Design for Disability Hozhoni Art Device

Final Proposal

Ahmad Alotaibi

Mohammad Alotaibi

Waleed Ahmad

Haitham Almohammedsaleh

Madison Douglass

2015-16

NORTHERN ARIZONA UNIVERSITY

Project Sponsor: CEFNS, ME Department

Faculty Advisor: Sarah Oman

Sponsor Mentor: Terri Engel

Instructor: Sarah Oman

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1 BACKGROUND

This section defines the problem addressed to the team by the client. It introduces the project's stakeholders and sponsors. It will describe the project and the original system. It addresses deficiencies of the original system in order for the team to fix them.

1.1 Introduction

The result of this project is an assistive device to help people with disabilities create art. The objective of the project is to provide a system to meet the needs of the artists at the Hozhoni Art Gallery. This project is of interest because it positively impacts the lives of those hindered by disabilities. Completing this project benefits the welfare of the public, which is an important code of ethics for the engineering department. This project benefits the Hozhoni advisers financially and the artists spiritually. It enables the artist to produce higher quality works with increased efficacy, as well as letting them know that people care about them and their skills. This boost in artist morale will result in improving the quality of their work, thereby allowing the Hozhoni Art Gallery to receive bolstered financial and reputational benefits. People with different disabilities have difficulty using regular tools easily and safely; by providing them with the right tools, we can help the artists at Hozhoni show the world how creative they are without limitations. The resultant product of this project should be a system that will provide a work surface that is wheelchair accessible and can provide a work surface for clients with limited mobility.

1.2 Project Description

This section consists of the original project description provided by the sponsor.

> "The Hozhoni Foundation in Flagstaff, AZ has an extensive art program with a large studio for clients to work in various media (paint, clay, weaving, etc.). The Art Program provides a therapeutic outlet for its clients with disabilities. This capstone team will determine their project scope and goal by interacting with these clients and interviewing the staff and instructors at the program. The customer needs and importance will be determined from those interviews and approved by Dr. Oman before proceeding with the project. This project gives the team the unique opportunity to shape the nature and scope of what they will be working on for the next two semesters." [1]

1.3 Original System

This section describes last year's project that the team is going to enhance based upon the Hozhoni Foundation needs and complains. It contains last year's design description and comments made from artists and advisors at the Hozhoni Foundation.

The following is a description for last year's project.

> "The primary goal of the Art Team's senior design project is the successful design, build, and implementation of an assistive working station for the comfortable holding of Hozhoni clients' work and supplies during creation. The Hozhoni Foundation is a local Flagstaff organization dedicated to the support of individuals with developmental disabilities [2]. While the foundation provides a number of services to its clients, one of the largest programs is the Hozhoni Artists Program—a nonprofit studio for Hozhoni clients where they can spend time on self-expression and creativity [3]." [4]

1.3.1 Original System Structure

The description of the original system structure, including the parts and the bill of materials, is provided. All figures and tables used are from the official website of the capstone team from last year. The original system is a simple easel with an adjustable workspace that can rotate upwards to the desired angle of the artist, as shown below in Figure 1.

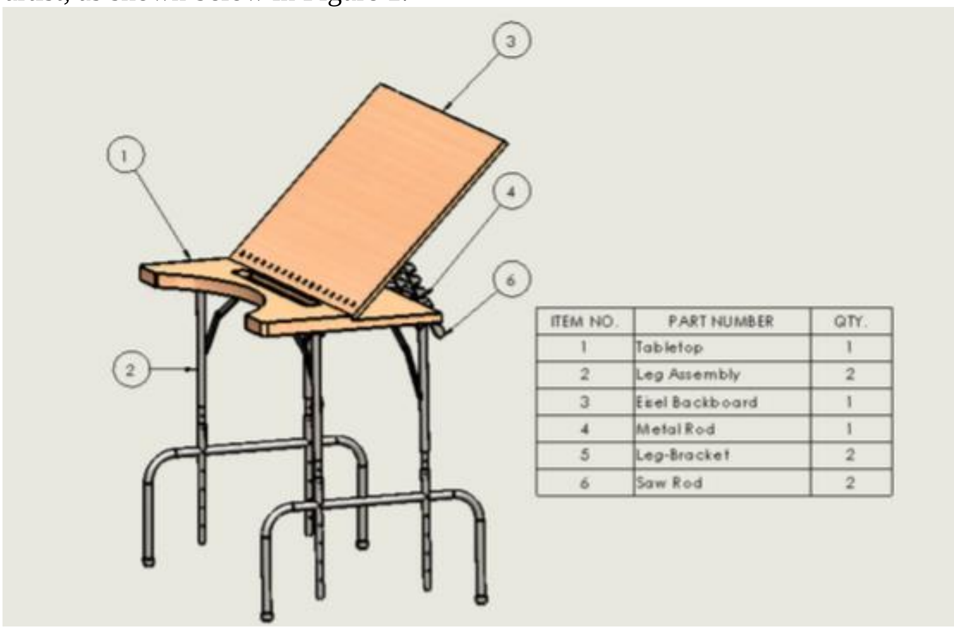

Figure 1 - Engineering drawing of the assembly for the existing design [4]

It is mostly built of wood and contains metal parts such as the aluminum rod support for the easel (4) and the steel legs (2). It has two wooden sheets: the first sheet is fixed in place (1) to hold the other adjustable sheet (3). Artists can clip their paper onto the adjustable sheet to use as a work surface. The second wooden sheet can be adjusted by changing the position of the aluminum rod in the saw teeth (6). All of these parts are supported by two folding legs that can change height. The layout drawings of the system can be found in Appendix A.

The Bill of Materials (BOM) of this project is shown in the next table, which explains the materials used to build the project and their quantity, price, description, and any comments about the provider or the material used.

Table 1 - Bill of Materials for the existing design

Item No.	Description	Material	Quantity	Price	Comments
1	Folding Legs	Steel	2	$50	Purchased from Amazon
2	Table Top	Wood Board	1	$50	1.5" from Home Depot
3	Saw Tooth Support	Aluminum	1	$20	Scrapped from Machine Shop
4	Brackets/Bolts/Screws			$50	Home Depot
5	Leg Extension	Steel	4	$35	Home Depot
6	Rod Support	Aluminum	1	$5	Home Depot

1.3.2 Original System Operation

This section describes the original system in operation at the Hozhoni Art Gallery. During our visit to the gallery on Thursday, September 15th 2016, our team noticed the system's main operations are to collapse for storage purposes and adjust the angle of the easel as necessary. The gallery advisors added a large paper clip in order to mount the drawing papers for the artists. The functions of the easel are described in Figure 2 and Figure 3, shown below.

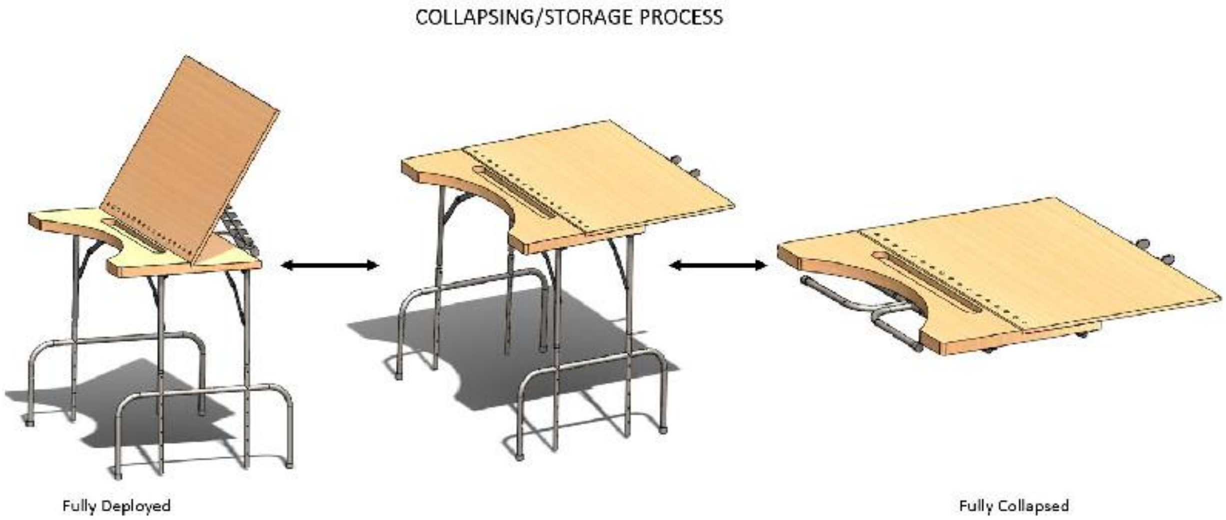

Figure 2 - Engineering drawing of collapsed system for existing design [4]

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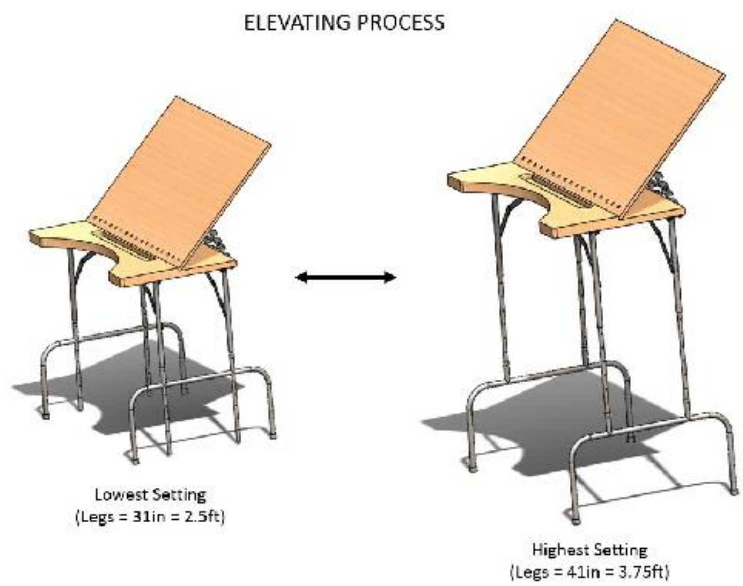


Figure 3 - Engineering drawing of elevated system for existing design [4]

1.3.3 Original System Performance

The system's performance and the clients' comments are described in this section. Both the artists and the Hozhoni art advisors described the system's perforce as unsatisfactory, and thusly it was abandoned in an empty corner. When asked about the original system's performance, artists described their difficulties using it due to lack of mobility preventing them from moving it into the garden, contrasting color of the two wooden sheets, and lack of smooth finish on the system that allows for dirt and debris (i.e., pencil and eraser shavings) to collect.

1.3.4 Original System Deficiencies

In this section, the operation of the system and how it fails to meet the artists' and art advisors' requirements from Hozhoni foundation are outlined. The original system met some, but not all, of the customers' needs. The artists did not like the color: changing this will make the system more enjoyable to use and aesthetically pleasing. The device is hard to move for the artists who have disabilities since it has no wheels. Because of this, the system is not very portable. The system needs to be more multi-functional and allow the artists to paint outside. Artists at Hozhoni commented on the system saying that if it has an adjustable umbrella it would be no problem using it in the yard.

2 Requirements

The team's goal is to create a device that fulfills all of the artists at the Hozhoni Gallery's needs. The team is required to design a system which accommodates the needs of those who have disabilities and will require accommodations for their capabilities. Hozhoni requires that these designs be functional, clear of obstacles, and effective in numerous fields, as will be discussed in the customer requirements section. This section introduces the requirements for the project.

2.1 Customer Requirements (CRs)

The customer requirements were provided through conversation with advisors and artists from the gallery. The team chose to focus on requirements for an assistive device for one particular artist with movement limitations on half of his body, therefore his needs extend beyond those considered in the previous assistive art device. Many of the people had trouble using the easel and other devices, so ease of use must be considered in the new design. The client wanted to be able to move the device outside, so portability and weight should be considered. There were complaints that the existing devices were still not adjustable or accommodating enough for different tasks. A common problem was that people did not want to use the device or thought that it did not "look nice". Lastly, the device must be safe and strong while staying within the budget and using parts that, if broken, could be reasonably replaced. The objective is to design a solution that will successfully meet all of these requirements and satisfy the needs of the artists and the Hozhoni Foundation.

These customer requirements have been approved from Terri Engel, the client from Hozhoni Art Gallery. Her approval email (Appendix B) shows her satisfaction for the team's choices.

2.2 Engineering Requirements (ERs)

After discussing the CRs, the team came up with multiple engineering requirements (ERs). Engineering Requirements are defined by translating the customer requirements into requirements to the sub fields of systems engineering. For the ERs, the team translated our CR of portable to an ER of having wheels, which scored the highest on our ERs. The second most important ER was the minimum leg height, which was translated from our CR of safety and ease of use. The least important ER was the dark color since being aesthetically pleasing is the second least important CR.

Table 2 - Engineering Requirements

Number	Engineering Requirement	Target with Tolerance
1	Low Amount of Force to Operate	147 ± 19.6 N
2	Attaching Wheels	4 Wheels
3	Strength to Cost Ratio	0.2 ± 0.1 MPa/$
4	Ductile Materials > 35 MPa	40 ± 1 MPa
5	Angle of Easel Hinges	120 ± 30 degrees
6	Color (Dark Color)	Black
7	Smooth Finish with Low Friction	Friction factor of 0.6 to 0.1
8	Edges with Fillets > 10 degrees	30 ± 10 degrees
9	Maximum Weight < 20kg	17.5 ± 2.5 kg
10	Standard Fitting Attachments	
11	Maximum Height/Width < 1.83 by 0.91 m	1.65 ± .1 m^2
12	Minimum Surface Area of Easel > 0.21 by 0.297 m	0.06237 ± 0.4372 m^2
13	Minimum Height of Legs > 0.686 m	0.7 ± 0.02 m

2.3 Testing Procedures (TPs)

The team will use these Testing Procedures (TPs) to make sure all the ERs are satisfied. Each ER has its own TP, which is listed below. Some are complicated and use measurement tools. Others are simple and only include using observation. The TPs are as follows:

1. To test the force needed to operate, the team will perform all the movements needed to adjust the easel. This can be accomplished by using a spring force meter to get an estimate of this force. The spring force meter will be borrowed from Dr. Mark Lamer.
2. The quality of wheels attached will be observed. Different types of castor wheels, plastic and metal, will be tested.
3. The strength to cost ratio will be determined by finding the material properties of the parts used online. The material properties can be found on Engineering Toolbox. The yield stress of these materials will be compared to the cost of the parts. According the ratio of Strength/cost, the higher ratio will be the best team choice.
4. The ductility of the materials will also be found by researching the material properties for all parts.
5. The possible angles of the easel will be measured with a protractor. The protractor will be purchased by the team.
6. The color will be observed. The team will try to find the most pleasing color by changing the color properties of the CAD model.
7. The finish of the surfaces will simply be observed from sense of touch. By sanding the surfaces, we can decrease the friction coefficient.
8. The fillet angles will be measured with a fillet gage. The fillet gage can be purchased by the team.
9. The weight will be measured on a scale. The team will try to weight the design using different materials, for example we will weight our design if made of wood and plastic.
10. The fittings will be compared to appliances used in the gallery and easily available parts from a hardware store.
11. The height and width of the system will be measured with a meter stick. The team will try to use the easel using two different system heights, and will decide which one is more comfortable to work with. The first height will be based on a height of a table that is often used by Hozhoni Art Gallery artists, while the second height will be determined by the choice of team members.
12. The area of the work surface will be measured with a meter stick. The team will obtain the used areas of drawing paper used at the Art Gallery.
13. The height of the legs will be measured with a meter stick. The team will try to use the easel using two different legs heights, and will decide which one is more comfortable to work with. The first height will be based on a height of a table that is often used by Hozhoni Art Gallery artists, while the second height will be determined by the choice of team members.

