1 BACKGROUND

1.1 Introduction

The Wonder Factory is a learning center that integrates art into science, engineering, and technology and provides interactive experiences for the young and young at heart. The Wonder Factory STEM Display B – Team 15, which will be referenced as "the team", has the opportunity to generate learning through play. The Wonder Factory staff, along with the team, feel passionately that the next generation must be given opportunities to have hands-on, interactive experiences to take their positions as the thinkers, makers, and creators of the future. Northern Arizona University will be sponsoring the project and will offer financial aid up to 1500$. Since this project is dependant on the team's idea, the budget might be more than 1500$. In this case, the team will ask the institution for help with The Wonder Factory project in order to build a much bigger project with the highest quality possible. Once the team is finished with the project, there is a possibility that it will be on display at The Wonder Factory, Inc. (TWF) in Flagstaff. Upon completion, children and students will have more incentive to visit TWF because the project will give them a more safe, interactive, meaningful, and enjoyable experience. With how the project is framed, it will take a high-level complex scientific theory and break it down to the simple level in which any age, with any experience, can enjoy and learn from. Because of this, there will be the opportunity to create a new generation, here in Flagstaff, that will be able to view and learn science from a young age in a way that they haven't been able to before.

1.2 Project Description

The Wonder Factory project is a project about generating a lot of interactive display ideas, building, and testing a final display that would be ready for public consumption. Seeing as how The Wonder Factory is a place for children, safety is our number one priority. Keeping safety in mind, we will be generating up to 100 different project ideas that can be virtually anything that will benefit the knowledge of the children at this center. Once we come up with a lot of the project ideas, we will eventually limit it down to the most interesting and interactive idea and then pursue this as part of our second semester. During this time, we will be designing, building, and testing (for safety first!) our project so that it is interesting, fun, and interactive for the children at The Wonder Factory.

2 REQUIREMENTS

STEM projects are exhibits that help children to develop their scientific, technological, mathematical and engineering principles. Some of the STEM projects include the design of a catapult, floating islands, etc. The designed project should be used by children easily so that they can learn basic scientific, technological, mathematical and engineering principles. These projects must meet the following requirements; functional, ease of use, durable, have aesthetics, affordable, portability, and safety. It is expected that designed project performs its intended function. For example, if it is a catapult it should be able to propel balls to a certain distance. The project should be easily operated since is meant to be used by children aged 8 – 12 years. Another requirement to consider is the physical appearance of the project. The project must be physically appealing. But, the functionality should not be compromised for the sake of aesthetics.

The designer must ensure that the device is affordable to most individuals by using cheap and available materials. Although the materials used should be cheap, their structural integrity should be sound so as to ensure the durability of the instrument. The other requirement of the project is that it should be portable. The portability requirements are achieved by having wheels, guideways or designing a light device that can be carried from one point to another. The last requirement provided by STEM design is that it should be safe to operate. Safety has aspects are guaranteed by having safeguards on the moving parts.

2.1 Customer Requirements (CRs)

The customer requirements for STEM projects include; portability, safety, multiple users, tactile, auditory, visual, project themselves into the role, aesthetics and simple. These projects are meant to be used by children to learn scientific, technological, mathematical and engineering principles. Therefore, one of the paramount requirements is that the device should be safe. The safety aspect of the project is achieved by covering the moving parts. The customers expect the device to be portable by having wheels or being light. A light project can be obtained by using a light material such as aluminum instead of steel. The customers require that the device should be able to be used by multi users by having features such as adjustable height. The customer also, expects the device to be functional in that children should use it effectively to learn scientific, technological, mathematical and engineering principles. The functionality of the device is achieved through features such as tactility, visibility, and auditory. The STEM projects are expected to be aesthetically pleasing. This feature motivates children to use the projects for their learning purposes. The last requirement by the customers is that the devices should be simple in construction and operation since they are meant to be used by children.

To design, these projects so as to meet customers' requirements, the design must prioritize the requirements using weights. The most important requirements are given weights of 5 while the least important requirement are given weights of 1. The prioritized requirements are summarized in a house of quality as given below.

2.2 House of Quality (HoQ)

As of now we have contacted our clients and we are waiting for approval of our House of Quality. We will update our HoQ once we have approval.

House of Quality (HoQ)

Customer Requirement	Weight
1.Portable	5
2.Safety	5
3.Multiple Users	3
4.Tactile	3
5.Auditory	2
6.Visual	3
7.Project themselves into role	4
8.Feel smart	4
9.Simple	5

Table : House of Quality

3 EXISTING DESIGNS

This section details the research conducted on the current processes used by other science centers and available interactive displays. The team evaluated several science museums/centers to gain information on what type of information is delivered to their visitors and how it was delivered. The team then went into further detail by examining interactive displays and how they communicate information to their users.

