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Marshall Classroom for Disabilities

Final Design Report 2017-2018

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DISCLAIMER

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EXECUTIVE SUMMARY

This project is about making such a useful item which can help the children with disabilities to move around and play with it as well as provide the learning tools to them. Therefore, a final design has been selected on the basis of customer requirements and engineering requirements that provide all the required facilities to the children with disabilities. Ten design ideas have been generated for this project and final design has been selected based on two methods which are Pugh chart and Decision matrix. The design is a rectangular sensory board which has a playing area in which children can play around with different gadgets and can learn from these learning tools. The product has implemented in SolidWorks in the beginning to justify the model. When the CAD model has been implemented, it has found that the sensory board can be built in real life. A bill of materials has used to finalize the materials for each part and then the product has been manufactured using the wooden box and around 20 parts attached to the sensory board. Before that, we had decided to use 30 gadgets but the space was not enough; Therefore, we decided to buy 20 parts for the sensory board. Final product has been tested and it has seen that it has multiple lights to attract the children and provide the bright view inside the board. All the lights were operational during the testing phase and each gadget was fixed at the location and everything was arranged. The project was successful due the team's hardworking and the instructor's advice as well as her guidelines.

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1 Background

1.1 Introduction

Children with disabilities faces different kind of challenges in their life when they were in a school; as they need to perform certain tasks which require constant movement. Consequently, it tires them so quickly because they burn a lot of energy during various manipulation exercises while using normal chairs and desks [1]. Consequently, they perform poorly in academics and thus denying them access to higher levels in education. Children with disabilities in sensory processing lead them to have a distorted sense of their localities, which at most times disturbs their exploration and learning of their world. Sensory incorporation was our brain's aptitude to interpret, comprehend and respond to sensory information. Individuals with sensory processing disorder at most times have trouble assimilating and retorting to this information.

For this purpose, the team decided to make the classroom area a play device which consists of a sensory board. We determined that the project scope was to create a classroom area system that children can play with that consists of a sensor board and other items to play with such as, sound, music, lights, alphabets and many other gadgets installed in the device. The device that the team built is for Marshall Elementary School. Children in that school could use the device regarding their various disabilities. The design that we built is based on what the team has seen in the school and what they noticed to be the most important device for them.

1.2 Project Description

The goal of this project was to teach children with disabilities how to write, read, stand, live their normal lives, and learn some basic life's skills. Normal people do not notice how hard for children with disabilities to learn skills. Children with disabilities need more attention to learn new materials and they can hardly store the new materials in their brain. Therefore, we were trying to create a device for them so that they can learn many things in our life. In addition to that, the device that was built is considered as an educational as well as entertaining device. Instructor and ME department provided the team with the following description regarding the project details.

> "This project calls for a learning device for the classroom that helps one or more children with disabilities during a regular school day. The project is open-ended and calls for the student design team to visit the classroom, understand how the children learn and play during the day in the room, and propose a project based off their observations and the classroom teacher's needs."

1.3 Original System

This project involved the design of a completely new disability aid product. There was no original system when this project began.

2 Requirements

By the end of the project the team have ensured that both of the customer and the engineering requirements were met. These requirements were contained in the final design system to facilitate effective functioning and also guarantee that the customer necessities were met.

2.1 Customer Requirements (CRs)

Customer requirement are the one given by client in the form of project description and so the table was developed for customer requirement which has shown below

Table 1: Customer Requirements

Customer Requirements	Description of customer requirement
Safe to use	Device must be safe to use by the children
Flexible design	The design should be adjustable to fit people of various sizes, and disabilities.
Sensory board	To guide students on various operations.
Spacious	Capable of holding multiple items.
Device Strength	Strong materials should be used to ensure the device lasts longer.
Comfortable design	The sitting area should be easy to stay in and the board should be a minimum height.
Durable design	The material used should be durable
Economical	It must be economical and low price. Within the budget of $2000

In the above table, customer requirements have been presented as per the specifications of the client. They were followed by the team when designing the device. The design was flexible to suit various sizes of the children with disabilities.

2.2 Engineering Requirements (ERs)

Engineering requirements were those which have devised from customer requirements and these were the technical requirements of the project as showing in table 2. These customer requirements were transferred into engineering requirements as shown in the following table.

Table 2: Engineering Requirements

Engineering Requirements	Targets
1.Flexible design	Adjustable to a length ranging from 5cm to 15cm
2.Strength of the device	Yield strength of at least 6Mpa.
3.Soft material	Low pulling force of below 5 Pascal
4.Adjustable length	5 cm length range
5.Containment through size	12 ft^2
6.Sensory Board	1 Ampere
7.Size	3 x 4 feet
8.Soft Edges	Round radius of 2 inches on each side
9.Height of Board	3 feet
10.Weight	120 lb.

The above engineering requirements were followed by the team in order to develop the project. When the device has implemented all of these engineering requirements were fulfilled by the design.

2.3 Testing Procedures (TPs)

Testing procedure section showed the ways of testing each requirement after the implementation of engineering requirements. All the tests have done on the manufactured product. The following were the testing procedures used to test each requirement. Testing standards were used where pertinent, while more clarity testing methods were used for all other tests

.

- Flexible Design

  It has tested by moving the front door which has the capability to lift for 5 cm front and back. So this design has tested and proved that engineering requirement is fulfilled by the design.

- Yield Strength

  Strength of material has tested before the manufacturing of product. The sensory board walls were put under the force per unit area a stress of 6 MPa has applied to the walls through the load and it was tested that walls were able to stay against that stress.

- Soft material.

  It was tested by applying the pressure inside the sensory board with the small value of 5 Pascal and the box was stayed against such pressure.

- Containment through size

  Size containment was tested by measuring the area inside the sensory board and it was less than 64 square feet. It was tested by the scale of 12 inches and then tested the area.

- Sensory board

  This has tested through the Ammeter used to measure the current available in the sensory board. Ammeter connected in series and determined that 0.98 Amperes of current was

running into the wires.

- Size
  Box size was tested by the scale feet of 12 inches. Outside measurement has taken through the scale and length and width was calculated.

- Weight
  The team weighed each part of the sensory board separately using a small scale and it was found that the device weighed 120 lb.

- Soft Edges
  Round edges were tested by the round scale which calculates the radius. It has tested that round edges were of 1.5 radius.

- Height of Board
  Height was tested by the feet scale and outside height was calculated and it was less than 10 feet.

2.4 House of quality

HOQ was applied to make the relation between customer requirements and engineering requirement's various parameters. The HOQ enabled the team to improve the original design to fit the engineering requirements.

Table 3: House of quality

Customer Requirement	Weightage(lb)	Weight(ft)	Yield strength of at least 6Mpa(Mpa)	Adjustable to a length ranging 5cm to 15cm(cm)	Use soft fabric	Containment about the size	Sensory board for current	Size	Soft Edges for round edges	Height of Board
Should be flexible	4			5	4	5	**6**		**3**	1
Should be strong and durable	5	3	4					**6**		
Comfortable design	4	1			5			**3**	**9**	2
Spacious Design	5		4			8	**9**			
Sensory board	4	5	4			8	**9**	**9**	**9**	3
Absolute Technical Importance (ATI)		5	4	4	5	5	5	4	5	2
The Relative Technical Importance (RTI)		7	9	9	7	6	9	8	4	7
Target(s), with Tolerance(s)		120± 1	6±1	5±2	30±5	12 ± 2	1 ± 0.2	3x4 ±1	0.2 ± 0.1	3 ±
The Testing Procedure (TP#)		**9**	1	2	3	5	6	**7**	**8**	**10**

Result of HOQ shown that strength of material, adjustable length and current present in the sensory board are most important requirements and after that soft fabric is important. Result have shown that least important engineering requirement was soft edges with round shape. In the implementation of this project all the engineering requirement were followed and as the priority list was obtained by HOQ so the list was strictly followed.

3 Existing Design

A variety of devices were designed to assist the person with disabilities in carrying out various day to day operations. In this regard, the team was made an extensive research to compare the various devices which were available to help people with disabilities. Different existing designs have found through research for this section.