2.4 Design Links (DLs)

In this section, the ER's will be compared with the design that the team decide to work on. Each ER will be compared individually and with one of the design parts to show that a specific part will be considered as a solution for a specific ER.

Certain designs can be used to complete our ERs. The design links are as follows:

1. Low operating forces will be maintained by using light weight and low friction parts.
2. To satisfy the ER of attaching wheels, Caster wheels will be attached to the system.
3. The strength to cost ration will be achieved by using Strong wood and plastic in our design.
4. The Ductile materials that the team will most likely use are materials like plastics and metals rather than ceramics.
5. The angle of easel hinges will be appropriate if the team uses strap hinges, this will also secure the easel.
6. The color that the team aims for is black, therefore; The system will most likely be painted black.
7. To obtain smooth surfaces, the team is going to use a sander with grit from 320 to 600. The sander will be used to smooth plastic in most cases since the surfaces that the team is looking for are mostly made from plastic.
8. Edges will be double rounded by rounding it at the machine shop.
9. Using PVC pipes and plastic as major materials will minimize the total weight of the device. These materials will keep the device under the maximum weight limit.
10. Basic fittings that are mass produced will be used.
11. For the maximum height and width, the system will be designed to fit through a door.
12. For the minimum surface area ER, the easel will be designed to hold at least a standard piece of paper.
13. The legs will be designed according to the standard height dimensions for a regular wheelchair in order to fit over a standard wheelchair that can be found in the Art Gallery

2.5 House of Quality (HoQ)

The House of Quality (HoQ) is used to show and link the CRs from the stakeholders and ERs. For this report, the HoQ includes the CRs and their weightings. The CRs' weights are values which represent the importance of the requirement. The system's top requirements are durability and safety, as these are pivotal components. The product must be able to stand and keep the occupants safe. The secondary requirements are ease of use, portability, and adjustability. Tertiary requirements are lightweight, multi-purpose, and being enjoyable to use. The least important requirements are aesthetics and cost effectiveness.

Included in the HoQ are the Absolute Technical Importance (ATI), and the Relative Technical Importance (RTI), of each ER. Also listed are the corresponding Testing Procedures and Design Links.

Table 3 - House of Quality

ERs / CRs	Weight	Low Amount of Force to Operate	Attaching Wheels	Strength to Cost Ratio	Ductile Materials	Angle of Easel Hinges	Color (Dark Colors)	Smooth Finish with Low Friction	Edges with Fillets	Maximum Weight	Standard Fitting Attachments	Maximum Height/Width	Minimum Surface Area of Easel	Minimum Height of Legs
Easy to Use	2	4	5	0	0	1	0	2	0	5	3	3	3	3
Portable	4	0	5	0	0	0	0	0	0	3	0	2	2	3
Cost Effective	1	0	1	5	2	1	0	1	3	2	1	0	0	0
Durable	5	0	4	4	5	0	0	0	1	2	0	0	0	1
Safe	5	4	3	0	2	1	0	2	4	5	0	1	1	4
Adjustable	4	4	4	0	0	5	0	0	0	0	1	1	1	2
Aesthetically Pleasing	2	0	1	0	0	1	5	5	2	0	1	0	3	0
Lightweight	3	3	1	2	3	1	0	0	0	5	0	5	4	3
Multi-purpose	3	0	2	0	0	3	0	0	0	0	5	3	3	4
Enjoyable	3	3	4	0	0	1	5	5	1	0	0	1	2	4
Targets and Tolerances		147 ± 19.6 N	4 Wheels	0.2 ± 0.1 MPa/$	40 ± 1 MPa	120 ± 30 degrees	Black	Friction factor of 0.6 to 0.1	30 ± 10 degrees	17.5 ± 2.5 kg		1.65 ± .1 m^2	0.06237 ± 0.4372 m^2	0.7 ± 0.02 m
ATI		70	115	31	46	47	25	44	35	84	34	56	62	90
RTI		4	1	12	8	7	13	9	10	3	11	6	5	2
TP		1	2	3	4	5	6	7	8	9	10	11	12	13
DL		1	2	3	4	5	6	7	8	9	10	11	12	13

3 EXISTING DESIGNS

Different approaches can be taken in order to create a design that achieves the team's goals and purposes. This chapter is intended to explain the research our team used in order to choose the designs that will enhance the performance of our project. This chapter includes the existing designs studied.

3.1 Design Research

This section explains the process of the team's benchmarking by researching existing designs. The team conducted research by examining systems that follow the project description and satisfy the CRs.

The team also divided the research into three areas, where each member researched a different type of device, which were: devices that help people to do art, devices that assist disabled people, and devices that help disabled people to do art. Additionally, another member researched information regarding the previous team and their approaches. Products fitting into the three systems were found using internet searches. The previous year's project was found through the CEFNS capstone website. All information was gathered through their webpage. Benchmarking provided the team with new ideas, new comments from stakeholders, and a starting point for decision making on the final device the team will produce.

3.2 System Level

The project is a re-engineering of the Assistive Art Workstation from last year's capstone class. The following is a description of the device and how it will be used as a reference to enhance the new design.

3.2.1 Existing Design #1: Assistive Art Workstation

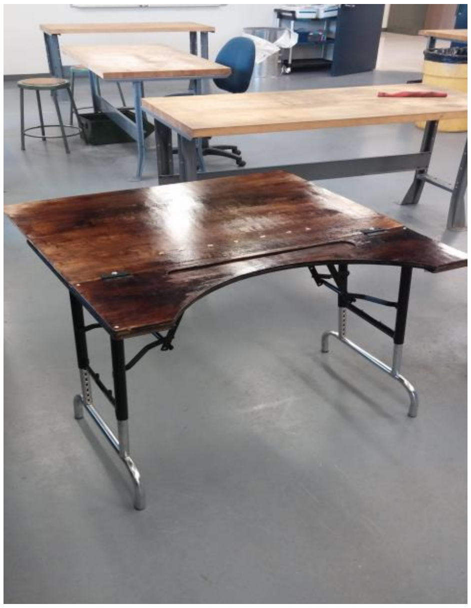


Figure 4 - Final Existing Design [4]

The product shown in Figure 4 is the design produced by the previous team. It was examined at the art gallery and the team recorded all the comments and complaints about the design. It is an easel that allows artists to manually adjust the height and angle. The cost of this design is affordable and made from strong materials which satisfy the cost effectiveness and the durability customer requirements.

3.3 Subsystem Level

Research conducted for the subsystem levels were broken down into types of products that fulfill aspects required for the design problem. These levels describe research of existing products used for making art in general, are used to accommodate people with disabilities, or are made to assist people with disabilities to create art.

3.3.1 Subsystem #1: Devices for Making Art

This subsystem includes devices that are used to create various mediums of artwork. They do not specifically cater to people with disabilities.

3.3.1.1 Existing Design #1: Drafting Table

Figure 5 - Studio Designs Deluxe Rolling Drafting Table Station [5]

This is a table made of metal frames with the adjustment capabilities. It has wheels to enhance its mobility, side drawers and trays for storage and easy access, and the working surface is interchangeable. The table price is $99.

3.3.1.2 Existing Design #2: Creative Brushes

Figure 6 - Brushes [6]

Figure 6 shows brushes with different foam tips. The brushes have long handles, making them easy to use. In art, brushes are used for painting and are a main tool of art. These brushes allow the painter to easily create different and interesting patterns. The price is $1.29 per unit.

3.3.1.3 Existing Design #3: Sponge Shapes

Figure 7 - Sponge Shapes [7]

Figure 7 shows sponges of different shapes and colors. They are used in painting for creating patterns. It allows the artist to easily paint different shapes. The price for these sponges range from $1.5 to $5 per unit.

3.3.2 Subsystem #2: Devices for People with Disabilities

This subsystem researches devices that are made to accommodate a person with a disability. These devices are not created for the purpose of making art.

3.3.2.1 Existing Design #1: Wheelchair Umbrella

Figure 8 - Wheelchair Umbrella [8]

The Wheelchair Umbrella has been recognized as needed function for the previous team's device in order to provide the artists with the ability to create art in a variety of locations. This product can be attached to any solid part of the wheelchair and has the ability to change the concentration of the shadowed area as the user sees fit. This design meets the safety and multi-purpose requirements since it can be used to protect the artist and the paint from sunlight and rain. The price for this product is $74.40.

3.3.2.2 Existing Design #2: Home Care Grab Bar

Figure 9 -Moen Home Care Grab Bar with Toilet Paper Holder [9]

The grab bar, which can be also used as a toilet paper holder, addresses one of the main problems for artists who cannot walk or stand well enough, or at all, to reach the high toilet paper holder. The device meets our safety requirement since it can minimize the risk of serious injuries while the artist trying to reach the papers. The price for this part is $46.99.

3.3.2.3 Existing Design #3: Writing Bird

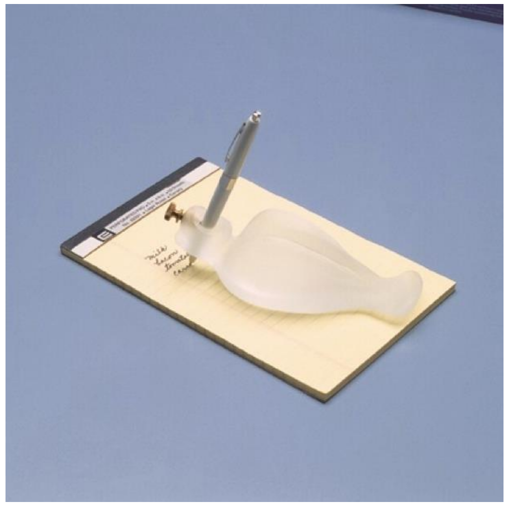


Figure 10 - Writing Bird [10]

The Writing Bird is an assistive device for people who experience hand tremors while writing or drawing. The design is easy to use and weighs less than other designs therefore meeting the ease of use and lightweight requirements in the CRs. The design price is $24.95.

3.3.3 Subsystem #3: Art Devices for People with Disabilities

This subsystem benchmarks existing art tools made to accommodate people with disabilities. This will provide ideas for combining designs from the previous two subsystems.

3.3.3.1 Existing Design #1: Head Pointer

Figure 11- Head Pointer [11]

The Ableware Adjustable Head Pointer is an essential aid device for people with limited hand use to overcome difficult actions (e.g., turning pages, drawing, or painting). Additionally, it allows those with limited verbal communication skills to use communication boards and gives them the ability to point. Also, it is excellent for pushing switches or pushing buttons. The Head Pointer consists of lightweight plastic bands secured by metal hardware and topped by a long aluminum rod. The forehead padding is comfortable and cool. The headband and cranial strap adjust to fit different head sizes and shapes. The pointer rod is fully adjustable for length and angle in any direction and is fitted with a removable pencil holder. The head pointer is less expensive, because it will cost between $142.00 and $176.30. This device meets with most of our CRs, which are: safety, ease of use, lightweight, portable, and cost effective.

3.3.3.2 Existing Design #2: Double Sided Easel

Figure 12 - Double Sided Art Easel with Built-In Drying Racks [12]

The Double Sided Art Easel (Figure 12) is a creative device to assist those with disabilities to create the arts and crafts with the new-and-improved art easel for students. It can be adjusted to two heights. This easel is equipped with two removable paint trays with 14 paint pots and spill proof caps when purchased. The paint tray slides on and off for easy cleaning. Additionally, it has one large tube that slides in and out for easy access to supplies attached to the easel. The Double Sided Art Easel prices range between $266.25 and $355.00. This Easel will satisfy our team requirements of being easy to use, portable, and can be used for multiple purposes.

3.3.3.3 Existing Design #3: Reflex Table

Figure 13 - The Alvin Reflex Table [13]

The front of the Alvin Reflex Table (Figure 13) is designed with a semicircle cut out for easy accessibility for wheelchairs. The top is constructed of scratch-resistant Melamine and has a raised, black, PVC edge that prevents items from falling off. The base of the table is wide enough to allow wheelchairs to maneuver easily. There are easy to grip knobs for adjustable telescoping legs that can be angled from 0° to 45°. This table folds flat for easy storage. The price of this table ranges between $427 $652. This table meets the CRs of being adjustable and aesthetically pleasing.

4 DESIGNS CONSIDERED

After a brainstorming session and utilizing a variety of concept generating methods, such as bio-inspired and morph matrix methods, the team created several concepts to consider for serving the need of our customers. These concepts were approved by Dr. Sarah Oman.

4.1 Functional Decomposition

The functional decomposition models the flow of energy through the system. It highlights all inputs and functions of the system. Provided in Appendix D is our model which is a visual representation of how the system transforms from one state to the next. The functional decomposition helped define what the project should accomplish. It will also assist the team while developing prototypes that will model each function of the system.

4.2 Design #1: Metal Easel

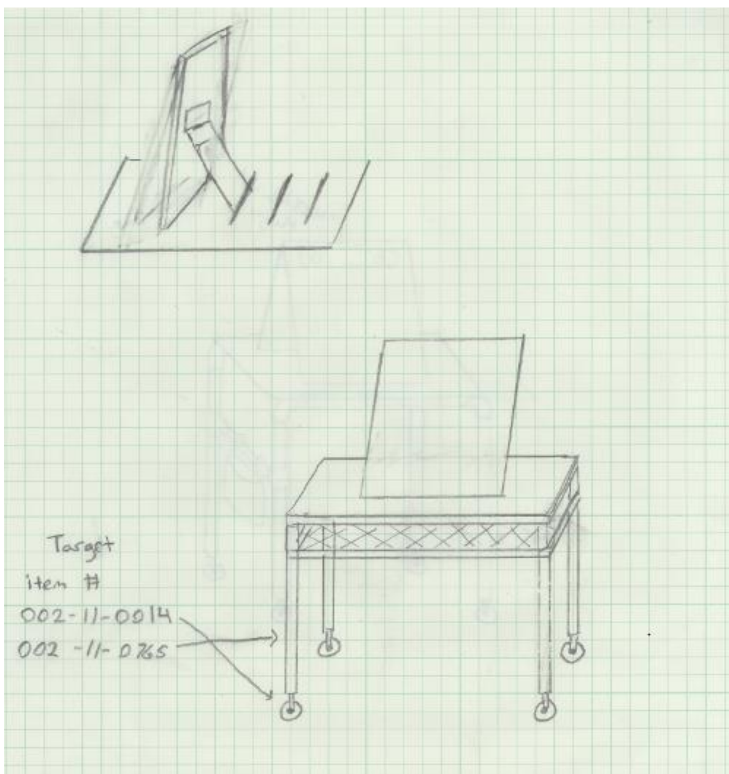


Figure 14 - Sketch of Metal Easel

The design featured in Figure 14 is an easel that uses a metal shelving unit that can be bought at Target. The shelves are already adjustable and come with many accessories, including caster wheels. This unit would make the easel easier to manufacture, but also markedly heavier. The legs have a maximum height, which may not reach the necessary. The top of the easel features a different system in order to change the angle of the work surface. Rather than using a complicated mechanism to change the angle, this system uses slots in which a hinged section of the easel can fit into. The work surface could either be fixed to the top or have a slot of its own it could be removed from. This system increases ease of use and provides the possibility of having multiple work surfaces on one easel.

