The Wonder Factory

Preliminary Report

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DISCLAIMER

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1 BACKGROUND

1.1 Introduction

Flagstaff, Arizona currently does not have a science center that enables the community to be involved with science, technology, engineering, art, and mathematics (STEAM) resources. Jackee and Steve Alston, have taken it upon themselves to develop a place where anyone can "learn through play". The Wonder Factory (TWF) is a science and engineering center that provides communities with opportunities to present classroom learning through interactive displays. These displays engage the user in performing tasks to understand underlying curriculum.

The Wonder Factory has asked our capstone team to develop a new display that will benefit the youth and young at heart. As a team, we are determined to design and construct an interactive display that educates the user about one or multiple STEAM concepts. The interactive display that our team selects to build will positively influence the Flagstaff community by getting their residents more aware and knowledgeable about STEAM. This report will outline the procedures and steps that will go into the process of defining which design meets customer satisfaction.

1.2 Project Description

Following is the original project description provided by the sponsor.

"Your task is to generate lots of interactive display ideas and to ultimately design, build and test one final display ready for public consumption."

1.3 The Wonder Factory

The Wonder Factory represents STEAM in all its concepts through interactive displays and learning modules. Originally, Jackee and Steve Alston decided to forefront this operation because Northern Arizona does not have a center that gets the community interactive with STEAM. The main goal of the Wonder Factory is "to lead the next generation of young minds into their place as the thinkers, the makers, and the creators of the future through hands-on interactions with science, technology, engineering, art, and mathematics."

1.3.1 The Wonder Factory Structure

The Wonder Factory is currently a mobile exhibition that has different events year-round. Its existing exhibits are built and designed by Northern Arizona University students. Since the Wonder Factory is the first of its kind in Northern Arizona, it can be known as a pioneering science center for rural communities. This type of outreach is important because Jackee and Steve are doing what they originally set out to do; give opportunity to communities that do not have access to STEAM education. This mobile unit provides a unique learning exhibition on wheels that will continue its outreach, even when a permanent place of operation is established.

The Wonder Factory is in the progress of finding funding to get a permanent place of residence for their interactive displays. When they do have a place of "brick and mortar" there will be different rooms that focus on areas of STEAM. There will be a Doctor's room that will consist of conceptual learning of anatomy and anything health-related. The toddler space will entail simple learning modules that incorporate basic motor skill development, and concepts that require rudimentary knowledge. These rooms will be filled with interactive displays that present one or more STEAM concepts.

These rooms are listed below.

- Doctor's room
- Scientists Lab
- Engineer's corner
- Geographer's shop
- Storyteller's café
- Naturalist's Playground
- Toddler space

1.3.2 The Wonder Factory Operation

Daily operations can be translated into monthly events held by the Wonder Factory. In the future when they have a building this might change based upon types of special events or include daily operations. Most of the events are not continuous and are up to change based on demand.

These events include:

- GEE WHIZ TRIVIA NIGHTS
- Factory after hours
- Wonder ambassadors
- Toddler times
- Field trips
- Birthday parties
- Special events hosting
- Tech bash shark tanks

1.3.3 The Wonder Factory Performance

The Wonder Factory is providing a service that was not initially met or recognized in Flagstaff and other northern regions of Arizona. This service is bringing fun interactive STEAM displays to the accessibility of communities that otherwise would not have them. The analysis below shows that there is a need of innovation of more interactive displays and extension of the preexisting TWF. As they progress in paving the way for a STEAM center in Flagstaff they still need more interactive displays because as shown in the survey below 84% of the community is eager to participate and come to the center. In all cases, there is room for expansion in creating educational interactive displays that create learning through fun because 71% of the community think the attractions already in Flagstaff are not suitable for children to have fun and learn. The community is eager to participate and come to the center but the goal should be retaining the consumers and making them want to come back or buy a membership. For any non-profit organization to thrive they need a relationship with the community to maintain the status of their structure and services.

Paid memberships will help sustain income and provide future development for expansion of The Wonder Factory.

The market analysis for the wonder factory includes these statistics:

- 71% of the people think that the attractions are not suitable for children to have fun and learn
- 84% of the people say that they would visit The Wonder Factory
- 58% of the people will go there once a month (these are people with memberships)
- 49% people say that they want interactive exhibits rather than visual ones
- 77% tourists spend 2.6 nights here and 23% of them will travel with children

1.3.4 The Wonder Factory Deficiencies

When interviewing Jackee, she had mentioned they were needing more interactive modules in a toddler dedicated space. Since most capstones teams are focused with upper level learning such as projectiles and wind vortexes they do not have a simplistic module for the younger generations. This could be a potential red flag when trying to find unmet needs of The Wonder Factory. The current system in place is gaining momentum with the incoming interactive displays but if the Wonder Factory is deficient in the toddler space, we want to investigate potential solutions or displays that would fill this need.

2 REQUIREMENTS

In the overview of the project description there are requirements that The Wonder Factory team should be considering throughout the progression of this project. One of these requirements is safety. During the client meeting, this was stated as their top priority. We should be keeping this requirement in mind when we are generating multiple concept variants because users will be interacting with our design and we want to minimize any injury. The capstone team is required to raise funds before the construction of the interactive display. There was not a given budget for the design, therefore we will be deciding this requirement in the future of the project.

Before the completion of the project we must select, design, build, and test one final design. This display will be expected to be used every day, we should test accordingly and make sure the design will last and have no occurrence of mishap. The Wonder Factory team should be following these standards to maintain complete clientele satisfaction throughout this capstone project.

Throughout the duration of this project, team members must interact with the clients until the completion of this capstone sequence. This is a requirement because for our design to meet customer satisfaction we need to be well informed of their expectations. We also need to know if they approve of specifications and if there needs to be any changes regarding our design or direction of the project.

2.1 Customer Requirements (CRs)

With client interaction, we will be gathering customer requirements. From key words and expressed concerns about project requirements we will deduce these into customer requirements. Customer requirements (CRs) are parameters that help engineers focus on the client's vision and standards of the design. By following these CR's the project will have more detailed information so engineers can translate these CRs into engineering requirements (ERs).

2.1.1 Safe & Simple instruction

Safety must be considered so that risk factor is minimized. Taking the necessary steps to figure out potential dangerous hazards is essential to making the interactive display as safe as possible. We want to establish a level of reverence with the community who are going to be using this interactive display. Depending on the design of the project we must account for safety, always, since the customer rated this at a 5. It is not only in the engineering discipline to design with safety in mind but it is important to the customer to have a safe product because lives could be at risk.

The customers expect the ideology of this design to be STEAM based concepts with the user interface of a "learning through play." The audience that will be interacting with our module will be assumed to have no foreknowledge of STEAM and will perceive the ideas as a student ready to learn. Thus, the design and display are easy to operate and understand so that the consumer does not need to be guided on every step. This also implies that it will be engaging enough that they will not lose interest. The customer rated this as a 5 because in the initial interview they mentioned that displays that attribute complexity fail. For example, a user will become disinterested with determining how to derive a calculus equation because it requires upper level skills of mathematics.

2.1.2 Hands-on & Wow factor

Hands on expresses a technique that gets the user involved in what they are learning. The customer requirements of hands on and education can relate to one another in this aspect. For instance, if the user is building something to compete they are applying what was taught to accomplish the task. If there is a requirement of interaction, physically, they are applying hands on interface while learning. The customer rated this CR as 5 because many learning practices require hands on experimentation and are proven to help grasp the subject matter.

