NORTHERN ARIZONA UNIVERSITY

College of Engineering, Forestry & Natural Sciences

The Wonder Factory STEM Display
B – Team 15

Background Report

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DISCLAIMER

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TABLE OF CONTENTS

1 BACKGROUND

This section provides information on the client, The Wonder Factory, along with the client's project description.

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 support up to $1500. Since this project is dependent upon the team's idea, the budget might be more than $1500. In this case, the team can fundraise in the Flagstaff community to pay for any additional costs. 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 safe, interactive, meaningful, and enjoyable experience. The frame of the project takes a complex scientific theory and breaks it down to a simple level. Because of this, the younger generation in Flagstaff, regardless of experience, will be able to enjoy and learn science in a way that they may not have been able to before.

1.2 Project Description

The following is the original project description provided by TWF:

> Your task is to generate lots of interactive display ideas and to ultimately design build and test one final display ready for public consumption. Your final design must:
>
> - Must be safe to all users per applicable safety standards. Safety is your first priority!!
> - Must be ready upon completion of this capstone sequence
> - Should generate up to 100 ideas – including existing, new, wacky, and off the wall concepts
> - Must select, design, build, and test one final unique idea
> - Should test the interactive display in a similar setting to expected everyday use
> - Must raise some of the funds required to finish the project
> - Must interact with the clients in order to maintain parity with their expectations [1]

1.3 Original System

This project involved the design of a completely new interactive display. There was no original system when this project began.

2 REQUIREMENTS

The team analyzed the project description and met with the client to create the customer requirements (CRs). These CRs specify and clarify the overall project objectives and were given a weighting based on importance. The team determined the engineering requirements (ERs) needed to evaluate the potential designs and future final design. The ERs were designed to be verifiable with target values with tolerances with their respective justifications.

2.1 Customer Requirements (CRs)

The CRs for this project include: portability, safety, ability to have multiple users, ability for users to project themselves into the role, aesthetics, and simplicity. Additionally, the project must have tactile, auditory, and visual aspects and must enable the users to "feel smart". 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 through the use of light materials, such as using aluminum instead of steel. The customers need multiple users to be able to use the device. This requires the project 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.

Each CR was given a weight based on importance. The most important requirements are given weights of 5 while the least important requirements are given weights of 1. The prioritized requirements are summarized in the House of Quality in Table 1 of Section 2.

2.2 Engineering Requirements (ERs)

The ERs were designed to provide a way to objectively measure specific parameters or conditions based on the CRs. Each ER was assigned a value along with a justifiable or rationale tolerance. In regards to portability, which has been gauged based on weight, fixtures, and durability of the components, a score of 5 shows that the designed object moves with ease, and the motion does not affect the functionality. Given that there is a range of area of portability, a score of 5 has been attained for an area of less than 200 $ft^{2.}$ Here, tolerance reduces outside the stated area of 200 ft^2. Regarding safety, the precautions include weight, power, and exposed faces. Here, the highest score of 5 is attained when the weight is low and no sharp parts are exposed. Regarding usability by multiple individuals, a system that accommodates at least two users has been regarded as multi-user. The highest score is given when more users can be served at the same time. Tactility is a measurement of the extent to which the product can be handled by human hands. In this case, the rating is based on the ergonomic aspect of the exposed parts as well as the power consumed. Also, the presence of sharp edges, which could injure the user, is a negative aspect thus would result in a lower rating. In regard to auditory and visual aspects, which majorly encompass the comfort of the user, based on how the product affect the hearing and the vision of the user, the rating depend on the power consumed and the higher the power consumed, the lower the above two aspects, given that there are audio and visual noises that affect the user negatively. The project attains high rating when it has an interactive display and offers an educational value during the use of the product. Finally, how smart the user feels and simplicity of use are two aspects regarded in this case too. In this case, the simplicity is determined by the display and educational aspect of the product.

2.3 House of Quality (HoQ)

The team's HoQ below has the customer requirements along with the respective weightings. The approval emails can be viewed in Figure 4 in the Appendix A.

