Designing Rehabilitative Devices for Elementary School Students

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Capstone Design Statement

In order to receive a Professional Engineering degree, the first step is to complete a college or university program accredited by the Accreditation Board for Engineering and Technology (ABET). One of the ABET requirements to graduate is for the student to complete a capstone design project. ABET Criterion 5 states, “Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier coursework and incorporating appropriate engineering standards and multiple realistic constraints" (ABET, 2017). This project has been submitted to fulfill our capstone design requirements. This project includes the design of two rehabilitation devices for Roosevelt Elementary School. The design addresses real-world constraints regarding rehabilitation, medical device design, manufacturing, and health and safety.

Acknowledgements

Our team would like to thank our MQP advisor Brian Savilonis for his time, guidance and advice throughout our project. We would also like to thank several other individuals within the WPI community who generously assisted us in our brainstorming, manufacturing and testing of both the light wall and the rocking horse: Ian Anderson (Sr. Instructional Lab Technician), James Loiselle (Sr. Instructional Lab Technician), Daniel Hanson (ElectroMechanical Technician), William Appleyard (Electronics Technician), and Galahad Wernsing (WPI ECE graduate student). Also, from the Roosevelt Elementary School we would like to thank Laurie Fazio (Occupational Therapist), Kelly Williamson (Principal), and all other Roosevelt teachers and aides for their time, constant communication and impartation of knowledge of their student's disabilities. Without these individuals, this project would not have been possible.

Abstract

Our client, Roosevelt Elementary School, is designing a sensory room for their students with various mental and physical disabilities that will feature several rehabilitative devices. The school has asked our team to develop a floor plan for their sensory room, finding practical locations for the school's contribution of devices and activities, as well as design and build two rehabilitative devices of our own to be used in the room and aid in therapy for the children, taking into consideration their wide range of disabilities. The first activity that we designed for the Roosevelt Elementary School's sensory room was a modified rocking horse that assists in core and back support for children with minimal muscle tone/function and moderate muscle tone/function. The second activity that we integrated into the Roosevelt Elementary School's sensory room was a light wall, which is aimed to mentally stimulate the children who will be using it, mainly geared towards those who have been diagnosed with Autism and Down Syndrome. Our light wall will constantly stimulate the children mentally and will allow them to continuously improve their coordination skills, while providing a fun and captivating game. The sensory room floor plan and two integrated activities that our group has designed are key elements to Roosevelt Elementary School's rehabilitative and educational program for their students with mental and physical disabilities.

1. Introduction

In the United States, nearly 120,000 babies are born each year with a disability [1]. A disability is defined as a physical or mental condition that limits an individual's movements, senses, or activities. Disabilities affect everyday life and can prevent those who have them from performing crucial activities of daily living (ADLs), negatively influencing their ability to develop and function independently. Rehabilitation serves to work towards improvements with disabled children and attempt to counter the effects of their disability, maximizing restoration of normal mental or physical functions. When a disability is not caused by an irreversible disorder, physical rehabilitation can significantly improve the capability of muscles and allow them to develop enough strength to perform ADLs. For disabilities that impact mental and emotional capabilities, several common mental rehabilitation methods exist to stimulate these individuals and work towards internal function and control. One rising method of rehabilitation with children is the creation of a sensory room. This sensory room is filled with different features/activities that allow users to enjoy themselves while strengthening their brain. Our project is working to combine mental and physical rehabilitation devices into one expanded sensory room in order to assist children with a wide range of disabilities.

More specifically our team is working with Roosevelt Elementary School, located on Grafton Street in Worcester Massachusetts. Roosevelt Elementary is a public school with about 650 students. Of these 650 students about 80 children have diagnosed disabilities, both mental and physical (Roosevelt). These children are taught in separate classrooms to cater to their specific learning needs and work directly with teachers that specialize in a variety of disabilities. At the school, there is an on-site occupational therapist and physical therapist, speech therapist, and one-on-one aides for 80% of the disabled students. Overall, out of all students at Roosevelt Elementary School, children with disabilities make up a significantly larger percentage of total students than percentages seen in other schools in the area, which is why our group chose this school.

2. Literature Review

2.1 Disabilities

Roosevelt Elementary School features 20+ disabilities which students in their programs suffer from. Since these children will be in contact with the sensory room and our rehabilitative devices, it is imperative to take their needs and abilities into consideration before beginning the design process. A brief description of each disability listed in the client statement is provided below.

- **Autism:** Autism refers to a developmental disorder that is characterized by difficulty in social interaction or communication and by restricted or repetitive patterns of thought/behavior [38]
- **Down Syndrome:** Down syndrome, sometimes referred to as trisomy 21, is a genetic disorder associated with physical growth delays, mild to moderate intellectual disability, and characteristic facial features [37].
- **Sensory Defensive Disorder:** defined as a sensitivity and negative reaction to one or more types of sensations including touch, movement, sound, taste, texture, and sound [36].
- **Speech Impairment:** Speech or language impairment is defined as a communication disorder that adversely affects a child's educational performance, such as stuttering [39].
- **Angelman Syndrome:** This syndrome is a genetic disorder that mainly affects the nervous system, resulting in severe intellectual disabilities or balance/movement issues. [18]
- **Hypoxic Ischemic Encephalopathy:** Hypoxic ischemic encephalopathy is a condition caused by reduced oxygen supply to the brain and other organs. [17]
- **Microcephaly:** This condition causes the head of a child to be smaller than normal, damaging developing brain tissue. [16]

- **Premature Birth:** A birth that occurs before the start of the 37th week of pregnancy is considered a premature birth, resulting in several medical complications ranging in severity. [14]
- **Stroke/Seizures:** A stroke occurs when blood circulation in the brain is disrupted. This causes electrical activity/signals within the brain to cease functioning accurately. [13]
- **Low Muscle Tone:** Individuals with low muscle tone have reduced muscle control and are not able to physically function as a normal individual would. [26]
- **Motor Function Impairment:** This condition results in partial or total loss of function of a body part, usually a limb(s), which may result in overall muscle weakness, poor stamina, lack of muscle control, or total paralysis. Motor function impairment can range in severeness, from minimal to moderate motor function. [27]
- **Rett Syndrome:** Rett syndrome is a rare genetic neurological disorder that occurs almost exclusively in girls and leads to severe impairments, affecting nearly every aspect of the child's life: their ability to speak, walk, eat, and even breathe easily. [28]
- **Cerebral Palsy:** Cerebral palsy is a group of disorders that affects a person's ability to move and maintain balance or posture. [29]
- **Muscular Dystrophy:** Muscular dystrophy is a group of diseases that cause progressive weakness and loss of muscle mass resulting from abnormal genes (mutations) interfering with the production of proteins needed to form healthy muscle. [30]
- **Visual Impairment:** Visual impairment refers to a decreased ability to see to a degree that causes problems not fixable by usual means, such as glasses. The term blindness is used for individuals suffering from complete or nearly complete vision loss. [6]
- **Cortical Visual Impairment:** Cortical visual impairment (CVI) refers to vision loss caused by damage to the pathways between the eye and the brain and the specific parts of the brain responsible for vision. In many cases, individuals with CVI have eyes that function normally. However, the translation of the image that the individual sees into a connected idea within the brain is absent or inaccurate. [7]
- **Hearing Impairment:** Hearing loss, also known as hearing impairment, is a partial or total inability to hear. An individual who has little to no hearing is considered deaf.

Hearing loss may occur in one or both ears and can be temporary or permanent. In children, hearing problems can affect the ability to learn spoken language and in adults it can create difficulties with social interaction and at work. [20]

- **Hydrocephalus:** Hydrocephalus is a condition in which excess cerebrospinal fluid (CSF) builds up within the ventricles (fluid-containing cavities) of the brain and may increase pressure within the head. [8]

2.2 Rehabilitation Techniques for Various Disabilities

Rehabilitation for disabilities varies depending on what part of the body is affected. In general, rehabilitation activities and devices can be categorized into four different categories: minimum motor function, low motor function, behavioral, and visual/hearing.

2.2.1 Minimum Motor Function

Individuals with minimum motor function use a wide range of rehabilitation technology to work towards restoring muscular ability. The main categories of rehabilitation for those with limited motor function are: occupational therapy, speech therapy, muscle training and exercises to help strengthen flexibility, balance, motor development, and mobility. An example of an exercise that works on improving motor control as well as hand dexterity is isolating fingers, which can be done by having the child squeeze a clothespin or push coins into the slot of a piggy bank. Another specific activity for children with minimal motor function focuses on bilateral coordination, teaching the child to control both sides of the body simultaneously. Some examples of this are drumming, pushing a rolling pin, or pulling apart legos. Upper body strength and stability is another focus for therapy with children who have limited muscle control. For this focus, some exercises that the child can perform include crawling, lying on their stomach while reading, or pouring water from a pitcher into a cup. Lastly, another focus for rehab is having children practice crossing their midline. This refers to teaching the child to reach across the middle of their body with their arms and legs, bringing each limb to opposite sides. Some activities that exercise crossing the midline are making figure eights with streamers or throwing balls at a target to the right or left of the center. Overall, rehabilitation for those with limited motor function tends to be practicing relatively simple tasks repetitively until normal function is regained [2].

2.2.2 Moderate Motor Function

Moderate motor function rehabilitation techniques, although less repetitive and more general when compared to minimum motor function techniques, are still crucial for muscle development. This rehabilitation focuses on reducing stress on the body, while still allowing the child to participate in physical activities. These activities or devices tend to focus on the core, arms, or legs through exercises including balancing activities, walking activities, or lifting weighted objects. By integrating these exercises into games or activities, the child is able to enjoy themselves while still strengthening their muscles. These exercises vary depending on the child's specific disability as well as severity of their lack of motor function. For children with moderate muscle tone, one exercise that they may partake in is the wheelbarrow walk. The child would have their legs picked up by another individual (most likely a personal trainer) and would walk/move using their arms. This exercise works both arms and core while also creating a fun atmosphere as the child attempts to see how far they can walk. If a child had a more severe low muscle tone the wheelbarrow exercise may not be possible and could further hurt the child. If this is the case, another exercise involving a walker may be more practical. A walker features a seat which supports the child and is attached to wheels to help make each step less effort. By allowing the child to walk with assistance instead of using a wheelchair, the child will be able to participate in more activities as well as strengthen their legs and potential work towards walking unsupported. [21]

2.2.3 Behavioral

Behavioral disorders, including Autism and Down Syndrome, are developmental disabilities that involve patterns in disruptive behavior. Children with behavioral disorders exhibit an inability to build and maintain relationships with peers, display inappropriate behavior under normal conditions, display sensitivity to certain touches, smells, noises, and colors, and display difficulty in sensory processing.

Early intervention with children who have behavioral disabilities is associated with social and cognitive improvement. Rehabilitation for children with Autism includes occupational therapy and speech therapy. Due to the different severities of each condition involved with each disability, it is important to note that certain therapies may be stimulating for one child while irritating the next.

Occupational therapy techniques are broken into different focuses: fine and gross motor skills, sensory processing and modulation, postural control and muscular coordination, and self care and school tasks. Therapy techniques for each focus are listed below.

Fine Motor Skills:

- Play with small toys to increase grasp and grip strength
- Play with putty or play dough
- Pick up different objects and textures with chopsticks

Gross Motor Skills:

- Army crawling, crab walking, bear walking
- Catching, kicking, throwing and rolling a ball
- Jumping, running, skipping, climbing

Sensory Processing and Modulation:

- Vestibular stimulation which is the use of back and forth, side to side, or spinning motion
- Utilization of muscles in activities like jumping, running, crashing, pulling, and pushing
- Deep pressure activities

Postural Control and Muscular Coordination:

- Sitting and bouncing on a therapy ball
- Laying on stomach while completing an activity
- Balance games

Speech therapy activities center on encouraging the child to speak. Techniques used are prompting commands, setting up request situations, and building conversational routines. For example, if a child is seated on a rocking horse, an aid can rock them for a moment or two and then stop to wait for the child to signal for "more" or say the word "more." Setting up request situations involves placing an object further away, requiring the child to communicate to request the object be moved. Routine is very important for children with behavioral disabilities, so building conversational routines is an effective speech therapy. For example, a child can be placed on a rocking horse and the aid can say "Ready, set…" and wait for the child to say "go" which will be rewarded by rocking the child on the rocking horse.

2.2.4 Visual/Hearing

Difficulty with vision or hearing for children are vastly different disabilities; however both can use similar rehabilitation tactics to help stimulate the respective weak sense. If the child has completely lost either the sense of sight or hearing, it is important to heighten other senses that are functional. The most common rehabilitation technique for both the visual and hearing impaired includes activities where the child can experience different textures and compare how items feel. Children who have very low vision or are considered legally blind will benefit from being given items that are significantly different in texture, while they are taught what they are interacting with [5]. Another option would be integrating braille into certain activities. Emphasizing auditory instruction while stimulating the child's sense of touch will strengthen each of these senses and allow them to become less reliant on sight.

For those with impaired vision that can still be rehabilitated, activities stimulating their sense of touch are still commonly used but not prioritized. Slightly different activities would assist in strengthening sight. Children with CVI have trouble connecting an image they observe with what it actually represents [6]. This includes differentiating distinct colors or common items that they interact with [7]. Therefore, activities including cause and effect buttons would allow the child to develop their sight. For example, the child would press a colored button and see a specific picture appear paired with a sound, which helps with association. The most effective colors to be used for a child with CVI are yellow and red. Coordination/balance exercises are very helpful for children attempting to improve sight, such as for those suffering from hydrocephalus [8]. For building coordination and balance, suction cups are often used. Removing suction cups from a surface and placing them in another location requires strength and precision, as well as visual effort.

For the hearing impaired, sight and touch are very commonly used for stimulating the child's other senses. Frequently used activities are: moon sand, gel bags, glitter bottles and colored spaghetti. Bright colors for these activities are integrated to stimulate the child's sense of sight. Additionally, the bright colors benefit children who are visually impaired, allowing them to easily distinguish different colors while playing. Overall, the most effective rehabilitation technique for children who are visually and hearing impaired would be a sensory wall. This wall would include areas of differing textures and activities that would stimulate the senses of sight and touch, benefiting both categories of disabilities.

