	S	S
Safe	3	+	+	+	-	D	-	S	S	-	+
Easy to use	2	-	+	+	+	D	-	-	S	S	-
Pluses		4	6	7	4	D	1	2	3	2	2
Minus		3	0	1	3	D	5	4	3	4	3

Now we have two final designs from Pugh chart, thus, we can now move on to the decision matrix and finalize the single design.

Table 5: Decision matrix

	Weightage	Moving Cart	Moving Wall
Fun apparatus	8	5x8=40	4x8=32
Play on outside	7	6x7=42	5x7=35
Withstand in weather condition	6	2x6=12	3x6=18
Portable	5	7x5=35	1x5=5
Easy to set up	4	7x4=28	2x4=8
Safe	3	5x3=15	4x3=12
Ease to use	2	5x2=10	2x2=4
Economical	1	1x1=1	2x1=2
Total		183	87

From decision matrix, the result we have found is the moving cart design. As shown, it resulted with the maximum points plus points which were generated from the customer requirements. So on the basis of these results we are going forward to build the moving cart design.

5.2 Design Description

The moving cart is the design which has been finalized on the basis of selection methods results. In this cart we will build a cart and a track and a display board. The cart will move over the track and the display board will hold over the cart as well as different types of pictures and icons on display. A simple basic view of our project model is shown in Figure 23.

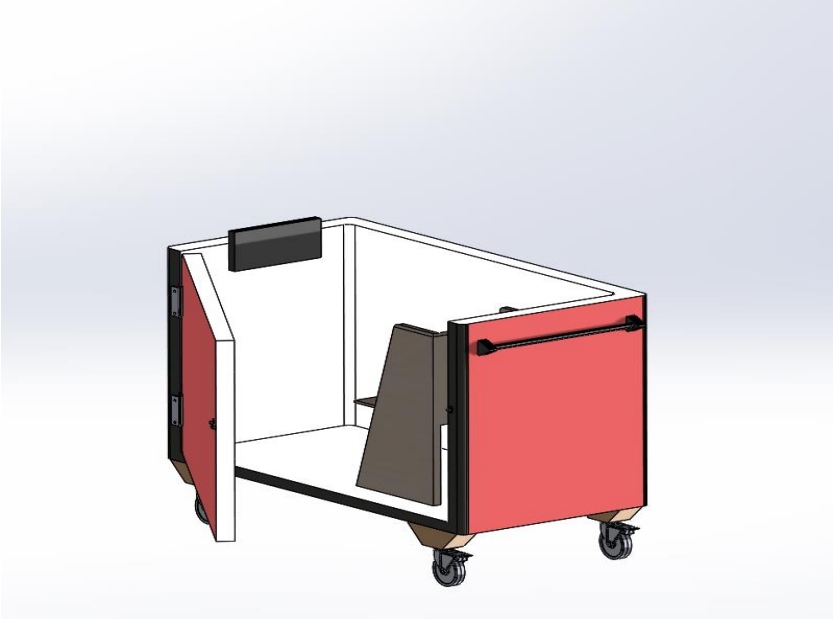


Figure 23: Finalized design model

5.2.1 Cart

The cart design is shown in appendix C, and basically the cart will have four tires and a handle that will be used by the teacher to move the cart by exerting mechanical power. The seating would be wide enough so that it will fit different waists of children whose age ranges between four to 7 years old.

5.2.2 Motivation board

The motivation board now is including with the cart. The board will be in front of the child seat. As the previous idea the board will have a few features such as, hands with different materials like, plastic, wood and iron. Second, the board will have a pictures for animals. The purpose from these features as team we required to have something educational, so we searched what is the best entertainments educational toys that could be placed on board.

5.2.3 Individual Analysis done by the team

The project is aimed at availing fun activities to children who have disabilities. Most of these children utilize walkers, strollers and gait trainers for their utility needs. So as to fit the needs of these children, the project is required to be portable, and be able to withstand harsh weather for improved durability. It also has to be safe enough for use by the children under minimal supervision. The analyses that was done by the team was mostly focused on the customer requirements. Below were the most important aspects that were analyzed, and they were:

Portability:

Where the team has been analyzing how the design will be portable as portability was one of the most important aspects of the design because the clients wanted to have the ability to move the device from a place to another. Therefore, we needed to analyze the movement for the apparatus is really important and also the rotational for the cart depend on the tires that we install so for example a triangle shape with three tires in the front, and the same on the back so we can control the movement of the cart easily so we will have total of six tires on the cart.

Weight trade off analysis:

We agreed that it would be very important to have one of the team members analyze the weight trade off. It will clarify, and show us how much each of the designs we came up with would weigh as a final weight. This will involve a lot of calculations, so the final weight of any device is determined.