Of these two customer requirements, the wow factor was rated at a 5. Jackee stressed this CR as important because it makes the interactor remember that display or learning module through amazement and wonder. Wow factor sets it apart from other interactive displays in a sense that it embodies something new and interesting. There were some concerns about wow factor and element of surprise being similar when presented to the main stakeholders. In the future, we will not be focusing on element of surprise since the customer expressed they were the same.

2.1.3 Simple to assemble & STEAM learning concepts

Complex assembly that requires extensive knowledge is not suitable for The Wonder Factory. As a team, we have considered that they are a mobile unit and do not have time to set up intricate displays. We need to transform complexity into simplicity to make sure assembly methods are easy and scalable for future use. As displayed in the house of quality in Appendix A, easy assembly is rated as a 4 which expresses their interests to have a display that can be set up within a reasonable amount of time. We also expect that we have fewer resources than other capstones with engineering laboratories so we need to make sure our display doesn't need extensive assemble or use of high machining technology.

In the project description, we are asked to make an interactive display that deals with STEAM concepts. We decided this was essential to incorporate STEAM because it is the backbone of the project but we want to apply these learning concepts in one or more forms. Meaning there could be more than one STEAM concept in our design. This CR is rated as a 4 due to the freedom we have and since STEAM concepts tend to be interwoven into each other as expressed by the client.

2.1.4 Narrative & Visual appearance

When interviewing Jackee we had questions regarding a hypothetical narrative and she informed us that interactive displays with narratives are more popular than others. This narrative could bring awareness to issues of daily life or around the world problems that need to be solved. The rating of 4 was the given for this CR because narratives could prompt the user to construct feasible solutions or introduce them to something they didn't originally recognize.

The interactive display should have appealing visual characteristics so viewers are fascinated and intent in participating in curriculum based STEAM methods. The customer deemed this CR as a 4. Visual appearance is vital when designing. It has been known that consumers are more inclined to use a product that looks superior than competitor products.

2.1.5 Relatable & Durable

The experimental setup should be based on real concepts and relatable material. We want consumers to gain an attachment through resemblance. This customer requirement is rated at a 4, if you can truly relate to something you will associate yourself with that subject. If the user can put themselves into the shoes of an engineer, an artist, and achieve rather than just be visual amused then we have accomplished our initial goal of getting the youth and young at heart educated and aware of STEAM.

When designing for something that will be used every day we need to account for long lasting and superior performance. Good quality raw material and mechanical components should be used to meet the requirement of durability.

2.1.6 Educational & Mobile

The educational feature will be incorporated into our design not only because it is a requirement but because it can positively impact the viewer. By gaining more knowledge they can apply it to real world applications and leave The Wonder Factory gaining a sense of understanding and accomplishment. This CR was rated at a 4 because the consumer must acquire information through a fun interactive element.

As the equipment, will be handled by the everyday person, mobility must be contemplated. The interactive display should be easy to handle and required simple movements to shift the display easily. The design should have the provisions to be readjusted per floor spacing and number of consumers present at any time.

2.1.7 Multiple Visitor

When an interactive display can only interact with one person the message is only received by one individual and the display is limited to collaboration. If we can get multiple participants interacting with the display this inspires team work and gets a message to numerous people. The customer assessed this requirement at 3 because it may not be as important as other customer needs, such as safety.

2.2 Engineering Requirements (ERs)

From gathered customer requirements, our team generated engineering requirements that outline specific measurable needs our designs need to meet. These engineering requirements have parameters and tolerances. These are visible in the table below.

(INSERT TABLE)

2.2.1 Attention of Audience & Comprehension of User

If our design is not getting over three peoples' attention at face value, it will be over looked and their interest will be lost. This engineering requirement will be measured by counting the number of people interested in our display. As a team, we decided it was paramount that there must be three people looking at or interacting with our display. This amount was determined based on previous benchmarking and viewing consumer interface. If a display could get many people intrigued it could achieve a level of popularity. We can account for the level of interest by incorporating visual and transparent elements that allow the user to see what is happening in the display. The users will be inclined to stay to understand the mechanical operations being carried out and the concepts behind them by visually seeing what is going on and engaging with the display.

The comprehension of the user is vital because the user is interacting with something they have no previous knowledge of. They need to be able to grasp what task they need to accomplish for the display to work. If the display has complex components, users will not know what to do and move on. This will be measured by observing how the user figures out what they need to do and if at the end of the task they understand what happened.

2.2.2 Display Preparation & Success Rate

The number of people that initially setup the display should be one to three people. We must account for easy assembly because if our display is too complex and has multiple parts, the display will not be worth putting together. If three people cannot put the display together, then there is a possibility of missing parts and overall functionality could be compromised by improper assembly.

The success rate is set at 100% because the final design must be fully functional and ready for consumption. If our design has any mishaps this could be a safety issue. Since our display is going to be used multiple times, we want to ensure it works and does not have any malfunctions. Users could be at risk if a component breaks and causes injury. If a problem persists, like a part malfunction over a certain period, then it must be rectified per use and replaced with another component that is better suited for that function.

2.2.3 Material Yield Strength & Number of STEAM Concepts

The raw materials and mechanical components used must have a high yield strength and stress bearing capacity. This equipment must be durable. Depending on material we could account for elastic strength as well by comparing different elastic materials. The chosen yield strength for materials should be over 150Mpa. We chose this because our display will be used by children and used regularly and we want to make sure there are no part malfunctions. If our display is undergoing heavy loads, we want to account for it by using high yielding material.

We decided to have a requirement of more than two STEAM concepts because we want users to gain as much knowledge as possible in a limited setting. These concepts are inter-related to begin with based upon benchmarking and customer interaction. For example, the helicopter ride at The Discovery Cube incorporates flight simulation and environmental sustainability. By incorporating different STEAM concepts, we will be maximizing visibility and absorption of multiple ideas, in a small-time frame.

2.2.4 Component Repair & Facial Features

We decided to make sure all components used in the construction of the display to be easily reparable or replaceable. If materials degrade over time we want The Wonder Factory to be able to find and purchase components effortlessly. If there is a component that needs to be custom made or manufactured that is broken this could make our design useless and nonoperation for an extended period.

For our project to succeed we must have learning through play and have an element of surprise. To measure the element of surprise we will be counting facial features and determine what kind of features are present while interface is occurring. While observing a display at TWF, they had an air gun that launched a rag into the air. When this happened, everyone would look up to watch it fall back to the ground. As displayed in the picture below, (Figure 1), these are the facial features of many observers. Although they were not directly interacting with the air gun, there was still excitement and an element of surprise.

Figure 1

2.2.5 Assembly Steps & Number of Inputs

The number of steps in the assembly should be kept below ten so the customer requirement of simple assembly is met. The reason why we want minimal procedures is because TWF is a mobile exhibit and they need to be able to set up displays with ease.

The maximum number of users we want interacting with our display is three. This will give our display multiple interface but also maximize safety by ensuring people are not over loading our system.

2.2.6 Skill Level & Center of Gravity

The skill level was determined to be novice because we are assuming the users have no previous knowledge of how to operate the display. The importance of basic skill level requires a growth of the user. As they operate the display they level up.

The center of gravity should be kept as low to the ground as possible for maximum stability. If the display cannot be structurally sound, then. The moment of inertia can be unsafe for the users of smaller age as the experiment will be difficult to handle due to larger weight lifting. The tipping point must be restrained to a maximum amount and instructions provided to avoid accidents.

2.2.7 Organized Components & Strength-Weight Ratio

This is an important requirement from the safety point of view as components must be well organized per the design. The electrical wiring and moving parts must be covered so that no one engages with them but only for repair and maintenance purposes. The design will have the hydraulic pipes covered for safety.