3.1 Design Research

A range of designs have been created to help children with disabilities. However, the designs were normally improved as time goes on so as to suit the needs of the users. The team analyzed a wide range of existing designs in the market so as to come up with an appropriate design. The team have done many research to figure out to finalizer their ideas. Research helped the team to organize their thoughts and it made them to think out of the box. In this way, the team can be creative when building their device. The teams have done a lot of research about wheel chairs, sensory boards, and other devices that can aid children with disabilities in their education. Wheel chair can students move from one place to another easily and it can help them perform as other students do. Sensory boards can help students with disabilities to learn how to push, pull, twist, lives' skills, and teaching materials for their school, such as Alphabet letters, numbers, …etc. Other devices that the team searched for were about clock and tires which could provide an entertaining area for kids.

3.2 System Level

System level design were the basic main designs and through the extensive research, it has been found some existing designs which is presented below.

3.2.1 Existing Design #1: Small Sensory Board

This small rectangular sensory board has many tools that children can enjoy and play with. It can be used as a teaching tool as well as a way to have fun. In addition to that this design can be easily built and it can be fixed at any time. However, two kids can play with this device while the other are waiting

Figure 1: Small sensory board

3.2.2 Existing Design #2: Semi Cubic Sensory Board

This design though can provide children with disabilities with more space to play with. It got a lot of teaching tools for children to have fun with and in this way they can learn something. The design is very attractive; therefore, it can distract children in class while the instructor is teaching them new materials. The semi cubic design is made of plastic and all parts attached can

be found in the market.

Figure 2: Semi Cubic Sensory Board [7]

3.2.3 Existing Design #3: Rectangular Sensory Board that can be folded

This amazing sensory can have a lot of materials attached to it. Also, this design can be very attractive by children with disabilities. It is easily portable and it can be moved from one place to another. This design is made also from wood and plastic and it can teach children a lot of teaching tools. However, this device does not provide for more kids to use; therefore, children would wait a lot for their turn. The device is as shown below.

Figure 3: Rectangular Sensory Board that can be Folded *[7]*

3.3 Functional Decomposition

In this project, the major aim was to design a device which could be used by students with disabilities while they were learning in class. Functional decomposition was the process that explained the input, output, and the inside working of the system.

3.3.1 Black Box Model

Black box model was the functional decomposition and it consisted of only inputs and outputs. It would give insight of the working system and how the system would work. Black box model basically explained the system working. Black box model for this project was showing in the figure 4.

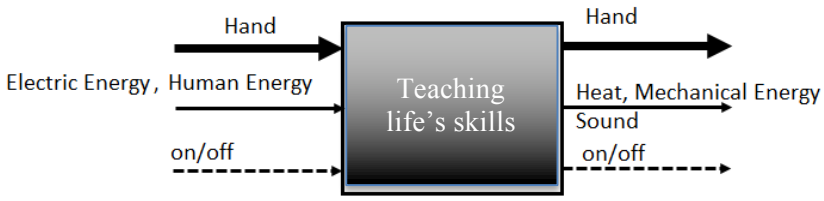

Figure 4: Black box

3.3.2 Functional Model

The functional model was the one which explained the system from inside. It told the process taken by the system from input to reach the output. This model was also important to completely understand the system. Functional model was taken from the black box model and it explained how the system would work. In addition to that, the functional model for our system was the working mechanism of the whole system. It gives more details of how the system would work from the inside and how the user reaches their outputs. Functional model is a very complex model; however, it gives more illustration if someone fully understands it. Figure 5 shows the complete functional model.

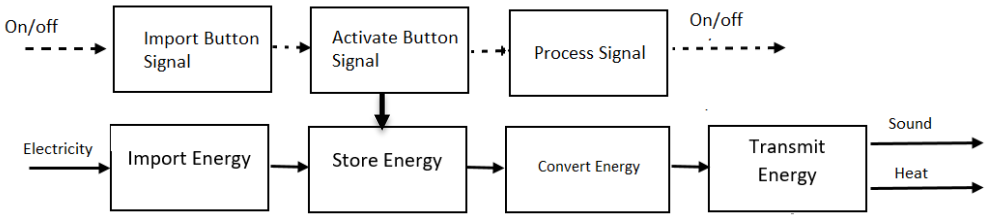

Figure 5: Functional Model

3.4 Subsystem Level

Each system divided into its sub-systems and these subsystems were presented in this section about the sensory board.

3.4.1 Subsystem #1: Tires

Tires was one of the most important subsystem used in the project. And existing designs about the tires were shown below.

3.4.1.1 Existing Design #1: Rubber Tires

A form of tires which were flexible and easy to rotate and it could provide soft movements. This was already built and it can be used in the project.

Figure 6: Rubber Tires [9]

3.4.1.2 Existing Design #2: Plastic Tires

Another type of existing design which was found was plastic tires. Plastic tires are also strong and it could be used for our project. These tires could be placed for our device to easily move from one place to another one.

Figure 7: Plastic Tires [10]

3.4.1.3 Existing Design #3: Wooden Tires

One other existing design was found for the tires. This was wooden tires which could be used in our project to be able to change the device from one place to another easily.

Figure 8: Wooden Tires [11]

3.4.2 Subsystem #2: Sensory Box

Next sub-system of our project was sensory box which could be developed through different materials.

3.4.2.1 Existing Design #1: Wooden Sensory box

An existing design was found which was wooden sensory box. This type of sensor board can be used in our project and at the end the team decided to go with something similar to this.

Figure 9: Wooden Box [12]

3.4.2.2 Existing Design #2: Plastic Sensory Box

Another existing design was found which was plastic sensory box and it could be used as our device. This was a good idea for looking at the kids while playing inside the box because it would be transparent. However, this would be hard to attach parts onto it because of the plastic material used. Figure 10 shows the complete design of a plastic sensory box.

Figure 10: Plastic Sensory Box [13]

3.4.2.3 Existing Design #3: Aluminum Sensory Box

Aluminum design was found as an existing design and it could be used as our final design. This aluminum sensory box could be used as a mirror because of the aluminum. This device would work very well; however, durability would not be met if this device was used.

Figure 11: Aluminum sensory box [14]

3.4.3 Subsystem #3: Clock

Another sub-system was a clock and its existing designs were found as well.

3.4.3.1 Existing Design #1: Round Clock

An existing design of clock was already available and that was a round clock. It was shown below in the figure.

Figure 12: Round Clock [15]

3.4.3.2 Existing Design #2: Square Clock

Another existing design was found which was square clock and it could be also used as a part in our project as shown below.

Figure 13: Square Clock [16]

3.4.3.3 Existing Design #3: Rectangular Clock

Another existing design was a rectangular clock that could be used in the sensory board and it is shown below as well.

Figure 14: Rectangular clock [17]

4 Designs Considered

The team produced a wide range of designs during the brainstorming process which were fulfilling the various customer and engineering requirements. The team still had to choose 10 designs and then finally weighed them in order to see which one would suit the customer and the engineering requirements. All 10 designs the team researched for is explained thoroughly are explained below.

4.1 Design #1: Wheel Chair with a Desk

The device has a board which can be utilized for writing and eating purposes. This would ensure that students carry out their tasks of readings and writing tasks easily by placing books on this board. It also has wheels to facilitate motion from one place to another. The major challenge with the board was that it must be removed every time the user was not using it.

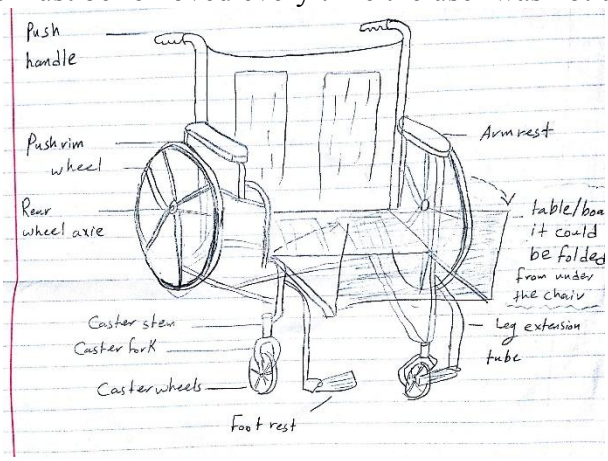

Figure 13: Wheel Chair with a Desk

Pros:

- *Easy to use*
- *Carry the student*

Cons:

- *No learning*
- *A supporting disability factor*

4.2 Design #2: Lap Hugger

The lap hugger provides an appropriate upper body support and also prevents the user from leaning forward. The hugger was made up of durable foam padding covered with vinyl hence making it easy to clean. It also has a clear window for storing reading material.