Analyzing the aspect of heat transfer analysis:

In order to perform a technical analysis on heat transfer in moving wall, it is also significant to consider the heat and thermal energy that the wall will experience at the outer surface as that will be directly proportional to the increase in temperature of the wall. According to CSA Z412-00 (R2106) Guideline [14] on Office Ergonomics, a general recommendation of temperature for human comfort in summers in the US is approx. 23-26°C and in winters is 20-23.5°C at 50% humidity levels. Keeping in consideration these limits of temperature, the wall temperature

should also be limited to these ranges. However, looking at the climatic conditions in Flagstaff, AZ, it can be observed that the temperature is quite lower in both winters and summers so the design has to follow specific limitations such as color and wall material. The material greatly influences the temperature as well as the color of the wall. The associated equations will include heat transfers based on the three basic phenomena of heat transfer i.e. conduction, convection and radiation

6 PROPOSED DESIGN – First Semester

Our design has been finalized and the final design selected is the cart and track with a display board. As the design will have the car which will move on a specific track. There will be a display board which will stand over the cart and that display board will have multiple icons. Figure 25 shows the body of the cart.

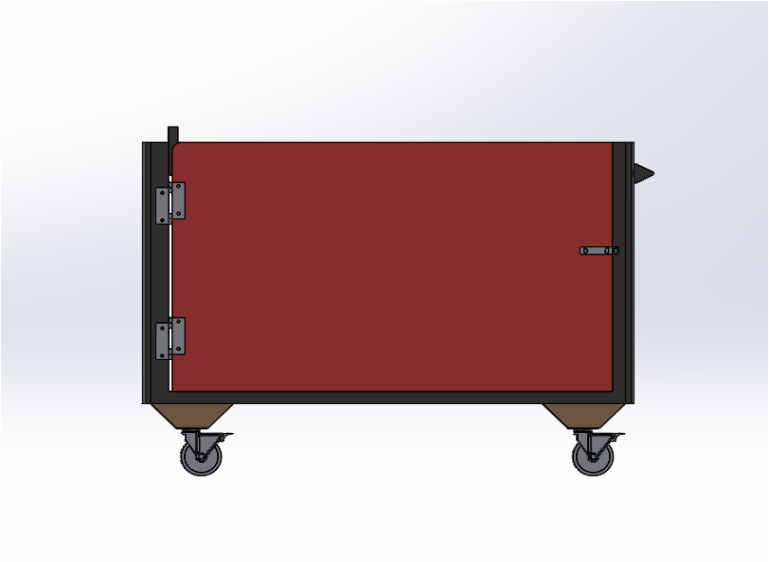


Figure 24: Side view of the cart

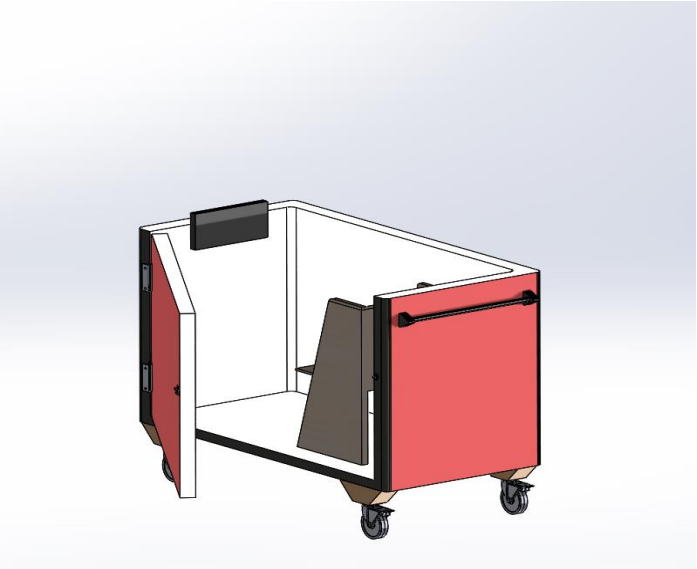


Figure 25: Iso view of the cart

6.1 Manufacturing Plans

At the beginning of the spring 2018 semester, we will start manufacturing process on our project, and we will work on the track and the cart which will be done at the machine shop (98C). Because our design is consisted from more than one part, and the manufacturing for those part need to be manufactured by our hands and many other useful tools that we looked at when the team has visited the machine shop area.

Implementation is a very big step to the team. As we know, first semester has no implementation of any parts of our design, as we have to start implementing it next semester. However, we have made our prototypes so it help us know how our design would be implemented, would the design be hard to create, what difficulties we might face, and will it meet the requirements of our clients or not. Those factors and thoughts have helped the team a lot in seeing what changes we need to make and how important these changes will be. After we have created our auto CAD and prototypes we have definitely faced issues and decided to go with some changes in the design.

Many parts in our design need to be manufactured. The design of the cart and track has many parts that we'll need to manufacture. The body of the cart will be manufactured and created by polyurethane and maybe a mix of some other materials with polyurethane. The track also needs to be manufactured. All individual analyses that were done by the team have helped us to ensure that engineering requirements have and will be met. The team have faced many iterations that we considered as a failing iterations of the design. A failed iteration of the design of the track occurred when we did our auto CAD where we went creating a track that shaped with a quadrilateral shape as shown in Figure 26.