The strength should be at maximum by keeping the weight minimum for easy handling along with the required durability. Metals typically have a higher strength and weight heavy and difficult to handle, so we must keep in mind that the customers can be of small age and cannot handle heavy components with safety. Except the applied weight everything is made from light materials instead of metallic ones.

2.2.8 Operation Steps & Life Cycle

The number of steps in the operation should be kept at minimum level so that the consumer can spend less time operating and more time learning. This is an important factor

We need to consider material life cycle since interactive displays will be used multiple times throughout events. The reason why I am mentioning this is because if something happens it is not only a safety concern but the display can no longer be used when malfunctions happen. To account for this in our project we must know stress limitations on the materials we use. This could be tested by stress cycles and looking at fatigue strength of specific materials. Ultimately we want a high cycle life or an infinite life.

2.2.9 Assembly Time & Weight

The time required for assembly should be less than two hours or even less because the daily time available is to be divided in such a way that the customer achieves multiple completions of the tasks in shortest time possible. The loss of interest happens when it takes too long to complete the task.

Weight of the setup should be around 75 pounds as it is easy to handle for people while doing the experiment. Also, due to the carrying capacity of the fluid and pipes the applied weight must be in the design limit. Furthermore, the components should be of light weight which is to be moved by the customer.

2.2.10 Corner Radius & Heat Generation

The components when setup and interface occurs must be safe. Corners radius of 2-1/2in will make the edges less dangerous when compared to a These types of edges are necessary as children will be using the experiments and they are not educated enough to handle sharp edged objects.

The heat generation in the mechanical components must be controlled and internal cooling should be provided if needed. If heat generation is not controlled by a cooling system may be required which will add to the cost or on the other hand a separate compartment can become necessary.

2.3 House of Quality (HoQ)

The House of Quality (HoQ) in Appendix A emphasizes customer and engineering requirements. We determined customer requirements through an initial interview with the client. These were then rated, five being most important and one, least. Appendix A also contains verification that both Jackee and Steve Alston rated these requirements and approved them. By gathering this information from the client, we can define important standards that must be incorporated into our design and then translate them into engineering requirements.

3 EXISTING DESIGNS

Northern Arizona University capstone teams, over the past years, have contributed largely to The Wonder Factory by designing and constructing interactive displays with STEAM concepts. This has allowed The Wonder Factory to expand its exhibits and give more opportunities to the youth and young at heart through fun interactive learning tools. Listed below are existing designs already in place at The Wonder Facotry.

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3.1 Design Research

Each member of the Wonder Factory team was assigned to do research regarding existing designs. This research not only had members looking up existing interactive displays but centers where these displays were presented. The goal for this task was to find different science centers and how they inform the community about the concepts of the displays.

Members had to answer why people were drawn to the displays in the first place, what the user was acquiring from this display, how they were absorbing the information, and the teaching style the center was exercising. The point of these questions is to get a better understanding of what is happening in the underlying methods of teaching users STEAM concepts. Most research was preformed through looking at science center's website and going through exhibits. Reviews on yelp of different centers were helpful in determining popularity and how those centers presented their displays.

3.2 Existing Centers

At the state and national level there are many places were all kinds of people can get introduced to STEAM. In this report, we will be describing these places and how they interact with consumers, what techniques they use, and how they correlate to our customer requirements. By identifying these requirements in different centers, we can see trends that will help our team identify what works when trying to design an interactive display.

3.2.1 Existing Center #1: Science Foundation Arizona

The Science Foundation Arizona focusses on STEAM education. Its mission is to diversify Arizona's economy, link the industry needs with university research, and ensure the education system that creates 21^{st} century workforce. This center has a wide network were students work on robotics. Projects require participants to be hands on and interactive like the customer requirements we determined earlier.

Students not only develop electronic, mechanical, drawing, software, and programming skills, but also teamwork and project management techniques. Students can participate in local and statewide competitions that motivate the individual to proceed in STEAM occupational fields. Recently the students made a clever robot that can perform many technical tasks such as: pass a ball, catch it, run down a field and launch the ball. This center makes connections and establishes fun and exciting new experiences with hands on opportunities which helps its community.

3.2.2 Existing Center #2: Amazement Square

The Amazement Square has the possibilities of learning more about structures and buildings and there is the usual experimentation that is also present for hands on practices. They have a separate section for the Harry Potter fandom which includes specific fan foods as well the best restaurants in town. The basic learning is centered for toddlers and children. It is open interaction and multiple members can accomplish a task. The visual scheme is very appealing especially the harry potter section. This science center is more related to science than engineering and it does not have moving mechanical machines. Many members want to come back because of the scientific laboratories that give them access to…...

3.2.3 Existing Center #3: Intrepid Sea, Air & Space Museum

This museum is unique in the aspect that it is located on an aircraft carrier base. It has hands-on-displays of items used in everyday life. There are views of the lower living quarters, and an outdoor flight deck with an assortment of fighter jets and helicopters. This center places ordinary people in WWII veteran's lives. Users leave with an extended knowledge of aviation and aerospace. There is a mix of hands on and informational teachings.

3.2.4 Existing Center #3: The Discovery Cube, CA

Similarly, to The Wonder Factory, The Discovery Cube is meeting a need for a specific region of Los Angeles (LA), California. While southern LA has many science centers, there are smaller communities within LA that do not have access to large science facilities. The Discovery Cube satisfies this need in the San Fernando valley. The Discovery Cube is 71,000 square feet but when compared to other science centers it is small. For instance, the California Science Center has over 200,000 square feet. When visiting this center, there were many interactive displays that correlate to what is happening in California, such as, water and energy preservation, the science behind The Kings hockey team, smart shopping, and technology integration with youths. These displays are all engaging the user to learn and develop strategies to think when it comes to daily problems in life. The exhibit that pertained to hockey gave children the opportunity to put themselves into the role as a hockey player and learn about friction on a puck, the force behind shooting a puck into a goal, and blocking an incoming puck. This exhibit also had displays for multiple users to compete in racing games and promote teamwork through getting a puck past a simulated goalie. Other displays incorporated proper ways to recycle, smart shopping strategies when faced with different styles of packaging, and concepts to better sustain the environment.

3.3 Subsystem Level

The Wonder Factory team had to complete an analysis of components of displays, how they functioned, and which ones were popular. This section will consist of how team members determined why these individual displays are popular based on consumer interface. We will also analyze how the center demonstrates the educational aspect and how the displays correlate to customer requirements.

Each subsystem has a theme: astrology, environmental, and aeronautical. Existing designs under these subsystems are similar in the aspect of what they are educating individuals on but different in how they relay or display this information. This will be essential in determining trends between different displays.

3.3.1 Subsystem #1: Astrology

Since we live in a vast universe, astrology is forever expanding. There are several ways interactive displays can educate a community on our planetary system and other aspects of the universe. The following existing designs are different learning modules from centers that demonstrate many aspects of astrology.

3.3.1.1 Existing Design #1: Star Parties: Hands on Optics & Astronomy

The purpose of the hands-on display below in (Figure 2) is to help students learn STEAM through astronomy by putting telescopes in the hands of middle class students. Just before the sunset or 2-3 hours later, students can observe the universe through a telescope. They are instructed on how to use the telescope, and the origin of the telescope.

Figure 2

The telescope is an invention to explore the universe. While commercial grade telescopes are bulky, the ones provided to these students are scaled down. Smaller telescopes are useful for understanding the importance of exploration at a more direct and portable teaching tool. These students look at distant objects to have a better understanding of space and to put the universe into perspective. Users are educated about how telescopes must have two properties, how well it can collect light and how well it can magnify the image. By visually showing these students constellations and providing a hands-on approach when using the telescope, they can travel further into the universe and explore astrology.