4.3 Design #2: PVC Pipe Easel

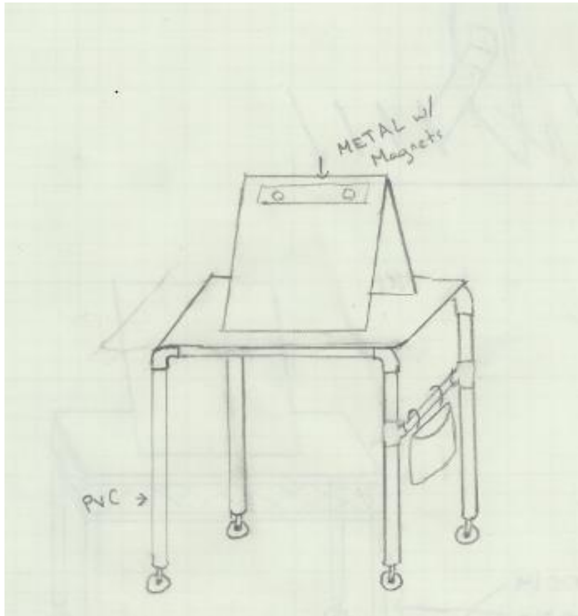


Figure 15 - Sketch of PVC Pipe Easel

This easel is inspired by the double sided easel from Chapter 3. The legs of this easel would be made out of PVC pipe, which is both lightweight and easy to work with. PVC is inexpensive and would leave more money to be allotted to manufacturing attachments, such as the pouch shown in the figure above. The PVC is not as strong as the steel from the previous model, but support sections can be used to bolster the stability. It can also be painted black to meet our ER for color. Also featured in this design is a metal bar with magnets to provide a simple and easy way for the clients to attach paper to the work surface.

4.4 Design #3: Remote Control Easel

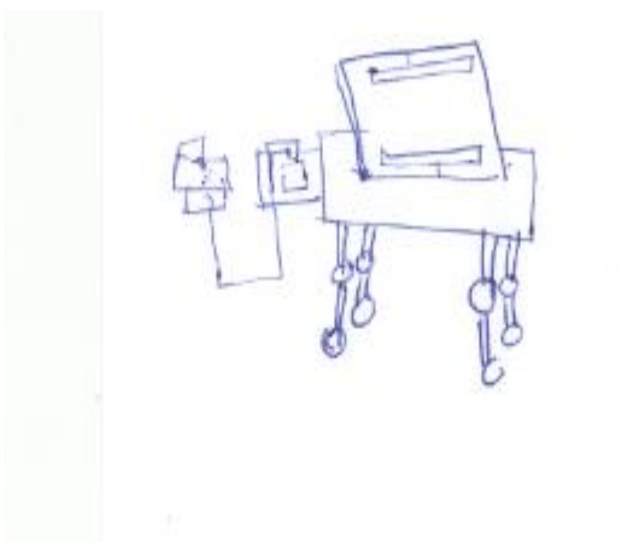


Figure 16 - Sketch of Remote Controlled Easel

This design has a sensor connecting the easel with the main board that can adjust the angle of the easel using a remote control in order to minimize the force needed from the artist. The legs have the ability to fold with an angle of 180 degrees to be stored in a small area. It also contains with a faucet and a sink that can be attached to a water source so that the artists can easily clean their instruments. The easel has built-in large paper clips that can hold different sizes of drawing paper. The negative aspects of this design are that it requires attachment to a water source and the stability from the collapsible folding legs.

4.5 Design #4: Anti-Gravity Easel

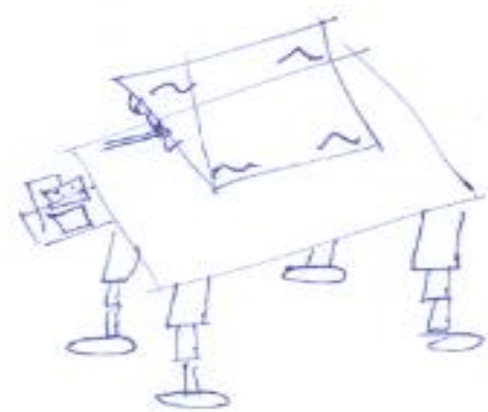


Figure 17 - Sketch of Anti-Gravity Easel

Anti-Gravity Easel design include an easel that has rubber bands to hold the drawing paper. It is also attached to a water dispenser to give the artist more functionality from the device. The design legs can be either extended or compressed to adjust the height of the easel. It is also provided with anti-gravity attachments at the end of each legs which will allow artists to move it smoothly. The positives of this design are that the artists will have to apply much less force to move the easel itself, and there is no need to be attached to a water source since the water dispenser can be filled and set into place. The drawbacks to this design are the cost for research and development, as the anti-gravity technology is theoretical in nature. The rubber band choice is also a negative aspect because rubber bands are not reliably durable and may not hold the drawing paper in a proper way.

4.6 Design #5: Paint cannon

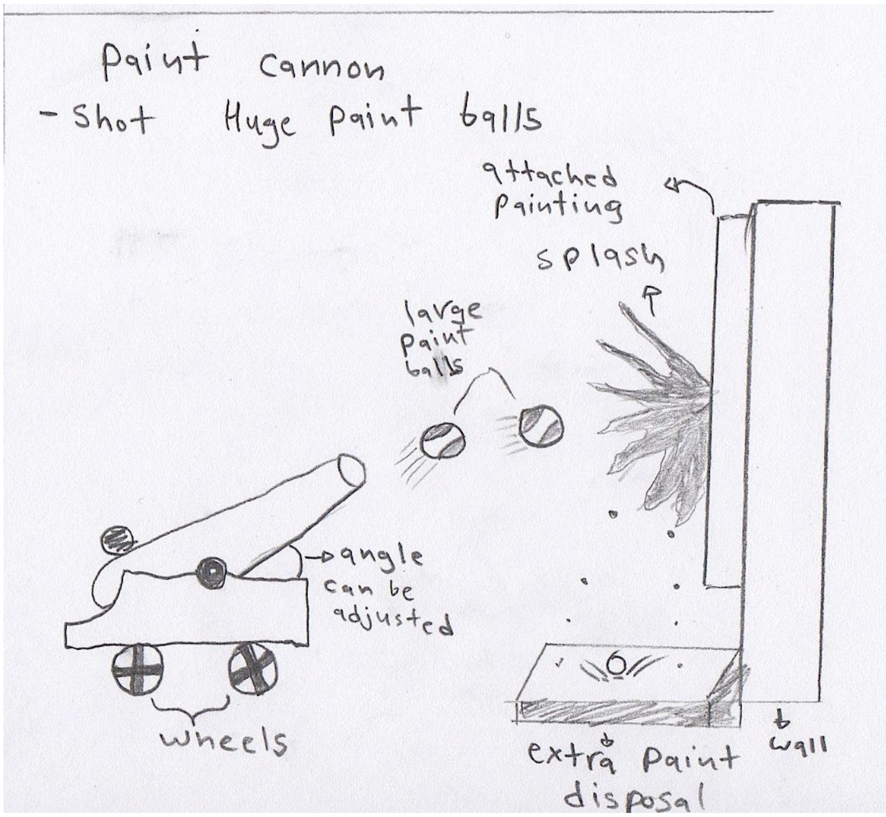


Figure 18 - Sketch of Paint Cannon

Figure 18 shows a paint cannon, designed to fire large paint balls at a fixed vertical wall. The angle of shooting is adjustable, and the cannon is able to be moved, as it is attached to a wheeled base. Additionally, a paint disposal tray would be attached at the bottom of the vertical wall to collect the run-off of the paint balls. The positives of the design are that it requires very little explanation, and would fulfill the CR of being enjoyable to use. The drawbacks are that it is both wildly impractical and immensely unsafe.

4.7 Design #6: Flying Easel

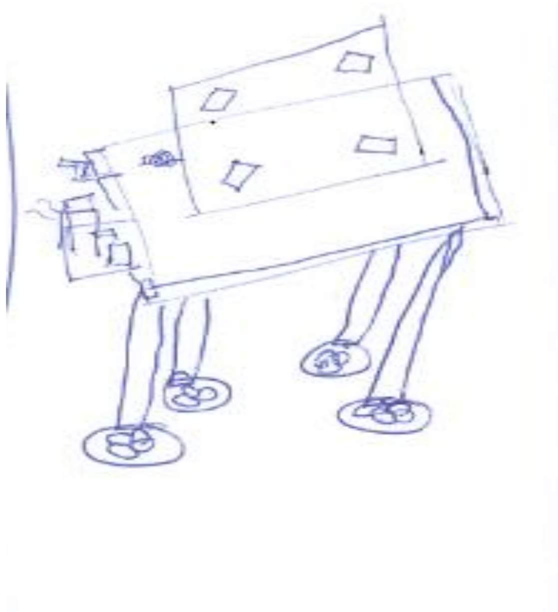


Figure 19 - Sketch of Flying Easel

The Flying Easel is designed with as easel that can be adjusted in its angle using a rotated beam connected to a spring on the backside of the easel. The easel is provided with a metal sheet attached to the front side of the easel to use magnetic bars to hold the drawing paper. The design also provides the artist with a water dispenser. The legs are fixed to the main board. The ends of the legs are connected to powerful fans that allow the device to lift into the air when movement is required. The positives of this design are that it would require little amount of physical effort on the artist's part in order to move the design itself, and the adjustable support beam on the back of the easel that angles the work station allow for little strain as well. The magnetic bars to hold the drawing paper are stronger than the currently used paper clips, so different types of drawing papers can be used easily. Additionally, the included water source allows for ease cleaning of brushes. One of the noticeable cons for this device is the safety of using the spring to adjust the easel, since there is a possibility that the spring can fail and cause injuries to the artist. Another cons is the cost of the design, as the modern fans for propulsion, such as those used in consumer drones are significantly more expensive than regular wheels with locks, and the noise and wind pressure created by the system would interfere with the artists' ability to relax.

4.8 Design #7: Bio-Inspired Easel

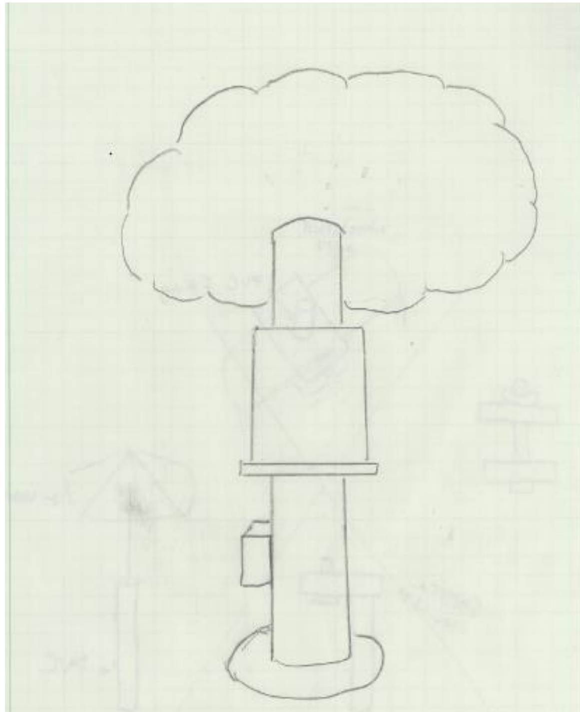


Figure 20 - Sketch of Bio-Inspired Easel

This design is inspired by a tree. One of the comments from the clients was that they wanted to have shade when they were working outside. This easel incorporates the shade-providing aspect of a tree. A cover made out of wood, or possibly material draped over a frame, is made to look like the leaves of a tree. This easel, however, is set up more like a classic easel made for someone to stand in front of. It does not allow the user to sit with their legs under the surface they are painting on. Instead, they would have to angle their legs and work over the side of their body. This may be difficult for many of the clients. It is also not designed to be lightweight or portable, which are two of the CRs.

4.9 *Design #8: Paint Can Opener*

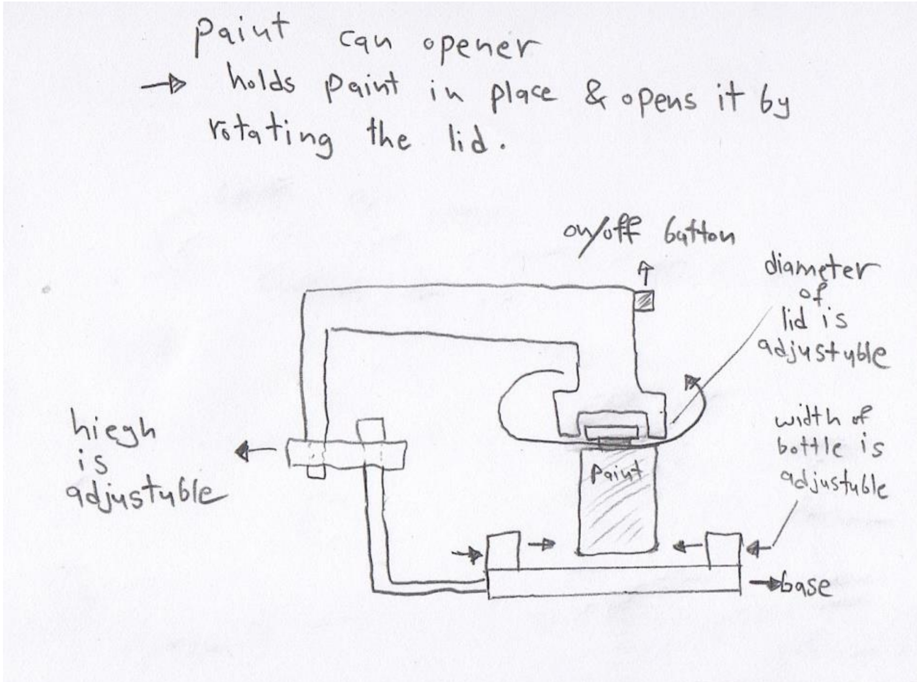


Figure 21 - Sketch of Paint Can Opener

This design shows a paint can opener. This design receives a paint can from the user and tightly secures it by adjusting to the width of the can base the width of the can lid, and the height of the paint can. After adjusting the dimensions of the paint can, the on/off button can be used to rotate the paint can lid and therefore open it. The pros of this design are that this design is easy to use, even for people who have disabilities, and this design is safe because the machine handles the work. The cons of this design are that it requires the artist to be using paint cans that have screw tops, rather than paint tubes or jars, as well as requiring an electrical source.