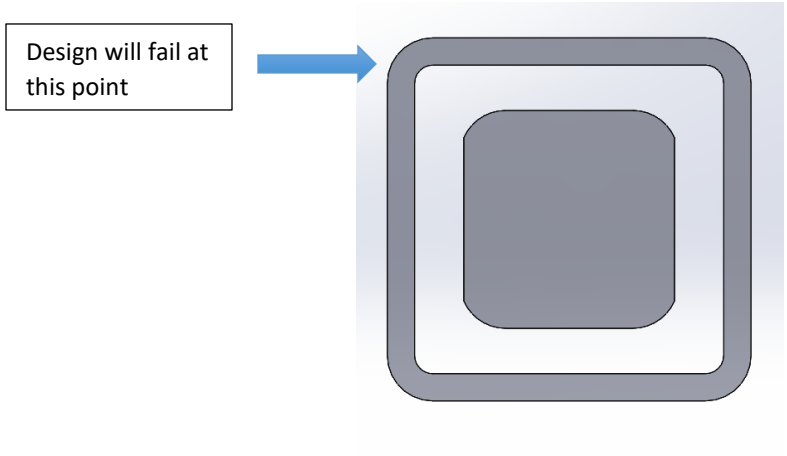


Figure 26: A failing design of the track (Old design)

An iteration of the design was needed at this point because it is impossible that the cart moves in a quadrilateral shaped track around the corner.

The team also had a continuous iterations for the choice of the tires. Meaning, we were not sure whether or not we'll use casters or rubber tires. This iteration was considered as a continuous

iteration because it's very dependent on the shape of the track. Since the team have decided to go with a straight track as shown in figure 26

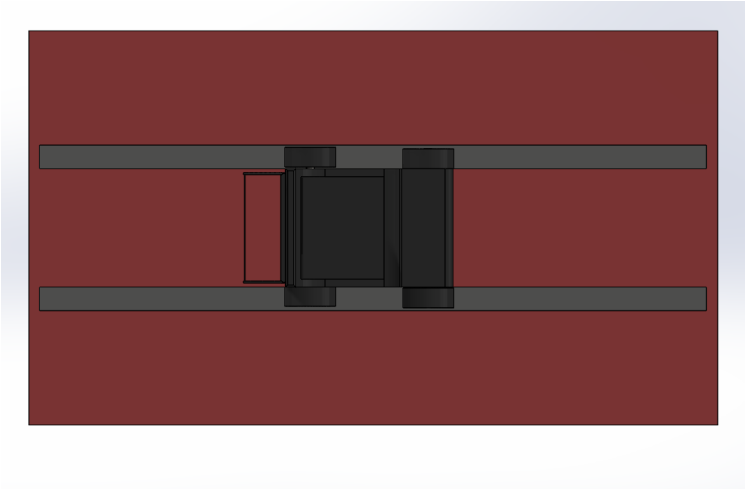


Figure 27: Final design of the track (Old design)

Thus, it won't be that important to actually be worried about the choice of the tires. Also, any sharp edges in the body of the cart will be manufactured by rounding edges by 3.175 mm and cushion rolls will be attached to edges. In Table 6 is a detailed explanation of how engineering requirements have met based on the manufacturing process of the design.

Table 6: How will manufacturing process meet our ER's

Engineering Requirements	Manufacturing Process
Body of the cart should be less than 13 kg	The manufacturing process will be met by the choice of the material that the cart will be made of.
The cost of the design must not exceed $2000	The current cost breakdown of the design is less by much than the provided budget as shown in our bill of materials in appendix A.
Round all sharp edges by 3.175 mm	Sharp edges will be manufactured by rounding all edges by 3.175 mm and cushion rolls will be attached.
Children ages ranges between 4 to 7 years	The seating of the cart will be manufactured by how much will the waists of those children is.

6.2 Some Design Changes

As this is only the first semester. The team have not yet started implementing the design. However, we have faced some problems when we assumed how the implementation process would go. Some of those problems are:

- The track is to be placed in an outside area permanently, and the problem of implementing this track is not in our clients' hands to ensure us an access so we go and implement whatever we want in regards of the track. Will the team change the design because of this implementation problem? The client contact of the team have met client Eva to discuss this issue, and she responses, "The people who are responsible of giving us an access to allow you to place the track outside are the people who work for the school which I will need some time to contact them regarding this issue, and therefore, we'll let you know whether or not you'll be able to implement your design. But I feel that 75 percent they will let you guys have access to do what you needed to do." Because the client have set a good percentage of saying that they will probably let us implement the design, the team will not change the design and the idea of having a track.

No other implementation problems that we faced unless the ones mentioned that we'll have in our design. The design of the track has changed due to its wrong shape not to how it will be implemented. Appendix B will show some CAD model of how the design of the track have been changed because of its wrong shape.

Updates on the design changes

The team decided to not go with the design of the cart & track because of many reasons involved within the agreements from the school and the limitations of the areas in the playground. The design of the track needs to be portable because the school will not allow us to place the track permanently outside as decided in our selection of the design. For that reason, the designing of the track will be a bit impossible to achieve just because of how much materials and budget will be spent. Therefore, we spoke with our clients regarding that, and they actually encouraged us with not doing the design of the track, and instead just build the cart itself.

7 IMPLEMENTATION – Second Semester

7.1 Manufacturing

Manufacturing was one of the important steps that the team considered and have had a lot of plans before we actually start manufacturing our project. As you were going through the above sections, you must have realized that our project is a combination of two sets. Which are the cart and track. We first have chosen a plan in our minds in terms of building the cart and track.