2.3 Sensory Rooms

The human brain functions by producing and regulating responses to the body's sensory experiences. This includes interactions through all five senses: touch, sight, smell, taste and hearing. The connection between the brain recognizing these interactions and the behavior produced as a result is called "sensory integration." [9] Normally, most people do not pay attention to how these signals translate into behaviors because this is an involuntary process. For individuals with developmental disorders, including mental and physical disabilities, this process is much different. Those with mental disabilities, including Autism or Down Syndrome, process these interactions with their senses very differently. This can lead to distress or discomfort [9]. Individuals with physical disabilities cannot recognize the input through whichever sense is impaired, and therefore struggle to behave in a normal fashion in response to a stimulus. In order to provide treatment to these sensory problems, an increasingly popular method is the use of a sensory room.

Sensory rooms are spaces specifically designed to stimulate and develop the user's senses through the room's atmosphere and activities available. The phrase "sensory room" is a general term that encompasses a variety of therapeutic spaces, specifically designed for target groups of users [10]. Although there are different ways sensory rooms can be adjusted depending on what types of benefits are desired, all sensory rooms generally have the same purposes. These purposes include creating a positive safe space, promoting self-car and recovery, and therapeutic engagement [10]. For young students, sensory rooms serve as a therapeutic space that provides children who have special needs with personalized sensory input. A sensory room assists in calming and focusing the students, better preparing them for learning and interacting with others and coping with seemingly normal experiences [9].

Equipment within this room, considered multi-sensory equipment, are very effective in the treatment of sensory disorders for children as well as adults. Activities can also be integrated into the room to stimulate the users' brains and make the room more engaging. These activities and equipment can help develop vocalization, motor skills, color recognition, cognitive development, coordination and several other key life skills. An example of a sensory room is shown in Figure 1, which is an image of a sensory room at the Hanover Elementary School in Meriden, CT [12].

Figure 1: Sensory Room at Hanover Elementary School (Meriden, CT) [12]

2.4 Psychological and Physical Effects of Movement

Many of the disabilities that children experience are related to muscular control. When children are diagnosed with genetic disabilities, depending on the severity of the disability, they can lose their ability to move at a very young age. Without natural daily movement, people lose their ability to perform activities of daily living. Biologically, movement is necessary to move the fluid in the inner ear which instructs the muscles on how to respond to a certain stimulus. The inner ear is associated with proprioception which tells the body how to judge position, direction, speed, and depth of a movement pattern. It also uses the information received from the eyes, ears, skin, nose, and mouth in order to make decisions on muscle movement. Bodily movement also applies to the mental development of children. A pediatrician explains that “Children learn by experiencing their world using all of their senses. The restriction of movement, especially at a young age, impedes the experiential learning process. Movement allows children to connect concepts to action and to learn through trial and error.” Movement is also associated with memory. This is because it is easier for a child to remember multisensory activities since their whole body is involved, so without these activities it is harder for children to remember how to complete simple tasks. Movement also gives children a sense of independence, even if it is as simple as rocking in a rocking horse.

Another important role that movement plays is vestibular stimulation, which is the input that the body receives when experiencing movement or gravity. This skill is particularly important for postural control, which is a complication for children with muscular deficiencies. Even when a child is not able to move on their own, they can be exposed to different forms of vestibular stimulation such as sitting buckled into place and moving on a supported rocking horse or swing. One case study researched vestibular stimulation on a 19-month-old boy with hypotonic cerebral palsy. Hypotonic cerebral palsy means that the child has very low muscle control and can not support their bodies due to “floppy” muscles. The 19-month-old had received physical and occupational therapy two times per week since he was five months old. Over these 14 months, he cried at almost every session and had shown little to no improvement. In the study, the baby was taken completely out of physical and occupational therapy and put into vestibular stimulation sessions for one hour, three times per week, for ten weeks. The 19 month-old's vestibular stimulation treatment was swinging and rocking (with high support for each). When he started stimulation, he cried the first couple of sessions but eventually became more excited and comfortable with the process and stopped crying. This decrease in being scared/crying is due to the idea that "sensory integration of the vestibular system provides a 'gravitational security' which helps with the emotional well-being of patients." This contributes to physical and emotional security; as the baby developed stronger vestibular response from the therapy, his body was able to be in more control of feeling safe and secure so he could relax and stop crying [23].

Over the ten week period the 19-month-old boy went from a mental developmental age of one month to four months (a three month improvement), and from a six month motor development age to a ten month one (a four month improvement). Although they ages still fall behind the 19-month development age that a healthy baby would be at, the 10 week stimulation proved to show better improvements than the therapy had over 60 weeks (15 months). Stimulated movement, in many cases like this one, have been shown to work as a highly effective rehabilitation device for children with muscular disabilities resulting from muscular diseases and behavioral disorders [23].

3. Project Strategy

3.1 Initial Client Statement

Our client, Roosevelt Elementary School, is building a sensory room for their students with disabilities that will feature several rehabilitative devices. The school has asked our team to develop a floor plan for their sensory room as well as to design and manufacture two rehabilitative devices to be used in the room to aid in therapy for the children.

3.2 Objectives and Constraints

3.2.1 Light Wall

The first activity that we are aiming to integrate into the Roosevelt Elementary School sensory room is a light wall. The light wall design is aimed to mentally stimulate the children who will be using it, mainly geared towards those who have been diagnosed with Autism and Down Syndrome. In order to develop this activity, we have based our designs off of an existing product. This wall, referred to as a tWall, is composed of a grid of several tiles that can be programmed to light up in a specific pattern. When the child touches the tile that is lit, another tile will light up in a different color. The tWall is typically made from LED multicolor lights, touch buttons (plastic, translucent white), and a frame made from either stainless steel or aluminum [19]. Available for purchase, a tWall ranges in size and price. It can come in three sizes: tWall 16, tWall 32 and tWall 64. These numbers refer to the amount of tiles within the wall, and cost about $6,000, $9,000, and $14,000 respectively [22]. The different types of walls are shown in Figures 2, 3, and 4. Our group will most likely be focusing on creating a variation of the tWall 16. Since these light walls that are currently on the market are significantly out of our price range, we have decided to use the design as a base for our project.

Figure 2: tWall 16 [22]

Figure 3: tWall 32 [22]

Figure 4: tWall 64 [22]

Implementing a light wall into the sensory room at Roosevelt Elementary School would be very beneficial to the children and will help mentally/physically stimulate them. This wall will improve motor and sensorimotor skills as well as muscle tone, by requiring the children to apply a force to the wall in order to select the tile that is lit. It will also develop physical mobility and physical endurance by requiring the children to move back and forth, depending on which tile they are aiming for. Lastly, the wall will train the children in coordination as well as reaction time. They will need to quickly differentiate which tile is lit and find patterns to predict which tile will be lit next. Overall this wall will stimulate the children and improve their neurological capabilities, which will be tested once the assembly is complete.

3.2.2 Rocking Horse

The second activity that we will be designing for the Roosevelt Elementary School sensory room is a rocking horse. Typically, there are two different designs for rocking horses currently on the market. In the first design, the horse/seat sits on a curved base that is in contact with the floor, allowing the entire seat and frame to rock back and forth. This assembly is shown in Figure 5.

Figure 5: First Rocking Horse Design [15]

The second design consists of the horse/seat hanging from a rigid frame by straps. In this design, the horse moves only relative to the frame, which remains stationary as shown in Figure 6.

Figure 6: Second Rocking Horse Design [15]

We have decided to use the first design of the rocking horse for the Roosevelt Elementary School sensory room. The team felt that the first design offered more structural security, allowing it to last longer and withstand more unexpected forces than the second design.

This design allows the user to enjoy a simple activity while working on their core strength. Students in Roosevelt Elementary School are unable to use a normal rocking horse due to their ranging disabilities; therefore a modified version is needed. This modified version must be able to assist in core and back support for minimum muscle tone and moderate muscle tone. The normal rocking horse design lacks the back support that is vital for a child with physical disabilities, preventing the development of muscle function. Therefore, our group will be designing interchangeable seat components that will make the rocking horse accessible for all children at the school.

3.3 Revised Client Statement

The Roosevelt Elementary School, our client, has asked our team to develop a floor plan for their sensory room as well as to design and manufacture two rehabilitative devices to be used in the room to aid in therapy for the children. After taking all of the children's disabilities into consideration, our group produced two different device designs for the room. The first rehabilitation device we developed was a rocking horse for children with muscular disabilities of all ranges. The second rehabilitation device was a light wall for children with behavioral and vision disabilities. The two devices were designed, prototyped, tested, and built and implemented into the sensory room in March 2020.

3.3 Project Approach

For planning a project approach, the team created a Gantt Chart. Every term, the team planned short term and long term goals as well as weekly tasks and assigned completion dates. This allowed for the team to remain on track and complete each portion of the project on time. The Gantt Chart can be seen in Figure 7.

NUMBER	TASK TITLE	START DATE	DEPENDENCIES	A term							B term							C term						
				Aug/Sept			Sept/Oct				Oct/Nov			Nov/Dec				Jan/Feb			Feb/March			
				1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	Meet with Occupational Therapist	8/28/19																						
2	Detemine Goals/Mission Statement	9/3/19																						
3	Determine Project Objective	9 /3/19																						
4	Background Research	9/3/19																						
5	Complete IRB	9/3/19																						
6	Background section of paper written	9/8/19																						
7	Develop list of rehabilitation devices	9/8/19																						
8	Choose 3 to focus on	9/8/19																						
9	Intro section of paper written	9/16/19																						
10	Begin Preliminary designs and develop SolidWorks Model and Drawings	9/16/19																						
11	Meet with Occupational Therapist and Roosevelt teachers to discuss design options	9/16/19																						
12	Research materials and edit designs based on feedback	9/23/19																						
13	Bill of materials	9/23/19																						
14	Methods section written	9/30/19																						
15	CAD 3 edited designs	9/30/19																						
16	CAD 3 testing on designs	9/30/19																						
17	Develop rough prototypes of 3 designs	9/30/19																						
18	Develop rough prototypes of 3 designs	9/30/19																						
	General																							
19	Bill of Materials	10/22/19																						
20	Send and Revise Floor Plan	10/22/19																						
22	Stress Analysis and Writing	12/2/19																						
23	B Term Paper (progress)	12/2/19																						
24	IRB	12/11/19																						
	Rocking Horse																							
	Welding Training	10/22/19																						
25	Practice Welding	10/28/19																						
26	Weld Base of Rocking Horse	11/11/19																						
27	Finalize Seat Design	11/25/19																						
28	Order Materials for Seat Design	12/2/19																						
29	Determine Seat Attachment Method	12/2/19																						
30	Bend Base	12/9/19																						
	Light Wall																							

	Rocking Horse	
	Welding Training	10/22/19
25	Practice Welding	10/28/19
26	Weld Base of Rocking Horse	11/11/19
27	Finalize Seat Design	11/25/19
28	Order Materials for Seat Design	12/2/19
29	Determine Seat Attachment Method	12/2/19
30	Bend Base	12/9/19
	Light Wall	
31	Meet with Professors for Research	10/22/19
32	Finalize Design	10/28/19
33	Order Materials	11/4/19
34	Cut Tiles	11/12/19
35	Determine Code for Raspberry Pi	11/12/19
36	Build Backing	11/18/19
37	Build Frame	11/18/19
38	Build Grid	11/18/19
39	Wire Lights and Buttons	12/9/19
	General	
41	Finalize Methods section	
42	Write Results section	
43	Design and print poster	
44	Present	
45		
	Rocking Horse	
46	Manufacture seat design	1/15/19
47	Manufacturing attachment method	1/27/19
48	Physically test rocking horse	2/3/19
49	Build aesthetics: head, hair	2/10/19
50	Bring rocking horse to school for use	2/17/19
51		
	Light Wall	
52	Test code in combination with light wall and wiring	1/15/19
53	Light wall aesthetics: paint, sandblasting	1/15/19
54	Develop implementation method for setting up light wall at the school	1/20 /19
55		
56		
57		

Figure 7: Gantt Chart

4. Design Process

To aid in therapy for the children in the Roosevelt Elementary school, our group has decided to design a light wall and a rocking horse.

4.1 Sensory Room Floor Plan

In order to begin the design of the rocking horse and the light wall, we determined the size restraints of each by planning the general layout of the sensory room. We collected the dimensions of the room and dimensions of the equipment that the school is planning on placing within the room. AutoCAD was utilized to model the layout and better understand the size constraints we had to consider when designing and manufacturing the light wall and rocking horse. We then sent this AutoCAD layout to the Roosevelt Elementary School to allow them to begin organizing the room. The AutoCAD sketch is shown in Figure 8.

Figure 8: AutoCAD Floor Plan Draft

4.2 Light Wall

4.2.1 Needs Analysis

The students at Roosevelt Elementary School would benefit from having a light wall implemented into their sensory room. This light wall would stimulate the childrens' brains and improve coordination, as they locate the illuminated LED. It would also allow them to be more physically active, as they apply a force to the wall selecting the tile that is lit. Through talks with the school's physical and occupational therapists, who work directly with the children, an activity that improves motor and sensorimotor skills and muscle tone, builds upon coordination skills and reaction time, and develops physical mobility is a necessity for their sensory room. Our group is aiming to fulfill this need and improve the neurological and motor capabilities of the students at Roosevelt Elementary School.

4.2.2 Design Requirements/Specifications and Industry Standards

To begin designing the light wall, the team identified several design specifications for our ideal final product. These design specifications are divided into seven categories: function/performance, safety, human factors, operating environment, manufacturability, maintenance and aesthetics. In total, the team recognized 18 design specifications and ranked them using a design matrix. A design matrix is a tool used to rank and compare the importance of design specifications using a -1, 0, or 1 value. All 18 design specifications are listed across the top of the design matrix, and the same specifications are listed along the left of the design matrix. The number values of -1, 0, and 1 indicate whether the design specification in the top row is more or less important than the specification in the left column. The -1 value means the top design specification is of less importance than the left design specification, 0 means the same importance, and 1 means the top specification is of more importance. A small section of this design matrix is shown in Figure 9. The complete design matrix can be found in Appendix A. Using the design matrix, the team determined that the specifications regarding safety were the most important: ensuring the wires are covered and that the wood would not splinter and injure the children.