3.1 Design Research

With the Wonder Factory being a learning center that integrates art into science, technology, and engineering while providing interactive experiences, the team researched other science museums and centers around the country. The team conducted this research by attending science events in Flagstaff where the Wonder Factory was a participant and by investigating other centers of science utilizing their official websites.

3.2 System Level

The research conducted at the system level was aimed to find what type of information is provided by other centers and how they deliver it to their visitors. This allowed the team to understand some what kind of information is provided by science museums along with current methods used to communicate it. The team investigated four different science centers in the United States: the Oregon Museum of Science and Industry in Portland, the Pacific Science Center in Seattle, the Arizona Science Center in Phoenix, and the Exploratorium in San Francisco.

[3.2.1] *Oregon Museum of Science and Industry* [Online]. Available :https://www.omsi.edu/exhibits

3.2.1 Existing System (center) #1: Oregon Museum of Science and Industry

Museums are known for educating the community by researching and collecting information. One of the most known museums that have followed this path of offering education to the community in the United States is Oregon Museum of Science and Industry [3.2.1]. Oregon Museum is found in Portland and aims at providing both engaging educational exhibits that focus on science, technology, engineering and mathematics (STEM). OMSI is the largest organization in the United States that provides education programs to families, children, adults, schools, etc. through presentations. The museum also offers financial assistance to students so that they can complete their scientific projects. The museum is about 219,000 square feet with about five halls that have numerous scientific exhibits and displays, a submarine display and a planetarium. The sections of the Museum are as described below.

USS Blueback

USS Blueback is a submarine located in the museum and used to educate the public about propellers. This display offers daily tours and also, visitors who want sleep over are allowed to.

Featured exhibit hall

This hall is used to display temporary exhibits. The exhibits may be produced by the museum personnel or may have been purchased from other institutions [3.2.1].

Turbine Hall

The exhibits found in the turbine hall are projects that apply the principles of engineering, physics, chemistry, and technology. The chemistry lab located in the turbine hall and has six stations that allow visitors to perform experiments that test nature of matter biochemistry, chemical reactions, etc.

The hall also is equipped with a physics lab, Laser/Holography, and Vernier technology laboratory. In the physics lab, exhibits such as electrical circuits, magnetism, motion detectors, etc. are displayed. The Laser/Holography lab is used to generate holograms and is opened one hour in a day. In the Vernier laboratory, the visitors get to learn the effects of technology on the society by investigating various technologies such as communication technology, robotics, biomedical technology among others [3.2.1].

Life sciences hall

This hall is located on the second floor of the museum and is divided into Life science hall and Earth science hall. The life science hall allows the visitors to study a wide variety of animals.

Also, there is an aging machine that enables visitors to create a picture of themselves as they age. The earth science hall displays the geology – orientations. The Earth science hall has a Watershed laboratory that allows the visitors to investigate on erosion cycle using a river model and the Paleontology Laboratory gives the visitors an opportunity to see the excavation process.

Science Playground

This is an area located on the second floor of the museum and serves children up to six years old. The science playground gives children security and allows them to learn scientific principle through play [3.2.1]. Examples of science exhibits found in these locations include; giant sandbox, reading area, etc. In the science playground, there is a discovery laboratory, which gives children an opportunity to develop their cognitive behavior.

Other sections of the museum are the planetarium and an Auditorium. The planetarium is used for the purposes of astronomy shows while the auditorium used for holding events such a science fair.

3.2.2 Existing System #2: Pacific Science Center

The Pacific Science Center in Seattle, WA, is a science museum that "brings science to life". The history of this science museum consists of very interesting milestones and dates. The Pacific Science Center began as the United States Science Pavilion during Seattle's World Fair during 1962. After millions of people had come to visit this place over the years, eventually the science pavilion was given a new life as a not-for-profit Pacific Science Center as we now know it today. This created history as it was the first U.S. museum founded as a science and technology center. Some interesting aspects of this science museum are that it contains programs for people of all ages, ranging from toddlers to adults, and exhibits for the everyday visitors [3.2.2].

Examples of some of the programs for the children and toddlers consist of many labs, camps, and clubs that they can join. Children can join anything from the "Preschool Family Play Lab" which gives the parents the tools in order to teach their young children some interesting science ideas through themes and songs, all the way to the "Scouts in the Wild" which gives children an after-school option to learn about badges, wilderness, and various other outside team building activities [3.2.2].

Some of the major exhibits that exist at the Pacific Science Center are "The International Exhibition of Sherlock Holmes", "The Studio". With "The International Exhibition of Sherlock Holmes", visitors are given the chance to discover how Sherlock Holmes used various observations and science techniques to solve crimes that were, at the time, considered impossible, and learn about how many of his techniques are still in use today. "The Studio" offers visitors the chance to observe and view current health related research that is occurring in the area [3.2.2].