3.3.1.2 Existing Design #2: Planetarium

The Adventure Science Center has a 63 feet dome called the planetarium consortium. It projects stars in the sky and gives audio presentations of past stories related to constellations. This center has research and experimentation facilities that involve multiple individuals into collaboration with one another involving any aspect of astrology or exploration. This center is delivering information through visual projection of astronomy by showing the galaxy we are living in. The ocular presentation is exceptional and the pleasant environment makes people relaxed. The space rides and the stories told here make a very constructive impression in the minds of the participants and they leave with concepts related to astronomy along with visual amusement.

Figure 3

3.3.2 Subsystem #2: Environmental

This subsystem focuses on displays that engage the user with renewable energy, and environmental disasters or phenomenon.

3.3.2.1 Existing Design #1: Catching the Wind

This display has users see what goes into converting wind energy into usable electric energy. The display ties into actual wind turbines and shows the user how energy is converted by having them not only view, but interact in the steps leading up to actual energy use. This display, as shown below in figure 3, educates the user of renewables and fossil fuel energies. Multiple users can be at different stages of the conversion

Figure 4

of renewable energy. Users are so drawn to this display because energy is essential to everyone’s daily life, we use it everywhere. It also informs of essential placement of wind turbines, boundary layers, etc. Through the exhibit’s live data tracking, visitors see which of the museum's own turbines are currently producing electricity and hear about why and how they installed them.

3.3.2.2 Existing Design #2: Flash floods:

There is an exhibit in the Smithsonian that takes the user down a dark hallway that has rain storm sounds. Users read lit up facts surrounding the canyon like walls that give information of flash floods and how fast they can occur. When you walk into the open area that are two plexiglas walls in the surrounding area and then water suddenly fills up the outer walls. This exhibit surprises users by showing them how fast flash floods occur and educating them of natural disasters. This is a popular display because it has that "Wow" factor and element of surprise. It makes the user think and gain a knowledge beforehand when the action takes place. They leave with a level of understanding from both informative and visual aspects. Since it is a walk through multiple users can go through at once all being surprised. The small space out of the safety from the user is water tight and filled with water by pumps.

3.3.2.3 Existing Design #3: Earthquake Simulator

At the California Science Center, there is an Earthquake simulator. This is a popular attraction due to the element of surprise that occurs when consumers engage in this display. This simulator not only shows how earthquakes feel but also informs them about certain buildings and how structural analysis can protect people from natural disasters. Illustrated below (Figure 5) is a review of someone's experience at this center. As you can see the interface communicates what makes buildings structurally enhanced to survive an earthquake. This is conveyed by allowing the user to reenact a scaled down version of an earthquake. Users step onto an area where the simulation takes place and get surprised by the vibrations made by a suspension system. When activated it


1/26/2017

This science center is free (except for the showings and the pixar exhibition) and donations are welcome.

When ever I go to a museum I expect to just look at things, but this museum is WAY different. I love the fact that it is HANDS ON, which makes it easier for me to ACTUALLY learn.

My favorite part was the free earthquake simulator. I learned about the how certain buildings are made in case of an earthquake. It made me learn that I want to be at the science center when an earthquake strikes.

Figure 5

3.3.2.4 Existing Design #4: Tornado Vortex

The Tornado Vortex (Figure 6) at The Discovery Cube has a panel that controls different settings of a giant tornado vortex machine. You can essentially control the speed, color, and amount of fog it gives off. The intake fan is located at the top of the ceiling which draws vapor up made from a fog machine. Users have total control of how the vortex is created. The interface system can be used by multiple persons but there is usually just one person in control. The educational aspect of this display is showing airflow and the science behind vortexes which can be seen in nature. Vortexes can hold lots of energy and they interact with gravity to create its form. Users liked to watch this phenomenon in a controlled space. It contained this wow factor because of the size and how fast you could make the actual vortex spin.

Figure 6

3.3.2.5 Existing Design #5: Home Section

This interactive display had users travel around a sized down home and learn about different utilities that are used in everyday life. This exhibit presented house hold items and how they use energy. For instance, pictured below in figure 7 is a measure of how much gallons of water someone uses in a time span when taking a shower.

Figure 7

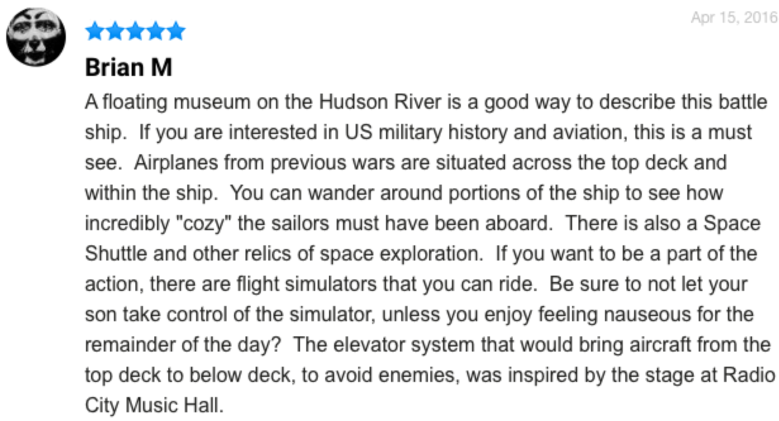
3.3.3 Subsystem #3: Aerospace/Aeronautical

This section focuses on aerospace or aeronautical concepts.

3.3.3.1 Existing Design #1: Flight Simulation

From reviews of the Intrepid Sea, Air & Space Museum it was discovered that the flight simulator is a popular exhibit that excites users by giving the illusion they are flying. This advanced technology makes users believe that they are in a virtual simulation. The review below in figure 8 wrote that it “puts you into the action.”

This interactive display has a hydraulic system that suspends the user in a virtual reality box. There are electrical/mechanical components that tie to software of the flight simulator. This learning technique makes the user not feel like they are learning because it requires the user to play a game.



Apr 15, 2016

Brian M

A floating museum on the Hudson River is a good way to describe this battle ship. If you are interested in US military history and aviation, this is a must see. Airplanes from previous wars are situated across the top deck and within the ship. You can wander around portions of the ship to see how incredibly "cozy" the sailors must have been aboard. There is also a Space Shuttle and other relics of space exploration. If you want to be a part of the action, there are flight simulators that you can ride. Be sure to not let your son take control of the simulator, unless you enjoy feeling nauseous for the remainder of the day? The elevator system that would bring aircraft from the top deck to below deck, to avoid enemies, was inspired by the stage at Radio City Music Hall.

Figure 8

3.3.3.2 Existing Design #2: Drones

The current focus of Science foundation Arizona is Aerospace & Defense Initiative. This center helps users design commercial unmanned aerial systems (UAS) and associated protocols for safe integration into national airspace.

Unmanned aerial systems are most commonly known as drones. This is an aircraft under remote control by a human or onboard computers. There are many types of drones as pictured below in figures 9 and 10. Drones are used for different purposes like surveillance, aerial photography, and military applications that are dangerous for human beings.

Figure 9

Figure 10

During flight drones usually require a controller. It is like what pilots use to navigate commercial planes for takeoff, and landing. Controllers communicate with drones using radio waves and are controlled by skilled individuals. This center provides hands-on training and experience in designing and aviation navigation. This is popular because it directly involves the users in implementing advanced technology while giving them experience of simulated flight and structural knowledge of these flight systems. Users leave this compound proficient in aeronautical awareness.