1		LED will light up	LED will shut off when button is pressed	LEDs will be randomized	Tile must withstand up to 325 lb of force	Button must be pressed with minimum force of 5lb	Spring must allow for movement with minimum force of 5lb	The wall will have an on/off button	Wires must be hidden	Wooden frame must be sanded to prevent splinters	LEDs and buttons must not be reachable by children, covered by tiles	LEDs must be bright enough for the children to see	Wall must be able to be hung on the Sensory Room wall
2	LED will light up	X	0	-1	1	0	0	-1	1	1	1	0	-1
3	LED will shut off when button is pressed	0	X	-1	1	0	0	-1	1	1	1	0	-1
4	LEDs will be randomized	1	1	X	1	1	1	-1	1	1	1	1	1
5	Tile must withstand up to 325 lb of force	-1	-1	-1	X	-1	-1	-1	1	1	0	-1	-1
6	Button must be pressed with minimum force of 5lb	0	0	-1	1	X	0	-1	1	1	1	1	-1
7	Spring must allow for movement with minimum force of 5lb	0	0	-1	1	0	X	-1	1	1	1	0	-1
8	The wall will have an on/off button	1	1	1	1	1	1	X	1	1	1	1	0
9	Wires must be hidden	-1	-1	-1	-1	-1	-1	-1	X	0	-1	-1	-1
10	Wooden frame must be sanded to prevent splinters	-1	-1	-1	-1	-1	-1	-1	0	X	-1	-1	-1
11	LEDs and buttons must not be reachable by children, covered by tiles	-1	-1	-1	0	-1	-1	-1	1	1	X	-1	-1
12	LEDs must be bright enough for the children to see	0	0	-1	1	-1	0	-1	1	1	1	X	-1
13	Wall must be able to be hung on the Sensory Room wall	1	1	-1	1	1	1	0	1	1	1	1	X
14	The LEDs must be seen in the room lighting available in the Sensory Room	0	0	-1	1	0	0	-1	1	1	1	0	-1
15	Light Wall must be under $500	1	1	1	1	1	1	0	1	1	1	1	0
16	Light Wall must be under 30 pounds	1	1	1	1	1	1	0	1	1	1	1	0
17	Tiles must be able to be cleaned with class/plastic cleaner without damaging materials or wiring	0	0	-1	1	0	0	-1	1	1	0	0	-1
18	Grid and frame must be able to be cleaned with household disinfectants (e.g. lysol wipes) without damaging materials or wiring	0	0	-1	1	0	0	-1	1	1	0	0	-1
19	The wall must have a black background to emphasize the red coloring of the LEDs	1	1	0	1	1	1	0	1	1	1	0	-1
20													
21	TOTALS	2	2	-10	12	1	2	-13	16	16	10	2	-12

Figure 9: Light Wall Design Matrix

Regarding industry standards, since the light wall will be used by the Roosevelt Elementary School's children with disabilities, safety was the team's main concern. Below is the list of all design specifications used in the design matrix. These specifications were also considered the industry standards for the light wall.

Design Specifications

- Function/Performance/Operating Characteristics
    - LED will light up
    - LED will shut off when button is pressed
    - LEDs will be randomized
    - Tile must withstand up to 325 lb of force [24]
    - Button must be pressed with minimum force of 5lb
    - Spring must allow for movement with minimum force of 5lb
    - The wall will have an on/off button

- Safety
    - Wires must be hidden
    - Wooden frame must be sanded to prevent splinters
    - LEDs and buttons must not be reachable by children, covered by tiles

- Human Factors
    - LEDs must be bright enough for the children to see

- Operating Environment
    - Wall must be able to be hung on the Sensory Room wall
    - The LEDs must be seen in the room lighting available in the Sensory Room

- Manufacturability/Cost
    - Light Wall must be under $500
    - Light Wall must be under 30 pounds

- Durability/Maintenance
    - Tiles must be able to be cleaned with class/plastic cleaner without damaging materials or wiring
    - Grid and frame must be able to be cleaned with household disinfectants (e.g. lysol wipes) without damaging materials or wiring

- Aesthetic
    - The wall must have a black background to emphasize the red coloring of the LEDs

4.2.4 Conceptual and Alternative Designs

Our next step for the light wall was to brainstorm design ideas, which we categorized into three levels of difficulty. For each of our three ideas, the concept remains the same: 16 clear tiles with LEDs behind each that are toggled with the activation of a push-button. From this base, our group produced designs for a wall ranging from easy, medium and difficult in both the manufacturability of the wall and user interaction once constructed. The first, easiest design features a wall where the tiles simply light up when touched and turn off when touched again. This wall would require little coding and wiring, and as a result would be the cheapest option requiring minimal effort to make. Regarding user interaction, the child using the wall would be exercising as they move around to select different tiles. However, the user would not improve their coordination or be significantly stimulated mentally. The next, medium-level design is built off of the previous wall and consists of a program beginning with the first LED illuminated. The program's pattern would then be triggered by an initial hit on the wall, which switches the first LED off and then toggles another LED on the wall. Once that tile is pushed, the same cycle continues until the last tile is hit. To manufacture this version of the wall, extensive coding and wiring is necessary. This wall would allow the children to be more involved and captivated than the first design, since the light pattern will serve as a game, and this wall will also build the user's coordination skills. One downfall to this medium-level design is that the pattern of lights will never change and can easily be memorized by the children, diminishing the stimulation of their brain. The most difficult design will aim to address this shortcoming. The last version of the wall will integrate a randomized feature that changes the lighting pattern each time the child uses the wall. This will constantly stimulate the children mentally and will allow them to improve their coordination regardless of the amount of times they have used the wall. More extensive coding is required for this version; however the wiring will remain the same. Our group aimed to create the difficult version of the light wall.

4.2.5 Feasibility Study/Experiments

After brainstorming the three design options for the light wall, the team needed to research the feasibility of each design. The team met with several ECE professors and technicians, CS students, ECE graduate students, and Washburn technicians to gather information on which design was most plausible. From each source, it was evident that the most difficult design was feasible. However, the team found that constant connection with the ECE department was necessary for successful and timely completion of the light wall.

4.2.6 Modeling

To begin building the light wall, our group decided to attack the two main aspects separately: the electrical/coding components and the mechanical components.

4.2.6.1 Mechanical Components

In order to begin constructing the mechanical components of our light wall, we established a list of materials needed. This list was revised and finalized through consultations with William Appleyard, an ECE technician, and Ian Anderson, an instructional lab technician in Washburn Labs. Our component and materials list can be found below:

- Backing: 36” x 36” plywood
- Frame: 4, 2” x 4” plywood pieces
- Grid: Plywood strips
- Clear tiles: 16 7.5” x 7.5” polycarbonate squares
- Springs: 64, 1.72 lb/in
- Shoulder screws: ¼” diameter nylon
- Lights: 16 red LEDs
- Buttons: ½” push-buttons, 16 for tiles and one extra for an off switch

A CAD model of this assembly, including each of these components, can be seen in Figures 10 and 11.

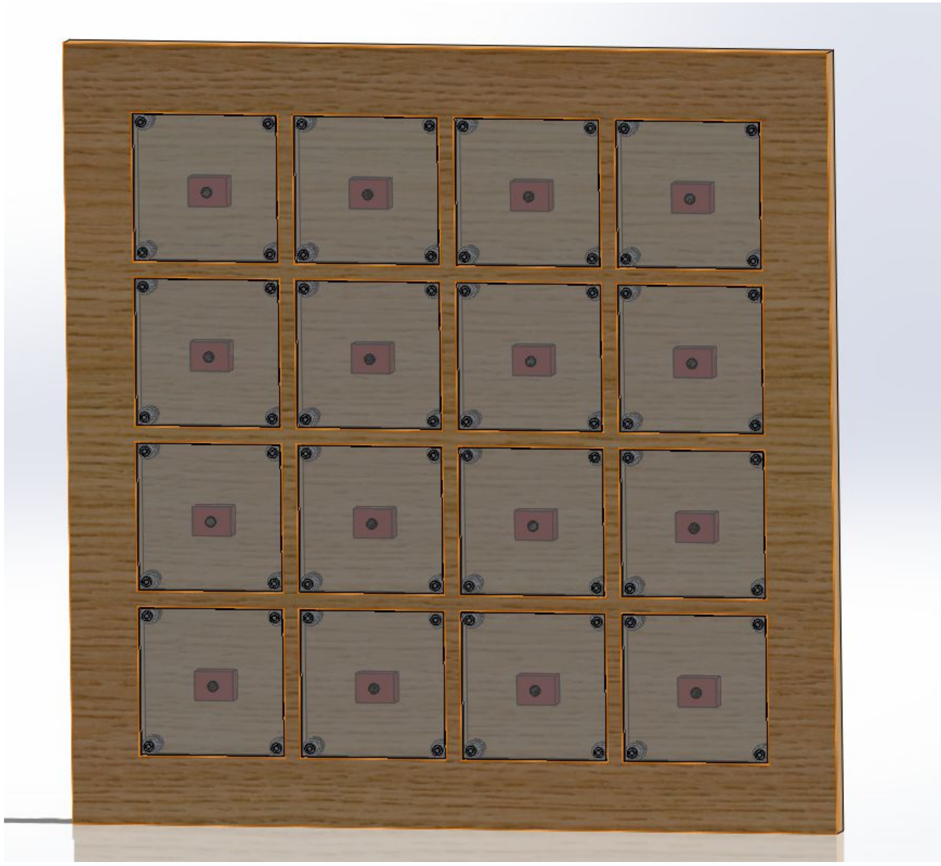

Figure 10: Design of Light Wall

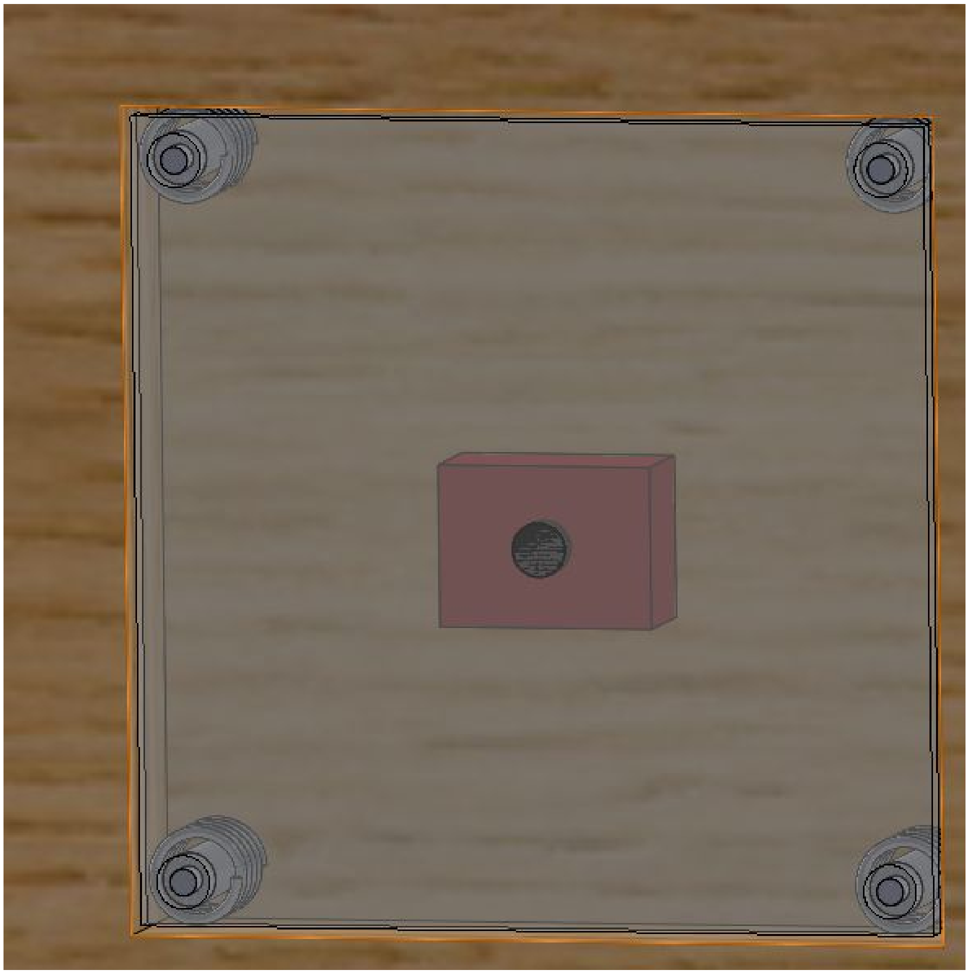

Figure 11: Close Up of Tile Setup

The wooden backing and frame provides a base for all other components, and allows for the entire design to be hung on the Roosevelt Elementary School's wall when completed. The grid, running between each tile, will prevent the tiles from getting stuck under each other as the children push them in. The LED and push button will sit behind each tile, allowing for the button to be in contact with the tile when pushed in but preventing the LED from being damaged by this force. Each tile will be held into place by four nylon shoulder screws, threaded through the back of the wooden backing. These screws will support the weight of the tiles while maintaining their position as the children use the design. Each of these shoulder screws is equipped with a spring, which will return the tile back to its original position after it is pushed by the user. The frame, backing and grid will be painted black to better illuminate the red LED. An image of the finished backing and grid, before being painted black, can be seen in Figure 12.

Figure 12: Grid and Backing

Figure 13 shows the backing and grid painted, drilled with holes for the tiles and for the wiring.

Figure 13: Grid and Backing, Drilled and Painted

4.2.6.2 Electrical Components

In order to begin manufacturing the electrical components of our light wall, our group completed extensive background research for the coding and wiring aspects of our design. We met with several Electrical Engineering students and Computer Science students to get a better understanding of the plausibility of our initial design idea. Two individuals who were instrumental in assisting the team in the electrical and coding elements of this project were Daniel Hanson, ECE technician, and Galahad Wernsing, graduate student. The components needed for this section are:

- Raspberry Pi 3

- Display, keyboard and mouse to complete coding on the device
- Wires
- Male/Female jumper wires
- Resistors: 4 100 kΩ, 4 220 kΩ
- 16 perfboards and 16 mini breadboards (for initial testing of the wiring)

Each perfboard will be drilled into place behind the clear tiles using 1 inch stand-off screws. These boards will hold the red LEDs and push buttons in place, each soldered to ensure durability. The wires and jumper wires will be used to connect the boards to power/ground and to the specified GPIO pins of the Raspberry Pi. The resistors will be used to ensure the correct amount of current flows through the circuit, preventing the Raspberry Pi or LEDs from damage. The wires from each perfboard will run through drilled holes in the backing to allow for a cleaner aesthetic and to keep them out of reach from the children.