4.10 Design #9: Analog Controlled Pen

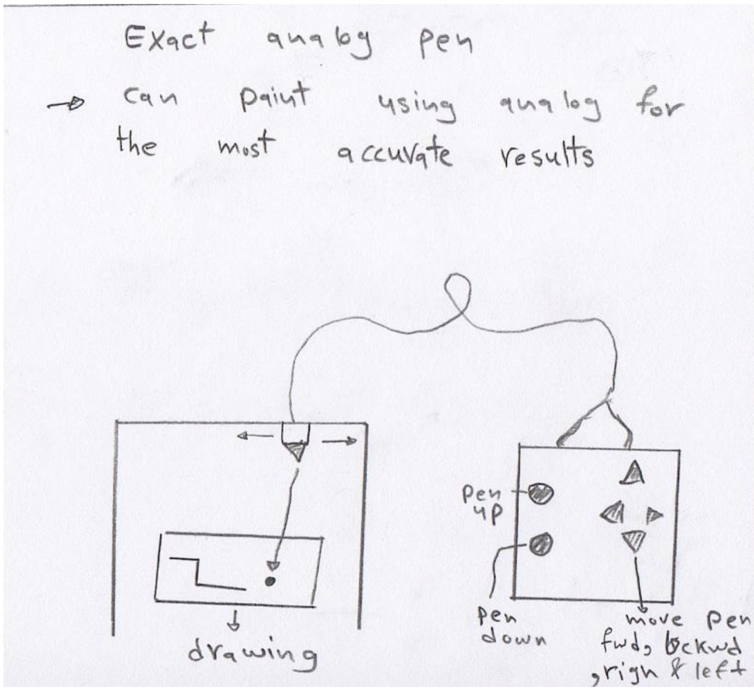


Figure 22 - Sketch of Analog Controlled Pen

This design represents an analog controlled pen. The controls of this design are move up, move down, move left, move right, pen up and pen down. The pros of this design are that it requires a low amount of force to operate and it is easily adjustable and operated for people with limited mobility in their extremities. The cons of this design are that it will take significant practice to become accurate enough to paint or draw the desired results, the difficulty with switching the utensil used, and the technology required to create it.

4.11 Design #10: Ultimate Easel

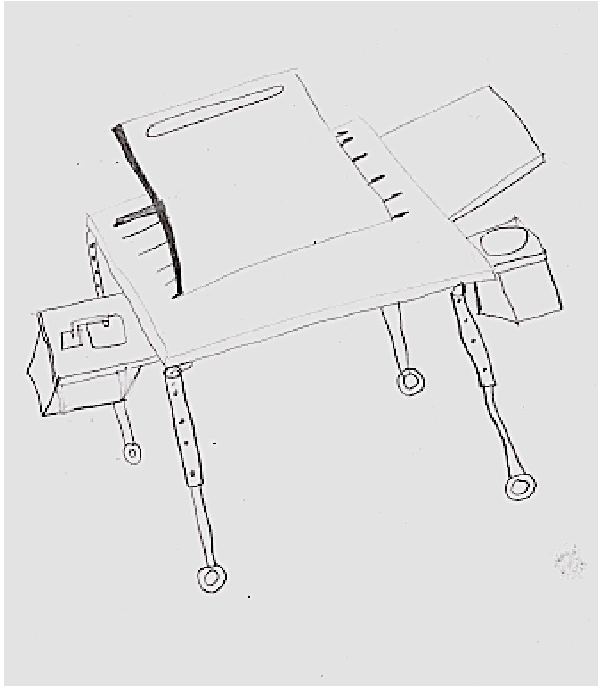


Figure 23 - Sketch of Ultimate Easel

The Ultimate Easel design shows an easel that has multiple attachments built in. It is inspired by two bio-inspirations: whales and chameleons. The water dispenser idea came from the whales when they surface for breath without needing to come all the way out of the water, so they pump the water in order to break the sea surface and breathe. The small attached table that can be hidden under the table was inspired by the chameleon that is fast and can hide itself. The legs of the easel are made from PVC pipes with small holes to allow the locking mechanism to set the height as desired. The easel is equipped with a long, metal paper clip that holds the drawing paper. The angle of the easel can be adjusted by changing the position of the top portion with the positioning of the sheet stand in the grooves on the main board. The attached water dispenser and a small table to hold the supplies can be pulled or pushed under the main board. It also has an attached cup holder for instruments such as brushes. The legs are on locking wheels that can hold the design in place while in use. The positive aspects are that it is multi-functional, since it meets a significant portion of the CRs. It is also lightweight because of the PVC legs instead of metal ones. The cons are the weight and the cost, since each additional function will add to both. The intricacy of installing the multiple locking mechanisms in the PVC legs and on the main board will add to the time consumption of the project.

5 DESIGN SELECTED

5.1 Rationale for Design Selection

In order to decide on the design that will satisfy the most of our CRs, our team created a Pugh Chart and a discussion matrix, shown in Table 4 and Table 5. A Pugh Chart is an easy way to compare several designs by first choosing a datum and then comparing the other designs to it. Table 4 shows the Pugh chart for our ten designs, where the datum here is the previous year's project. The plus sign (+) in the Pugh chart indicates the design is better than the datum in satisfying the CR; S indicates that the design is in the same level of satisfying the CR; the minus sign (-) indicates that the datum satisfies the CR more than the design selected. The Pugh Chart shows that designs (1,2,7,8,10) have scored the highest. In order to decide which design of those five designs is the best, our team created a decision matrix: Table 5. The decision matrix uses numerical weightings instead of the positive and negative signs. The decision matrix allows the team to rank the designs based on the CRs, where if the design scores high in an important CR, the score will be multiplied by a numerical number that represents the importance of said CR (weighting). Using a decision matrix allowed the team to know which design satisfied the critical CRs best. Based on the results from the Pugh Chart and the decision matrix, Design 10; The Ultimate Easel, which is shown in Section 4.10, is the design that will satisfy our CRs most accurately.

Table 4 - Pugh Chart

Evaluating / Synthesizing Design Concepts											
Concept	Assistive Art	Design									
CVs	Workstation	1	2	3	4	5	6	7	8	9	10
Easy to use	D A T U M	+	+	-	-	-	S	+	-	-	+
Portable		+	-	s	+	+	-	-	+	-	+
Cost effective		-	+	-	-	-	-	+	+	-	-
Durable		s	-	-	s	-	-	-	-	-	+
Safety		-	-	-	s	-	-	-	-	-	S
Adjustable		+	+	-	-	-	S	S	-	-	+
Aesthetically pleasing		s	S	-	s	+	+	+	+	+	+
Lightweight		-	+	-	-	-	+	+	+	+	S
Multi-purpose		-	S	+	+	-	+	-	-	S	+
Enjoyable		s	S	+	+	+	-	+	+	+	+
∑+		3	**4**	2	3	3	**3**	5	5	**3**	7
∑-		4	3	7	4	7	5	4	5	6	1
∑S		3	3	1	3	0	2	1	0	1	2

Table 5 - Decision Matrix

Concept / CVs	Weight	**Design 1**		**Design 2**		**Design 7**		**Design 8**		**Design 10**	
Easy to use	10	**7**	70	**6**	60	**7**	70	**9**	90	**9**	90
Portable	10	**6**	60	**8**	80	**5**	50	**7**	70	**8**	80
Cost effective	4	**2**	8	**3**	12	**3**	12	**2**	8	**16**	64
Durable	20	**2**	40	**3**	60	**7**	140	**11**	220	**13**	260
Safety	20	**4**	80	**7**	140	**8**	160	**8**	160	**7**	140
Adjustable	10	**3**	30	**2**	20	**7**	70	**6**	60	**8**	80
Aesthetically pleasing	5	**5**	25	**4**	20	**4**	20	**3**	15	**4**	20
Lightweight	7	**6**	42	**3**	21	**6**	42	**6**	42	**5**	35
Multi-purpose	7	**1**	7	**5**	35	**4**	28	**3**	21	**5**	35
Enjoyable	7	**1**	7	**7**	49	**4**	28	**5**	35	**6**	42
Total	100	**37**	369	**48**	497	**55**	620	**60**	721	**81**	846
Relative Rank		**1**		**2**		**3**		**4**		**5**	

5.2 Design Description

In this section, the team design will be fully detailed and the design will be justified using the analysis information gathered by the team members. In order to imagine the design better, a prototype of the design was made using SolidWorks, a computer-aided design (CAD) software, shown as Figures (24-26). By prototyping the design, the team discovered this design may require some minor changes. Each team member completed an individual analysis to justify the validity of our design. The following sections include a brief description of each individual analysis:

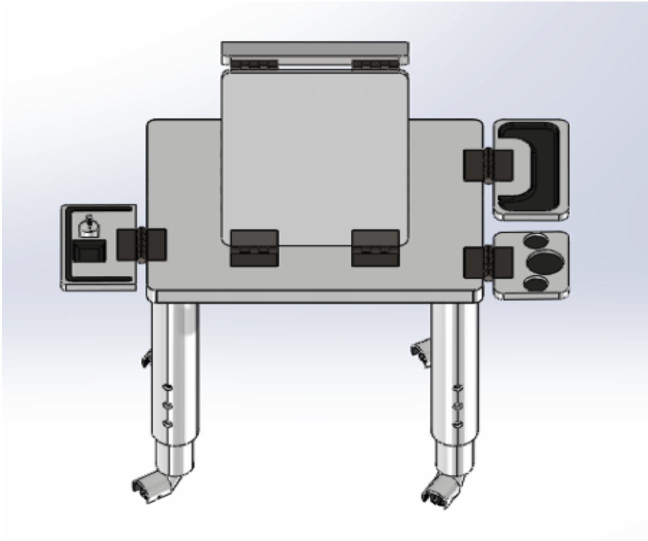


Figure 24 - Complete Design A

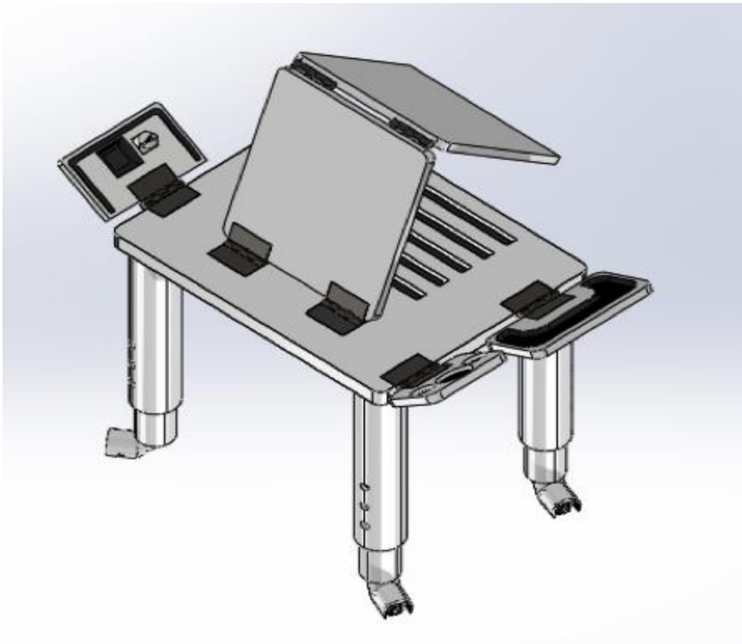


Figure 25 - Complete Design B

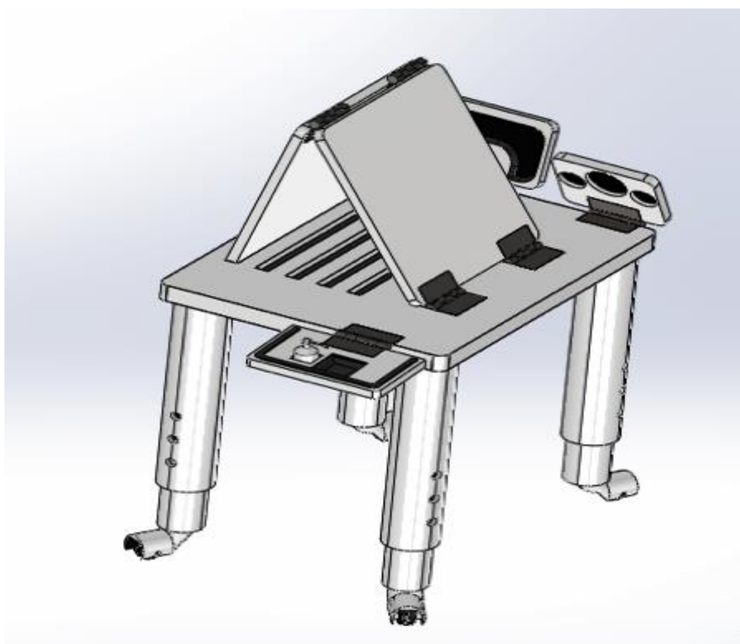


Figure 26 - Complete Design C

5.2.1 CAD Analysis

The purpose of the CAD analysis was to allow the team to image the design, and therefore be able to make changes and improvements. This analysis is also a better way to show our clients and customers what we are going to do, and to receive feedback and, ultimately, approval. In addition, SolidWorks allows the user to change the colors of surfaces easily, and this will help us by showing our clients several figures of our design, where each figure has different colors to get a sense of which they find most aesthetically pleasing in order to reach maximum satisfaction of the CRs. More information about the parts used in making this CAD model can be found in Appendix E.

5.2.2 Strength of Legs Analysis

Since the legs must support the design's weight, an analysis of the strength of the legs is needed to ascertain what materials can be utilized without design failure. The results of this analysis show that we should be able to hold all the weight of the materials plus a person with the 1 inch PVC. The maximum weight that each material can hold based on the dimensions that we have for the legs is shown in Table 6. More information about the calculations made to find the results of the strength of legs analysis can be found in Appendix F.

Table 6- Materials to Be Used vs. Maximum Weight

Material	Maximum Weight (lbs)
1" aluminum angle	632.9572
1" PVC	396.4919
1.5" PVC	641.8208
2" PVC	862.5847

5.2.3 Environmental Impact Analysis

Since resources are limited and population is increasing every day, the team decided to do an analysis that shows the environmental impact of the design by comparing the impact of creating the design using wood, aluminum, and PVC. The environmental impact analysis shows that the team can reduce their negative environmental impact by taking some positive steps: using recycled PVC, and avoid using wood (which will somewhat lower the rate forest cutting and wood burning). A complete analysis of how each material listed above can affect the environment can be found in Appendix G.

5.2.4 Total Weight Analysis

As mentioned before, the prospective users of this design include (and is targeted towards) people with disabilities, which means that device portability is an important factor. The total weight analysis was implemented by taking into account the potential future struggles of the clients. The total weight analysis revealed using wood as a material for the device is better than the other two noted materials, since the final design will weigh less. Conversely, plastic materials can last longer than the other two materials, since it is waterproof, whereas wood is not, and it conducts less heat than aluminum, which is better for the stakeholders. Table 7 shows the resulting total weight of all the materials considered. The calculation that were made to show the reliability of this analysis can be found in Appendix H.

Table 7 - Materials Considered and Resulted Total Weight of Each Material

Material considered	Total design Weight
Wood	47.24 lbs.
Plastic	58.2 lbs.
Aluminum	157 lbs.

5.2.5 Strength of The Easel Analysis

To satisfy our customers as much as we can, the team decided to make the easel adjustable. The adjustability in the design will require the team to increase the strength of the easel itself to support the whole weight that the user applies when drawing, since it will be placed on the easel only. For this reason, the team decided to conduct an analysis for the strength of the easel considering wood, plastic, and steel as the materials that may be used to create the easel. The strength of the easel results show that plastic material would be sufficiently workable, cost effective, and is user-friendly due to its lightweight properties. The calculations that were made to find the best material to use for the easel can be found in Appendix I.

6 PROPOSED DESIGN

In order to implement our design to satisfy our customer, the team will create two prototypes using either cardboard and tapes or using a 3D printer. The first prototype will be made based on the current final design, which is inspired by the CAD package and the team members' comments. Once the first nonfunctioning prototype is made, team members will bring the first prototype to the artists at Hozhoni for comments and feedback for development of the final design. After the feedback from Hozhoni artists, the second prototype will be made to resemble the final design. After the team is done building the second prototype, the team will start building the actual final design.