3.3.3.3 Existing Design #4: Helicopter ride

This ride is featured at The Discovery Cube in Los Angeles. When you enter the helicopter like door (Figure 11) you walk into a small room that has two sets of three rows that face a white screen. When the presentation starts, it projects you into a role as a pilot. The room is setup to look like the helicopter cockpit and you get to fly around the Los Angeles area. While the presentation progresses, you learn about water resources and how you can limit your water use to help the current drought in California. It informs the user about water ways and how water can be recycled through a water treatment plant. While this interactive display is mostly visual, there is a part where the video makes you feel like you're crashing which is exciting and gives the illusion of danger. People leave the display more aware of the limiting water resources and a sense of accomplishment from surviving a crash.

Figure 11

4 DESIGNS CONSIDERED

After benchmarking different centers and interactive displays team members came up with concept variants that had ranging topics of STEAM. These designs were compared to a datum in a Pugh chart that is in Appendix B. Each design will be compared to customer requirements to indicate which one the team will pursue.

4.1 Design #1: Pendulum Wave

This design consisted of a life-sized pendulum but instead of the usually same length weights hanging from wire, each ball would be staggered slightly below the one before to make a diagonal decent. Users pull the weights to a certain height and let go of them at the same time to make a pendulum wave. This would educate the user on the fundamentals of gravitational pull, potential to kinetic energy, and teamwork. Pendulums are normally used to showcase how energy can be transmitted from one object to another. This is defined from Newton's 2nd law, each action creates an opposite and equal reaction. This design would be scaled up and create a wow factor from its visual performance when users let go of the multiple weights. (Figure 12) shows this design. While this is a great technique to show how gravity works there would be an issue with safety. This model would require it to be bolted down because we want a secure display that will not tip. Since the balls are staggered it would have a center of gravity that would make it likely tip.

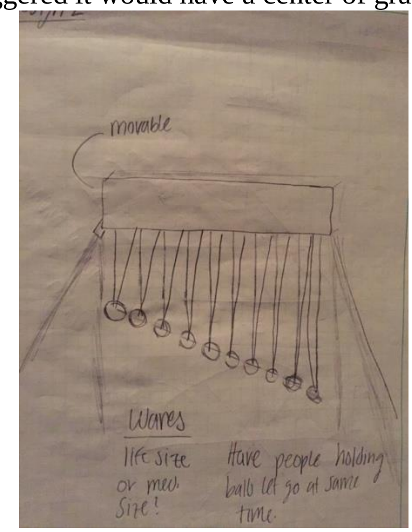


Figure 12

4.2 Design #2: Make Music with Water

Making music with water would entail having large cylindrical glasses (Figure 13) filled with certain levels of water. These cylindrical glasses would then be hit with rounded wooden hammers to create sounds. How this happens is that when force is applied to the glass, vibrations are made through the water resulting in a tone. These vibrations or sound waves are heard at different pitches depending on the level of fluid in these glasses. For instance, if it is a high pitch it would be associated with the glass filled to a smaller level because of the fewer vibrations traveling through the water. Multiple users could be interacting with display making music and playing with different pitches of sound while learning about sound waves and vibrations. This model could not meet the requirement of durability because over time users would hit this display and eventually it could collapse resulting in a safety issue. Glass is a brittle material which is hard to exactly determine when it will shatter when compared to ductile material that display deformations.

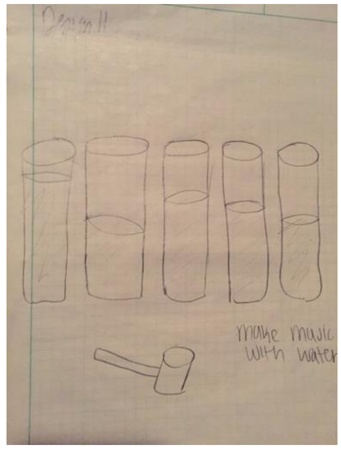


Figure 13

4.3 Design #3: Hydraulic Lift

This hydraulic design would be built by using two syringes connected to each other using plastic tubes as shown in (Figure 14). A two-way valve would act as a free way allowing water to be transferred from a bucket (reservoir) to one syringe that would simulate a water pump. This pump would push water to a larger syringe using a certain amount of pressure to lift a weight. These concepts are the fundamentals of a hydraulic system. A hydraulic system must have a water reservoir, a pump that can output a certain amount of force measured in pounds per square inch (psi), two pistons that are proportional in diameter, a two-way valve, a certain amount of surface area and volume, and a system that contains the fluid (incompressible fluid). When a child can simulate a pump pushing water using the small syringe and filling another larger syringe with water to lift his/her parents they will be amazed they can do this task. Normally their parents can lift them up and carry them with ease but if they were to try to simply lift their parents in return they would not be able to.

When the two-way valve is open, it allows the water to run back through the tubes and into the bucket. This would allow multiple simulations of the display. When users pump the water, they are essentially multiplying their force to the larger syringe. While this has a great educational aspect of hydraulic systems, water is needed to do the heavy lifting. The amount of pressure applied when moving the fluid needs to be accountable because if there is not enough (psi) the object cannot be lifted. Another precaution would be over loading this hydraulic system and making sure leaks do not occur. If there are leaks in this system, it will not work because the water will not be incompressible and energy and work put into the system will be lost.

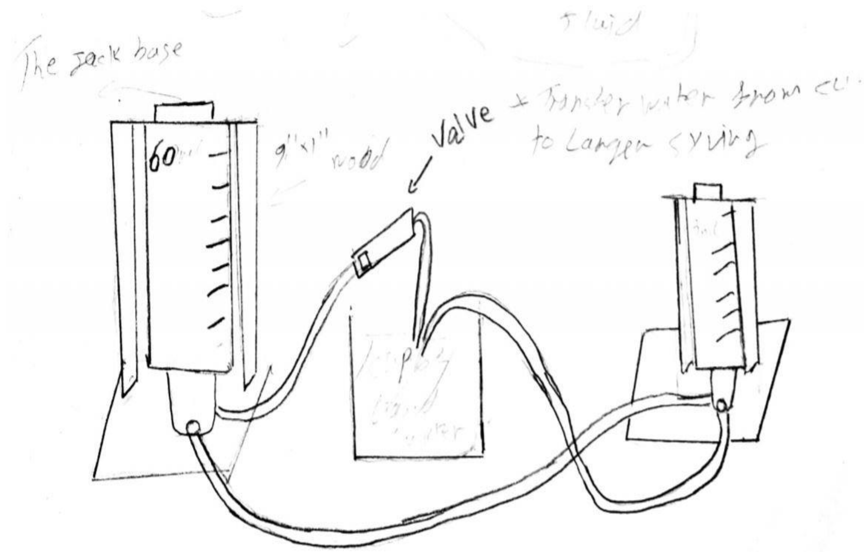


Figure 14

4.4 Design #4: Make a Bridge

This design has the compatibility with both making a suspension bridge and truss bridge. The provision is provided with detachable parts made of non-metallic materials which have no sharp edges. The design includes customer requirements that include safety, easy assemble and multiple users. This design has the element of creativity as the customers must construct a bridge themselves and then check if it holds the required weight or not. Minimum number of removable trusses should be used and at the end with hands-on experimentation the customers will learn about the load distribution and failure of bridges in daily life. The customers however require some pre-learning about the usage of pieces in construction.