7.1.1 Cart Manufacturing

The cart's manufacturing plan was that we wanted to mold and cast our own intended shape of the cart. Why did we choose to go with casting? We felt that it is going to be better for us if we mold our own part because we could have instead bought a body cart in the market and simply make changes to it, however, it will not be easy for us to find a cart that is going to be similar to the shape that we intended to have as our exterior design of the cart. The team therefore moved on with the idea of casting and have actually bought the necessary tools and kit for the procedure of molding. The team then realized that we lacked a bit of experience with molding, and that we did not actually have a good area to mold, thus, we got a contract with one of the companies to only mold the exterior body of the cart. It was easy and not that expensive to take this step because we have actually made the plug first, and then we delivered the plug, the kit and tools that we bought along with the plug which actually turned out that the money we paid for the company was only for molding excluding everything else.

Pictures of the plug that we created with wood before it got delivered to the company.

Figure 28: Plug with a hole cut out

Figure 29: Side walls of wood

Figure 30:Plastic sheets coverage

Figures 31: Drywall applications

Figure 32: Rounded steel bars

Table 7: Descriptions of Figures 27 – 32

Figure #	Description
28	This is the top of the plug which has a hole cut out, so the child torso, head, and arms will be outside of the cart.
29	Those would be the side walls from wood to get the part ready for molding. Everything is lined with plastic, but it's hard to see. Basically, a plastic sheet is wrapped around every piece of wood.
30	That's an outside look of how the plastic sheets works on one side, and then secured on the other side. Noting that will prevent it from getting contacted with the fiberglass resin.
31	Round corner molds that are typically used in drywall applications, and we used it and taped it in the corners to have a molding part with no sharp edges.
32	This figure shows the three-way intersection. It will come out of the mold rough, and it will be sanded to a smooth round corner.

We waited 4 days for our molded part to be ready. Figure 33 shows the finished molded part that we picked up. Before delivering the plug, Team F4 have had everything ready and set so we go

right away and continue manufacturing the cart as soon as we pick it up. What we ended up having as problem is that when we had the molded body placed and secured in one of our teammates' garage as shown in Figure 33, wrinkles in the body occurred when the molded part was left for one day which had put us in a problem that we needed to fix. Figure 34 will show you how those wrinkles looked like. The fiberglass resin should have pushed those wrinkles down, but it happened because probably the resin was not enough or wasn't molded correctly. Therefore, we went again to buy more fiberglass resin to cast those wrinkles and make them look better. An iterative procedure for molding happened when we used fiberglass resin to cover those wrinkles. We molded and casted the part three more times to make sure those wouldn't occur again.

Figure 33: The molded exterior body of the cart.

Figure 34: Wrinkles of fiberglass resin

After we did molding again three times, the casted body was thereafter ready, so we continued on manufacturing. The next step after a very long process of molding was painting and attaching the caster wheels. We used one color for the paintings which was red. In the sake of having the cart look professional we used stain, as well as clear coats. The only body work or body filler that we needed to do before painting would be in all the corners, so they're blended. We then painted, stained, and clear coated the cart. The idea of staining and using clear coats turned out to have the cart be in a very good quality in terms of paintings as shown in figure 35. After painting was done, we have attached wood panels to the bottom outside body for the caster wheels which would add some structural stability. After we attached the wood panels, we then put the wheels, and tested whether or not they're were stable enough, and it was actually very stable and had a smooth movement. Figure 36 shows the wood panels with the caster wheels attached to the body of the cart. We are not 100% finished with manufacturing the cart, thus, this section will be updated as we move forward with manufacturing.

Figure 35: The cart after it got painted with attaching the clear coats


Figure 36: The wood panels and the caster wheels

7.1.2 Track Manufacturing

The manufacturing of the tack has been dependent on the authorization from the school at which our client is an employee at. Getting an authorization and an approval from the school so we place the track outside in the playground area have had the team be behind the schedule because we have not yet started manufacturing the track, and that was because we need to speak with whomever is responsible of that in the school. Our client suggested that we should come by the school with the design of the track that we have and find out who is exactly the person responsible of reviewing our design and telling us whether or not we could have an approval to move forward with manufacturing. All the materials needed to manufacture the track were purchased and ready which would ease out manufacturing to us until we receive the authorization. This section will be updated when we finish manufacturing the track.

7.2 Design Changes

Some changes occurred when we started manufacturing our project. One of those changes that we felt are worth of mentioning was when we first started doing the plug of the cart body, we used foam, so we create the plug as the intended design. The team encountered many problems while creating the plug out of foam. Cutting the foam was hard and we needed to be very careful because if we screw small things in the foam plug which can easily happens, we would end up with a funny shape. We tried cutting the foam with a foam cutter, but it did not work well at all. We wasted a lot of foam for the plug after the sixth try, and thereafter we decided to change the material of the plug to be wood. When we tried wood, it turned out to be very good and much easier than the foam.

Moreover, the possibility of changing the design of the track is high. The track design that we currently have might not be approved by the school which might put us in the risk of changing the design. Thus, the team have made another two designs for the track as a plan B if somehow the current one will not be approved.