The wiring was constructed in a matrix configuration. This reduced the number of pins needed on the Raspberry Pi, while still allowing complete control of each button and LED. The wiring diagrams for the buttons and LEDs are shown in Figures 14 and 15.

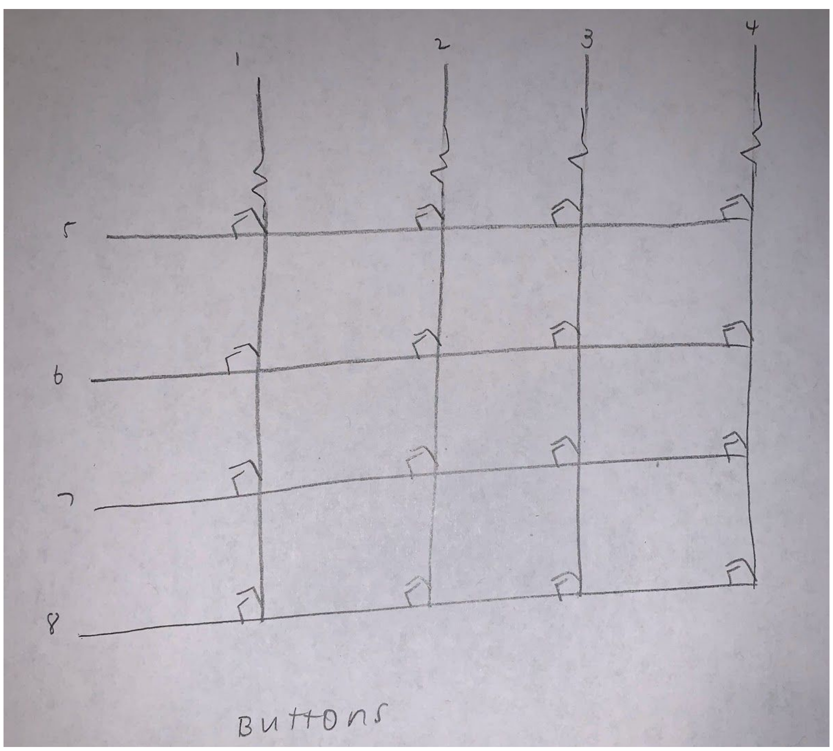

Figure 14: Matrix Wiring Diagram for Push Buttons

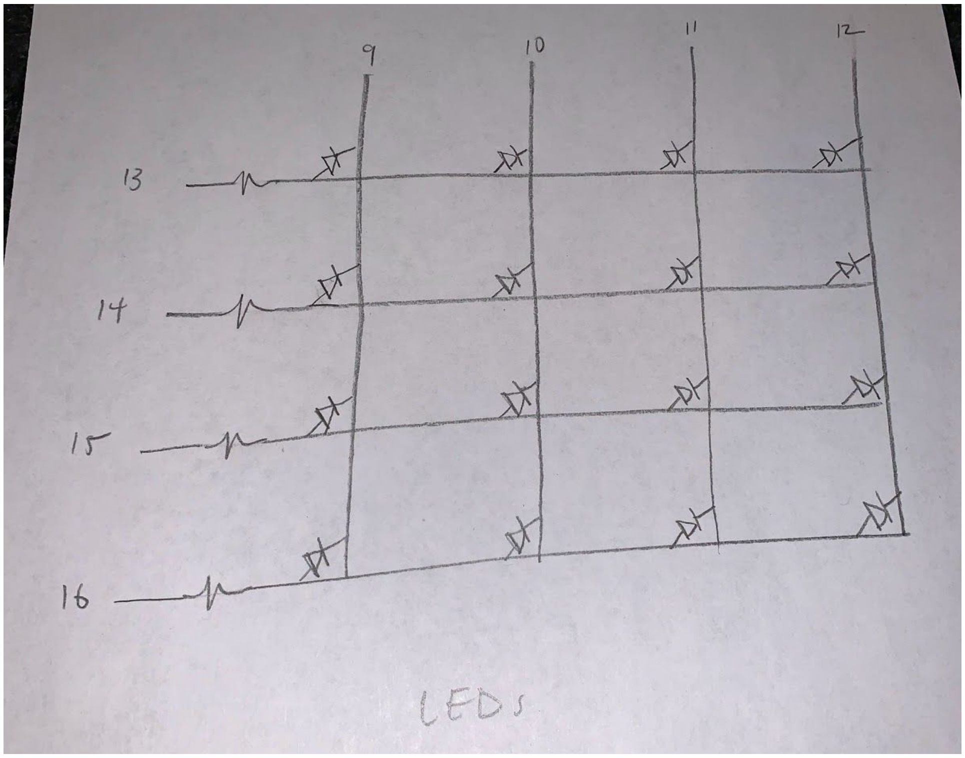

Figure 15: Matrix Wiring Diagram for LEDs

In total, the wiring of push buttons and LEDs used 16 GPIO pins on the Raspberry Pi: 8 pins for the buttons and 8 pins for the LEDs. Each button or LED is located using 2 pins, one from a column of the respective wiring diagram grid and one from a row. For example, to locate the top leftmost LED from Figure 14, one would use GPIO pins 9 (from the column location) and 13 (from the row location). The same location process applies to the push buttons.

The coding aspect of the wall was imperative for the activation of each LED and recognition of each button. The light wall code can be found in Appendix B. This python code, which runs on the Raspberry Pi, initially lights a random LED. Then, the user will press the tile that corresponds to the LED that is lit, which triggers the button and shuts off the initial LED. Once this LED is turned off, another randomly selected LED is switched on. This pattern repeats indefinitely until the light wall is turned off.

The python code above first calls the definition "light_on()." This function first ensures that all LEDs are powered off. Each GPIO pin, shown by the numbered lines in the wiring diagrams (Figures 14 and 15), can be manually set to "high" or "low" in the python code. "High" is equivalent to setting the GPIO pin to 3.3V, and "low" is equivalent to setting the GPIO pin to ground. With the group's wire set up, setting the LED columns to "low" and the rows to "high" would cause the current to run from the row, across the LED up through the column. This results in the LED turned on. For the project's purposes, as stated above, the "light_on()" definition first powers all LEDs off. This is done by reversing the current flow in each LED, setting the GPIO columns "high" and the rows "low". As a result, the current flows in the incorrect direction across the LED and does not power the LED. Next, in order to randomize the light pattern, the code calls for a random integer from 0-15. The diagram in Figure 16 shows the integer assignment for each LED.

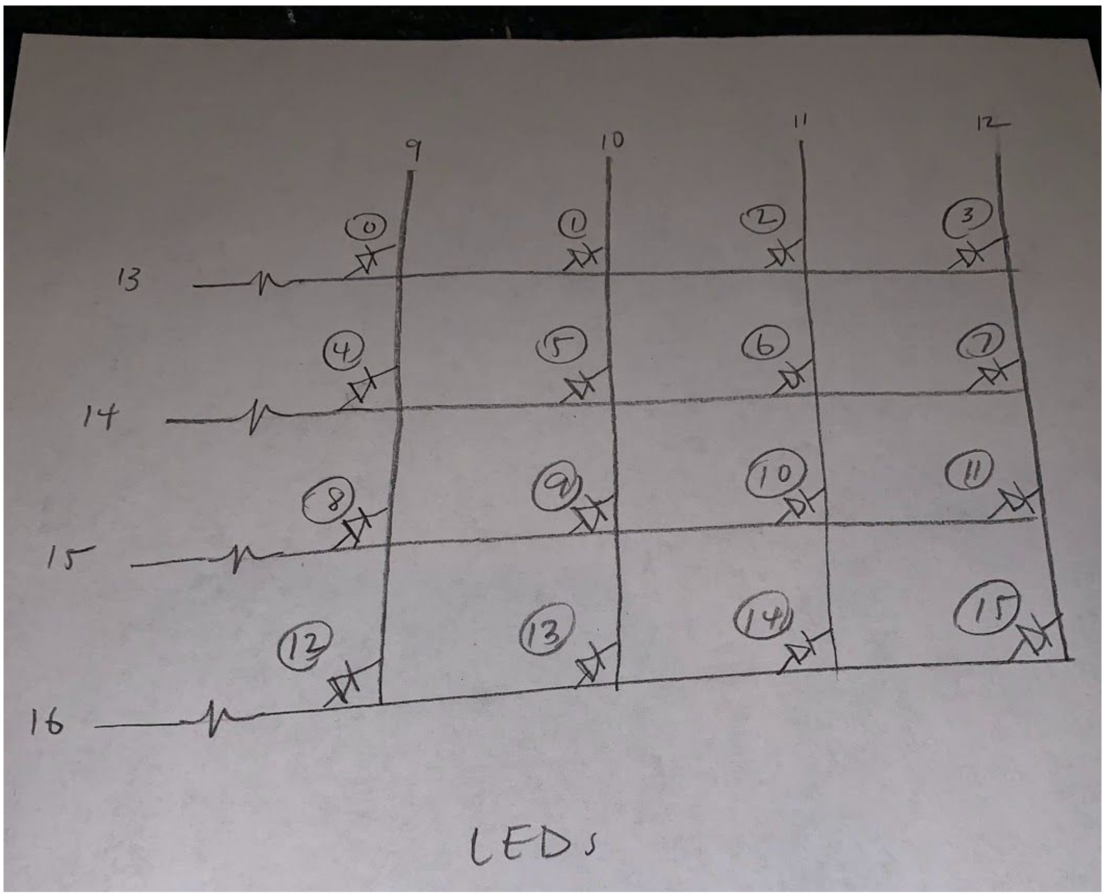

Figure 16: Integer Assignment for LEDs

Once the random integer is selected, the code identifies the grid location (row and column pin numbers) of the LED that corresponds to the random integer. After this information is found, the "high" and "low" GPIO settings for this row and column will be switched; the respective column is set "low" and the row is set "high." This toggles the random LED on.

Next, once the random LED has been switched on, the python code calls the "push_button()" definition. This function will wait until the button paired with the illuminated LED is pushed. The function searches for a drop in current over the previously specified row and column, which occurs when the respective button is pushed. A drop in current in any other location on the wall, which indicates the wrong button being pressed, will result in no change. Once the correct button is pushed, the code will restart. Restarting the code shuts off all lights and illuminates a new random LED, waiting for the button in the same random location to be pushed. The process of illuminating a new LED once the correct previous button has been pushed is instantaneous.

Another aspect of the code that was implemented was an off switch. Unplugging a Raspberry Pi without shutting down the program can severely damage the device. Therefore, the team added a definition called "Shutdown()" that turns the Raspberry Pi off when the children are done using the wall. When the off button is pushed, the "Shutdown()" definition is performed and the light wall powers down.

After the code was complete, the last step to complete the electrical portion of the wall was to allow for the code to run on the Raspberry Pi without need for a display and keyboard. This is called running the Raspberry Pi "headless." Once this setting was achieved, plugging in the light wall resulted in the code running immediately upon boot of the Raspberry Pi.

4.2.7 Preliminary Data (Final Light Wall First Iteration)

The combination of the mechanical configuration and the electrical components completes our light wall design. This wall allows for a randomized pattern of LEDs, activated by the pushing of the tiles, to stimulate the children's brain and build their coordination skills. The first iteration of the final assembly of the wall can be seen in Figure 17 below.

Figure 17: Final Light Wall, First Iteration

4.3 Rocking Horse

4.3.1 Needs Analysis

After speaking with the teachers, and the physical and occupational therapists a Roosevelt Field Elementary School, we determined that a device to provide a rocking motion would help to improve the core strength of students with varying disabilities and would serve as a rehabilitative device for children with minimum and moderate motor function. There is currently not a device that mimics the benefits of a rocking horse for kids with disabilities. Rocking motions are important therapy techniques for many disabilities, including Autism and Down Syndrome, therefore all children who will have access to the sensory room will be able to use the rocking horse (Christy, 2017).

4.3.2 Design Requirements/Specifications and Industry Standards

Before beginning the design of the rocking horse base and seat, we developed a list of design specifications for our ideal rocking horse design. These specifications fell under several categories: function/performance, safety, human factors, operating environment, manufacturability and aesthetics. Then, we determined which specifications were the most important using a design matrix. Our design matrix discusses the specifications of our design and compares the importance of each specification with a ranking system. All of our specifications are listed on the top row of the matrix, and the same specifications are listed in a column on the left of the matrix. In each cell there is a ranking of -1, 0, or 1. Negative 1 is of lower importance and positive 1 is of higher importance. This number indicates whether the design specification in the top row is more or less important than the design specification in the left hand column. We identified a total of 33 design specifications for our rocking horse; A snippet of the matrix is shown below. The entire matrix can be found in Appendix C. From this matrix, we determined that the specifications addressing safety of the design were the most important and needed to be included in our plans for possible configurations.

	Rocking horse must rock back and forth without tipping	Rocking horse must be able to rock back and forth while holding children in a weight range from 33-128lbs	The curved base of the rocking horse is inclined 20 degrees from the floor on each side	Rocking horse must withstand force used by Aid to move the horse and child	Manual pushing by caregiver	Interchangeable seats attached through adjustable crutch-like push button system
Rocking horse must rock back and forth without tipping	X	0	-1	0	-1	-1
Rocking horse must be able to rock back and forth while holding children in a weight range from 33-128lbs	0	X	-1	0	-1	-1
The curved base of the rocking horse is inclined 20 degrees from the floor on each side	1	1	X	0	0	-1
Rocking horse must withstand force used by Aid to move the horse and child	0	0	0	X	0	-1
Manual pushing by caregiver	1	1	0	0	X	0
Interchangeable seats attached through adjustable crutch-like push button system	1	1	1	1	0	X
Buttons: 5.5 ounce or 0.377 lbf start button activating force	1	1	1	1	1	1
Button diameter >= 5in	1	1	1	1	1	1
Handle on front and back must be able to stop rocking of the horse with a child on it	0	0	0	0	-1	-1
Straps and headrest to secure body	0	0	-1	0	-1	-1
No sharp edges in contact with body - use of foam to cover hard areas	0	0	-1	0	-1	-1
Maximum tipping angle: 40 degrees from horizontal (Floor)	0	0	-1	0	-1	-1
Lifetime ~ 5 years	1	1	1	1	1	1

Figure 18: Rocking Horse Design Matrix

As for industry standards the team had to consider two industries: the rocking horse industry and the rehabilitation device industry. From the rocking horse industry we used the angle that the bent base of a rocking typically makes with the floor and performed tipping tests on CAD to ensure that this angle would work for our design. We also considered the typical design of a rocking horse which inspired our three beam support on each side connecting to the base. Because our rocking horse is very different from those typically on the market that was all we could use from that industry. The rehabilitation device industry was very helpful with guiding the team on what safety mechanisms needed to be implemented. We found that typical rehabilitation devices require a safety factor of 4 as a rule of thumb, but you can find exact factors depending on what specifically you are designing.[34] To be extra safe, because the rocking horse will be used by children with special needs, we decided to use a safety factor of 10. With the materials and design that we were using it was relatively easy to achieve this safety factor. With the research found from both of these industries we were able to maximize the safety of our design.