3.2.3 Existing System #3: Arizona Science Center

Intro and explanation what they have and how they show it off.

The Arizona Science Center in Downtown Phoenix is a great example of science made fun. The science center is split up into permanent exhibits mixed in with an ever changing cast of rotating educational science shows. Many of their exhibits are hands on and give people and kids a first hand experience with the science being shown. The presentation of their exhibits are very eye catching and hard to miss.

Their permanent exhibits are split up into Nine different sections. Each section talks about a different aspect of science in a way people can understand. Their Nine exhibits are: All About Me, American Airlines Flight Zone, Evans Family SkyCycle, Forces of Nature, Get Charged Up, Making Sense of Your Dollars and Cents, My Digital World, Solarville, and The W.O.N.D.E.R. Center.

The All About Me Exhibit is a showing of how the human body works and shows things like surgeries and how they are done by professionals. The learning is not all just visual, people are also given the opportunity to hear and smell what it is like to digest food.

The forces of Nature exhibit is a great meteorology learning experience. People can experience the “Magic Planet” Which allows you to see the last six weeks of weather patterns around the planet. You will also be able to see the cloud and air patterns that create major storms around the world. [3.2.3]

Their non-permanent exhibits also look very interesting. One of them is called “Alien Worlds and Androids”. The exhibit asks if the human race is really alone in the universe and talks about A.I., Robots, and Aliens. This is a more interesting exhibit than it is educational, but it still has the science feel to it.

Besides their exhibits, the Arizona Science Center also provides training and development courses for students and teachers. These courses are more STEM orientated and look like very good opportunities to learn STEM skills.

3.2.4 Existing System #4: Exploratorium

The Exploratorium in San Francisco, California consists of six museum galleries which focus on different areas of exploration. All of their exhibits are interactive and allow their visitors to touch, feel, and operate various displays. The six galleries are: South Gallery: Tinkering, East Gallery: Living Systems, Osher West Gallery: Human Phenomena, Bechtel Central Gallery: Seeing and Listening, North Gallery: Outdoor Exhibits, and Fisher Bay Observatory Gallery, Observing Landscapes.

The Tinkering Studio allows visitors to “think with their hands and explore your creativity” by using exhibits such as the marble machine, a non-electronic “tinkerer’s clock” that is full of chimes and a device that counts the rotating put into while while you explore your own participation and patience [3.2.4]. Inside the Living Systems gallery, the visitors are able to learn about to learn about life around them such as the hourly height of the tidal of the San Francisco Bay, the various plankton in different parts of the ocean, and view different life forms under a microscope. The west gallery allows visitors to “experiment with thoughts, feelings, and social behavior” by discovering more about the science behind sharing, building an arch and exploring the science behind it, and walking through a completely dark dome where the visitors are able to explore their different senses [3.2.4].

The gallery of seeing and listening provides the visitors with options to experiment with light and sound through exhibits such as the monochromatic room that is colorless, standing in front of the “giant mirror” and also by playing an instrument that the user can vary its pitch [3.2.4]. The outdoor exhibits of the north gallery allow visitors to “investigate forces shaping the City, Bay, and region” by observing how the wind and tide affect the exhibits. Some of the exhibits include a 27-foot tall harp that uses the wind to create sound and observing how the tide flows by watching arrows in the ocean change [3.2.4]. The Fisher Bay Observatory Gallery provided an opportunity to view the geography, history, and ecology of the San Francisco Bay area by having an exhibit that is a large-scale relief map of the area and seeing what kind of data is being collected by the environmental field station project.

The museum also hosts public events where exhibit designers and special guests talk about their contributions to the museum and current science events. The museum's website also provides links and videos to events around the world such as solar eclipses and live deep-sea exploration. There are sections that give teachers opportunities to conduct in-class learning sessions, as well

3.3 Sub System Level

The team evaluated four different designs that are either currently used in science museums or are capable of being an interactive display. The goal was to understand how a smaller system delivers information to its users and what can be learned from them.

3.3.1 Existing Design #1: My five senses

[3.2.1.1] OMSI (2016, May). OMSI. My five senses project. Retrieved September 26, 2016, from http://www.omsi.edu

OMSI project benchmark: My five senses

OMSI plans events whose is to provide a platform for young students. In this case, the students are provided with hands-on, exiting and explorative activities. As such, the students manage to enjoy and develop the urge to engage in the scientific learning process. In this case, the projects are organized as events, where the scientific world is presented in a simplified manner, for the young students to understand. Among the projects planned is "my five senses."[3.2.1.1]

"My five senses" is a project whose aim is to provide students with an environment that enable them to learn the science behind the five human senses. These senses include hearing, sight, impulse, taste and smell. In this case, the organizers provide the scientific equipment, which can replicate our senses. As such, the students attain a scientific perspective towards the subject thereof.