8 TESTING

Our testing plan helped us to specifically know what are we looking for, and how will we meet all the design and customer requirements for our project. The team did not face any issue or problems during testing the requirements of the design which was great. On whether or not we changed some designs due to some failed testing procedures. We have not failed in any of the testing parts that we tested during the week of testing and during manufacturing.

Table 7: Important testing parts

Part Tested	Testing Procedure
Portability	Portability was proved tested by attaching wooden panels to the caster wheels.
Withstand various weather conditions	Heat transfer calculations were made to prove that fiberglass resin would withstand various weather conditions
No sharp edges	Round off sharp edges have been tested using Solidworks
Different sizes	This means the size of the seating belt needs to satisfy all children's waists sizes

Portability: Portability is one of the very significant customer and design requirements of the project. It was tested mostly by looking at how much will the cart weight? All what we need is that we need the cart to be portable so it can be taken back inside the classroom when children are done using it. That was actually done by forcing ourselves to not exceed a weight of ~ 35 kg so a human can lift it up. Thus, this was tested and approached by testing each material and how much can it affect the weight of our device, and it was found by the team that the polyurethane and fiberglass is a very good choice for the body of the cart. We have also added wood panels attached to the bottom body of the cart and then placed the caster wheels to these wooden panels, and we tested the movement of the cart, and it turned out to be very easy and smooth. Figure 39 and 40 will illustrate how the part of the wheels were put together, and then tested.

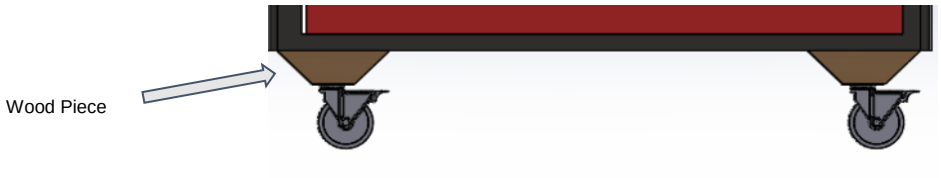


Figure 39: CAD model of the caster wheels

Figure 40: Real part for the caster wheels

Withstand various weather conditions: The team chose a heat transfer analytical analysis to analyze different materials. This is how this design requirement got tested. Many calculations and researches have been done by the team to see how we can satisfy this design requirements. Calculations done regarding the heat transfer analysis is shown in appendix D. We took the properties of the fiberglass and calculated them with relating the temperature of at Flagstaff. Thus, this proved to us that fiberglass can handle different weather conditions without getting damaged.

No sharp edges: First procedure and iteration that was done for this engineering requirement was testing this part using Solidworks. We have created the body of the cart with the dimensions we chose, thereafter, we tested more than one fillet on all sharp edges of the cart's body to see what dimensions should round our edges in real life. We then figured out the dimensions which were close to 1.375 mm, and placed steel rounded bars in the plug as shown in figure 41 which produced a really nice rounded edges all around the body of the cart.

Figure 41: Steel rounded bars

Different sizes: As the children's ages range between 4 to 7 years old in the classroom. This means the size of the seating needs to satisfy all children's waists sizes. That's why the team have made the size of the cart's body and the seating place wide enough, so it fits all children waists. The seat belt was attached to the corners of the seat from both sides, and we used the seating belt as shown in figure 42 which can handle different children waists.

Figure 10: Final construction of the seat

Long-life: Since it was required from the client that the device should stand for at least two years. We have tested the material of the track since it's going to be placed in an outdoor areas, and we found that the track should be made of steel so it doesn't get ruined when time passes.

Choices of materials: Our design is a set of more than one part. Which means that not all parts will have the same material. So this design requirement have been tested by the team by looking at first what part of the design are we trying to choose a material for? How big this part is? And will this part be left outside permanently or not? In this way, we have been able to satisfy the requirement and chose the best material that this part needs to be made of.

9 CONCLUSIONS

Creating designs that are useful on a larger scale can prove rewarding for those working in their design and implementation. However, sometimes the issue is that they are created on a larger scale and miss the mark on helping those who are generally overlooked. Our design aimed to provide a fun, interactive apparatus that could be used by disabled children around the age of 5. As this was our first attempt at such a large-scale project, we undertook some tasks that we were not successful in but those failures would help us to grow and better understand our project. We had many successes and this report contains detailed information of them as well as our failures, from which we learned. There were many requirements but as a group we were able to traverse them and create a product that would show our students how much we appreciated them. The successes are divided into categories outlining main categories that discuss the tools, training, management, communication, group dynamics, technical elements, and an 'other' information category.

9.1 Contributors to Project Success

Technical Elements

The technical elements included work in AutoCAD and design procedures such as black box modeling and HoQ reasoning, among other things. We had varied success in these areas. Our group leaders in these areas were proficient in them prior to beginning this project but others were not. We were successful in the sense that we fostered an environment of learning that helped grow those who were not as versed in technical design. We had problems initially with creating wheels that matched what were needed for the track. Where AutoCAD is concerned, the dimensions could be correct, but assessing forces and the reliability and safety of different features was not easy. Understanding how different materials work together, such as deciding whether metal wheels would be more efficient than plastic or rubber, was difficult and required calculations we were not prepared for. However, through research we were able to find solutions for our questions and create a better design as a group.