4.3.3 Conceptual and Alternative Designs

4.3.3.1 Conceptual and Alternative Designs of Rocking Horse Base

The rocking horse was designed to be made of a base and two interchangeable seats. We sketched out multiple rocking horse base designs beginning with a thicker base and box like seat support as shown in Figure 19. The holes in the base would have allowed the seating system to be adjusted in a similar way to crutches.

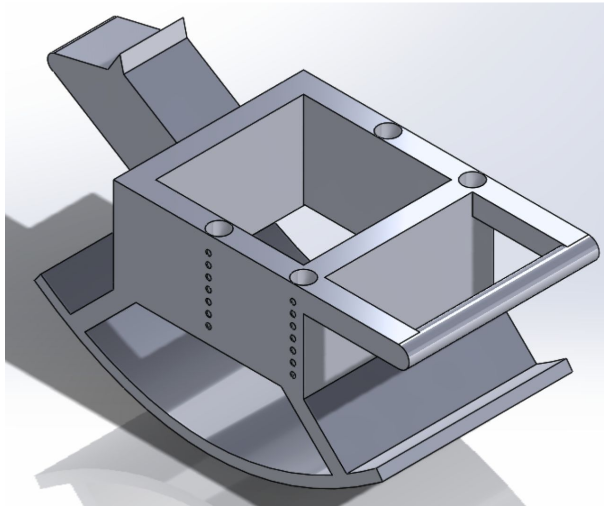

Figure 19: Initial Design of Rocking Horse Base

We then changed our design to have two individual bent base beams because the solid base added too much unnecessary weight and material. We also chose to make all of the solid metal sections around the midsection of the horse to hollow aluminum tubing to reduce the weight. Using the aluminum tubing instead of the solid metal would make the horse easier to manufacture. We chose to make the midsection of the rocking horse a 3'x 2' box-like structure because with the straight square tubing a square was the only option for a shape to make. We chose 3'x 2' because we needed room for kids, aged 5 to 12, to fit inside with ample room so as to not make them feel confined or restricted. We also needed our seating systems to fit comfortably. One seat is a full size car seat, 12.38 x 20.25 x 17.38 inches. The other is a saddle which needs to accommodate male and female children aged 5-12 years. The smallest weight and height the seat would need to accommodate would be approximately 40 pounds and 3.5 feet tall [25]. The largest weight and height would be approximately 90 pounds and 5 feet tall [25]. The rectangular bar extended off the back is a handle. The handle was necessary because the rocking horse needed to be able to accommodate the kids who do not have the strength to rock themselves and therefore, require an aid to do so. In order for the aid to rock the horse comfortably and be able to stop the horse at any time, we included a handle out of the back of the horse. We decided to put it on the back of the horse for 2 reasons. The first reason is children with muscular disabilities will use this as a rehabilitation device to give them movement and it has been studied that it is more effective for them to feel a sense of independence when experiencing vestibular stimulation. By putting the handle in the back they cannot see the aide pushing them and therefore can feel a sense of independence during movement. The second reason for the handle in the back is for aesthetics. We wanted to maintain the look of the horse in order to make it more appealing for young children so we needed to keep the front of the horse free for the head of the horse. As for the bent base beams, we choose to angle them at 20 degrees above the floor. We chose 20 degrees because we found that most of the rocking horses currently on the market maintain angles between 18 and 22 degrees. Because we are working with a larger rocking horse we decided to go with the middle ground of those, which led us to 20 degrees. In order to confirm the safety and reliability of 20 degrees we performed a tipping test on CAD and it passed all of the requirements to not tip (a more descriptive section of this test can be found in 4.3.3). With all of these aspects in mind we drew a sketch of our proposed design which can be found along with a CAD model, below in Figures 20 and 21.

Figure 20: Sketch of Second Base Design

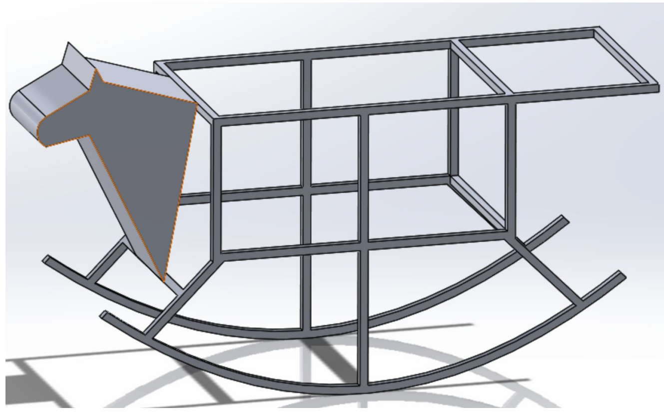

Figure 21: Second Base Design

For the final design of the rocking horse base, we added five additional cross beams to sit between the two bent base pieces. We added these beams for structural support because when we switched from having solid metal pieces around the midsection to the hollow aluminum tubing pieces, we lost some of our safety factor, so in order to get that back up around 10 the support beams were necessary. The extra beams can also serve as leg support for the children in the saddle seat. The final design also includes the holes needed for the two seating systems.

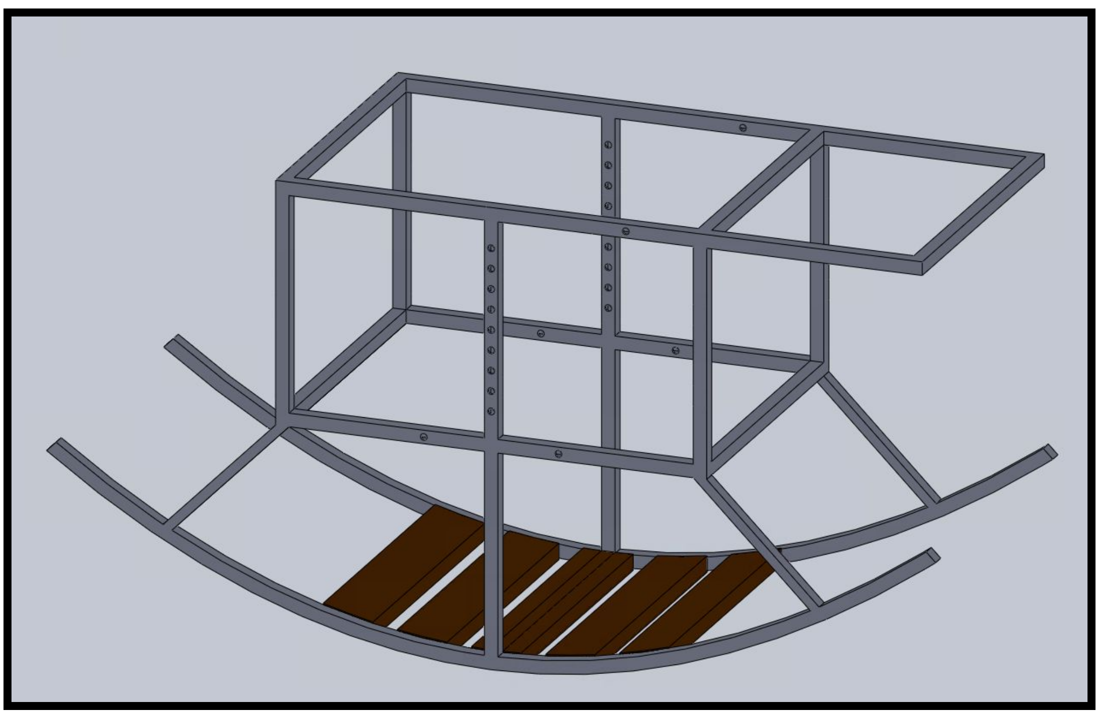

Figure 22: Final Base Design

4.3.3.2 Conceptual and Alternative Designs of Seating Systems

The rocking horse was designed to include two interchangeable seats allowing for children with a wider variety of disabilities to benefit from the device. One seat was designed for children with moderate to high motor function. This seat design enables the child to utilize their core and stabilize themselves while rocking. The chair mimics the design of a walker already used in therapy at Roosevelt Elementary, which is shown in Figures 23-25.

Figure 23: Seat Design Example Open

Figure 24: Seat Design Example Fully Extended

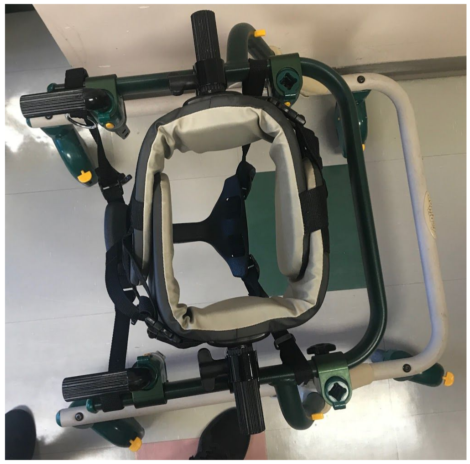

Figure 25: Seat Design Example Fully Closed

The moderate to high motor function seat we designed is made up of a crutch system that allows the seat's height and width to be adjusted as well as to attach to the rocking horse. The seat is also made of a saddle like seat base exemplified in Figure 26, and a foam back support exemplified in Figure 23-25. The straps and the buckle around the foam back support ensure the seat is adjusted to the size of the child and secured on the child's waist. The seat base allows the child to stand, using a dog bone shape that will fit in between the child's legs. The base will be strapped onto the beams of the base of the rocking horse similar to what is shown in Figure 26.

Figure 26: Seat Base Design Example

Our design allows for attachment to the middle beam of either side of our base, as indicated in Figure 27. The chair is designed to use a crutch-like system made of aluminum to lock into the base and allow for adjustment in the height and width of the chair, which accommodates the different sized children using the device. Holes about an inch apart on the middle beam of each side of the base were included in the design to serve as a crutch-like height adjustment. We decided on inch increments, because this accounts for the varying heights of the children and allows for small adjustments to be made. The height adjustment was designed to be a solid aluminum rod that fits into the middle beam of the rocking horse base. The holes allow for height adjustment and the pin shown in Figure 28 secures the seat into place at the selected height. A hollow aluminum rod sits on top of the solid aluminum rod. Another solid aluminum rod is able to move through the hollow aluminum rod to attach the seat to the base of the horse and serve as a width adjustment. The solid rod pushes against an aluminum plate sewn into the side of the foam seat. The aluminum plate is designed with two slots for the straps that wrap around the seat to fit through as well as a circular indent that serves as a place for the aluminum rod to sit. A nut and bolt system secures the solid aluminum rod used for width adjustment into place. The system allows for the adjustment of the seat's width to accommodate different sized children. A sketch of the moderate motor function seat system design is shown in Figure 29.

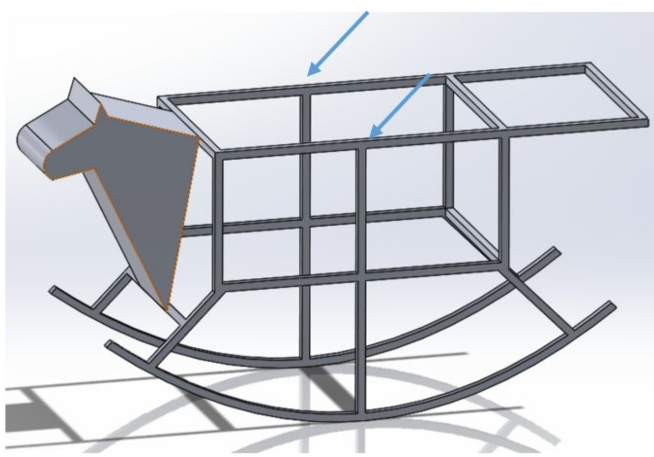

Figure 27: Rocking Horse Base Middle Beam Indication

Figure 28: Quick Release Pin

Figure 29: Sketch of Moderate to High Motor Function Seat System

The seat for children with minimum motor function was designed to mimic a tomato seat shown in Figure 30, which is commonly used to support children with Cerebral Palsy. Unlike the moderate motor function seat, the minimum motor function seat is designed to attach to its support system, so both the support system and the seat are inserted or removed when the seat is being switched out. The design of the minimum motor function seat support system consists of 3 aluminum tubing beams horizontally attached to the bottom and back of the seat. Two bars are attached to the bottom of the seat and one bar is attached at the top of the back of the seat. L-shaped aluminum bars are then attached to the edges of the aluminum beams on the seat, allowing the seat to be able to sit in the rocking horse base. Holes are included in the design for pins as shown in Figure 28 to secure the seat in place. The design of the system requires an aide to remove the seating system from the rocking horse by pulling the pins out of all three parts of the midsection and then maneuvering the seat out of the horse. A sketch of this system is shown in Figure 31, the placement of where the system attaches to the base is shown in Figure 32.