Once the final design is built, the team will bring it to the Hozhoni Art Gallery to be used for a trial period of one week to see any problems arise. If a major problem appears in the design, the team will fix the problem and send the design back to the artists of Hozhoni for another test. This process of testing will continue until the design has no major problems and the client feels their needs have been met.

To familiarize ourselves with the design and the design parts, the team created an exploded view for the design (Figure 27) and an assembly view (Figure 28). These Figures diagram the parts for the designs. In order to keep track of our budget, the team created an anticipated bill of materials (BOM) that includes the quantity, price, and source of each part for our design (Table 8). The updated Gantt Chart that shows the schedule that the team will follow is included in Appendix K.

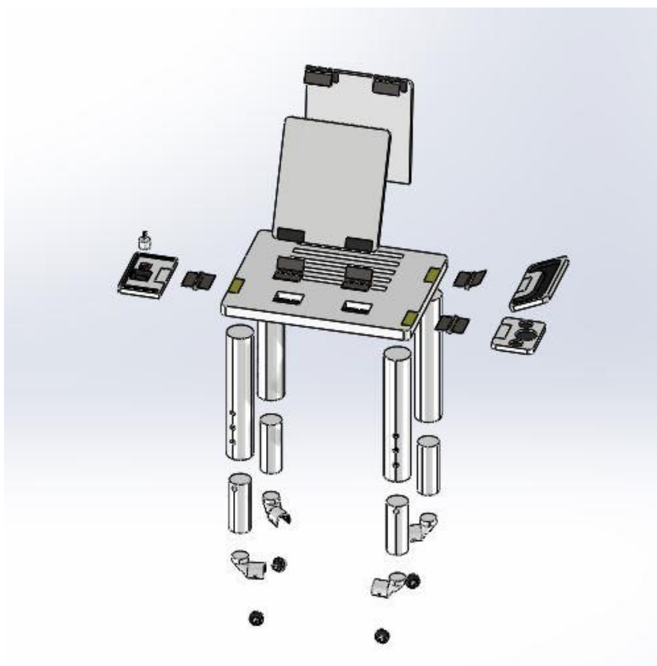
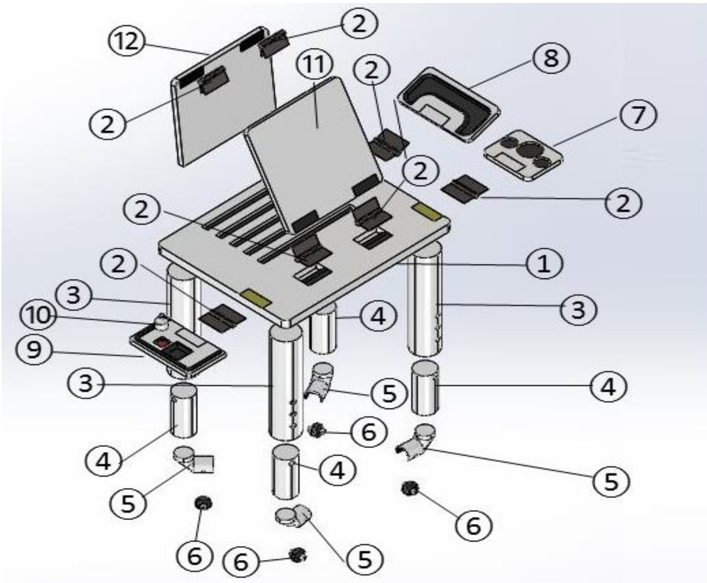


Figure 27 - Exploded View of the Model



Part number	Part name
1	The base
2	Hinges
3	Legs part 1
4	Legs part 2
5	Wheels base
6	Wheels
7	Right bottom attachment
8	Right top attachment
9	Left attachment
10	Water dispenser
11	Easel
12	Easel support

Figure 28 - Assembly View of the Design

Table 8 - Bill of Materials

Item No.	Description	Material	Quantity	$ Price	source
1	Casters	Rubber	4	33.88	Home Depot [14]
2*	Plastic Sheet	Polypropylene	3	165.63	US Plastic [15]
3	PVC Pipe	PVC	7	121.60	Home Depot [16]
4	Cup Holder	Plastic	1	7.95	Walmart [17]
5	Screw	Zink	36	14.96	Home Depot [18]
6	Hinge	Nickel	7	19.46	Home Depot [19]
7	Water Dispenser	Glass	2	15.98	Target [20]
8	Universal Ball	Stainless Steel	4	24.00	Omnitrack [21]
Total Price				$403.46	
Budget	$1500	Available Budget		$1096.54	

* This Item will be machined at the Machine Shop in order to design the main board, easel, attachments, and easel stand. This process will not cost the team because three members of the team took the advanced machine training on Lathe and Mill.

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Appendices

Appendix A: Solid Works Parts Drawings

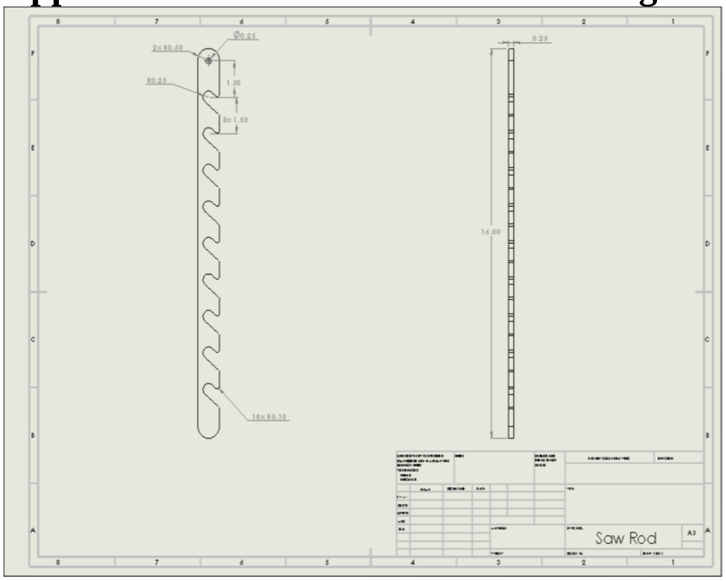


Figure A1 – Last Year Team SolidWorks Measurements

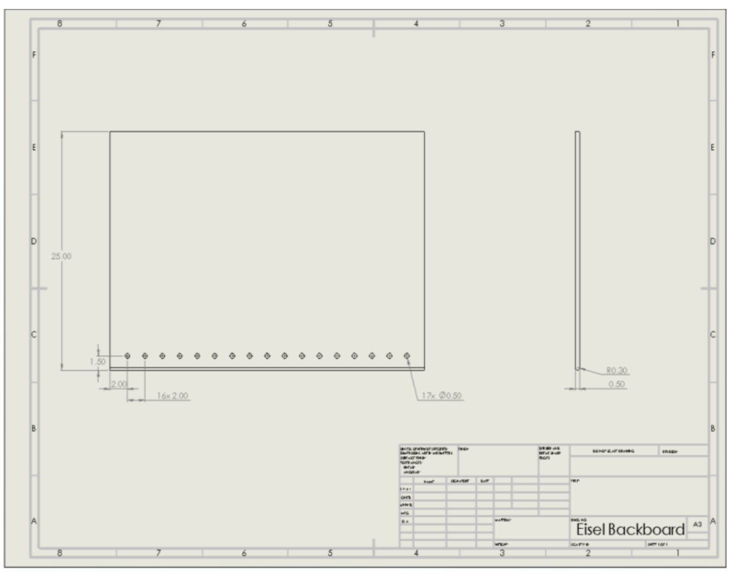


Figure A2 - Last Year Team SolidWorks Measurements

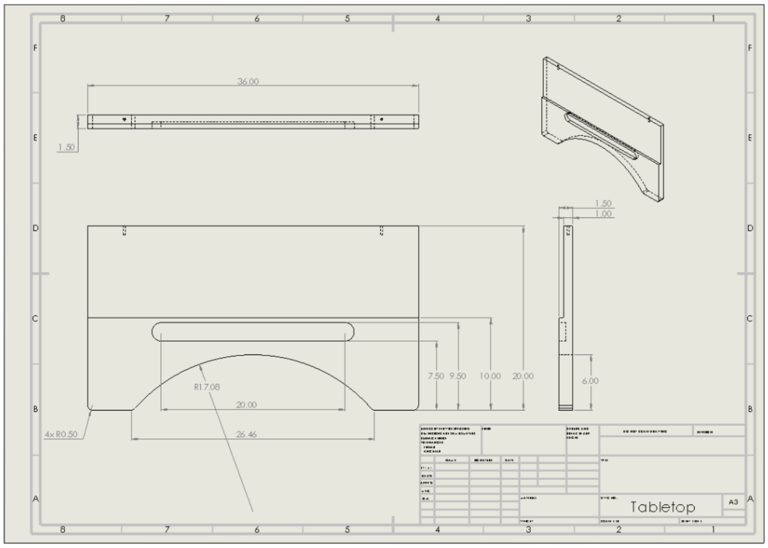


Figure A3 - Last Year Team SolidWorks Measurements

Appendix B: Customer Requirements Approval

Terri Engel
to me

Thank-You This is acceptable.
Terri

From: Haitham Almohammedsaleh [mailto:hha26@nau.edu]
Sent: Friday, September 23, 2016 2:03 PM
To: Terri Engel
Subject: Customer Requirements

HOZHONI Foundation, Inc.

Changing Perspectives, Promoting Possibilities

Flagstaff Office: 2133 N Walgreen Street Flagstaff, AZ 86004 ♦ **Ph** 928.526.7944 ♦ **Fax** 928.526.5909
Prescott Office: 1060 Sandretto Drive Prescott, AZ 86305 ♦ **Ph** 928.445.6996 ♦ **Fax** 928.445.6985
www.hozhoni.com

Figure B1 – Client Approval

Appendix C: Gantt Chart

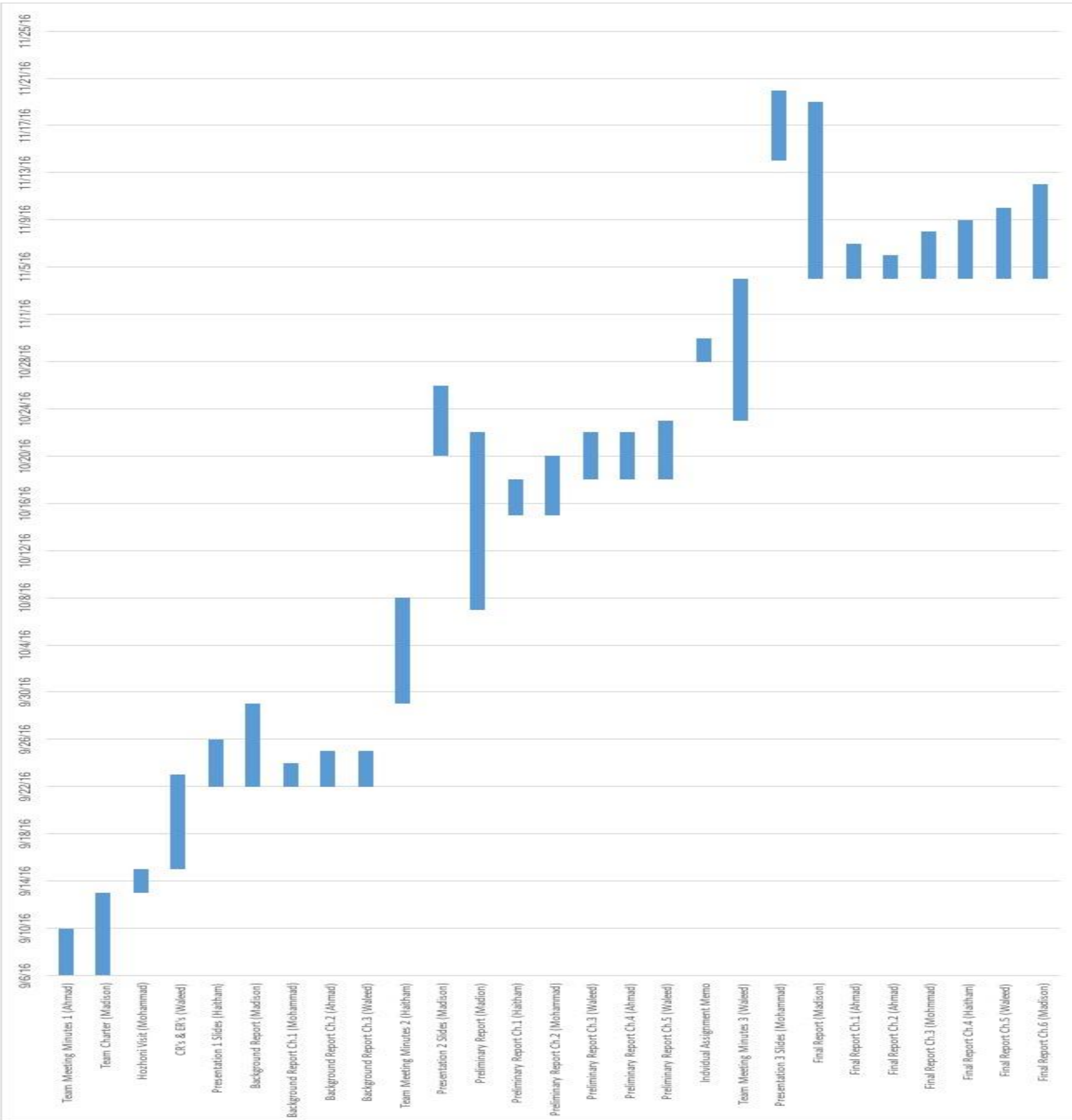
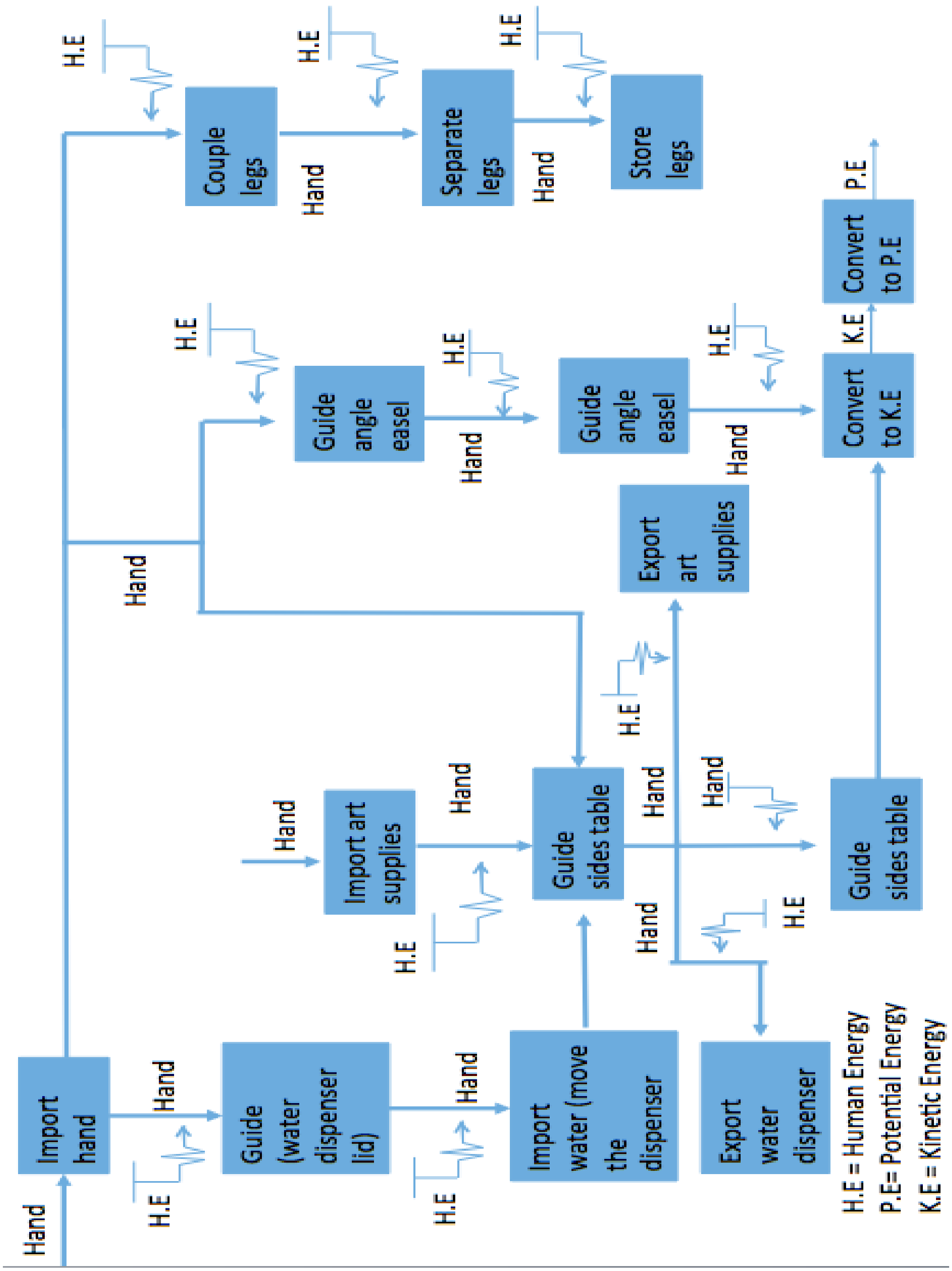