Group Dynamics

As engineering students, we are commonly placed into groups. Sometimes those groupings are successful, other times they are not. In our case, we worked very well together. Having a small group and having the same background helped us create a positive environment. It can be frustrating when someone listens to our broken English and has to find meaning in things that, for them, are incoherent. Having all experienced the same issues helped us become more patient and understanding. When one of our group members had a hard time putting into English a concept, we were able to walk him through it, having gone through the same struggle for years now. Discussing among each other who was best endowed in an area and assigning them leadership there helped us distribute the power among us while maintaining our training plan and the integrity of the group. Abdalaziz was efficient when it came to organizing and assembling the group and the work. He was given a leadership role that best suited his strengths there. Saad and Abdullatif were creative and helped in developing new ideas and solutions for existing problems. Mohammad and Khaled were prolific in design so helped in drawing up parts. All managed areas they were most proficient in while training and helping the rest to grow in those areas with them, creating a positive, beneficial group dynamic.

Management

Management was among our greatest areas of success. Our team was composed of five people with similar backgrounds. This enabled us to communicate in our English as well as our native language, allowing us greater depth of understanding than we are sometimes afforded as English is not our first language. An example is the naming of tools and research into design ideas. We did not know what the tools were named and struggled often to find what we were looking for online. Using a translator and the help of a more English-versed teammate we were able to communicate what the tools and parts were named in order to create a better design. Design ideas were also difficult and research into a segment that is fairly specific, such as playgrounds and equipment for children with disabilities, meant we had to search in a more specific way. We delegated someone to help with translation and retain a dictionary for our group that had some translations from English into Arabic and vice versa. Delegating someone to help with translating and others to help in searching meant we were able to manage our research and understanding in a more efficient way.

Communication

As mentioned in the conclusion, communication was among our strongest traits as a group. Because we are all from the same area and speak the same language, we were able to communicate more effectively here in a group than in almost any other class or group. We were fortunate to have a team that responded constantly in a timely manner and was keen to work together. We had some miscommunications when looking into dimensions of the materials. Where someone understand something to be in meters and on a grander scale, the first person relaying that information meant it in feet to be on a more economical, reasonable scale for production. Through some areas of training that we had developed initially, we were able to move past these small discrepancies and still create a successful product.

Training

Our training was successful in some areas and had areas of improvement in others. Initial design conception went well. We worked together to discuss feasibility and to create models to assess the viability of the different project ideas. Our training plan initially worked as we were not working on one concept but had less detailed work on more concept ideas. As those began to narrow down and become more detailed, we found we became stuck in some areas. We were successful up until we became more focused on our final project design. There were some areas in our initial training plan that we did not address in order to complete our project. This is not an indication of failure but rather it meant we altered our plans to better fit the course we found ourselves on later in the project. Although our initial training plan was simple, we were able to train in more areas better than expected. Where some of us expected to devote more time to physical design rather than computer-based designs, we found we could cross-train and better understand more areas together in doing so.

Tools

In working on a project this large, we inevitably used a variety of tools. As we began the project, we were not certain of which design we would use so created several different design ideas. There are physical tools involved in this project. They include things like cardboard, wood, tape, glue (Elmer’s school glue, Gorilla glue, etc.), scissors, box cutters, knives, wheels, measuring tools (rulers, tape measure, cloth measure, radial measuring tools, etc.), foam pads, and nails, among others. These tools were used in

creating the physical manifestation of our design. Other tools we used include some we learned throughout our tenure as engineering students including AutoCAD and black box models.

Using AutoCAD, we were able to create complex diagrams and models of pieces we wanted to use in our final design. Creating models enabled us to assess the feasibility of the overall design and separate pieces without having to physically create them. We create CAD models of the cart, the base, shafts, the rubber pieces, the tires, tracks, and rings. After creating the pieces separately, we combined them into a final design that encompassed all of the successful individual pieces. We were successful in this aspect of our report as, although we encountered some difficulty, were able to create a successful model based on the dimensions and pieces generated in AutoCAD.

9.2 Opportunities/areas for improvement

In retrospect, we could have allocated our time more successfully and assigned some parts in a more efficient manner. It is easy to look back and say "things would have been better if…" but our overall project was successful and provided us a wholesome idea of what an engineering project entails. Where we spent a significant portion of time on the project idea development, we should have been more focused on creating less detailed variations and more focused on working on the project we moved on with instead. Also, when working on the initial project conception after choosing a design, we spent more time on the design than was necessary. We would later make significant changes to the design as well as the materials used. Researching the efficacy of the materials, identifying safety parameters, and deciding on materials that were cost efficient, were areas that we would have been better off dedicating more time for.

Although there were allocations of time that were not as efficient as we would have liked, overall we worked well together to create a fun apparatus for students that may appreciate our efforts more than the product itself. Our work on this began as a project but became something larger as we had more interactions with the students that would be using them as well at the teachers and administrators that are dedicated to them. This was our first opportunity to create something that allowed us to use every component of mechanical engineering we had gained through the years on a large-scale design. On the whole, we felt it was successful and produced a fun and exciting toy.