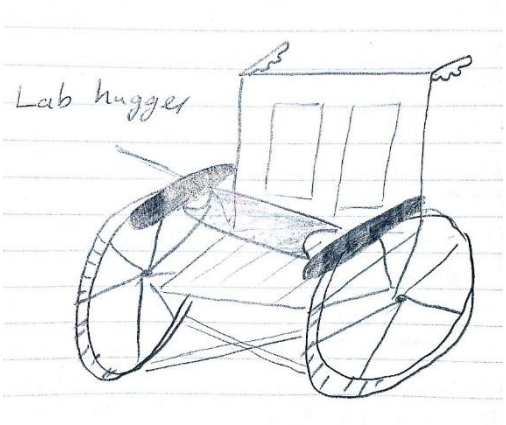

Figure 14: A Lap Hugger

Pros:

- *Easy to use*
- *Carry the student*
- *Handle two children's*

Cons:

- *No learning*
- *A supporting disability factor*

4.3 Design #3: Wheel Chair with a Seat Belt

The design comprises of a safety belt which was fastened around the waist. This was beneficial because it prevents falls, prevents forward sliding, it has a soft breathable foam to facilitate comfort. Also, the closer was capable to be positioned for self-releasing or even more restrictions.

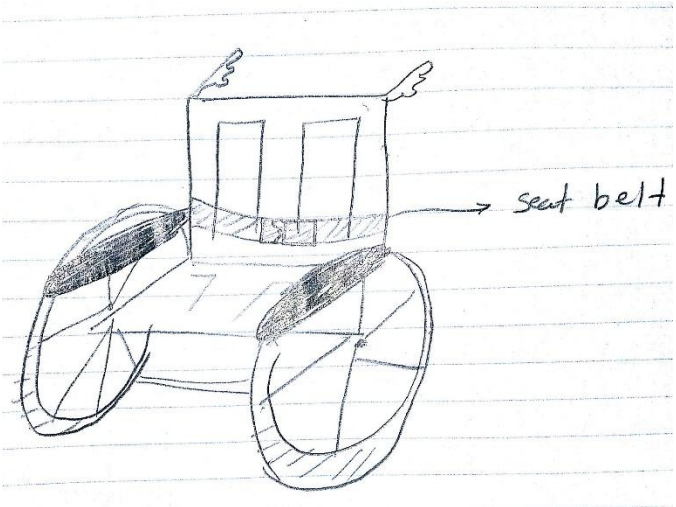

Figure 15: Wheel chair with Seat Belt

Pros:

- *Easy to use*
- *Safe for the children*
- *Carry the student*

Cons:

- *No learning*

- *A supporting disability factor*

4.4 Design #4: A Hexagonal Containment

A hexagonal containment that has a door. Once the child was in, he could play around with a sensory board surrounding them.

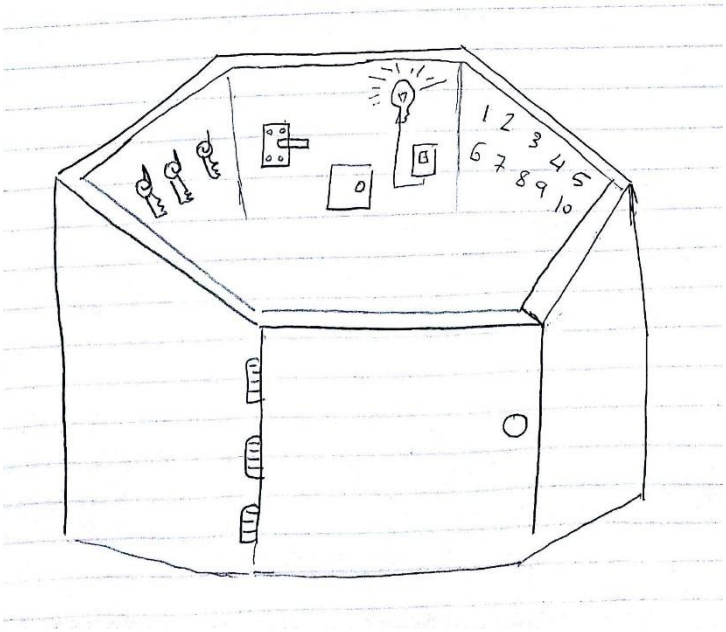

Figure 16: Hexagonal Containment

Pros:

- *Easy to use*
- *Learning*
- *Entertaining*

Cons:

- *Difficult to operate by children*
- *Not moveable*

4.5 Design #5: A Hexagonal Containment Sensory Board with Wheels

A hexagonal containment made of word and it has a door which enables the child to get inside. Once the child touches the wall and play with the materials, the wheels would rotate. Consequently, energetic kids do not fell board because they could move from one place to another but inside the hexagonal.

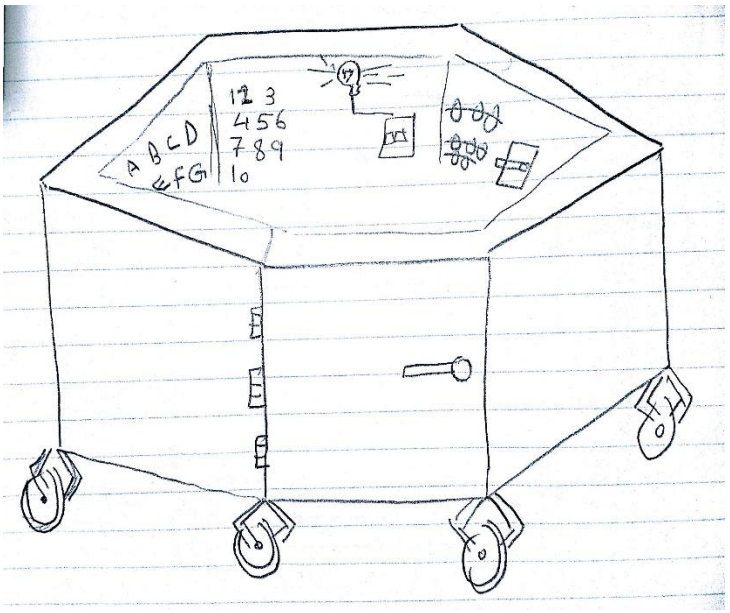

Figure 17: A Hexagonal Containment Sensory Board with Wheels

Pros:

- *Easy to use*
- *Learning*
- *Entertaining*
- *Moveable*

Cons:

- *Difficult to operate by children*

4.6 Design #6: Trampoline Containment Sensory Board

A hexagonal containment has a door and it was made of wood. The base of it was a trampoline shaped. This can entertain the child while he was learning the hexagonal.

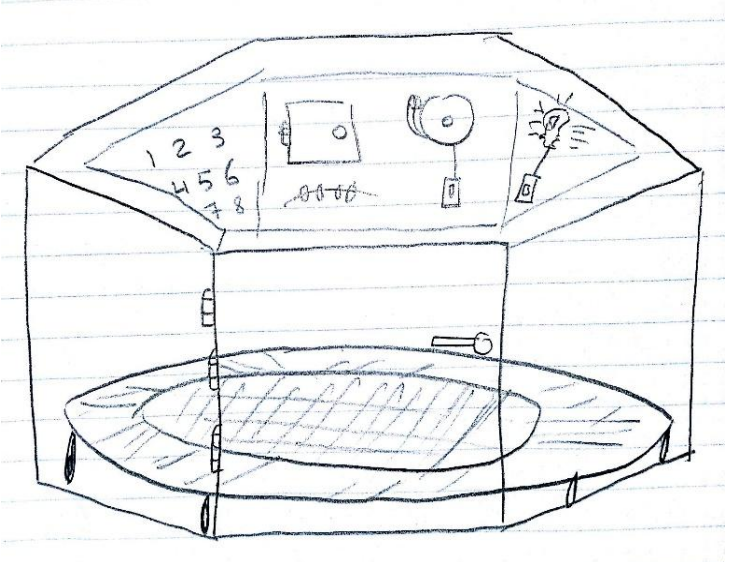

Figure 18: A Trampoline Containment Sensory Board

Pros:

- *Easy to use*
- *Learning*
- *Entertaining*
- *Moveable*

Cons:

- *Difficult to operate by children*

4.7 Design #7: Sensory Board to the Wall

This sensory board was mounted to the wall. This design could enable all kids in the schoolroom use this available learning tools.