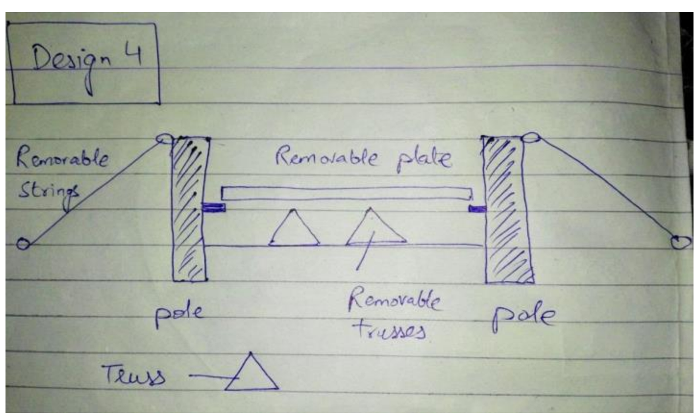


Figure 15

4.5 Design #5: Ball Propeller

This design has a hollow pipe and rubber ball which can be kicked into the pipe tunnel, with a fan in the pipe bend that will send the ball in the air and back to the person kicking it. The true angle of projection can be made adjustable as well for extensive learning. This design is safe to use but only one person can use it at an instance. It also has a factor of amazement because the fan will be invisible to the customer and they might wonder how the ball comes back to them. The basic concept learned in this experiment is the wind power which can be used to carry out mechanical operations. The second concept is the projectile motion of an object which is thrown at a specific angle and its landing point with respect to the projection angle.

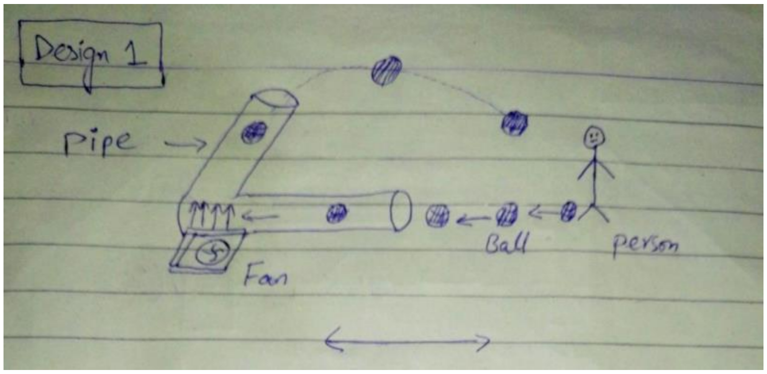


Figure 16

4.6 Design #6: Hill Climbing Racing

The facility has a race track made of plastic and a small vehicle with detachable magnets on its top. There is an electromagnet controlled with switch in the start. When we switch on the electromagnet is activated and the momentum is generated in the car to take it forward till the end. The basic concept learned in this experiment is the power of electromagnet and the use of momentum in scientific applications. The electromagnets is of specific power and detachable magnet has different sizes. Only one size will make the vehicle go till the end due to momentum. The design is very safe to use and electric supply used is of low voltage and it includes very important scientific concepts learned by easy experimentation.

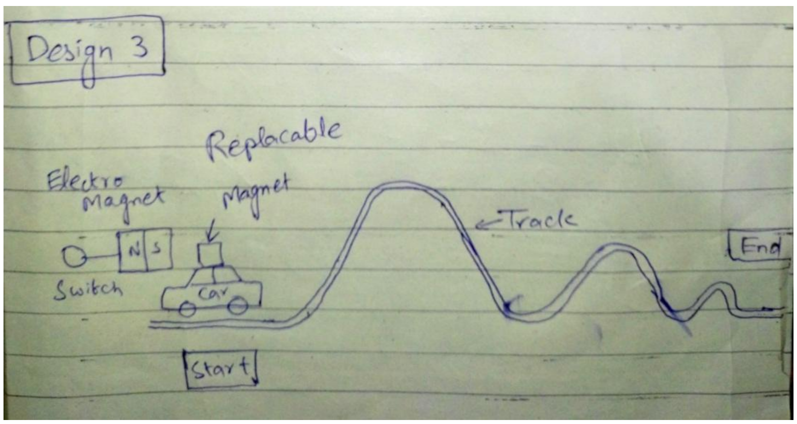


Figure 17

4.7 Design #7: Boat Sailing

The facility shown in the figure has a water tank with water supply through a pump. Detachable nozzles are present for mounting at the end. The water level will be adjusted in an order that only one tank is to be used. This experiment is safe to use and there is no involvement of electricity on front end as well. The experiment is based on the principle of fluid energy and its uses with an additional aspect of learning about the different nozzle designs and their ranges when fluid is thrown out of them. The nozzles will be available in different opening sizes and only one of them will make the boat reach the other end exactly. If a customer uses other nozzles, then the boat will not reach at the end.

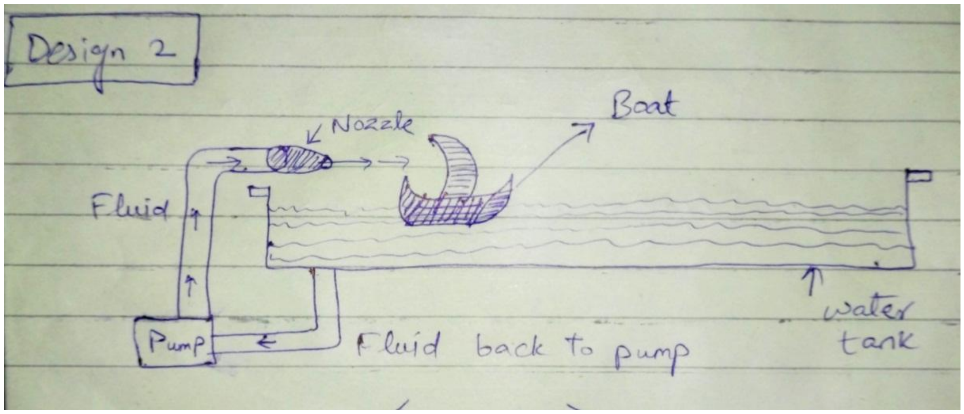


Figure 18

4.8 Design #8: Handle Wind Power

The main idea of this design is to build a wind turbine using gears and a handle shaft connected to plastic fan blades. The device should be built based on gear type and gear ratio to find out torque and how much power the fan will produce. The user can rotate the handle to transfer human energy into rotational energy. The blades will simulate wind energy when the actual energy is human. This design covers the concept of gears and teaches the user how the rotation of gears produces usable energy. Although, this idea is not safe for the consumer because if the blades were rotating too fast a child could be struck and the energy could be transferred into the child instead of the generator. The design also needs complicated machined blades which we cannot do. Another aspect to consider is that this design is only one user compatible.

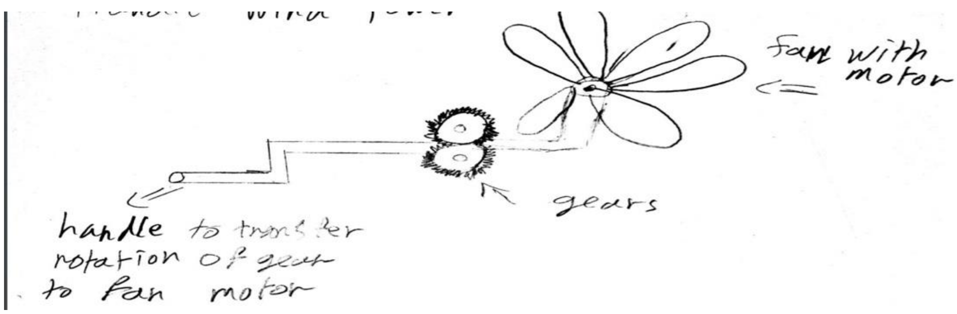


Figure 19

4.9 Design #9: Ball Race

This design focuses on expanding the toddler space. It is essentially foam pieces that can be put together to make a ball track. This design (Figure 20) is simplistic and requires competition in racing different colored balls down the constructed track. The foam pieces are light weight and can be handled by children. This would challenge rational thinking skills in constructing the best race track but since it is such a simplistic design it does not have a wow factor. Children will not be as interested in this because it is such a simple concept.