10 References

[1] P. Family, “Great Toys for Children” available [online], http://www.parenting.com/gallery/10-toys-great-for-kids-with-special-needs

[2] PBS parents, ‘Learning Disabilities’ available [online],

http://www.pbs.org/parents/education/learning-disabilities/types/mathematics/math-strategies/

[3] S. Toys, “Bump N Go Bubble Train”, available [online], h ttp://www.specialneedstoys.com/uk/bump-n-go-bubble-train.html

[4] C. Board, “Commercial Plastic Brown Board”, available [online], https://www.cuttingboard.com/commercial-brown-plastic-cutting-board-24-x-18x-0-5/

[5] A. Express, “Natural Rubber tires”, available [online], https://www.aliexpress.com/promotion/promotion_toy-tyre-promotion.html

[6] C. Toy, “Iron Toys”, available [online], https://classic-tin-toy-co.myshopify.com/collections/toy-replacement-tires-and-wheels-1?page=3

[7] A. Express, “Anna Zahng Train”, available [online], https://www.aliexpress.com/store/product/Best-Christmas-holiday-gift-Coal-carriage-Excavating-machinery-Transport-electr-running-train-suit-with-rail-way/1382871_32540445977.html

APPENDECIES

APPENDIX A: Bill of materials

	A	B	C	D	E	F	G
1	Bill of Materials						
2	Item No.	Title	Desc.	Qty.	Seller	Price per unit (pre-ta	Unit of Price
3	1	Nordstrand Fiberglass Chopped Strand Mat Cloth 50" x 360" 1.5 oz	E-Glass Fiber Roll CSM GRP for Molding Roofing Boat Marine Repair - Resin & Epoxy Compatible	1	Smart Parts US	55.99	USD $
4	2	2x3-96" Stud	1.5in x2.5in-96in Select Stud	2	Home Depot	2.25	USD $
5	3	92-5/8 Stud	1.5in x2.5in-92.625in KD Prime Stud	4	Home Depot	3.27	USD $
6	4	FIBGL Resin	Bondo 404 Fiberglass Resin 1 Gal	4	Home Depot	189.85	USD $
7	5	9" ADHCOVER	Better 9in Adhesive and Epoxy Roller	2	Home Depot	4.97	USD $
8	6	4" FMBRSHWDN	Chip 4.0 Flat Brush	1	Home Depot	3.97	USD $
9	7	10x25 3.5mil	10'x25' 3.5 MIL CLR Plastic Sheeting	1	Home Depot	10.98	USD $
10	8	Tray Liner	Linzer 9 in pet tray liner white 1pk	1	Home Depot	0.98	USD $
11	9	1" Drywall	1" Coarse Drywall Screw 1LB	1	Home Depot	6.28	USD $
12	10	3/8 PART BD	0.369 in 3/8 cat pb 48in x 96in	1	Home Depot	9.98	USD $
13	11	PRECONCGRY	1-Kote 80lb gray premium concentrate	1	Home Depot	16.45	USD $
14	12	LAG SCREW	5/16"X4"HEX HD LAG SCR HDG(BWO)	1	Home Depot	10.08	USD $
15	13	LIQ NAIL HD	LN HEAVY DUTY 10 OZ	1	Home Depot	10.27	USD $
16	14	RVT PAK	STANLEY 3/16" LONG ALUM RIVETS 50PK	1	Home Depot	5.89	USD $
17	15	POLYACRGLSQT	MINWAX POLYCRYLIC GLS QT 275V	1	Home Depot	15.79	USD $
18	16	VARABARNRDQT	VARA 3X STAIN OIL BARN RED	1	Home Depot	8.48	USD $
19	17	WODGLUMAX8	ELMERS CARPENTERS WOOD GLUE MAX	1	Home Depot	7.98	USD $
20	18	Caster wheels	CASTER NON-MARK RUBBER 5" RIGID	4	Home Depot	43.88	USD $
21	19	PRO AEROSOL	0.106IN X 48IN X 96IN	1	Home Depot	10.89	USD $
22	20						
23	21				Total	418.23	USD $
24							