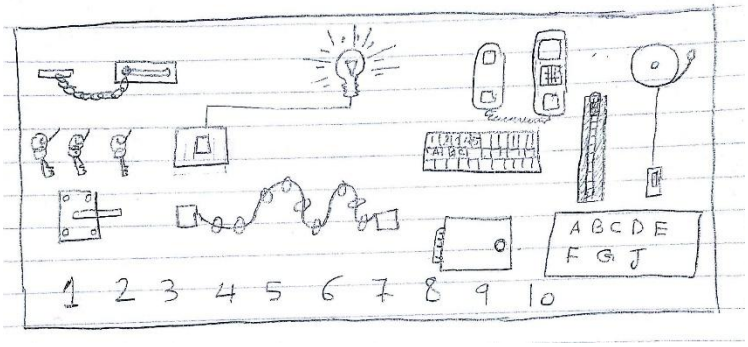

Figure 19: Sensory Board to the Wall

Pros:

- *Learning*
- *Entertaining*

Cons:

- *Difficult to operate by children*

4.8 Design #8: Rectangular Sensory Board

The design comprises of a sensory board which has digitized controls. The board has a wide variety of buttons, door knobs, and some puzzles. Also, the sensory board has different lights which blink followed by a voice prompt either to caution or assuring the user of the correctness of performing a particular action. The unique about this design was that it has wheels which facilitate moving it around the class without exerting any efforts. In addition to that, we were incorporating in this design a stand that can help a child with disabilities to get used to stand up and play with the board because of some of the kids that the team observed struggle when getting up. The cubic sensory board would attract kinds; and therefore, help them strengthen their knees.

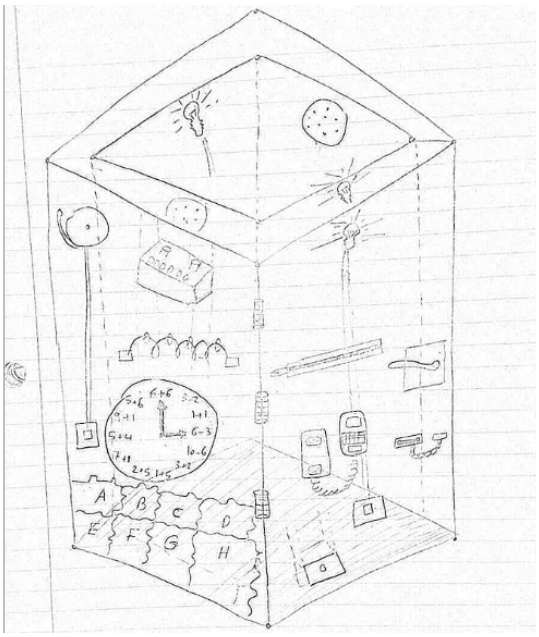

Figure 20: Rectangular Sensory Board

Pros:

- *Easy to use*
- *Learning*
- *Entertaining*
- *Moveable*

Cons:

- *Size of box is large*

4.9 Design #9: Rotating Circular Sensory Board

This design comprises of different kinds of audios that can teach children with disabilities how to read letters, numbers, days, and months. Kids, in general, do not like to be forced when learning, so we can make this more attractive by making the circular sensory board flashing while rotating. In this situation, kids with disabilities were more into learning because it was considered as a game for them.

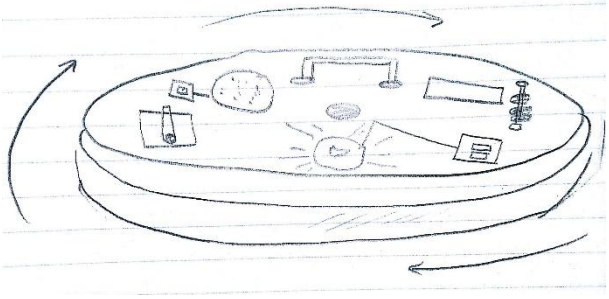

Figure 21: A Circular Rotating Sensory Board

Pros:

- *Learning*
- *Entertaining*

Cons:

- *Difficult to operate by children*

- *Not moveable*

4.10 Design #10: A Folded Sensory Board

The purpose of this design was also to teach children with disabilities life's skills such as, pulling with some resistance, pushing, twisting, switching lights on/off, and zipping. However, the significant thing about this design was that it could be folded and taken away using a handle so that kids do not play with it without their instructors' permission. Also, this folded sensory board could be turned to a desk. The unique about this device was that it could serve many several things at the same instant.

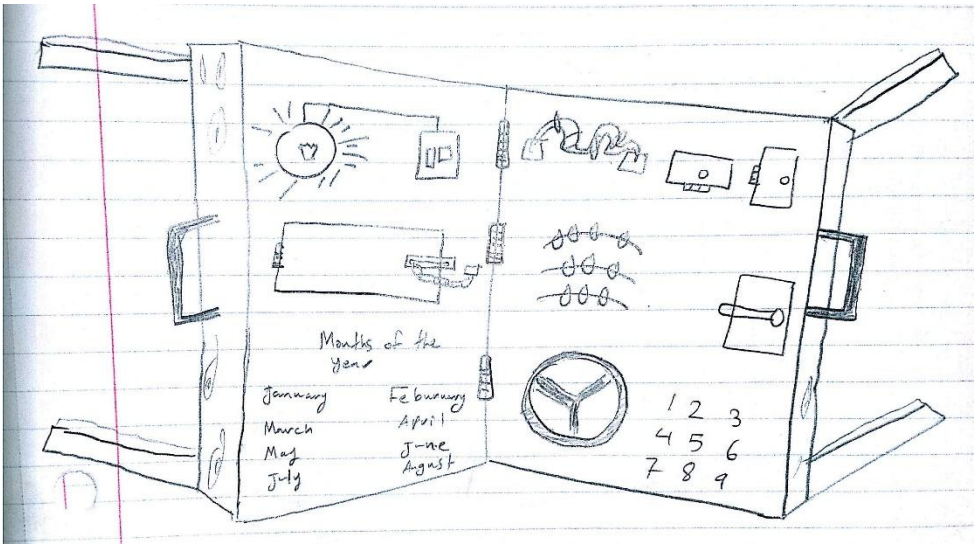

Figure 22: A Foldable Sensory Board

Pros:

- *Learning*
- *Entertaining*
- *Moveable*

Cons:

- *Difficult to operate by children*

5 Design Selected

This design was ought to be taken after what the client needs and connected our building prerequisites. As we did in configuration considered for the 10 outlines. Everyone has distinctive thoughts and diverse approaches to utilize. Therefore, the team had to make sense of which one was better and considering the clients' needs. After putting thoughts into this, the team decided to select the design on the basis of Pugh chart and decision matrix. Pugh chart will narrow down the results to final three designs and decision matrix will narrow down the result to a final design.

5.1 Rational for Design Selection

As it was stated that design has selected using the Pugh chart and decision matrix. This way could help narrowing down to a final design which could meet the clients' needs.

Pugh Chart

It has a table which identify if the requirement is present in the design idea or not. If it is present, then plus sign is placed in the box and if it is not present then minus sign is placed.