Figure 30: Tomato Seat

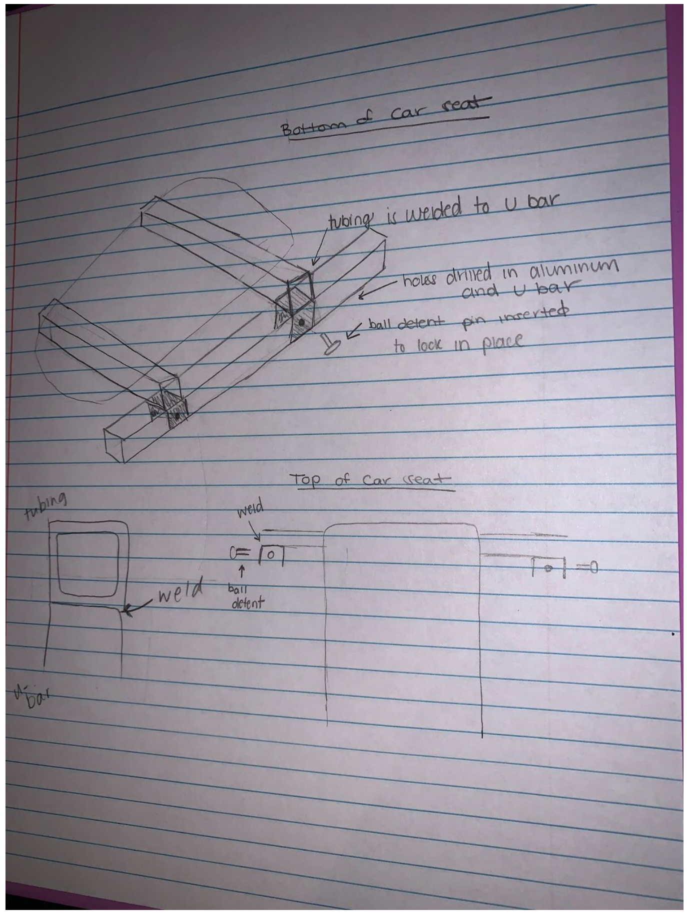

Figure 31: Booster Seat Attachment System

Figure 32: Indicated Areas for Booster Seat Attachment

4.3.4 Feasibility Study/Experiments

After brainstorming the different design options for the rocking horse base and seat, the team needed to research the feasibility of each design. The team met with the machine shop specialists to gather information on which design was most plausible. From our sources, it was evident that the designs were feasible and manufacturable as long as light-weight materials, such as the aluminum tubing, were used. The CAD model was also used to test the feasibility of the design. Tip Over testing and Static deformation analysis were performed in SolidWorks to ensure the design would be safe. Static Stress analysis was also performed on a force plate to ensure the correct weights were being considered in testing the materials used and the final rocking horse. These studies are expanded upon in the Design Verification section 5.2.

4.3.5 Modeling

When choosing what material to build the rocking horse base out of we had to take into account two factors: strength and weight. Because we decided our rocking horse has to support children up to 300 pounds (to account for double the largest child) performing all types of uncontrolled movement, we had to choose a metal that would support that weight. With this in mind we looked at yield strength and ultimate tensile strength (UTS) of many different metals. We also had to account for the weight of the rocking horse because it needed to be easily transportable for us to get the rocking horse to the school and for the school to move it around as needed. With weight in mind we looked at strength to weight ratios. After extensive research, we narrowed it down to steel and aluminum and analyzed the chart shown below.

Figure 33: Steel and Aluminum Chart [31]

From this chart we found that the yield strength and UTS of aluminum was plenty strong enough to support the 300 pound weight that we set as our safety weight and it had a much better strength to weight ratio than aluminum. Also we took into account the ease of welding both aluminum and steel and found that aluminum is much quicker because it has a higher thermal conductivity than steel which allows it to heat up faster making for a faster weld and also allows the weld to solidify much quicker [32]. As for the shape of the aluminum, we chose square because welding a square is much more effective and allows for a much stronger and easier weld. When choosing the wall thickness and diameter, we met with a machine shop specialist and he suggested that a 1’’ diameter with a 0.0625’’ wall thickness would be strong enough and not jeopardize the light weight of the rocking horse. So with this information we used these dimensions to CAD the design and performed extensive stress tests to ensure that this size aluminum tubing would be strong enough. When we saw that this size was plenty strong (a safety factor larger than 10), we used a thinner wall thickness and performed the CAD tests again and the aluminum didn’t fail but the safety factor heavily decreased and we wanted to keep it up around 8-10 because our device is going to be used for high risk children. Ultimately, we decided on 1" x 0.625" aluminum square tubing based on safety, weight, strength, and welding abilities.

Figure 34: Aluminum Square Tubing

We cut the aluminum tubing to size using a band saw and a hack saw based on the dimensions in our CAD model. We welded the base of the rocking horse together using tig welding. We chose TIG welding after research and consultation with a machine shop specialist. TIG stands for tungsten inert gas. The tungsten and weld puddle are protected with an inert gas, which in this case was Argon. Welds were placed where beams connected to each other and were placed on all four edges of the square tubing. Each side of the rocking horse was welded together first and then the cross beams were welded on to attach both sides. We then welded the beams that attach the main component of the base to the bent beams on the bottom of the base. The bottom beams were bent using the mechanism shown in Figure 35 below.

Figure 35: Beam Bending Mechanism

After the beams were bent, we welded them to the beams attached to the main component. After all the welds were completed, we grinded and sanded them down to ensure they were strong and smooth. We did this to make sure no aid or student would be cut by any sharp edges created by the welds or by the aluminum. Black rubber caps were then placed on the ends of the aluminum tubing that were exposed as a safety precaution and to improve aesthetics. We then drilled ¼ holes, each an inch apart, into the middle beam of the base for the crutch system of the moderate to high motor function seating system. We also drilled holes into the beams of the rocking horse for the low motor function seat. The welding process is shown below in Figures 36-40.

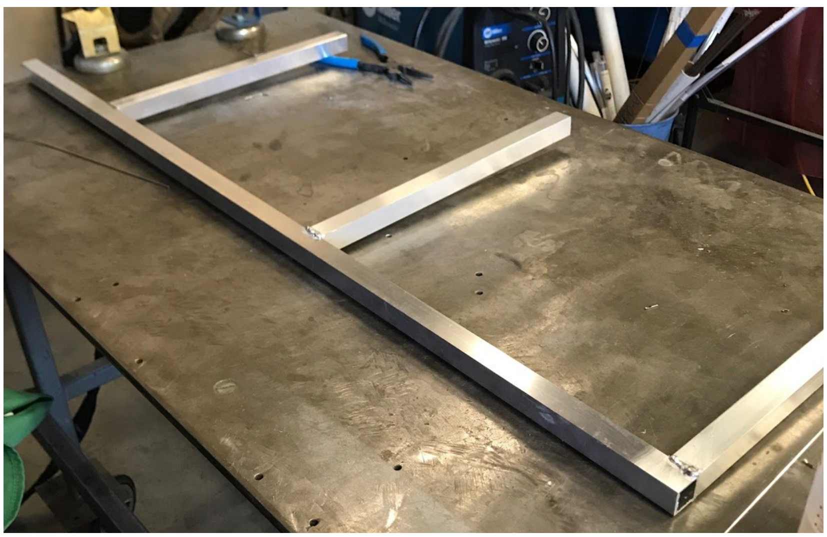

Figure 36: Welding Progression 1

Figure 37: Welding Progression 2

Figure 38: Welding Progression 3

Figure 39: Welding Progression 4

Figure 40: Welding Progression 5

In order to manufacture the low motor function seat we used a kids' car seat. The reason for this choice was because the carseat most closely mimicked the tomato seat within our budget. Aside from our budget, because of the strength of our horse we did not want to use a tomato seat. A tomato seat weighs about 13 pounds which is a lot of additional weight to account for, whereas a car seat only weighs about 2 pounds [33]. We also felt that the car seat was an appropriate substitution for the tomato seat because tomato seats are the primary seat used for students with low motor function and it has a weight limit of about 110 pounds. [33]. Our car seat also has a similar weight limit (100 pounds), and reinforcements were added which increases this weight limit at least 10 pounds, so we felt that this seat would cover all students properly. One difference between the car seat and the tomato seat is the strapping. A tomato seat has shoulder strapping as well as torso, whereas the car seat only has torso strapping. In order to compensate for this, additional straps that cover the shoulder section were sewn into the booster seat as shown in Figure 41.

Figure 41: Strapping System that was Sewn onto the Booster Seat

The support system for the seat was made of the same aluminum tubing used for the rocking horse base. The reason for choosing aluminum is because part of the support system had to be welded to the base of the rocking horse and the base is made of aluminum. The other reason is for its strength. After extensive testing, we found that aluminum is plenty strong to hold up the car seat as well as the child up to 300 pounds. The support system for the car seat consists of three 1''x 0.0625''x 24'' square tubes of aluminum and six L-shaped aluminum bars. The L-shaped bars rest on the top, outside corners of the square aluminum mid section of the rocking horse as shown in Figure 32. In order to get the L shaped beams fit to the square aluminum tubing, a hammer was used to mold the bars to the tubing. Each of the three square 24'' tubes was welded to the L-shaped bars, one on each end of the tube. With the tubes welded to the bars, they now act as cross beams that rest on the midsection of the rocking horse to hold the car seat up. Two of the L-shaped welded beams were placed on the bottom beam of the rocking horse to support the bottom of the carseat and the third one was placed towards the back of the top beams of the midsection of the rocking horse. A clearer image of this setup can be seen below in Figure 42. The L-shaped welded beams were then attached to the car seat for stronger support. The bottom support beams were attached by drilling ¼''x 3" screws upwards through the bottom beams and into the bottom of the car seat. The screws were then secured with nuts and bolts. The back support beam was attached to the car seat by drilling ¼''x 3'' screws through the back of the beam into the back of the carseat. In order to keep the L-shaped bars in place along the midsection of the rocking horse, a 1/4" size hole was drilled into it and through the midsection beam to create a hole through both parts. Then a pin, which is shown in Figure 18, was used to insert through both holes and lock the L-shaped welded beams, and ultimately, the car seat, into place.

Figure 42: Low Motor Function Seat Placement

The moderate to high motor function seating system was manufactured out of foam, aluminum, vinyl, straps, and delrin. The body of the seat was made of two foam rectangles. The foam was thick and durable enough to withstand wear and tear. The foam is shown below in Figure 43. Medical grade vinyl was sewn using a sewing machine to mimic a pillow case, and the foam placed inside. Vinyl was used to ensure the seat would be durable and easy to clean. The open seams were then hot glued to fully enclose the foam with the vinyl. A small pocket of vinyl was then sewn to the outer side of each vinyl enclosed piece of foam. This pocket holds the metal plates that attach the seat to the rocking horse base. The metal plates were machined using a Haas CNC Milling Machine. Two slots were machined into each aluminum plate. The plates were each ⅛” thick. The slots were 1” long and ¼” wide. These dimensions were determined based off of the straps that would feed through the plate. Straps were used to allow for further width adjustment and to allow for the child to be secured in the seat. A circular indentation was also milled into each plate to indicate where the solid aluminum rods would be welded. Each solid aluminum rod was then welded to each plate. We used a drill press to drill a ¼” hole into the two hollow aluminum rods. We then threaded the hole for a ¼" thumb screw into the top side of each of the hollow rods. This was done to manufacture the system that is used to secure the solid aluminum rods for the width adjustment. We then used a drill press to drill a ¼" hole into each square aluminum rod for the height adjustment system. The pins were a ¼" which is why we chose this dimension for the holes. The square aluminum rods were then each welded to the bottom of the hollow aluminum rods. Delrin inserts were then machine using the Haas CNC milling machine. Delrin was chosen so the metal would not be sliding against metal creating more wear. Delrin is also easier to machine. The delrin inserts were placed on either side of the hollow rod and allowed the solid aluminum rod to slide evenly through the hollow aluminum rod and reduced the play. The delrin inserts are shown in Figure 44 and 45 below and one side of the crutch system is shown in Figure 46 below.

Figure 43: Foam pieces

Figure 44: Delrin insert

Figure 45: Delrin Insert in Hollow Rod

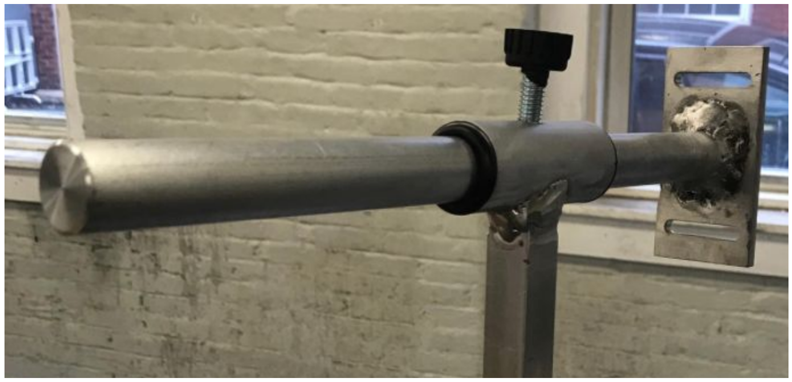

Figure 46: Crutch System

Once the seats and the base were modeled. We then used foam noodles to pad the metal to ensure safety for the students. We chose foam noodles because they could easily fit around the entirety of the beams of the rocking horse and were the most cost effective option. The foam padding is shown in Figure 47 below.

Figure 47: Foam Padding

After the rocking horse was completely padded, we covered the horse in a brown blanket to mimic the look of a horse and add a soft feel to the horse. The covered horse is shown in Figure 48 below.

Figure 48: Fully Covered and Padded Rocking Horse

5. Design Verification

5.1 Light Wall Design Verification

To verify the team's final design for the light wall, several tests were performed. For this testing, protoboards, also known as breadboards, were used. Breadboards are typically used for short term projects to validate circuit configurations and accompanying coding. Therefore, the tean wired the buttons and LEDs for each tile together using breadboards and ran the completed code on a display connected to the Raspberry Pi. This allowed us to tweak certain aspects of the code to ensure that the relationship between LEDs and buttons was correct. Figure 49 shows one test performed with the breadboards to verify the wiring and coding aspects of the light wall.