APPENDIX B: Track design changes

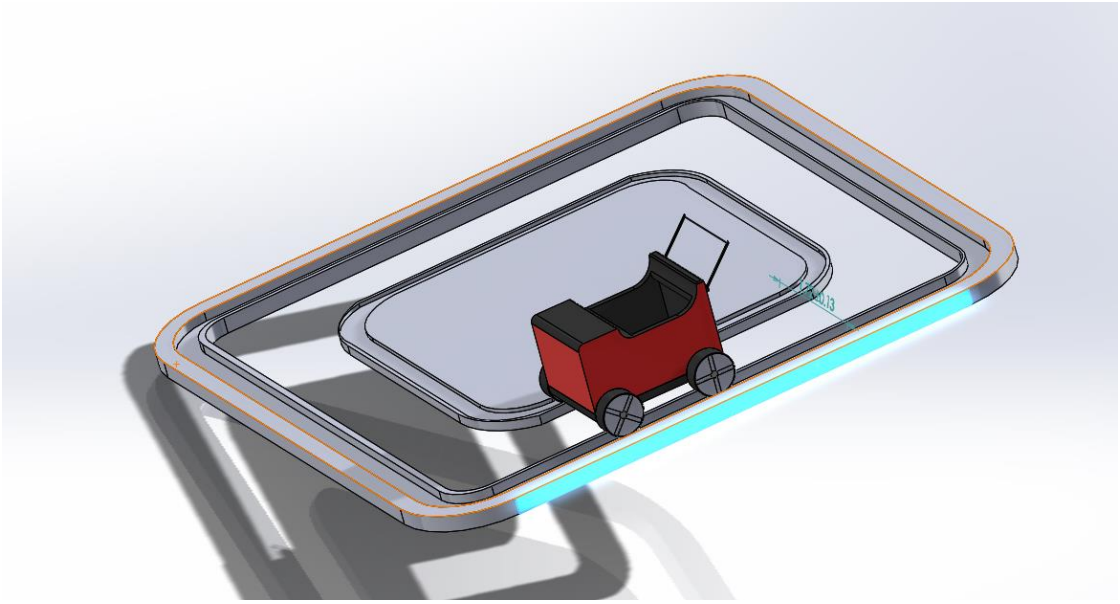
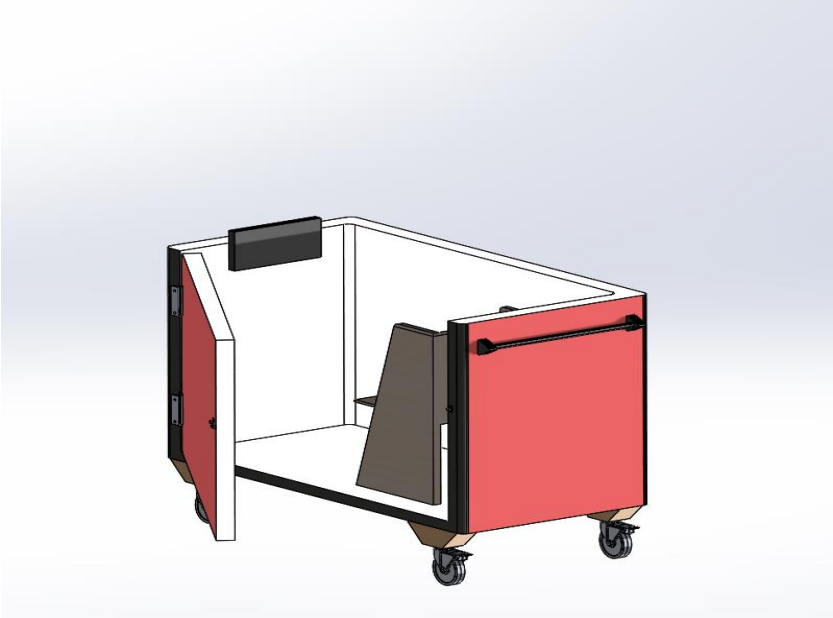
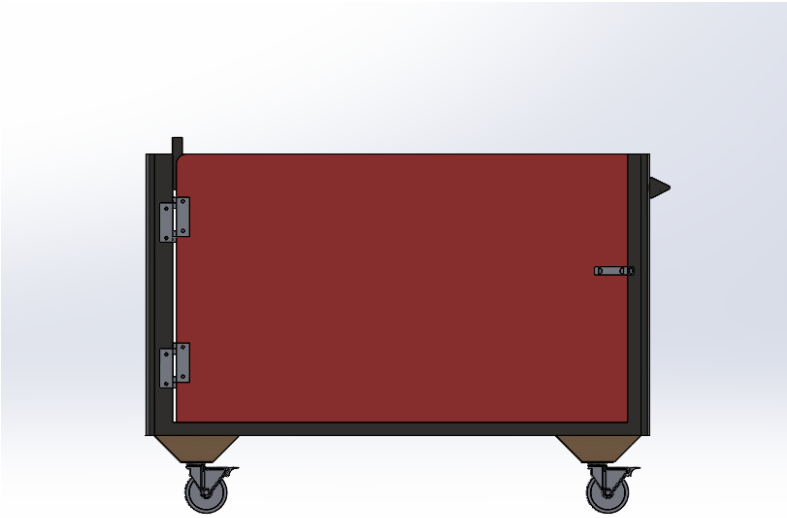


Figure: The old failing design of the track and the cart

APPENDIX C: CAD model the design





APPENDIX D: Calculations

3.6 Additional Calculations

If we consider a wall of the following parameters, we can also analyze the heat transfer behavior in case of conduction for a better understanding. Will use winter case because the summer on flagstaff are cool. By Fourier's Eq: $Q = \frac{KA(T_{surface} - T)}{d}$

d = 0.15 m

Height of wall = 2 m and width of wall = 2 m

T = -8°C and $T_{surface}$ = 20°C

Case 1: Material -> Iron

k =79.5 W/m K [4]

Q = 59360 W

Case II: Material -> Wood/Composite

k = 0.12W/m K [4]

Q = 89.6 W

Case III: Material -> Aluminum

k = 205 W/m K [4]

Q = 153066.6 W

As we can see from the values of heat transfer for iron, wood and aluminum, wood seems to be a better option as it does not conduct heat at a high rate.

APPENDIX F: Final Construction of the Design