Table 4: Pugh Chart

10 Concepts	Weightage	Wheel chair with a desk	Lap Hugger	Wheel Chair with a Seat Belt	A Hexagonal Containment	A Hexagonal Containment Sensory Board with Wheel	Trampoline Containment Sensor Board	Sensory Board to the Wall	Rectangular Sensory Board	Datum Design	Rotating Circular Sensory Board	A Folded Sensory Board
Safe to Use	8	+	+	+	+	+	-	-	+	D	+	-
Flexible Design	7	S	S	+	-	-	S	+	+	D	+	+
Sensory Board	6	-	+	+	+	-	-	S	+	D	-	-
Containment	5	+	+	+	+	+	S	-	+	D	-	S
Device Strength	4	+	S	+	S	+	+	-	-	D	S	S
Comfortable Design	3	+	+	+	-	-	-	S	+	D	-	+
Durable Design	2	-	+	+	+	-	-	-	+	D	S	-
Economical	1	-	+	-	-	-	-	+	+	D	-	
Pluses		4	6	7	4	3	1	2	8	-	2	2
Minus		3	0	1	3	5	5	4	0	-	4	3

From the above table, it has cleared that the top three designs which got the maximum points and these three designs were fulfilling the customer requirements at the best. Next went towards the decision matrix to get the final result.

Table 5: Decision Matrix

DECISION MATRIX	Safe to Use	Flexible Design	Sensory Board	Containment	Device Strength	Comfortable Design	Durable Design	Economical	Total
Weightage	8	7	6	5	4	3	2	1	
Rectangular Sensory Board	6x8=48	7x7=49	4x6=24	5x5=25	6x4=24	6x3=18	4x2=8	2x1=2	198
Wheel Chair with a desk	5x8=40	5x7=35	4x6=24	2x5=10	3x4=12	3x3=9	3x2=6	3x1=3	139
Lap Hugger	3x8=24	4x7=28	3x6=18	1x5=5	4x4=16	4x3=12	2x2=4	2x1=3	110

Decision matrix gave the final result in which the highest marks have obtained by the rectangular sensory board. It has been the highest because it meets all customer and engineering requirements provided and explained previously. This design could be creative and could include all teaching and entertaining tools

5.2 Rationale for Design Selection

The rectangular sensory board as shown in Figure 23 could have many parts attached to it in some way. Some parts could be fastened, glued, and velcroed to the board. This sensory board could be used by more than 6 students in the class and it could play a significant role in the classroom settings. This sensory board could be a teaching tool, in addition, it could be used as an entertaining tool as well. These all specifications which made up the final design.

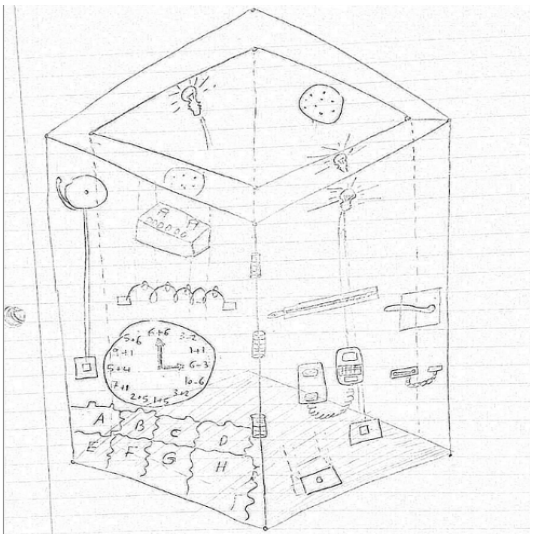

Figure 23: Sketch of Selected Design

Benefits of this design:

- Entryway swings 180 degrees
- Whole unit was set on a base intended to avert tipping
- Highlights an elastic secured, in a flash flexible foot stage
- Assists with a patient's initially attempt at working in a standing position
- Spring lock furnishes greatest security with one simple change

This was a fundamental cut out table for the patient's initially attempt at working in a standing position. The standing box includes an elastic secured, in a split second customizable foot stage. The elite Bailey outlined spring lock furnishes most extreme security with one simple modification. The whole unit was set on a base intended to avoid tipping. Entryway swings 180 degrees.

Table 6: Features of the Selected Design

Individual Child Standing Box	Individual Adult Standing Box
Top Measurements: 61 cm x 76.2 cm	**Top Measurements:** 76.2 cm x 76.2 cm
Height from Floor: 85 cm	**Height from Floor:** 137.2 cm
Foot Platform Adjusts: 3.8 cm to 29.2cm from floor	**Foot Platform Adjusts:** 3.8 cm to 29.2 cm from floor
Cut Out Size: 17.8 cm x 25.4 cm	**Cut Out Size:** 30.5 cm x 38.1 cm
Box Dimensions: 35.6 cm wide x 35.6 cm deep and 81.3 cm high	**Box Dimensions:** 40.6 cm wide x 35.6 cm deep and 137.2 cm high

Figure 24: Final Design

6 Proposed Design

Final design has presented before; in this section we were presenting about the process of implementation. Final design was rectangular sensory board in which multiple items were hanged and provide the learning to the children with disabilities. It was moveable and easy to use. This device could be used by more than 6 students. Students could play in the outside and the inside of the box. This was considered one of the advantage of the product. Final design CAD model and a prototype is shown below:

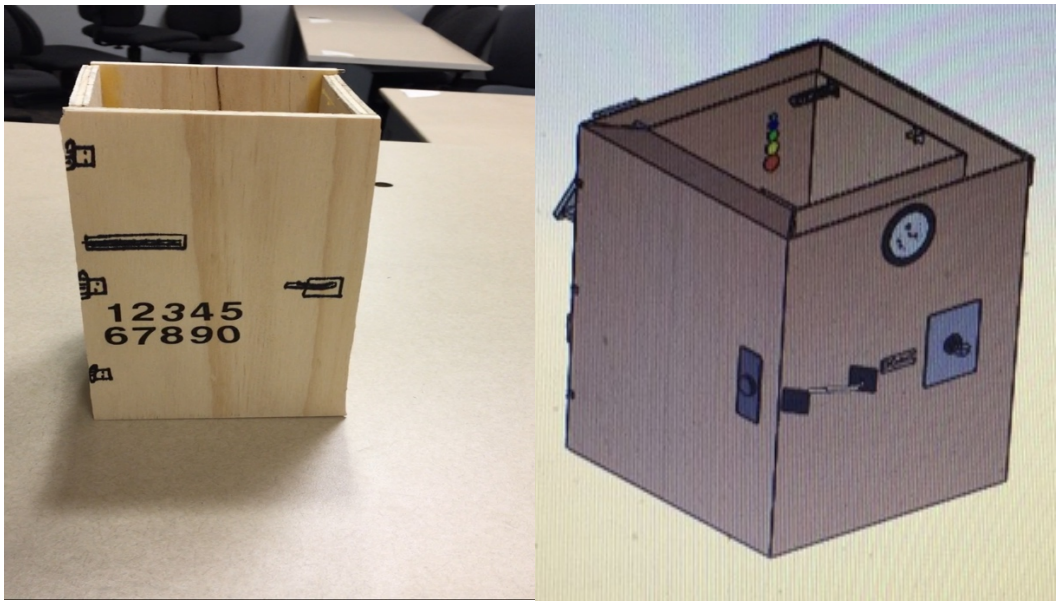

Figure 25: Primary design CAD model and the prototype.

6.1 Implementation Plan

Implementation plan can show how the team built the final design. It showed step by step how the team reached to their final design and the building procedures. Implementation plan is showing below following by the Gantt chart. The Gantt Chart has organized the tasks the had to be performed and it kept the team on track in regards of purchasing the iterms to build and updating everything that was required in this course.

Table 7: Implementation Plan

Implementation
Abstract
Detailed Design
Purchase the items
Manufacturing of first sample
Test the first sample
Do the modifications in the sample
Final Test
Product is ready after final modifications

Gantt chart is showing below for the complete work.