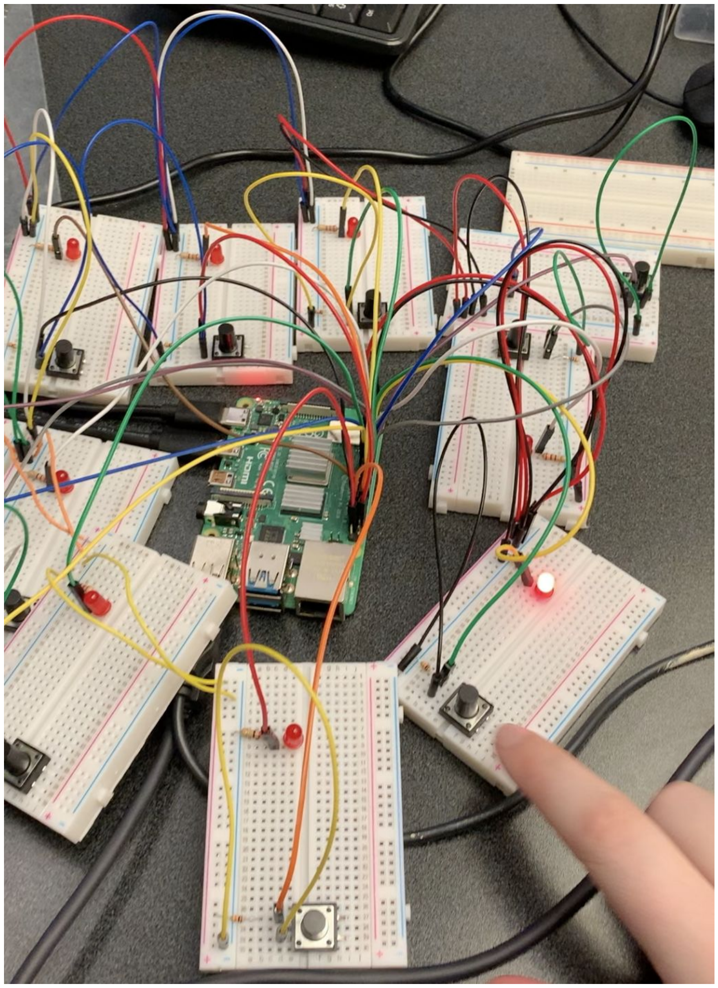

Figure 49: Breadboard Testing for Light Wall

5.2 Rocking Horse Design Verification

Following the design drafts the team conducted several tests in order to make sure that the structure would be to allow safe use without failure, even in extreme conditions. The first tests which were performed were as follows:

- Static Stress analysis
- Static Deformation analysis
- Tip Over testing at extreme points

5.2.1 Static Stress Analysis

The stress analysis was performed using Solidwork analysis on the computer animated design of the rocking horse. The stress test was set up with a force of 300lbs in the negative Y direction distributed at four points on the top of the frame signifying the strap locations of the harness seat. 300 pounds was chosen because we are building the horse for kids up to sixth grade and according to a study by livestrong, a heavy sixth grader weighs around 113 pounds [35]. Because children will be playing around and possibly jumping and quickly leaning on our rocking horse, we have to account for the total maximum force a child of 113 pounds can put on the rocking horse. In order to test this we performed a force plate experiment. We found a volunteer that weighed 120 pounds and brought her into the lab and had her perform squat jumps on a force plate to record her maximum landing force. From this experiment we collected the data shown below:

Figure 50: Force vs Time Graph of a Squat Jump

The data shows that Sofia's maximum landing force was about 1180N. We converted this to pounds to get about 265 pounds of force. To ensure that we cover anyone that might be slightly heavier than Sofia and the weight of the seating systems, we chose 300 pounds as our safety force that we wanted our rocking horse to support.

When testing our horse on Solidworks, we chose the fixed location as the very bottom of both base pieces of aluminum where the middle beams connect to the base. As shown by figure 51, the highest points of force are at the vertical aluminum rods in the middle of the frame. These rods are exposed to a stress of 15.91 MPa which is well under the yield strength value of 215 MPa. This means that our frame would work, even in this extreme case, with a safety factor of over 10. The team recognizes that a safety factor this high would not be ideal for mass production of this device as it increases the amount of material needed, as well as the cost of production. However, because our device is for a high risk community and we are only producing one, a safety factor of ten is acceptable.

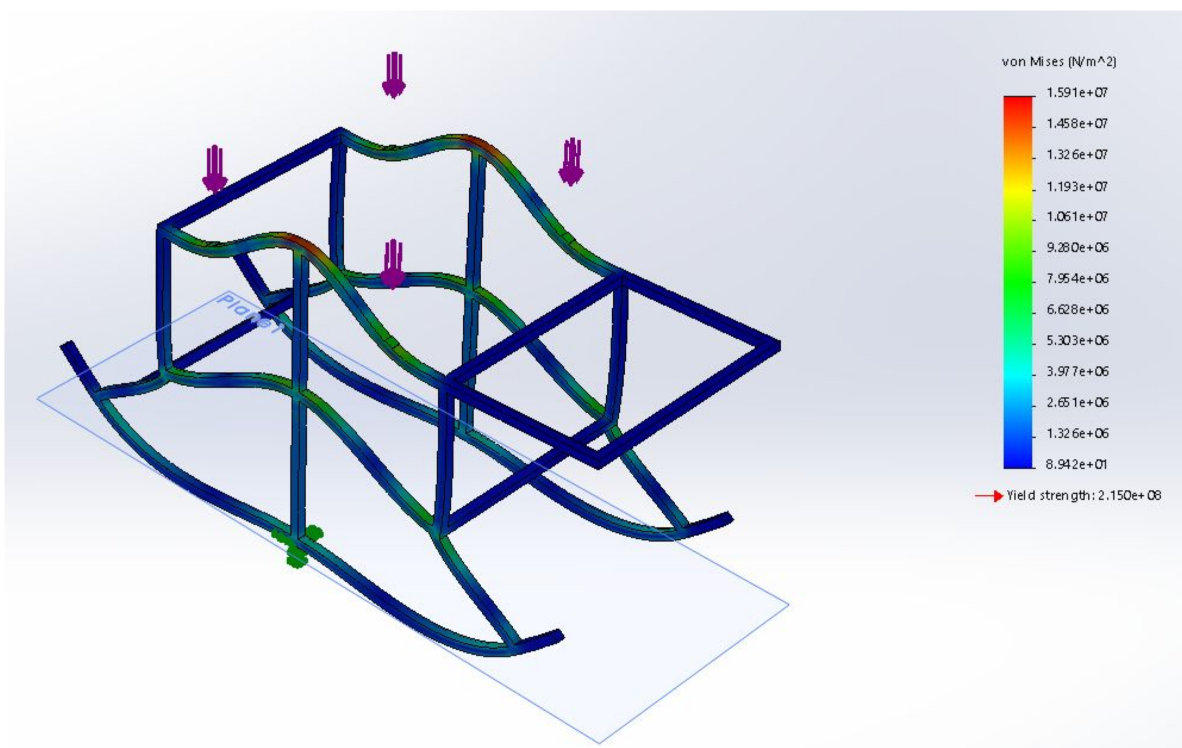

Figure 51: CAD Results for Stress Test Analysis

5.2.2 Static Deformation Analysis

The static deformation analysis was tested using Solidworks analysis on our computer animated design. The deformation test was set up the same as above: with a force of 300lbs in the negative Y direction distributed at four points on the top of the frame signifying the strap locations of the seat and fixed only at the bottom of the base aluminum. As shown by figure 56, the highest points of deformation occur at the points furthest away from the middle beam. This result seems at first glance to be extreme, however on closer inspection it is reassuring for the frame's structural integrity. This deformation is at a max, 4.775 mm which is total deformation. This deformation will not be permanent because it is considered elastic deformation, due to the stress being well below the yield stress, which means the structure will return to its original shape. Also the deformation is under 5mm which is a relatively small number in retrospect.

Figure 56: CAD Results of Displacement Analysis

5.2.3 Tip-Over Testing

For the tip-over analysis, we used solidworks to simulate a 300 lb weight placed on top of the frame on one side. The reasoning for the placement at this location was to simulate an extreme case in which a child would put all of their weight onto one side of the frame, which could happen if a child wanted to get into the horse and decided to jump onto the frame while their teacher wasn't paying attention. As shown in figure 57, the center of mass remains within the limits of the rocking horse's contact on the floor, therefore, no tip over would occur in this scenario.

Figure 57: Tipping with Weight on the Side of the Frame

6. Final Design Validation

6.1 Light Wall Design Validation

After verifying the coding and wiring configurations with breadboards, perfboards were substituted for the breadboards. Perfboards are more permanent and less vulnerable to degradation over time, therefore are essential for the light wall. The LEDs, buttons and wires were soldered into the perfboards to eliminate the possibility of wiring coming undone. Figure 58 shows the finalized backing and wiring of the light wall.

Figure 58: Final Assembly of Light Wall (Without Tiles)

Once the electrical and mechanical components were completed and successfully combined, team members tested and validated the final light wall. This is shown in Figure 59.

Figure 59: Team Member Validation of Light Wall

After ensuring that the light wall functions correctly and safely when operated by team members, the light wall was ready for implementation into the Roosevelt Elementary School sensory room. The team transported the wall to the school and introduced it to two children with Down Syndrome and Autism. Overall, after the first few tiles, the children caught on to how the light wall was operated. Both children greatly enjoyed using the wall and did not want to turn it off. The teachers, occupational therapists, and physical therapists were impressed and grateful for our work. Figure 60 shows one child using the wall.

Figure 60: Final Assembly of Light Wall, Used by Roosevelt Elementary School Children

6.2 Rocking Horse Design Validation

Figure 61: Rocking Horse being Used by Roosevelt Elementary Student

6.2.1 Post Manufacturing Testing

Following the rocking horse being fully built, one of our team members acted as a test subject and was placed in both seats. Once placed inside, the subject placed all weight possible on each seat, and then were pushed by another team member, simulating the actual rocking for a child. The team member weighed 165lbs and was 5'9'', which is above all expected heights and weights, therefore would be an extreme for the rocking horse. The tomato seat and frame held fine, no signs of deformation in any piece was found and the team member was held safely the entire time, never once feeling discomfort or felt as they may fall out or be harmed. The test subject also stood on both sides of the frame and put weight backwards, without tipping the device over, therefore reaffirming the tip over test done prior to manufacturing.

The second seat (high to moderate muscle function seat) was unsuccessful in this same test. The test subject was well below what would be a comfortable location in the horse, preventing difficulty in ability to sit while comfortably getting support for the abdomen via the belt and crutch system. Following this result, due to time constraints and being unable to buy new material, the team decided to move forward with only the tomato seat as a deliverable for the school. The second seat was saved for future work, if another group wanted to continue to work on this project.

After ensuring that the rocking horse functioned correctly and safely when operated by team members, the rocking horse was ready for implementation into the Roosevelt Elementary School sensory room. The team transported the rocking horse to the school and introduced it to a child with Cerebral Palsy and a child with Autism. Both children greatly enjoyed using the rocking horse. The teachers, occupational therapists, and physical therapists were impressed and grateful for our work.

7. Discussion

7.1 Light Wall Discussion

The light wall was a successful product in the end, as shown in section 6.1. The team delivered a full functioning light wall that allowed the children to enjoy an activity while working on hand eye coordination. Though the device was a success, the team encountered many difficulties and limitations during the building process. This team is composed of strictly biomedical and mechanical engineers, and had very limited knowledge in the area of electrical components and coding. This led to a lot more time being spent trying to figure out certain parts of manufacturing that would have been greatly reduced by having a electrical engineer or computer science major on the team. It also proved to be much more difficult and time consuming due to the choice of a Raspberry Pi as the operating system. Due to the lack of time available at the end, the team also noted that the wiring in the back was also rather unorganized and could cause difficulty for teachers if an electrical issue arises in the future.

The team also noted some mechanical features that could have been improved. The wooden frame had uneven tile slots, which lead to tighter spots for some polycarbonate tiles than others. Though to the eye this was not noticeable, some tiles failed to smoothly move and occasionally were momentarily stuck. This would have been a larger issue if the tiles were hit with a fist, however the children tended to push the tiles with consistent pressure and therefore was not an issue for them. The reason the kids had to push was the button being substantially lower in the slot than the tile, something also to note. Finally, if the child had used a closed fist and punch with full force it is possible that the tile would hurt their hands. Polycarbonate is a strong rigid plastic that has little give when hit.

7.2 Rocking Horse Discussion

Overall the rocking horse was a success; children that were placed in it loved the sensation and felt safe and comfortable. The device achieved the goal of allowing kids with low muscle function the ability to enjoy using a rocking horse. The manufacturing process took a long time and required many months of welding and machine shop work to put together the two seats and the base. Some struggles that the team encountered throughout the manufacturing process were welding issues, hole drilling issues, and exact measurement issues. It took the team about 4 weeks to get comfortable enough with welding to work on our own project and even then, there were days where none of the welds were connecting or reactions would occur the second the weld touched the metal and created big black stains on the horse. Also, there were a few times that the supplies needed to weld that day were not available. As for drilling holes to make the crutch system, the team did plan ahead well. Because the rocking horse was already all put together, the beams where holes needed to be cut did not fit into the drill press which would've made perfect straight holes. Instead the team drilled holes by hand which made the process about 5 times longer and created slightly inaccurate holes which had to be fixed by filing the holes by hand to be bigger so that the pin would fit through the holes. This created a slight delay in our finish date but the group persevered and made it work. The final issue that the team ran into with the rocking horse was imperfect measurements of the actual metal rods and beams and when lining up our rods/beams to weld them together. Some inaccurately measured beams cause others to have to sit at angles which then made it very difficult to weld two ends of an angled piece across a straight line. The group had to make use of clamps and tools that were strong enough to bend the slightly angled beams so that they were straight and could weld across a straight line. This caused some difficulty and worried the team at times about compromising the strength of the rocking horse, but with extensive testing, we trusted the strength was still there. In the end, only the tomato seat was used, as mentioned earlier.

The tomato seat was the only seat which the team felt was manufactured well enough to provide a safe and comfortable ride for the children. We eliminated the saddle seat because it allowed the child or user to drop too low in the device while the crutch system remained very high, creating a region much too large between the two sections. The saddle seat also did not have a great mechanism of attaching the horse and keeping the child sat upright. It allowed for a lot of forward and backward movement which posed some danger for the students that we did not want to risk. Also the bracing system on the saddle seat was slightly too stiff and large because we wanted to account for the largest kid in the school, which made it very uncomfortable for smaller kids. Due to time and costs, the aesthetics were also limited to blankets being cut and glued together. Lastly, there was difficulty getting team members into the tomato seat. It should be noted that the students the team observed were able to be lifted in with ease.

Despite the difficulties encountered, the horse was structurally sound, holding weights up to 175 pounds as tested by the test subjects which surpasses all weights of the students that will be using the horse. The blanket that was used as an aesthetic piece was also noted by the occupational therapist to be a strong positive to the children. She explained that sensory stimulators can be very positive to the children using the horse and the blanket allows the students to find comfort and touch stimulation all the while they are also experiencing the movement stimulation form the rocking. Stimulating these two senses at once is great therapy for the students, so the blanket addition was much appreciated by the staff at the school. The best part of this whole experience for the team was watching the first student experience the rocking horse. The OT placed the student with muscular dystrophy into the horse and the student immediately started laughing as the horse rocked and was squeezing on to the soft blanket. This satisfaction of helping a student use movement simulation for therapy made all of the hard work worthwhile. Aside from the students, the teachers were very grateful. They stressed the satisfaction that they had in the product as well as reassured the team that many students would get much use and joy out of the device.