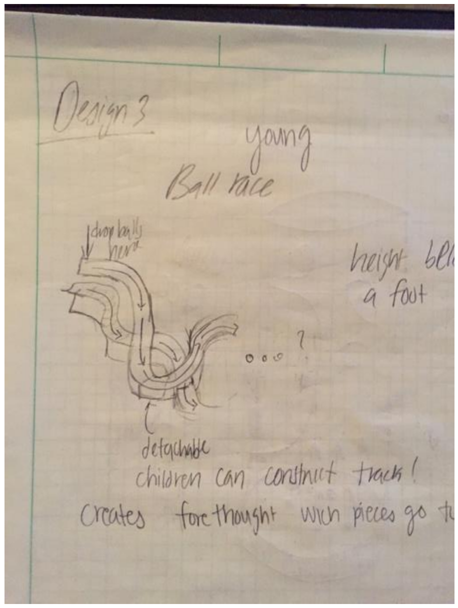


Figure 20

4.10 Design #10: Wind Tunnel

The wind tunnel displayed below in Figure 21 depicts a capsule that can hold up to three people. When the user steps into this cylindrical container they push a button and the internal fans below the bottom start up. The fans intake air and push it past the users to get up to 70 mph wind speeds. This display shows the user how fast wind currents are and can even elaborate on the internal speeds in a tornado. This would be an expensive display that has electrical components and hard to manufacture materials.

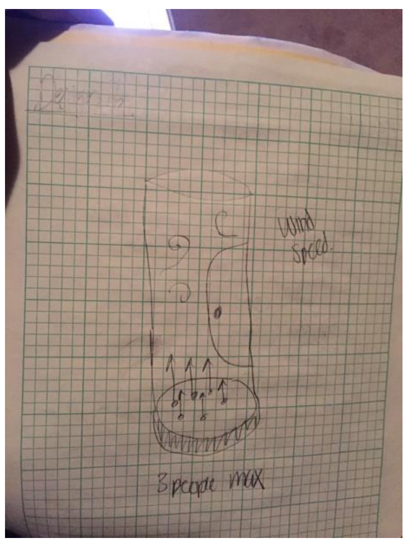


Figure 21

4.11 Design #11: Weight Lifting

This design is for children to show them how they can carry large weights based on the science of physics. As shown in the figure below, the design is made by a steel stand to hold a long steel shaft or a pipe. At the end of one side of the shaft, a rope will be tied up to the shaft so the user can hold it and pull the weight down. The weight will be 100+ kg. The main concept used for this display is that the pulling force which the user will pull, will allow the shaft to swing on top of the stand and make the weight move up from the ground. This is a multiple users design and inexpensive to build. The disadvantage of this design would be that it needs a larger space to be applicable.

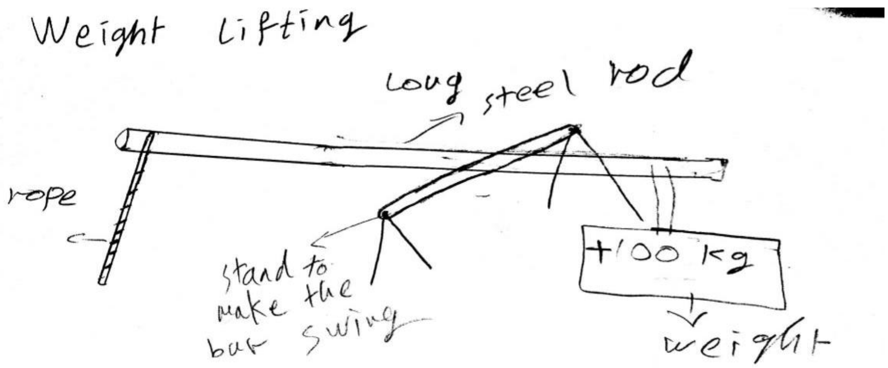


Figure 22

4.12 Design #12: Electric Train

The goal of this design to teach the customer the main goal of magnetic fields and how magnetic power is greater than mechanical power. The design as shown in figure 23 below is simply a made of copper wire, neodymium magnets and dry battery cell battery 6V or 9V. Magnets radius have to be bigger than the battery radius. The area between the magnets and electric current will flow to a coil which will cause the movement of the battery. Copper wire will act as a track for the Magnet train and by applying the battery inside the wire. Both sides of the magnet poles against each other very hard and force become bigger inside the track. For faster train, need a battery with bigger voltage. Advantages for the design are cheap to build, safe and easy to assembly. The only and most important disadvantage would be, the difficulty to deliver the scientific concept behind the design which is electric and magnetic sciences.

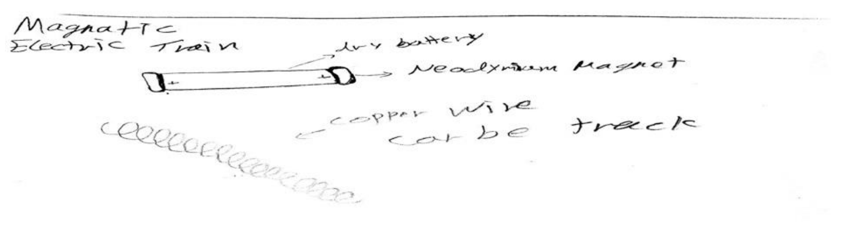


Figure 23

5 DESIGN SELECTED

5.1 Rationale for Design Selection

The design selected from the Pugh chart is found in Appendix B, was the hydraulic lift. This was chosen based upon the criteria of the customer requirements. Since we wanted to better design a hydraulic lift, we concluded to go back and redesign multiple designs of a hydraulic system to determine which one we could select to focus….

5.1.1 Hydraulic Chair

The hydraulic chair is like our original system but is redesigned into a chair support. The chair would be where users can comfortably sit while themselves or their child can pump water into the larger cylindrical piston.

5.1.2 Accordion Hydraulic Lift

The accordion lift or sometimes known as the scissor lift is a general design which is seen in many warehouse departments. Its goal is to lift the user up several feet into the air using a hydraulic, pneumatic, or mechanical system. In our case, we want to incorporate hydraulics and a fundamental hydraulic component that teaches….

5.1.3 Board Hydraulic Lift

This system could be built into the ground or be just above the ground. It would gradually rise multiple users above the ground. This hydraulic system would involve four components working together to lift any weight.

5.1.4 Hydraulic Arm

This design was used as our datum.

Hydraulic

The design covers most of the customer requirements such as safety for the users and multiple users can use it and most important, that it covers two science concepts that STEAM stands for. At the end, customers can learn more about how a small amount of water can lift big objects or even their parents using the mechanism of pumping water through tubes and syringes.

[Use this section to explain / justify the design solution selected. Your selection must be one of the possible solutions described in the previous chapter or a combination of several, and you should discuss why, given the various advantages and disadvantages of all of the options given, the selected solution is most appealing. All teams must include a Pugh Chart and Decision Matrix to justify their findings. Use an Appendix for any lengthy engineering calculations or large figures/tables.]

[Include in Preliminary Proposal and all subsequent reports.]

6 CONCLUSIONS

……..