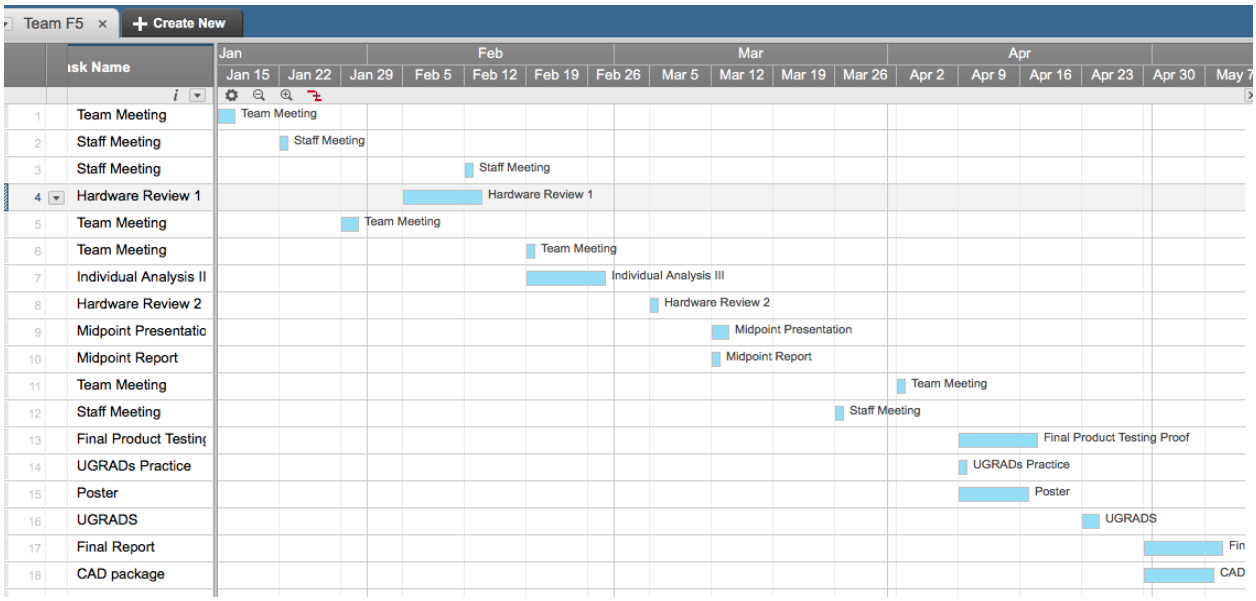

Figure 26: Gantt chart for Product Implementation

BOM (Bill of Materials)

Bill of Material is showing in Appendix A with all the details provided in it about the materials that was used for manufacturing. It also gives all details and parts that are attached to the sensory board

CAD Model

Updating the cad was one of the important step in the designing process in order to know which parts need to be added and which could be replaced by something more useful. The updated cad is shown below.

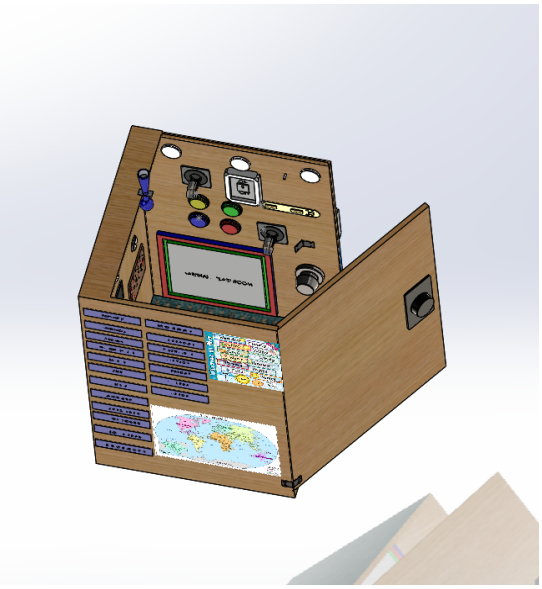

Figure 27: Isometric view of the design

Figure 28: Different Isometric view

See appendix c for more figures regarding the cad package.

7 IMPLEMENTATION

Implementation of project has done and final product has developed. The process of implementation has shown in the manufacturing section.

7.1 Manufacturing

Manufacturing of product has done in the following steps

- First of all, the wooden sheets have been taken and cut down in the size of 3 x 4. All 6 sides have developed for the wall. One side has a door which has cut down in smaller size.
- Join the walls to form the box, the box has implemented by hooking the nails in the walls and a box has been formed.
- The hinges for the doors were installed using nails to make it moveable.
- Then the hooks were fit to close the door.
- Put the hooks inside the box to hang all the necessary items.
- Items have been attached on the walls
- Fit the carpet on the floor
- Hang the clock on the outside wall.
- Fit the lights inside the box surrounding it

Following are the items which have been hanged inside and outside the box.

Figure 29: Item that are adding in the box

Building the box was the most challenging part because the team needed to buy heavy duty wood and to make sure all sides of the wood are well done attached to each other with strong screws. The team built the wooden box within six days. After that, all sides of wood have been sanded for safety purposes and to make the wood smoother. In addition to that, plastic corner capping was placed on the outside and the inside sharp edges to make the device safer to be used by kids. Also, the team built three thick supports on the top of the device for making sure that the device does not tip over if someone leans on it. Then, parts were attached to the sensory board according to the clients' needs. The more attractive parts were attached inside the box and the less attractive ones were placed outside of the box to avoid distracting kids in class. After all parts in the above figure were placed in their right location, lights were added to make the device more attractive. In addition to that, parts are attached to the board in different ways. some parts are fastened, some are glued, and others are attached using Velcro. The parts that the team used Velcro for is because of batteries change. In this way, users can maintain all parts without taking parts off, then putting them on again for batteries replacement. The whole device has been manufactured for approximately 19 days and it has functioned successfully.

7.2 Design Changes

There are many changes in our design that occurred during testing and implementation. There are three main changes in the final.

- First, parts attached to the wall of the sensory board have been decreased from about 30 parts to 20 parts which results in size change of the design. The device was 5*6*6 ft to 3*4*3 ft according to the clients' requirements.
- Secondly, trampoline has been removed from inside the device due safety issues. It has been looked it from different perspectives and it has been concluded that it is not safe at all and it has to be removed and replaced by something else. We thought to use soft balls inside the design instead of the trampoline; however, it has been considered as it is not safe because it might hurt kids' ankles.
- Lastly, team will not use a car battery as a source of power due to its size, cost, and safety reasons. Instead, the team bought sensory parts which have their own batteries. Both bill of materials from last semester and this semester is shown in appendix B, in table 8 and 9 to highlight the differences between old design and new design.

In addition to that, there are two main reasons why the old design has been changed. One is that the design does not meet the safety requirement which was emphasized many times by the instructor as well as the clients. Safety to use is one of the team's priorities; however, it has been looked it from different perspectives and found that it can not be safe enough for kids to be used. Another reason for changing the complete design was the space issue. Marshall Elementary school has small classes; therefore, the old design would take a large space which results to a small area for teaching purposes. Those are the reasons for changing the complete design. The figures below show details pictures of the inside and outside device.