8. Conclusions and Recommendations

8.1 Conclusions

Overall the project was a success. The team delivered two products to the school which functioned properly, allowing children at the school with disabilities the ability to participate in activities which will stimulate their senses in a safe and fun way. The process was difficult, but very rewarding. The team learned new skills and strengthened others. The team learned how to use many devices in the machine shop and honed their skills in design and problem solving. The team enjoyed working with Roosevelt Elementary School, who was very helpful and positive throughout the process. Not only was the team able to help the school, but the team also learned from the school. Dealing with specific client needs to deliver a product and work with the client along the way was crucial for the success of this project.

8.2 Recommendations

8.2.1 Light Wall Recommendations

Many minor points of interest were mentioned in section 7.1 for the light wall. If this product was to be reproduced, the team recommends some alterations to consider. First, look into using an Arduino Board or two to run the program instead of the Raspberry Pi. This would allow a much less intricate code to be used to get the same result. The change would also allow for less wiring to be needed, making manufacturing easier as well as a cleaner back of the wall and wire set up. This would allow for easier maintenance if an electrical issue arose. Another element to fix would be the frame. The frame should have all the exact same size slots and with room to spare for the tiles to ensure smooth tile movement in and out of the board. Along with this would be making the buttons closer to the tiles so less movement is needed for the child user. This would allow very physically weak children the chance to use the wall. Finally, the team suggests looking into other clear plastics with a little more give to allow for some of the force from a singular punch to be absorbed and not returned to the child's hand.

8.2.2 Rocking Horse Recommendations

The team agreed that if the rocking horse was to be recreated, alterations would be made. If another team were to recreate the device from scratch they should consider a new system to get a student in, nicer looking aesthetics, and a successful second seat. The system to get a student into the seat could be done in a few ways, either a hinge on the front creating a door, or lowering the entire seat so it's closer to the ground making it easier to lift the child over. For making it look more aesthetically appealing the team recommends sowing the blanket instead of hot glue, or looking into alternative ways to decorate the frame and seat. Finally, creating a second seat with a higher saddle seat and smaller crutch/belt component would be the biggest recommendation. This could be its own MQP if made well enough, as many components go into this piece.

8.2.3 General Recommendations

After working closely with Laurie and Roosevelt Elementary students for seven months, the team has created a very strong relationship with them. They asked about future projects and if there could be a more consistent relationship between the elementary school and WPI senior projects because of their satisfaction with the rocking horse and light wall. The team believes that there should most definitely be more projects done with Roosevelt Elementary because of their willingness to help and abundance of students with disabilities. Making a difference in the lives of others is so important and this is the perfect way to do it.

Appendices

Appendix A- Light Wall Design Matrix

	Wall must be able to be hung on the Sensory Room wall	The LEDs must be seen in the room lighting available in the Sensory Room	Light Wall must be under $500	Light Wall must be under 30 pounds	Tiles must be able to be cleaned with class/plastic cleaner without damaging materials or wiring	Grid and frame must be able to be cleaned with household disinfectants (e.g. lysol wipes) without damaging materials or wiring	The wall must have a black background to emphasize the red coloring of the LEDs
Button must be pressed with minimum force of 5lb	-1	0	-1	-1	0	0	-1
Spring must allow for movement with minimum force of 5lb	-1	0	-1	-1	0	0	-1
The wall will have an on/off button	0	1	0	0	1	1	0
Wires must be hidden	-1	-1	-1	-1	-1	-1	-1
Wooden frame must be sanded to prevent splinters	-1	-1	-1	-1	-1	-1	-1
LEDs and buttons must not be reachable by children, covered by tiles	-1	-1	-1	-1	0	0	-1
LEDs must be bright enough for the children to see	-1	0	-1	-1	0	0	0
Wall must be able to be hung on the Sensory Room wall	X	1	0	0	1	1	1
The LEDs must be seen in the room lighting available in the Sensory Room	-1	X	-1	-1	-1	-1	0
Light Wall must be under $500	0	1	X	0	1	1	1
Light Wall must be under 30 pounds	0	1	0	X	1	1	1
Tiles must be able to be cleaned with class/plastic cleaner without damaging materials or wiring	-1	1	-1	-1	X	0	-1
Grid and frame must be able to be cleaned with household disinfectants (e.g. lysol wipes) without damaging materials or wiring	-1	1	-1	-1	0	X	-1
The wall must have a black background to emphasize the red coloring of the LEDs	-1	0	-1	-1	1	1	X
TOTALS	-12	3	-14	-14	2	2	-7

Appendix B- Light Wall Code

final code.py - /Users/madelinechudy/Desktop/final code.py (3.8.2)

```python
                    return True
        return False
    #
    def waitForKey():
        kk = Key()
        waitKey = kk.NO_KEY
        while(waitKey == kk.NO_KEY):
            waitKey = getKey()
        return waitKey

    def getState():
        return self.key[0].kstate
    #
    def keyStateChanged():
        return self.key[0].stateChanged

    def bitWrite(self,x,n,b):
        if(b):
            x |= (1<<n)
        else:
            x &=(~(1<<n))
        return x
    def bitRead(self,x,n):
        if((x>>n)&1 == 1):
            return True
        else:
            return False


#LEDS


GPIO.setup(9, GPIO.OUT)  #column1
GPIO.setup(10, GPIO.OUT)  #column2
GPIO.setup(11, GPIO.OUT)  #column3
GPIO.setup(12, GPIO.OUT)  #column4
GPIO.setup(13, GPIO.OUT)  #row1
GPIO.setup(14, GPIO.OUT)  #row2
GPIO.setup(15, GPIO.OUT)  #row3
GPIO.setup(16, GPIO.OUT)  #row4

#BUTTONS (columns are inputs)

GPIO.setmode(GPIO.BCM)
GPIO.setup(1, GPIO.IN)  #column1
GPIO.setup(2, GPIO.IN)  #column2
GPIO.setup(3, GPIO.IN)  #column3
GPIO.setup(4, GPIO.IN)  #column4
GPIO.setup(5, GPIO.OUT)  #row1
GPIO.setup(6, GPIO.OUT)  #row2
GPIO.setup(7, GPIO.OUT)  #row3
GPIO.setup(8, GPIO.OUT)  #row4


#Turning on random LED

current_led = random.randint(0,15)

def light_on():

        GPIO.output(9, 1)                   #turning all LEDs off
        GPIO.output(10, 1)
        GPIO.output(11, 1)
        GPIO.output(12, 1)
        GPIO.output(13, 0)
        GPIO.output(14, 0)
        GPIO.output(15, 0)
        GPIO.output(16, 0)

        global current_led              #generating random integer from 0 to 15

                                            #locating the LED based off of random integer
        row = current_led//4
        column = current_led%4
```

Ln: 149   Col: 14

```
        global current_led              #generating random integer from 0 to 15

                                            #locating the LED based off of random integer
        row = current_led//4
        column = current_led%4

        GPIO.output(row+13, 0)              #turning on random LED
        GPIO.output(column+9, 1)

        break

#Verifying if button pushed is correct button

ROWS = 4
COLS = 4
keys = [    1, 2, 3, 4,
            5, 6, 7, 8,
            9, 10, 11, 12,
            13, 14, 15, 16  ]       #setting up button matrix

rowsPins = [5,6,7,8]                        #defining pins for rows/cols
colsPins = [1,2,3,4]

def push_button():
    keypad = Keypad.Keypad(keys, rowsPins, colsPins, ROWS, COLS)    #defining keypad
    keypad.setDebounceTime(50)
    while(True):
        key = keypad.getKey()               #retreiving key that was pushed
        global current_led
        if(key == current_led+1):           #ensuring that key is the same location as LED
            light_on()                      #if key is correct, start light definition again

#for shutdown button

GPIO.setmode(GPIO.BCM)
GPIO.setup(17, GPIO.IN, pull_up_down = GPIO.PUD_UP)

def Shutdown(channel):
   os.system("sudo shutdown -h now")

GPIO.add_event_detect(12, GPIO.FALLING, callback = Shutdown, bouncetime = 2000)

if __name__ == '__main__':                  #program starts here
    try:
        light_on()                          #call initial light_on function
        push_button()                       #call push_button function right after
    except KeyboardInterrupt:               #when ctrl+c is pressed, exit the program
        GPIO.cleanup()
```

Ln: 266   Col: 0

Appendix C- Rocking Horse Design Matrix

	Rocking horse must rock back and forth without tipping	Rocking horse must be able to rock back and forth while holding children in a weight range from 33-128lbs	The curved base of the rocking horse is inclined 20 degrees from the floor on each side	Rocking horse must withstand force used by Aid to move the horse and child	Manual pushing by caregiver	Interchangeable seats attached through adjustable crutch-like push button system	Buttons: 5.5 ounce or 0.377 lbf start button activating force	Button diameter >= 5in	Handle on front and back must be able to stop rocking of the horse with a child on it	Straps and headrest to secure body	No sharp edges in contact with body - use of foam to cover hard areas	Maximum tipping angle: 40 degrees from horizontal (Floor)	Lifetime ~ 5 years	E w th
Rocking horse must rock back and forth without tipping	X	0	-1	0	-1	-1	-1	-1	0	0	0	0	-1	
Rocking horse must be able to rock back and forth while holding children in a weight range from 33-128lbs	0	X	-1	0	-1	-1	-1	-1	0	0	0	0	-1	
The curved base of the rocking horse is inclined 20 degrees from the floor on each side	1	1	X	0	0	-1	-1	-1	0	1	1	1	-1	
Rocking horse must withstand force used by Aid to move the horse and child	0	0	0	X	0	-1	-1	-1	0	0	0	0	-1	
Manual pushing by caregiver	1	1	0	0	X	0	-1	-1	1	1	1	1	-1	
Interchangeable seats attached through adjustable crutch-like push button system	1	1	1	1	0	X	-1	-1	1	1	1	1	-1	
Buttons: 5.5 ounce or 0.377 lbf start button activating force	1	1	1	1	1	1	X	1	1	1	1	1	1	
Button diameter >= 5in	1	1	1	1	1	1	-1	X	1	1	1	1	1	
Handle on front and back must be able to stop rocking of the horse with a child on it	0	0	0	0	-1	-1	-1	-1	X	0	0	0	-1	
Straps and headrest to secure body	0	0	-1	0	-1	-1	-1	-1	0	X	0	0	-1	
No sharp edges in contact with body - use of foam to cover hard areas	0	0	-1	0	-1	-1	-1	-1	0	0	X	0	-1	
Maximum tipping angle: 40 degrees from horizontal (Floor)	0	0	-1	0	-1	-1	-1	-1	0	0	0	X	-1	
Lifetime ~ 5 years	1	1	1	1	1	1	-1	-1	1	1	1	1	X	
Ensure that child's arms would not get caught in the rocking horse	0	0	-1	0	-1	-1	-1	-1	0	0	0	0	-1	X
Saddle Seat: Must include adjustable arm bar for children to hold on to in front of them from 8-12 inches away from the back of the chair depending on their arm lengths	1	1	0	1	1	1	-1	-1	1	1	1	1	-1	
Saddle Seat: Must include arm bar below seat for children to place their hands on 8 to 12 inches below chair	1	1	0	1	1	1	-1	-1	1	1	1	1	-1	

	Rocking horse must rock back and forth without tipping	Rocking horse must be able to rock back and forth while holding children in a weight range from 33-128lbs	The curved base of the rocking horse is inclined 20 degrees from the floor on each side	Rocking horse must withstand force used by Aid to move the horse and child	Manual pushing by caregiver	Interchangeable seats attached through adjustable crutch-like push button system	Buttons: 5.5 ounce or 0.377 lbf start button activating force	Button diameter >= 5in	Handle on front and back must be able to stop rocking of the horse with a child on it	Straps and headrest to secure body	No sharp edges in contact with body - use of foam to cover hard areas	Maximum tipping angle: 40 degrees from horizontal (Floor)	Lifetime ~ 5 years	Ensure that child' would not get cau the rocking horse
Saddle Seat: Back support must be adjustable to accommodate different sized children	1	1	0	1	1	1	-1	-1	1	1	1	1	-1	
Saddle Seat: Height of seat must be adjustable to accommodate different heights of children varying from 30 to 60 inches and a seated height of 12-24 inches	1	1	0	1	1	1	-1	-1	1	1	1	1	-1	
Saddle Seat: Must support child's lower back and hold them upright at a 90 degree angle	1	1	0	1	1	1	-1	-1	1	1	1	1	-1	
Tomato Seat: Holds patient in upright, seated position	1	1	0	1	1	1	-1	-1	1	1	1	1	-1	
Tomato Seat: Hip angle between 80-90 degrees to reduce amount of tone	1	1	0	1	1	1	-1	-1	1	1	1	1	-1	
Tomato Seat: Buckles to hold in the tomato seat in place behind the seat, can be removed for the saddle seat	1	1	0	1	1	1	-1	-1	1	1	1	1	-1	
Must include footrest for the children to strap their feet into the rocking horse	1	1	-1	1	0	1	-1	-1	1	1	1	1	-1	
Caregiver needs to be able to apply a force of at least X to push/stop the rocking chair	1	1	1	1	-1	0	-1	-1	0	1	1	1	-1	
Must be able to function on the tile floor	1	1	1	-1	1	1	-1	-1	1	1	1	1	-1	
Fit through hallway/doors - less than 32 inches wide	1	1	1	-1	0	1	-1	-1	1	1	1	1	-1	
Less than 50 pounds	1	1	1	-1	1	1	-1	-1	1	1	1	1	-1	
Less than $400	1	1	1	-1	1	1	-1	-1	1	1	1	1	-1	
Materials: Wood, Metal,Foam	1	1	1	-1	1	1	-1	-1	1	1	1	1	1	
Cleanable with common household disinfectants (e.g. lysol wipes) without damaging decals or wiring	1	1	1	-1	1	1	-1	-1	1	1	1	1	-1	
Rocking horse must be visually appealing and resemble a horse	1	1	-1	1	1	0	-1	-1	1	1	1	1	-1	
Make the seat look like a saddle	1	1	-1	1	1	0	-1	-1	1	1	1	1	-1	
TOTALS:	24	24	2	10	10	9	-31	-29	22	24	24	24	-25	

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