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APPENDICES

APPENDIX A

Table 1: House of Quality

Customer Requirement	Weight (Rank)	Engineering Requirement	Moment of inertia (low center of gravity)	Corners must have a raidus of curvature (2-1/2 Corner Radius)	Weigh less than 75lb	High yield strength of materials greater than 150MPa	Strength to weight ratio	Life cycle must exceed 100 operation hours	# of audience paying attention to display	Cannot exceed 10 assembly step	Minimal level of comprehension for user	Easy repair components	Cannot generate heat that exceeds room temperature	Wiring/tubing of any kind must be placed in an orderly manor	Must have 2 or more STEAM concepts	no operation mishap (100% success rate)	no more than 3 inputs at a time	No more than 5 steps to operate	Skill level: Novice to operate	# of excited facial features needs to be 4 or more	Cannot exceed more than 3 people to set up	Assembly time <2hrs
1. Safe	5		9	9	3	9	3	1	0	1	0	1	9	3	0	9	1	1	0	0	1	0
2. Simple instruction	5		0	0	0	0	0	0	1	9	9	3	0	0	3	0	1	9	9	0	9	3
3. Hands-on	5		0	0	0	0	0	1	0	1	1	1	0	0	0	1	9	3	1	0	9	1
4. Wow factor	5		0	0	0	0	0	0	9	0	0	0	0	0	1	0	1	1	0	9	0	0
5. Simple to assemble	4		0	0	1	0	0	0	0	9	0	9	0	3	0	9	0	1	1	0	9	9
6. Integration of mult. STEAM concepts	4		0	0	0	0	0	0	1	0	1	0	0	0	9	0	0	1	0	0	0	0
7. Narrative	4		0	0	0	0	0	0	3	0	3	0	0	0	3	0	1	0	0	1	0	0
8. Visual appearance	4		1	3	3	9	1	0	9	0	0	1	0	9	0	0	1	0	0	3	0	0
9. Relatable	4		0	0	0	0	0	0	9	0	9	1	0	0	1	0	0	0	9	0	0	0
10. Durable	4		9	3	1	9	9	9	0	1	0	9	3	0	0	9	0	1	0	0	0	0
11. Educational	4		0	0	0	0	0	0	9	0	9	0	0	0	9	0	1	0	3	9	0	0
12. Mobile	3		3	1	9	1	9	0	0	3	0	1	0	9	0	0	1	0	0	0	3	3
13. Multiple visitor	3		0	0	0	0	0	9	3	0	1	0	0	0	1	0	9	0	0	3	0	0
Absolute Technical Importance (ATI)			94	60	62	120	82	73	183	104	141	108	57	90	111	122	102	82	102	106	140	65
Relative Technical Importance (RTI)			12	19	18	5	14	16	1	9	2	7	20	13	6	4	10	15	11	8	3	17
Target(s), with Tolerance(s)																						
[add or remove T/T rows, as necessary]																						
Testing Procedure (TP#)																						
Design Link (DL#)																						

Approval

Team member 1: London Starlin LS 3/24/17

Team member 2:

Team member 3:

EMAIL PROOF:

Jackee Alston <thewonderfactoryflagstaff@gmail.com> Feb 15

to Abdullah, me, Mohammed

Hi All,

Steve and I filled these out. Should Vicki fill one out, please disregard it. She's just learning how to make exhibits but I'm glad she came along to meet you guys. Thanks!

Talk to you soon,

Jackee

APPENDIX B

Table 2: Pugh Chart 1

Customer Requirements	Weight lifting	Handle Wind Power	Water Cycle	Ball Race	Catapult Rubber Gun	Wind Turbine Using Gears	Lifting Jack Using Gears	Magnetic Train	Pendulum Wave	Wind Tunnel	Musical Water	Life Size Operation
Safe	0	0	0	0	-1	0		0	-1	0	-1	-1
Simple Instruction	0	-1	-1	0	0	-1		-1	0	0	0	0
Hands-on	0	0	-1	0	0	0		0	0	-1	0	0
Wow Factor	1	1	0	0	1	0		0	1	0	1	0
Simple to assemble	1	0	0	1	1	0		1	1	0	0	1
mult. STEAM concepts	0	0	0	-1	0	0	D	0	0	0	0	0
Narrative	-1	0	0	-1	-1	0	A	-1	0	0	0	0
Visual appearance	1	1	1	0	0	1	T	0	1	1	1	1
Relatable	1	1	0	0	1	1	U	1	0	1	0	0
Durable	0	0	-1	0	-1	0	M	-1	-1	0	-1	-1
Educational	-1	0	0	-1	-1	0		-1	0	0	-1	0
Mobile	0	0	1	1	1	0		1	1	0	0	0
Mult. visitors	1	0	0	0	0	0		0	1	1	0	1
Positive	5	3	2	2	4	2		3	5	3	2	3
Negative	2	1	3	3	4	1		4	2	1	3	2
Same	6	9	8	8	5	10		6	6	9	7	8
Total	3	2	-1	-1	0	1		-1	3	2	-1	1

Table 2: Selected Designs (Pugh Chart 1)

Customer Requirements	Weight lifting	Handle Wind Power	Pendulum Wave	Wind Tunnel	Hydraulic Lift
Safe	0	0	-1	0	0
Simple Instruction	0	-1	0	0	0
Hands-on	0	0	0	-1	0
Wow Factor	1	1	1	0	1
Simple to assemble	1	0	1	0	1
mult. STEAM concepts	0	0	0	0	0
Narrative	-1	0	0	0	0
Visual appearance	1	1	1	1	1
Relatable	1	1	0	1	1
Durable	0	0	-1	0	0
Educational	-1	0	0	0	0
Mobile	0	0	1	0	1
Mult. visitors	1	0	1	1	1
Positive	5	3	5	3	6
Negative	2	1	2	1	0
Same	6	9	6	9	8
Total	3	2	3	2	6

Appendix C

Table 3: Pugh Chart 2

Customer Requirements	Acordian Lift	Hydraulic Arm (DATUM)	Chair Lift	Board Lift	
Safe	0		0	-1	
Simple Instruction	0		0	0	
Hands-on	0		0	0	
Wow Factor	1		1	1	
Simple to assemble	-1		0	0	
mult. STEAM concepts	0	D	0	0	
Narrative	0	A	1	0	
Visual appearance	0	T	0	-1	
Relatable	0	U	0	-1	
Durable	0	M	0	0	
Educational	0		0	0	
Mobile	0		0	0	
Mult. visitors	1		1	1	
Positive	2		3	2	
Negative	1		0	3	
Same	9		9	8	
Total	1		3	-1	

Appendix D

Figure 24: Black Box Model – Hydraulic Lift

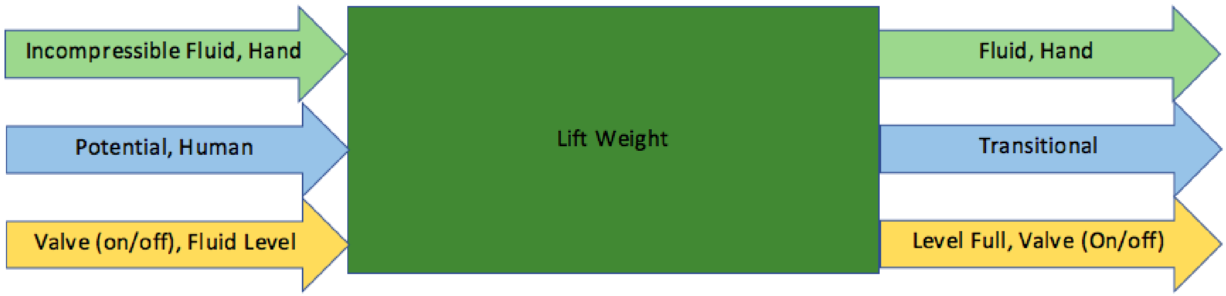

Figure 25: Functional Model –Hydraulic Lift (THIS WILL BE CHANGED)