Figure 30: Outside View of Box

Figure 31: Door from outside

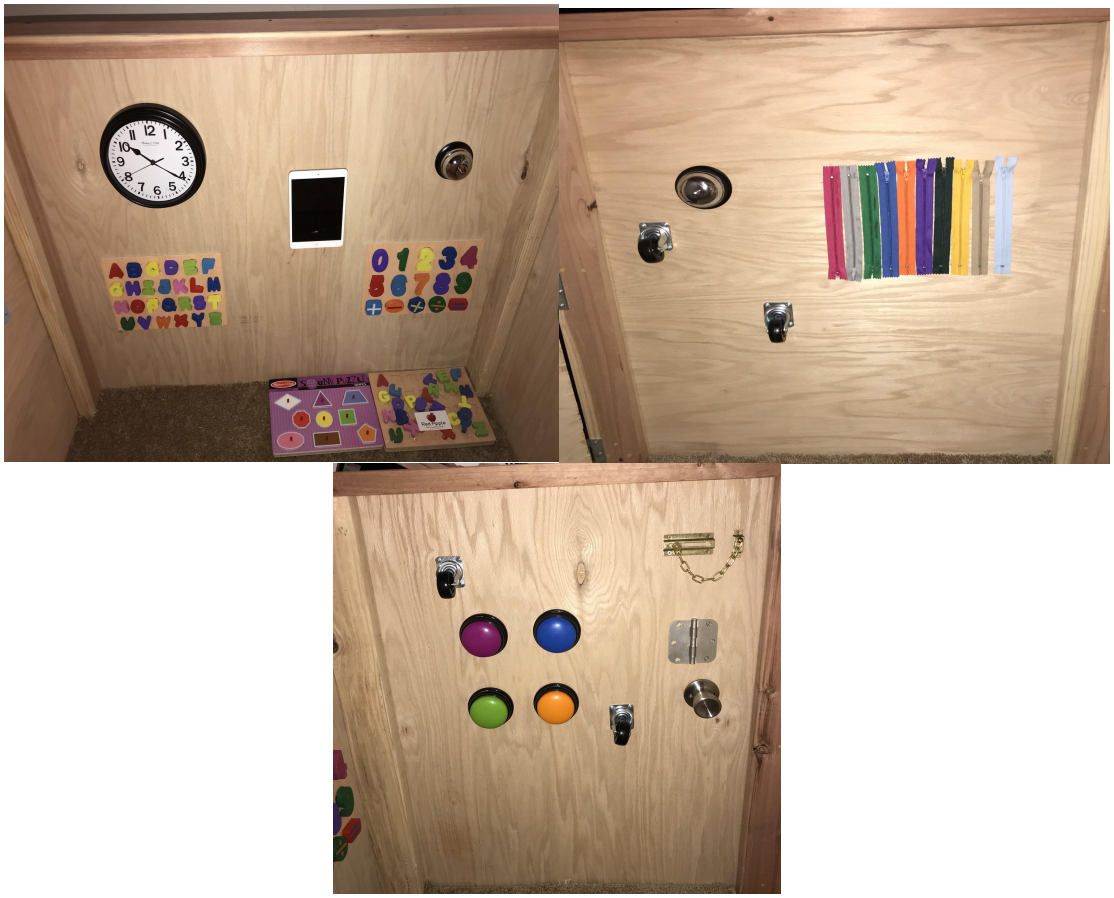

Figure 32: Inside View of the design

8 TESTING

Testing of the manufactured product has been done and it has found that most things are working perfectly fine. There were some issues found while testing it. All the lights were operational, sound system was operational and all other gadgets were properly hanged. Some new parts were added during the testing procedure. It can be seen from the following figures taken during the testing.

Figure 33: Testing Pictures

The above figures show that we have added new parts which are attached to the sensory board. These parts are added to make this sensory board more attractive and to let more students play with them. Also, most of them are teaching tools to make sure that everyone is learning and at the same time is having fun. This is one of the engineering requirement and it has been met. In the testing procedure, we have mainly focused on four things: corners, stability of the device, base, sides of wood. The following table shows the tested parts and the strategies used.

Table 10: Testing Procedure

Parts Tested	Strategies
Corners	Plastic corner capping
Stability of the device	Used supports as shown in figure 33
Strong base	Resists more than 1000 lbs
Sides of wood	Sanded all sides of wood

Furthermore, there are a lot of obstacles that the team encountered during the testing and Manufacturing. First, the biggest concern the team strived to solve was the safety. This was done by sanding all sides of wood and cover all sharp corners using plastic casing. Secondly, the team struggled brainstorming and get more ideas to make sure that the device does not tip over. The team succeeded in making sure that the does not fall when someone leans on it by using redwood surrounded the device on the top and on the bottom. Lastly, meeting the budget planned was one of the biggest problem for the team. The team has a budget of $2000 and it was planned to only use $1000. This was hard because everyone bought high quality materials and at the same time cheap in price. The team met the budget limit planned by searching for all materials online and by comparing their prices from all stores.

All design requirements have been met. The design requirements are met due to the team hardworking and progress. The design requirements that are met are dimensions of the device, cost, safety, durability, and finally making the device entertaining as well as educational.

9 Conclusion

This project is about the implementation of something which is useful for children with disabilities so that they can use it for playing and learning as well. Therefore, a sensory board has been selected which will provide learning and can easily use by children with disabilities. Sensory board has manufactured using the wooden box. Inside the sensory board, there are plenty of learning games and puzzles. Different lights have fit in the box to make it very attractive in order for children like playing with it.

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9.1 Contributors to Project Success

This project has been done with the help of advisors who helped the team at many points. Advisors and the clients helped us in selecting the design. During the manufacturing phase, our advisor has given us some solutions including the type of materials. Other than that, the whole team has played competent roles in the project and finished the project on time as well.

W.L. Gore helped us with providing enough budget for the project. Without getting enough budget, we were not able to complete this project. As this was a design project, it may need some extra budget to do some experiments for making the project successful. Therefore, W.L. Gore help was really a big contribution in the success of our project. With no budget, such a project is impossible to be built.

Also, we do not forget the instructor help and her advice. The instructor made us focus on two main things while building our device which are safety and how to make sure the device does not tip over. Because safety is an important factor to consider, we performed many real life experiments to make sure that the device is safe enough. For example, we sanded all wood sides to make it smooth with no sharp edges. Also, the team covered the corners by plastic casing.

Furthermore, we received some help from other instructors in the engineering building. The team asked many professors about drawing a free body diagram in order to calculate the forces in the x-axis and the y-axis. The sum of these all forces has to equal to zero to reach our equilibrium phase. With their assistance, we were able to build a balanced device. In addition to that, our machine design professor helped us calculate the tensile strength to avoid breaking parts. Their contributions were very helpful and based on their help, we built a beautiful device and it can be seen that it is one of the best and creative sensory board in the market

Mechanical department has given us the opportunity to work on this project and some tools have been used from the machine shop to complete the manufacturing step. In the workshop of mechanical department, we have developed the sensory box. NAU campus has provided us the chance to do the creative work. Our sponsors have helped a lot in building the device and without their help, this project was not able to be manufactured. All of these have played an important role in project success.

Moreover, the team charter plays a big role for the success of the project. In the team charter, the team set up goals and we had to meet them as the semester goes. The team fully respected their goals and everyone was doing his work. Mohammad is responsible for setting up appointments with the clients as well as writing the meeting minutes. Taha was the website developer. Abdullah Almutairi has priced all materials that will be used for the project in order to meet the budget limit. Yousef is the document manager. Abdullah Ali is responsible for updating the cad as well as responsible for making the team be on track. All of them followed the ground rules and coping strategies that was set in the first meeting last semester. These ground rules helped create a successful team because they make them learn how to work not only as a team but as an engineer working in the field or building a project.

9.2 Opportunities/ area of improvement

The project we have implemented is a complete project but still nothing can be perfect. Therefore, if we focus deeply, a lot of improvements can be done in this project in the future. However, the project is perfectly working as expected and it is fully complete. By improvements, it does not mean there are things which are incomplete. One Improvement can be taken into consideration is how to make the device less heavy and easy to move from one place to another. This was made according the clients' requirements; however, still the team have not thought about ideas on how to make the device less heavy. The problem is that it is hard to move the device from one place to another. The team could have thought about adding tires below the device along with brakes to stop them at any times. This way the clients can change the place of the device when needed for learning purposes. Furthermore, another thing that needs improvements is using more parts and increasing the playing area so that more kids can use the device at the same time. Increasing the parts attached to the board would allow kids explore more things and can let them learn many new materials. Also, by adding more parts and increasing the playing area, children can interact with each other and can learn from one another. With taking these improvements into consideration, the team would have built an unforgettable and a very useful device which can be used for years.

For further improvements, the team could have built two doors so that kids can enter the playing area from two sides. This way, if we a door breaks or not functioned properly, we have another working door. Also, for more safety, the locker for the door should have been placed higher so that kids can not get in without the instructors' permissions. With considering the above problems, the team would have built a perfect device that is free of flaws.