Figure C1- Gantt Chart

Appendix D: Functional Decomposition



Appendix E: CAD Analysis

Analytical tasks assignment MEMO

From: Waleed Ahmad
ME 476C
Section: 2
Team : 17
To: DR. DAVID WILLY, DAVID TREVAS, AND SARAH OMAN
SUBJECT: ANALYTICAL TASKS ASSIGNMENT
Date: 11/18/2016

The aim of this memo is to ensure the validity of the team final design by using the CAD (solid works) drawings, to show if the final design of the team can be made in the real life. The design that will be discussed in this memo is a design of an easel that helps disabled people to do art, especially wheel chaired people. The team was having problem to imagine the final design and therefore there was a difficulty for the team members to suggest changes to enhance the final design. The best solution was to use the CAD, which will make it easier for the team to imagine the whole design more accurately and it will be easier for the team members to make changes to the final design by changing the CAD drawings of it. However, this CAD Drawing may not exactly match up with the team's final design, but it will allow the team members to imagine the design and it will prove the concept that the team is trying to show.

There were some assumptions while making the CAD drawing. The assumptions were that the dimension are based on the standard tables used for wheel chaired people and that the materials that will be used are PVC plastic for most parts and steel for the hinges. In addition, hinges in real life usually have holes in them but in the Cad design in this memo, hinges don't have holes and, and this is because the team haven't decided the type of hinges that will be used and the dimensions of them.
The following sections will describe the CAD Parts and discuss some information about them.

1- The Base

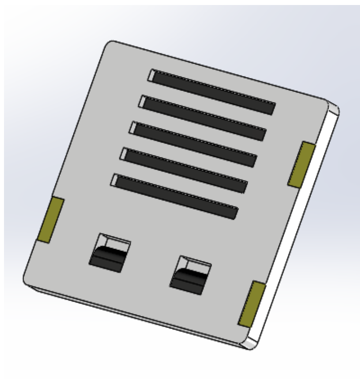


Figure 1: Easel Base isometric view

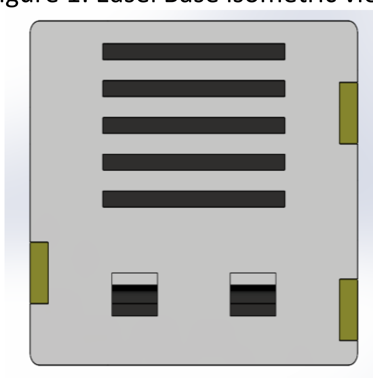


Figure 2: Easel base top view

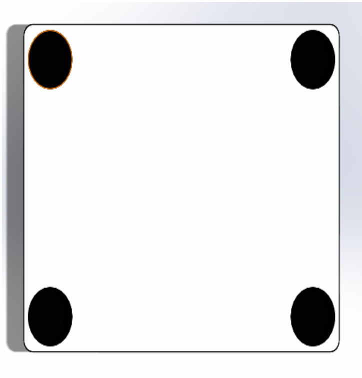


Figure 3: easel base bottom view

The easel base is to be to be made from PVC plastic (Figures 1-3), the Black and yellow colors indicates a place for the holes for the hinges to fit in in order to connect the Base of the design with all other parts. The base is (28*36 *2) inches, those dimensions were taken from the standard tables dimensions.

2- The easel

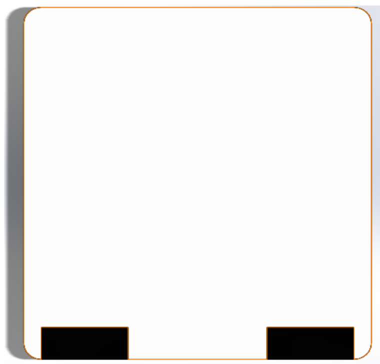


Figure 4: Easel front view

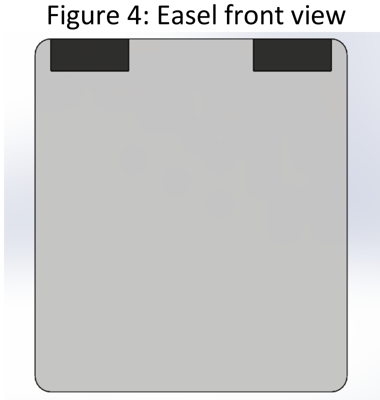


Figure 5-Easel Back view

The easel part will be made of PVC plastic (Figures 4-5). The easel will be connected to the base and the easel support using hinges, which will be placed in the areas colored with black. The easel dimensions are (22*20*1) inches.

3- Easel support

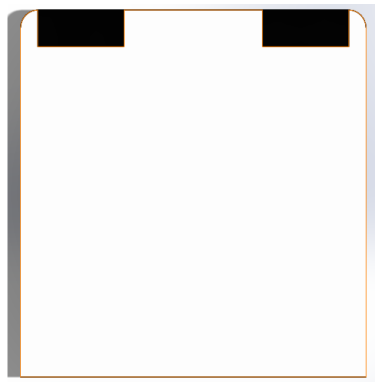


Figure 6: Easel support front view

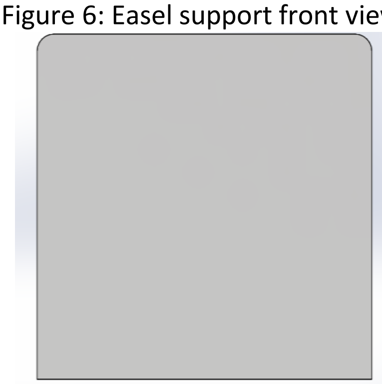


Figure 7: Easel support back view

The easel support Figures (6-7) will support the easel parts and make it adjustable by allowing the user to change the angle of drawing. The easel support can be placed in any of the parallel caving made in the base. The easel support is made of PVC plastic and have dimension of (20*20 * 1) inches

4- Hinges

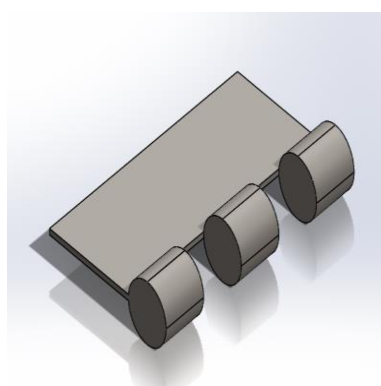


Figure 8a: Hinges part 1

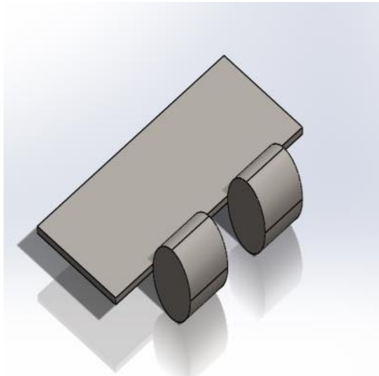


Figure 8b: hinges part 2

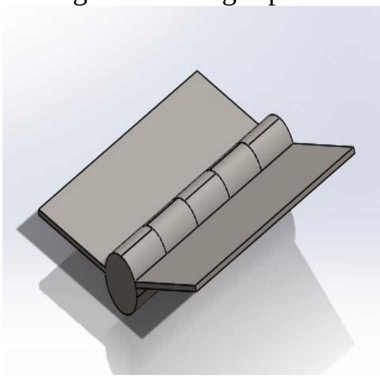


Figure 9: hinges full part

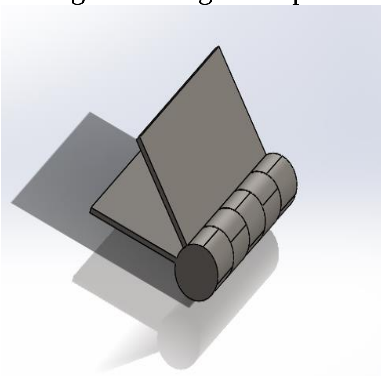


Figure 10: Hinges full part 2

Hinges are the most important parts in connecting this design parts. Hinges are made of steel (carbon steel). This material that most hinges nowadays are made of is steel, and this makes it easier for the team to find hinges online or at local stores. The hinges are usually made of 2 parts connected to each other (Figures 8a &8b) and those two parts from a one part that connect any 2 objectives. If the objectives were fixed to the hinges appropriately, the hinges will allow the user to perform a rotational adjustment by moving one of the hinges sides while fixing the other side (Figures 9-10). Hinges parts dimensions are (5*3.1*1) inches for each part.

5- Legs

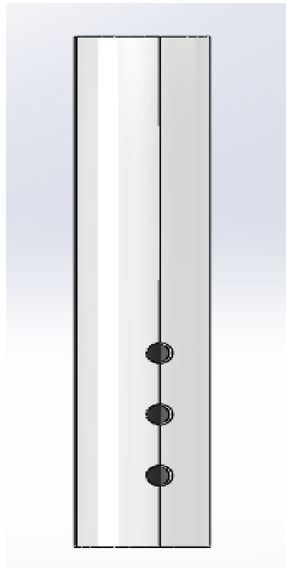


Figure 11: legs part 1

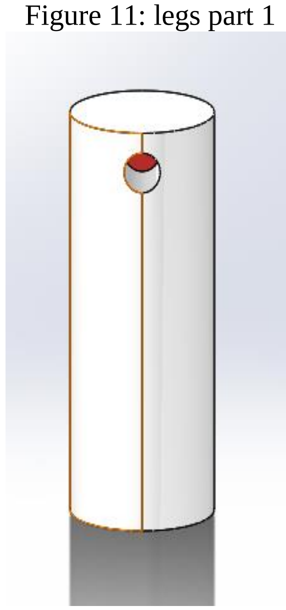


Figure 12: legs part 2

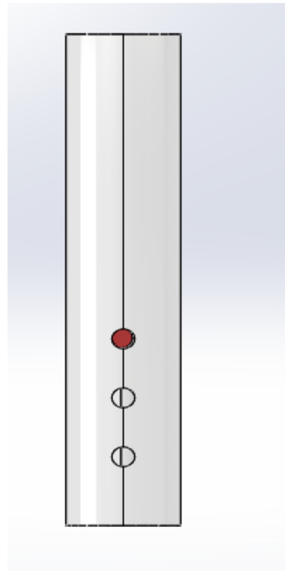


Figure 13: Legs at minimized height

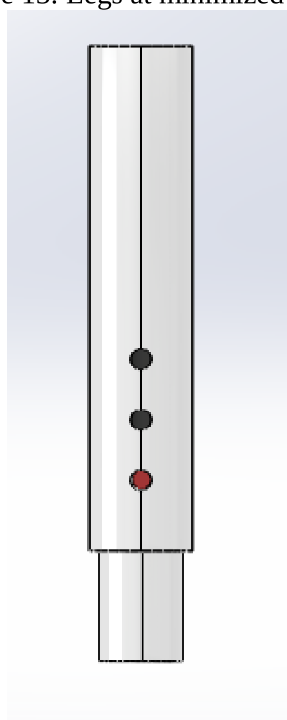


Figure 14: legs at maximized height

Legs should be able to endure the wright that the users put on it. In this design legs were made to adjustable, by making the legs height range from 0.7 to 0.76 meters. The top side of the legs part 1 (Figure 11) will be connected to the bottom side of the base, in addition legs part 2 will fit inside legs part 1. The red dot of legs part 2 should match up with one the black dots in legs part 1. If the red dot is matching the highest black dot the legs height will be smallest (Figure 13) and if the red dot matches the lowest black dot the legs height will be the biggest (Figure 14). To fix the legs height at a certain height The team will use a screw that fits in the black and red dots holes, the screw is not included in this design since that the team haven't decided the size of the screw that we will use. Legs are to be made of PVC

Plastic since it’s easy to make hole in PVC plastic, and in our case, PVC plastic won’t likely fail t the use of our customers.

6- Wheels

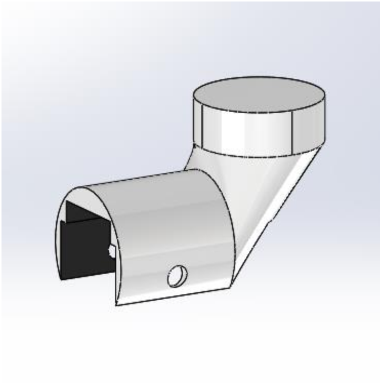


Figure 15: wheels base

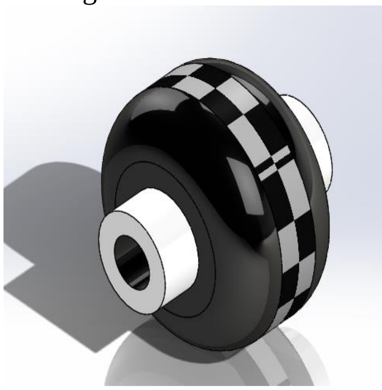


Figure 16: Wheels

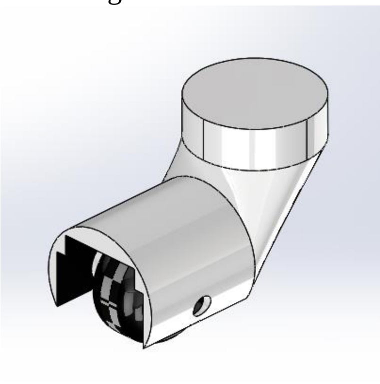


Figure 17: Wheels unit

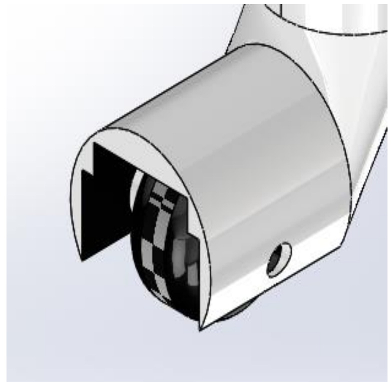


Figure 18: Wheels unit with wheels rotated

The suggestion of adding wheels to the design was made by our customer, our customer wanted the design to be portable because they indicated that they like to draw outside the building sometimes. Every leg of the design with be attached to a one wheel's unit, which consists of a wheel base (Figure 15) and the wheel itself (figure 16). Usually, those 2 parts are sold together in stores as a one part that looks like figure 17. The texture in the wheels were made to show that the wheels can rotate because the texture will position will change when wheels rotate (Figure 18). The material that will be used for the wheel's unit is not yet specified, but the team is looking for PVC plastic.