Theoretical background of the design is the biology of human sensory organs. In this case, the parts of the sensory organs, how the organs function and their relationship to our daily activities are studied. Then, the theoretical aspect is redesigned and fabricated to present visual and audio presentations, which provide a more elaborate and comprehensive learning environment[3.2.1.1].

Having the project done by the students themselves provides the students with a platform for direct involvement in the systematic process of research[3]. As such, the students develop a positive attitude towards science and the practical nature of the subject. In addition, the students can engage with their instructors in a different environment, which breaks the monotony of theoretical lessons.

The five senses project provides also enables the students to relate the lessons they learn about human senses, to the scientific thinking and design process. The students are required to make the sense organs using the provided materials and organize them to serve the roles of the human organs. Here, the relation is derived from the systematic disassembling and assembling of the models of the human sensory organs. As such, the students manage to attain lessons that they can apply in other areas of study. Also, the students have the ability to ask questions, which is a critical step in STEM and overall, the scientific study and research process[3.3.1.2]. It is also noteworthy that the students also gain interest in following a systematic process in the study, which includes problem statement, statement of constraints, the definition of method of implementation, following a set procedure and finally analysis and presentation of results.

3.3.2 Existing Design #2: Strandbeest

[Describe this system-level existing design and explain how it relates to your requirements.]

There are so many different types of this product and this figure is one of the many works by Theo Jansen. This work does not use any motor or engine to function, but instead uses only the simple resource, wind, to power it.

The basic concept of this product is getting energy from wind and changing it to linear and rotational motion, so it will move forever unless the wind stops. This product is showing a good example of the how legs will normally cycle when in motion.

3.3.3 Existing Design #3: Radiation Concentrator Competition

[3.3.3.1] *Concentrated solar power* [Online]. Available https://en.wikipedia.org/wiki/Concentrated_solar_power

This design takes some inspiration from our heat transfer class and want to try to teach these kids about solar radiation. The systems would be small and we would provide different materials for the kids to build their concentrator with. The goal would be to heat up a temperature sensor as fast as possible using only a source of heat radiation and many different types of materials. They could use the sun or try to capture as much of their radiation source as possible.

This project would let the kids think and design their own solar concentrator. This is the type of project that needs to be made for the wonder factory. Not this exactly, but something that there is no one right answer for. Their only limitations should be their imagination and our materials.

3.3.3.1

Something like this, but on a very small scale. Safety would be a key factor. There will be a sensor that will shut off the radiation source before unsafe temperatures are met.

3.3.4 Existing Design #4: Marble Machine - need to edit

In San Francisco, CA, there is a museum of science, art and human perception called the Exploratorium. Inside this museum, they have an area called the “Tinkering Studio.” This studio is “an immersive, active, creative place where visitors can slow down, become deeply engaged in an investigation of scientific phenomena, and make something – a piece of a collaborative chain reaction – that fully represents their ideas and aesthetic” [3.2.4]. This correlates closely with the goals of The Wonder Factory in the sense that both places want to encourage their visitors to engage their minds and learn while having fun.

At the Tinkering Studio, there are various projects that visitors are able to participate in and put their creative minds to work. Some examples of these are a musical bench that makes music when people touch, a wind tube that allows you to design a small machine using everyday objects to explore its aerodynamics, and even plastic fusing where you are able to turn old plastic bags into fashionable items. The project that interested me most and that I thought could be a good interactive display for The Wonder Factory is the marble machine.

The marble machine is a creative ball-run contraption, made from familiar materials, designed to send a rolling marble through tubes and funnels across tracks and bumpers until it reaches a catch at the end. This marble machine uses a peg board as a stand and allows the user to create an infinite number of possible runs while using problem solving skills combined with trial and error to get the marble from the top to the bottom. This machine engages the user's mind and gives them the freedom to use any of the parts any way they choose. The marble machine is an example of an interactive display that is fun, simple, and the complexity can be defined by the user.

4 REFERENCES

[Include here all references cited, following the reference style described in the syllabus. If you wish to include a bibliography, which lists not only references cited but other relevant literature, include it as an Appendix.]

[3.2.1] *Oregon Museum of Science and Industry* [Online]. Available :https://www.omsi.edu/exhibits

[3.2.2] *Pacific Science Center* [Online]. Available: https://www.pacificsciencecenter.org/

[3.2.3] *Arizona Science Center* [Online]. Available: http://www.azscience.org/

[3.2.4] *The Exploratorium* [Online]. Available: http://www.exploratorium.edu

APPENDICES

[Use Appendices to include lengthy technical details or other content that would otherwise break up the text of the main body of the report. These can contain engineering calculations, engineering drawings, bills of materials, current system analyses, and surveys or questionnaires. Letter the Appendices and provide descriptive titles. For example: Appendix A-House of Quality, Appendix B- Budget Analysis, etc.]