Furthermore, the team spent a lot of money during testing and manufacturing. We, in the beginning, did not cut the wood following the measurements given; therefore, we had to buy more wood to fix that problem. Also, at the time of attaching parts to the sensory board, there were some parts broken during fastening them, so we had to buy new ones. This affected the budget of the project. However, the team built a high quality device. Moreover, time management was a big problem for the team. The team hardly can find a time that fits all team members; therefore, most of the team meeting minutes were conducted with two or only three team members at a time. Nevertheless, the team managed to complete the project on time and perform very well either on the poster or the presentation.

The team encountered a lot of problems this semester. They, sometimes, do not split tasks to all team members equally. This results to not high expectation work and it breaks one of the ground rules which are set in the beginning. This engendered hatred between team members and this would result in an unfinished work. Another problem that the team faced was on how to build and manufacture the device. None of the team members have any experience with that and none of them have taken manufacturing process course to be able to cut the wood and connect the wood together and so on. Therefore, the team did their best and asked for a lot of help from the instructors as well as the clients to give them advice. The students learned many lessons from their mistakes which are treating people fairly and know that asking questions to the right person would not hurt. These two lessons that the team should learn because it drove to a lot of problems that they are not in need of. Despite of all these problems, the team strived to build something that can please children with disabilities. They built a perfect sensory board for kids in spite of the all barriers that they encountered.

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APPENDICIES

APPENDIX A: Bill of Material

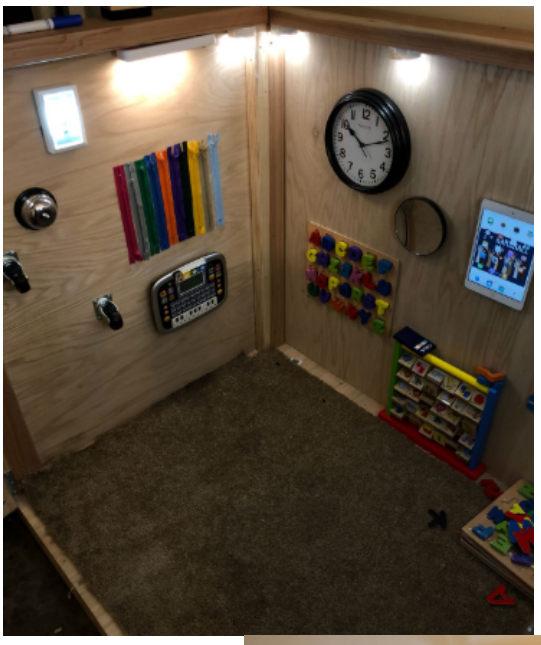
Table 8: Last semester BOM

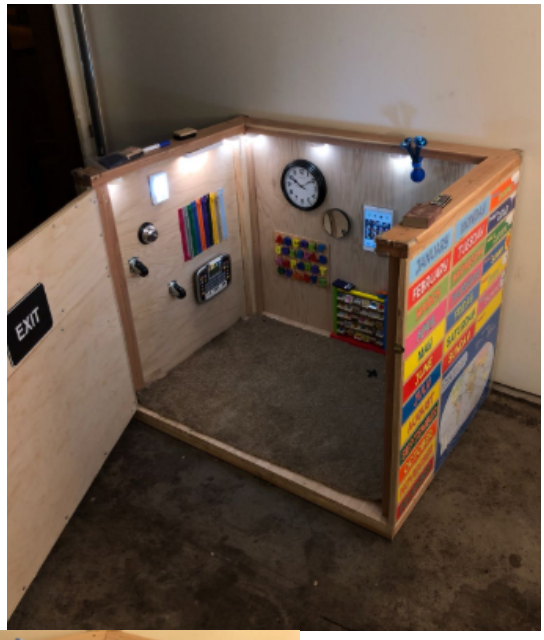
	Materials	Cost in $	Quantity	Total cost
1	Door Knobs	$3.47	5	$17.35
2	Light bulb	$2.17	4	$8.68
3	Light switch	$2.97	4	$11.88
4	Car Battery	$49.88	1	$49.88
5	Drawer	$31.98	1	$31.98
6	Bell	$5.88	2	$11.76
7	Door hinges	$1.56	3	$4.68
8	Zip	Owned	2	N/a
9	Speaker	$9.49	1	$9.49
10	Wood	$19.95	8	$159.60
11	Telephone	$5.98	2	$11.96
12	Alphabet Puzzle	$4.82	1	$4.82
13	Learning clock	$6.97	1	$6.97
14	Bead Maze	$8.29	2	$16.58
				$345.63

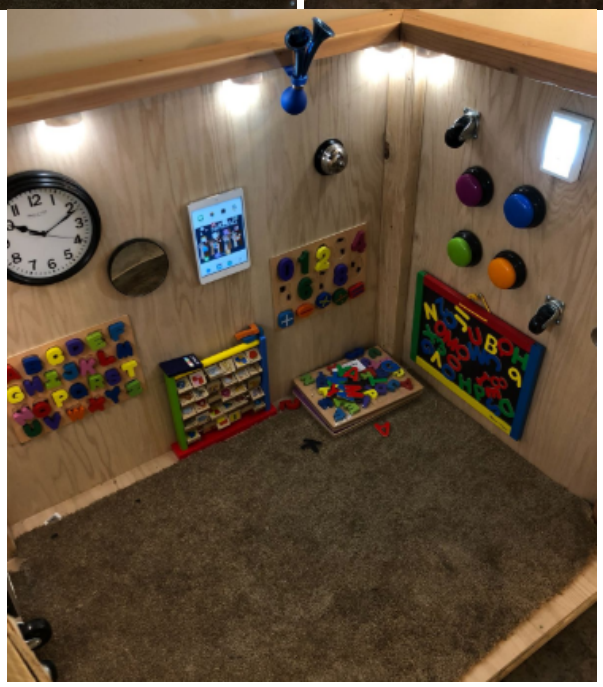
Table 9: New BOM

	Materials	Cost in $	Quantity	Total Cost $
1	Alphabet and number puzzle	$29.99	2	$59.98
2	Bell	$5.85	2	$11.70
3	Zippers	$7.50	1	$7.50
4	Buzzers set of 4	$18.97	1	$18.97
5	Tax	$1.70	N/A	$1.70
6	Days cards	$6.99	1	$6.99
7	Monthly calendar cards	$5.99	1	$5.99
8	US map chart	$3.49	1	$3.49
9	Shapes Sound Puzzle	$12.99	1	$12.99
10	Tax	$2.64	N/A	$2.64
11	Wall clock	$3.88	1	$3.88
12	BP DOOR CHN	$3.97	1	$3.97
13	NK RD DR HNG	$2.97	1	$2.97
14	3 BRRL BOLT	$2.67	1	$2.67
15	2 WD SCRW	$0.97	1	$0.97
16	TAX	$1.29	N/A	$1.29
17	CASTER SWVL	$2.94	4	$11.76
18	DRLCK HALLCL	$7.87	1	$7.87
19	Wall clock	$3.88	1	$3.88
20	TAX	$2.10	N/A	$2.10
21	WORLD MAP	$3.49	1	$3.49
22	MAGNETIC CHALKBOARD	$19.99	1	$19.99
23	TAX	$2.11	N/A	$2.11
24	DOOR HANDLE	$12.05	1	$12.05
25	MAGNETIC TAPE	$3.88	4	$15.52
26	TAX	$1.39	N/A	$1.39
27	WOOD 0.725IN *48IN * 96 IN	$49.98	3	$149.94
28	WOOD 1.5IN *3.5IN * 96IN	$9.77	8	$78.16
29	SCREWS	$8.38	1	$8.38
30	HINGS	$3.67	3	$11.01
31	TAX	$22.15	N/A	$22.15
32	WOOD CEDR .216IN*23.75IN*47.75IN	$16.92	2	$33.84
33	TRIM BOARD	$3.22	3	$9.66
34	TAX	$3.88	N/A	$3.88
35	TAPE FOR THE IPAD	$6.97	1	$6.97
36	AAA BATTERY	$11.78	1	$11.78
37	AA BATTERY	$6.94	1	$6.94
38	TAX	$2.30	N/A	$2.30
39	IPAD Mini	Owned	N/A	Owned
TOTAL COST: $572.87				

APPENDIX B: Testing Images







APPENDIX C: CAD Model