7- Attachments

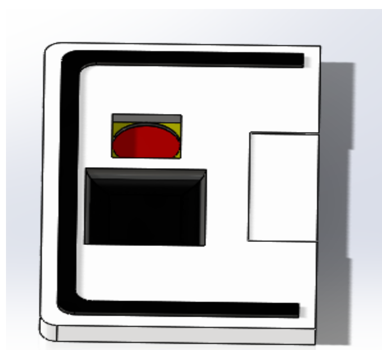


Figure 19: Left attachment

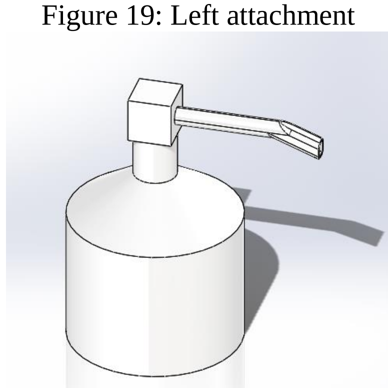


Figure 20: Water dispenser

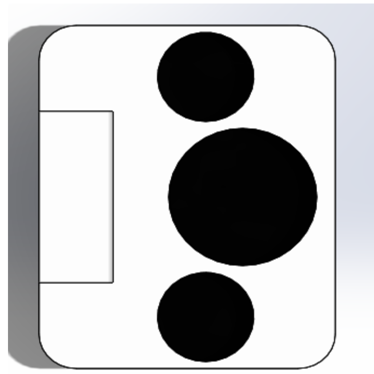


Figure 21: Right bottom attachment

Figure 22: Right top attachment

In order to make the design a multi-purpose one, the team decided to add attachments to the design, all attachments will be connected to the base using hinges, the place where the hinges of the attachments will fit in is labeled with a yellow color (Figure 2). The left attachment (Figure 19) will be connected to base at the left yellow carving. The left attachment is basically a place where the user can find a water source, instead of moving and struggling the reach another source for the water, and this was done because our customers told us that some of them find difficulties to reach the water sinks, especially the wheel chaired ones. The yellow and red holes in the left attachment are places where the water dispenser (water source) (Figure 20) will fit in. The diameter of the red hole is the same as the length of the yellow hole. The water dispenser the team is looking for is not specified yet, but, the team was thinking to get a soap dispenser from any supercenter store and use it as a water dispenser. The right top and right bottom attachments will be connected to the yellow carvings in the base. The right bottom attachment has three holes in it, the hole in the middle have the dimension of a standard water bottle, the other holes are smaller and it most cases they will be used to store art tools like pens. The right top attachments have a hole that is made to store the liquid colors like a palette. The attachments will be made in a way that makes it easy to unconnect them from the base, which makes it easy for the user to clean the attachments. The attachments will mostly be made from PVC plastic expect the Water dispenser, which will be bought online or at a local store. The team will try to find hinges that only can rotate at 180 degrees angle instead of some full rotation ones.

After all parts were done the assembling parts come to place, if the parts were connected to the base using the proper use of hinges, the parts together will assemble the final design (Figure 23). In order to show that the team worked to satisfy our customer needs for the design to be adjustable, more figures for the final design were added, where each figure shows the final design in a different position

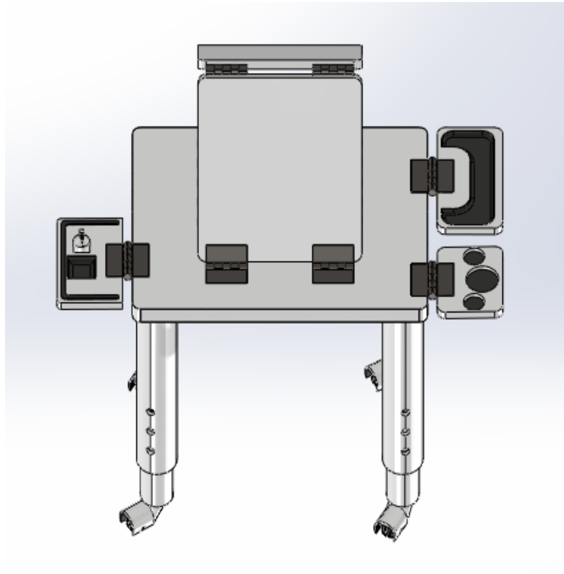


Figure 23: the final design

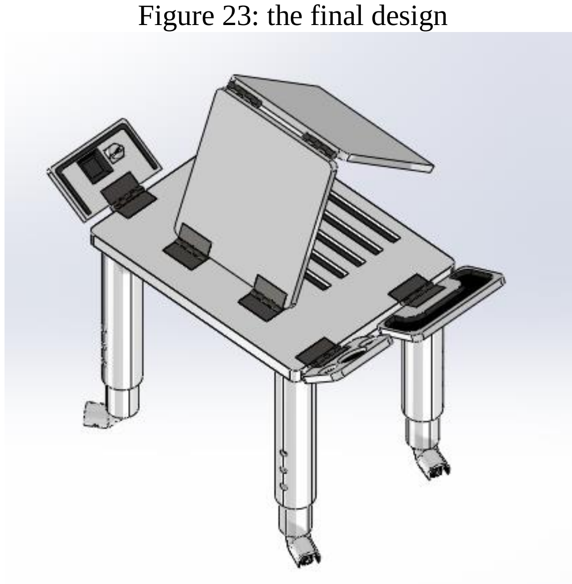


Figure 24: final design position 2

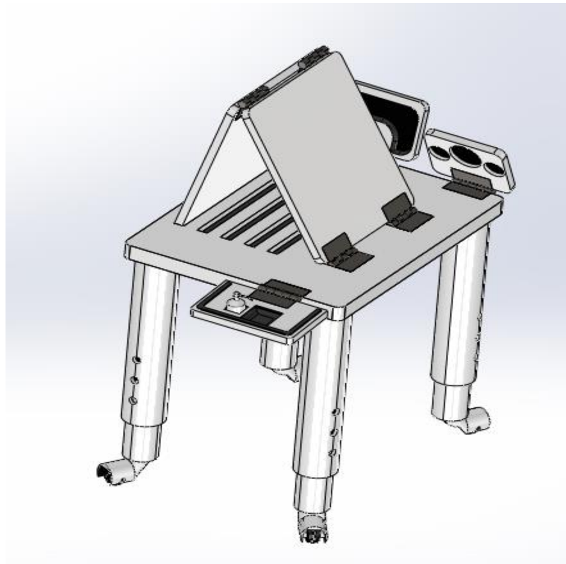


Figure 25: final design position 3

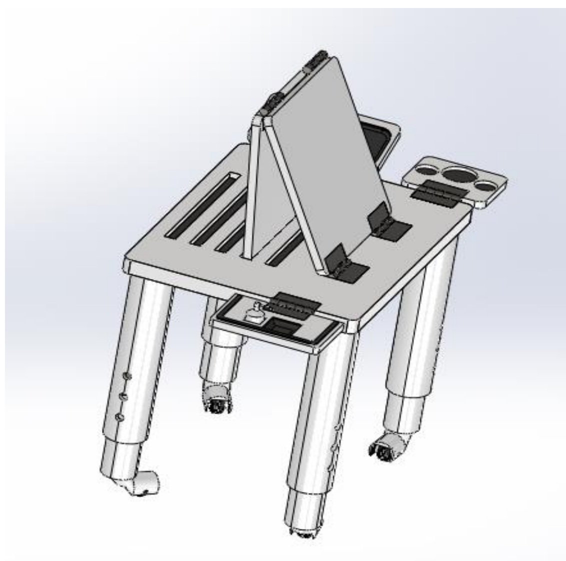
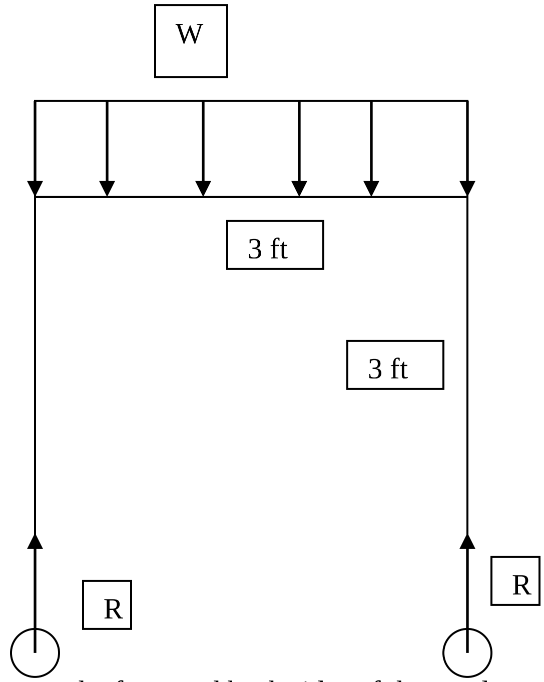


Figure 26: final design position 3

The final design in the CAD drawings will influence our team project by making it easy for team members to imagine the design, and therefore suggest changes and developments to it, this is also a better way to show our clients and customers what we are going to do, to get them approve and feedback. In addition, the Solid work allows the user to change the colors of surfaces easily, and this will help us by showing our customers a several figures of our design, where each figure have different colors than the other, in order for the team to get a better understanding of what our customers like, to reach the maximum satisfaction we can provide to them.

Appendix F: Strength of Legs Analysis

Madison Douglass
Individual Analysis
ME 476C
Hoz Art Team A, #17
Strength of Legs



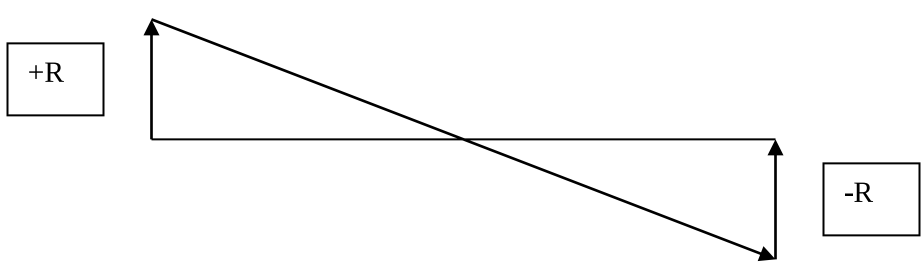
I have simplified the legs to be two rectangular frames on the front and back sides of the easel. The diagram of the frame is shown above. The weight of everything on top of the legs is estimated as an evenly distributed force. Possible materials along with their area and yield strength is listed below.

Material	Cross sectional area (in^2)	Modulus of elasticity (psi)	Yield stress (psi)
1" aluminum angle	0.140625	10.8*10^6	40,000
1" PVC	0.4939	420,000	9,600
1.5" PVC	0.7995	420,000	9,600
2" PVC	1.0745	420,000	9,600

To find the max weight due to compressive force, the reaction force must be calculate. The reactions will both equal half of the weight on the frames. Since there are two frames, the reaction will be equal to a quarter of the total weight.

To find the max weight due to shear force, shear force diagrams will be made. The maximum shear in the frame will dictate the weight that can be applied.

Shear force diagram on the top of the frame is shown in the drawing below.



The maximum shear is also equal to the compressive strength. The maximum weight allowable will be the same for each of these forces.

The maximum allowable weight from compression and shear for the easel (excluding the legs) is given bellow for each of the possible materials.

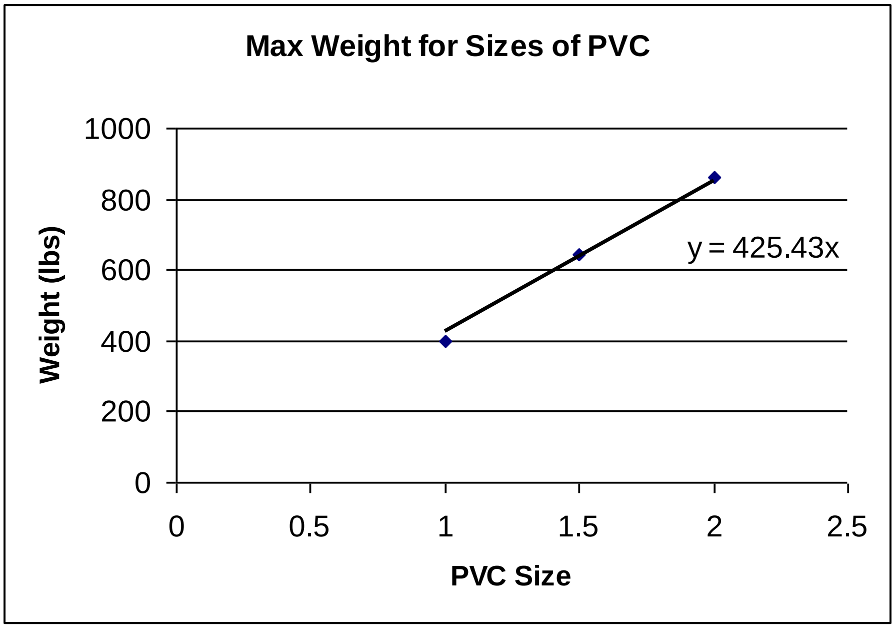
Material	As (in^2)	R (lbs)	Weight (lbs)
1" aluminum angle	0.140625	5625	22500
1" PVC	0.4939	4741.44	18965.76
1.5" PVC	0.7995	7675.2	30700.8
2" PVC	1.0745	10315.2	41260.8

It is apparent that the legs will not yield due to compression or shear forces. Next, I will calculate the allowable weight due to the flexure of the legs.

The maximum bending moment occurs in the middle of the top of the frame. The bending moment is equal to half of the total weight times half of the width. The maximum total weights are listed below for each material.

Material	Bending Stress (psi)	Ix	M	Max W (lbs)
1" aluminum angle	35000	0.203451	5696.615	632.9572
1" PVC	14450	0.324739	3568.428	396.4919
1.5" PVC	14450	0.759525	5776.388	641.8208
2" PVC	14450	1.275969	7763.263	862.5847

The legs are much more likely to break from flexure but are still able to hold up a large amount of weight. We should be able to hold all of the weight of the materials plus a person with the 1" PVC. The final decision for what size PVC we use will probably be based more on simplicity of design than for strength. If we decide to chose a PVC pipe that is of a different size, the maximum allowable weight can be estimated by using the trend line below.



References

https://www.professionalplastics.com/professionalplastics/PVCPipeSpecifications.pdf
http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6061t6
http://www.homedepot.com/

Appendix G: Environmental Impact Analysis

Mohammad Alotaibi

11/18/2016

Team#17 Design for Disability Hozhoni Art Gallery

Analyze the Device's Environmental Impact

Section: Wednesday 5:30-8:00 p.m.

Introduction:

In our design the material that we will made the design from is one of the most challenging part that we as a team face, which will fit out constraint. We decide to make a distinguish between these three material and figure which one is best to make our design from. The three materials are aluminum, wood, and PVC. These three material is the best choice to build our design from, but we will figure the best one between these three to make our design more useful and perfect. This part is about how the material could affect the surrounding environment and how can it be recyclable, because we want to provide a green design for our customer and our client. Below the distinguish and differences between the three material and how each one effect the environment.

Aluminum:

The aluminum is most widely used metal. It is the 3rd most abundant resource on our planet. Aluminum is commonly known as innocent compound. It is very rare in its free form. Approximately 1 ton of aluminum oxide is produced from every 4 tons of mined bauxite. In addition, I choose reference 1 to find the product that made with aluminum and how aluminum can affect the environment.

Products made with Aluminum [1]:

- Cement
- Aspirin
- Roofing
- House siding
- Vehicles
- Planes

Effect on environment by use of Aluminum [1]:

- When we talk about transportation system, aluminum helps to reduce the weight of car, buses, trucks, planes, trains etc. By reducing the weight of vehicle, the energy consumption during transport is reduced.
- When we talk about building construction, we know that building consume around 40% of world energy demand. Aluminum have some properties that is used to achieve the low energy consumption buildings.
- Aluminum in packaging is environmentally benefit due to weight reduction. Because by the reduction of weight, energy for transportation also reduces. It also reduces the food loss due to degradation reduces the environmental foot print of food production.
- Aluminum is a recycling material. It can be obtained from primary aluminum as well as recycling aluminum.
- Aluminum may also accumulate in plants and cause health problems for animals that consume these plants.
- In acidified lakes have lot of concentration of aluminum that causes problems for fishes present in lakes. The no of fishes in lakes is reduced due to the reaction between aluminum ions with protein.
- The concentration of aluminum do not only effect the fishes but also effect the air also. The animal that breaths aluminum through air may be lungs problems, weight reduction.
- In the ground water table, large concentration of aluminum is also present. It indicates that the aluminum will damage the plants roots production when present in ground water table.

Wood:

Wood is a fibrous structural tissue found in stems and roots of trees and other woody plants. It is used from thousands of years for fuel and construction material as well. In low energy ages, wood was the natural material of choice. References 2, and 3 was chosen for wood because they are good websites that describes wood and how can wood effect the environment.

Wood Products [2], [3]:

- Veneers
- Plywood
- Fiber Boards
- Chip boards
- Block boards
- Lamina boards
- Batten boards

Effect on environment by use of Wood [2], [3]:

There are some positive and negative effects of wood product on environment which are listed below:

- Wood is obtained by cutting down of trees. It destroys habitats, kill whole species, decrease amount of oxygen producing, atmosphere cleaning plants.
- Cutting down of wood also contribute to land erosion.
- The manufacturing of wood uses lot of energy from cutting, to transport, manufacture and again transport.
- Energy for transportation of wood is obtained from coal and fossils fuel which is bad for environment.
- Wood used for burning release greenhouse gases which pollute the atmosphere and contribute to smog.
- Wood is renewable resource that's why it is environment friendly.
- Use of wood products in building helps to reduce global warming.
- Wood products are encouraging to forestry expand, increase the carbon sink effect.
- Timber frame houses use low energy.
- Wood is the lowest energy consumption and lower CO2 emission than the other materials.

PVC:

The word PVC stands for polyvinyl chloride. It is the 3rd world most produced synthetic plastic polymer. It has two basic forms which are rigid and flexible. The rigid PVC used for construction purpose while flexible PVC used for other purpose. I choose references number for finding product made from PVC. Also, how can PVC impact the environment

Products made by PVC [4]:

- Pipes
- Doors
- Windows
- Bottles
- Cards
- Plumbing
- Electrical insulation material
- Signage

Effect of PVC on environment [4]:

- PVC is everywhere around us. But for environment point of view, PVC is most toxic plastic.
- In the vinyl life cycle, larger quantities of hazardous oregano-chlorine by-products are formed released into the environment and pollute the environment.
- Another significant issue is the production of dioxin and related compounds during uncontrolled burning of PVC in building fires creates health problems.

- Vinyl manufacture is associated with the release of more than 3500 pounds of mercury into the environment every year.
- When we burn PVC, it produced toxic gases in air which causes the negative effect on respiratory system and is the main cause of cancer.
- PVC is not a decomposable material.
- PVC contaminate the food also, toxic gases released while burning of PVC is the main cause of lungs problems and cancer as well.
- It is suggested that the recycled PVC should be used. Because in recycled condition it will not produce toxic by-products.
- PVC last for longer duration. It has very long life cycle.

Conclusion:

We have seen that these three mentioned materials (Wood, Aluminum and PVC) have some positive as well as negative effect on environment. All these materials are widely used around us. We cannot destroy them or stop using them. We can reduce their negative effect on environment by taking some positive steps. Nothing will be 100% accurate thing in the World. But we can have reduced their effect on environment by using recycled PVC, Renewable Aluminum, and avoid forest cutting, wood burning with some other important steps also.

References:

[1]"Water Treatment Solutions," Aluminium - (Al) - Chemical properties, Health and Envrionmental effects. [Online]. Available: http://www.lenntech.com/periodic/elements/al.htm. [Accessed: 18-Nov-2016].

[2] "Specific aspects of forestry and forest products to be considered in LCA," Environmental and energy balances of wood products and substitutes. [Online]. Available: http://www.fao.org/docrep/004/y3609E/y3609e07.htm. [Accessed: 18-Nov-2016].

[3] "Reduced Impact," Wood is Renewable and Reduces Impact | reThink Wood. [Online]. Available: http://www.rethinkwood.com/wood-renewable/reduced-impact. [Accessed: 18-Nov-2016].

[4] "Breaking News," PVC - Toxipedia. [Online]. Available: http://toxipedia.org/display/toxipedia/PVC. [Accessed: 18-Nov-2016].

Appendix H: Total Weight Analysis

DFD HOZHONI ART DEVICE

Josh T.

, ME476C Sect. 02 Wed. 5:30-8:00 pm

Introduction

This report is meant to discuss the total weight of the Design for Disabilities device for team seventeen. Since the project is designed for people with disabilities, that means that we should consider the total weight of the design in order to allow the users to move it and work on it. That means that the team should consider minimizing the total weight to a limit that the artists can handle it. On the other hand, the weight should not be too light so that it will not be stable at any surface and it will be not useful for the stakeholders. The approach that will be considered in this report in order to solve this issue for the team will be considering three materials for the easel and the main board, and always assuming that the legs will be made of PVC pipes and the wheels (casters) will be for one specific brand. The report will include national and/or U.S standard sizes for some of the part, for example: the length of the legs and the width of the device.

Assumptions

Equations:

1) V= L*W*h

V: Volume
L: Length
W: Width
h: height

2) m= ρV

m: Mass
ρ: *Denaity*
V: Volume

Device parts and materials:

The materials have been chosen regarding to the strength, and durability of it with considering how safe will it be if it used by artist. Glass has been excluded since it is not safe for the artist and it can cause harms to them. Most of furniture have been made of plastic, wood, and aluminum, because of that we considered these three materials to design the main board, attachments, and easel, and PVC pipes for the legs.

Legs: made of PVC
Main Board: made of Plastic, Aluminum, or wood
Easel: made of Plastic, Aluminum, or wood
Attachments: Plastic, Aluminum, or wood
Wheels: will be specific casters that will be noted in the calculation part

Calculation:

Average Densities:

The following values have been collected from different sources and some of them were in a range so the final value was the average number between the ranges.

1- Wood: 44 lbs./ft^3 [1]
2- Plastic (Polypropylene): 56.3 lbs./ft^3 [2]
3- Aluminum: 167 lbs./ft^3 [3]
4- PVC: 50 lbs./ft^3 [4]

Design dimensions

Some of the parts volumes have been selected from the last year project since this year team is enhancing their design. Attachments dimensions have been chosen approximately and they are subject to change depending on the need of the design.

Table 1: Main Board, Easel, and Moving Table dimensions

Parts / Dimensions	Main Board	Easel	Moving Table
Length (inches)	20	25	9
Width (inches)	36	30	18
Height (inches)	1.5	0.5	0.5
Volume (inches)	1080	375	81

PVC Legs:

- Outside Radius [5]: 2.375 inches
- Length [6]: 30 inches
- Inside Radius [5]: 2.067 inches

The length of the legs was taken per the standard dimensions for a wheelchair table which the team assuming Ed (the artist on Hozhoni Art Gallery who will be mostly the user of our device) according to the art advisers' comments who is a wheel chaired person.

- Casters Weight: 1.1 *4 = 4.4 lbs.

Device Calculation Based on materials:

By applying the second equation for the dimensions given, then plugging it to the third equation to find the weight in lb. After that, we can add the total weight of the parts to find the final weight for the device using that specific material we will end up with these values.

- Wood:

Device Total weight: 47.24 lbs.

- Plastic:

Device total weight: 58.2 lbs.

- Aluminum:

Device total weight: 157 lbs.

Conclusion

In conclusion, after calculating these parts it has been concluded that using wood as a material for the device is better than the other two noted materials, since the final design will weigh less. On the other hand, plastic as a material can last more than the other two material since it water proofed comparing to the wood and it conduct heat less than aluminum which is better for the stake holders. These results will allow the team to decide earlier which materials are the members going to use for building up our design and this decision will authorize the team to start ordering the needed materials and parts to reach the goal of this project.

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Appendix I: Strength of The Easel Analysis

Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

Individual Analytical Analysis
Haitham Hussain Almohammedsaleh
STRENGTH OF AN EASEL
November 18, 2016
DfD Hozhoni Art Device
ME-476C Sec02
Team 17

This project of coming up with a comfortable working station for artist with disability is based on the last year project shortcomings. As such, the work for this year's project is to improve the last year's easel to make it more comfortable and easier for the artists with disabilities to work on it. The previous easel had the following problems, which apparently form the basis for this year's project

a) It was hard to move since it was heavy and did not have wheels. This made it difficult for people with disability to use it
b) As per the artists comments the easel could be made more useful by adding some umbrella so that they could work with it in open sun environment if need be

c) The artists as well did not like the color of the previous year easel

In light of the above contemporary issues arising from the artist's complaints about last year's project product, out project this year is working towards resolving the above issues by

i) Designing a highly portable device-reducing the weight of the device and addition of wheels
ii) Designing adjustable and accommodative device that made it easy for the people with disability to use
iii) Designing safe, strong and easy to maintain device
iv) Increasing the device aesthetic beauty of the device so that it could be attractive to users. This improvement involves changing the color designs.

For purposes of this progress report, I am going to report on the analysis of the easel strength. In light of the above client needs easel strength is important because loads are placed on it and as such are likely to exert a lot of force on it. It is therefore important for easel to be stable to allow artist to accomplish their work without interruption of easel breakage. While the strength of the easel is important, lightness is also an important consideration given that the easel is supposed to be portable. The easel was made long to spread the load weight, increase its stability and working space. The material preferred was plastic because it is considered strong enough, light to carry and repair is relatively easy not to mention the low cost of the material compared to others. Other materials under consideration were wood and metal

Assumptions that drive the calculations

1. The measurements made for all materials are the same.
2. Same Loads are applied to the same cross sectional area of each material
3. Loads are subjected to the material in the same length of time

Equations used

1) Stress:

Stress =load/area($\sigma = \frac{F}{A}$)

S= stress(psi or lbs of force per in^2)

F= applied force (lbs of force)

A= cross-sectional area(in^2.)

This refers to the ratio of applied load to the cross-sectional area of an element in tension and it is expressed in terms of inch per square millimeter. In this easel case it will measure the ability of the various materials making the easel to withstand load when an artist is working on it.

2) Strain

Strain=change in length/original length ($\varepsilon = \frac{dl}{I_0}$)

ε = strain – unitless

dl = change of length (m, in)

I_0 = initial length (m, in)

Measures the extent to which a dimensionless material is deformed when load is placed on it. In this case of making easel this will measure the extent to which each material is deformed when same load is placed on it

3) Modulus of elasticity

This measures the elasticity of a material

Equation

Elasticity =stress/Strain ($E = \frac{FL}{A\Delta L}$)
E= the young modulus in space(Pa)
F= force in newton's(N)
L= original length meters(m)
A= area in square meters(m^2)
$\Delta L = change\ in\ lemght\ in\ meters(m)$

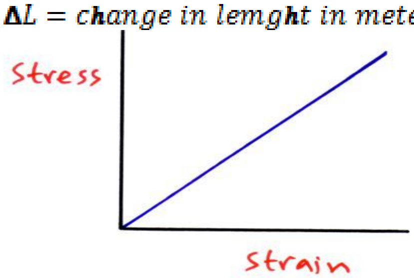

Figure 1: Force against extension

In t ity of stress to strain for each material.
Modulus is not affected by the temperature of the material

4) Poisson's ratio

This is the ratio of lateral to longitudinal strain of a material

Poisson ration =lateral strain/ longitudinal strain ($\mu = -\frac{\varepsilon t}{\varepsilon i}$)
$\varepsilon t = the\ lateral\ or\ Transverse$ $\varepsilon i = th\ longitudinal\ or\ Axial\ Strain$
$\mu = the\ Passon's\ Ratio$

5) Bending stress

Bending stress =$3PL/2Wt^2$
P-load
L-beam length
W-beam width
T-beam thickness
Y-deflection at the load point

6) Flexural modulus

Flexural modulus=$PL^{3/}4Wt^3y$
Table showing all the measured characteristics measured for each material

Material	Stress (psi)	Strain	Modulus of elasticity 10^6psi	Poisson ratio	Bending stress	Flexural modulus
Wood	4060	0.003	0.00005	0.4	0.005	0.006
Plastic	6050	0.4	0.005	1	0.2	0.3
steel	5040	0.002	0.004	0.8	0.01	0.032

Explanation

Wood:

Wood might be the obvious option out of the three, as it is the most commonly used in the making of easels. It is easy to deal with, simple to maintain and strong enough for the most part. Wood is not an isotropic material, meaning that its strength properties differ along its different axes.

Different types of wood produce different results:

- Strain parallel to grain: Wood is strongest when it's induced to stress parallel to grain.
- Compressive strength perpendicular to grain. Compressive levels perpendicular to grain range between is low

Steel:

Steel's mechanical properties vary depending on several factors; first of which is its chemical composition, heat treatment etc. Steel is a strong material which is known for its compressive and tensile strength, and it is therefore used in reinforced concrete in order to make up for the tensile strength which concrete does not have. It is stronger than wood. Finally, as we know that our project for disability people which's meaning we trying to do our best to make it light.

Plastic:

Plastic, especially vinyl, is a preferred choice for it has many desirable properties, amongst those is that it's lighter, yet more durable when compared with wood for instance. It's also important to note that plastic is basically maintenance free, as there's no danger of rot or corrosion Although plastic can deteriorate if exposed to sunlight for long periods of time. Although it has less compressive strength than wood and steel, it still yields very well and is therefore a material of choice.

Conclusion:

As per the information given above, the easel's best bet is to go for plastic material since it would cover all the factors mentioned or at least be sufficient enough to be workable and cost effective. Moreover, it is user friendly for the disabled due to its lightness and lesser hazards.

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Appendix J: Full CAD Package

Appendix K: Updated Gantt Chart