Table 1: House of Quality

House of Quality (HoQ)

Customer Requirements (1 - 9):	**Weight**	**Engineering Requirement**	fits in set-up area	low total weight	low cost	meet power/voltage potential	no exposed sharp edges	visual display added	multiple, simultaneous operation	educational level
1. Portable	5		5	4				1	2	
2. Safety	5			4		3	4			
3. Multiple User	3								5	
4. Tactile	3					2	4			
5. Auditory	2					2				
6. Visual	3					2				
7. Project into role	4							5		4
8. Feel smart	4							4		5
9. Simple	5							3		5
Absolute Technical Importance (ATI)			25	40	0	31	32	56	35	61
Relative Technical Importance (RTI)			7	3	8	6	5	2	4	1
Targets; with Tolerances			100 ft^2; <200 ft^2	90lb; <150lb	$1200; <$2000	16V; 14V> & >20V	1/8" corner radius; <1/6" 1/16" edge chamfer <1/8"	1 display; > 3 total	4 users; 2< & >6	tailored to age 10; 6<

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 TWF being a learning center that provides interactive experiences using STEM integrated with art, the team researched other science museums and centers around the country. The team conducted this research by attending science events in Flagstaff where TWF was a participant and by investigating other centers of science utilizing their official websites. The team chose four science centers in the United States to evaluate and determine what kind of information is provided to their visitors, what type of exhibits are available, and how information to delivered to the visitors. At the subsystem level, the team found four different interactive displays or exhibits that are either currently operating in a science center or could potentially be an interactive exhibit. These four subsystems were assessed to establish a benchmark on what is currently being used in the industry and what information is provided through each exhibit.

3.2 System Level – Science Centers

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 Existing Center #1: Oregon Museum of Science

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 [2]. Oregon Museum is found in Portland and aims at providing both engaging educational exhibits that focus on 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 are the USS Blueback, the Featured Exhibit Hall, the Turbine Hall, the Life Sciences Hall, and the Science Playground

The USS Blueback is a submarine located in the museum and used to educate the public about propellers. This display offers daily tours and visitors how the option to sleep over. The Featured Exhibit Hall is used to display temporary exhibits. The exhibits may be produced by the museum personnel or may have been purchased from other institutions [2]. 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, and biomedical technology among others [2].

The Life Sciences 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. The Science Playground 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 [2]. 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 Center #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].

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 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].

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].

3.2.3 Existing Center #3: Arizona Science Center

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 is 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 [4]. Their non-permanent exhibits also look very interesting. One of them is called “Alien Worlds and Androids”. The exhibit asks if humans are 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 Center #4: Exploratorium

The Exploratorium in San Francisco, California consists of six museum galleries which focus on different areas of exploration. All 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 you explore your own participation and patience [3.2.4]. Inside the Living Systems gallery, the visitors can 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 can explore their different senses [5].

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 by playing an instrument that the user can vary its pitch [5]. 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 watching how the tide flows by watching arrows in the ocean change [5]. 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 Subsystem Level

The team went into further detail by examining interactive displays and projects. We evaluated four designs: “my five senses”, a strandbeest, a radiation concentrator competition, and a marble machine. These designs are either currently used in science museums or are capable of being an interactive display. The goal was to gain an understanding of how a smaller system delivers information to its users and what the user can learn from them.

3.3.1 Existing Design #1: 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, f or the young students to understand. Among the projects planned is “my five senses.” [2]

“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 [2].

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 can ask questions, which is a critical step in STEM and overall, the scientific study and research process [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

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.

Figure 1: Strandbeest Machine [6]

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

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 the team 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 TWF. Not this exactly, but something that there is no one right answer for. Their only limitations should be their imagination and our materials.

Figure 2: Solar Concentrator Thermal Power Plant [7]

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

Inside the Exploratorium in the gallery called the Tinkering Studio, there is an exhibit called the marble machine. 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" [5]. This area correlates closely with the goals of TWF in the sense that both places want to encourage their visitors to engage their minds and learn while having fun. Inside the Tinkering Studio is an exhibit called the marble machine.

Figure 3: Marble Machine [5]

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 and 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.

3.4 Functional Decomposition

Functional decomposition is a diagrammatic representation of a process, which entails the components and how they interact to achieve a defined goal. In this project, functional decomposition has been employed to represent an engineer's pit race display. In this case, the aspects represented include the components involved, which include hand, circuit, gears and the CRT display.

Here, the hand-actuated the electric circuit, which activated the conversion of electric energy to kinetic energy, which could initiate the motion. Also, the hand activated the gear mechanism, which was recognized as human energy. Conversion of human energy is to potential energy and then to rotational energy. The combination of the two energy types initiated the motion of the hand, with some energy losses as heat and sound. All the processes could be displayed on a CRT display. Thus, the process could be monitored. The developed functional model is shown in Figure 4.

Given that the issue entails interaction of processes, the user's hand must be placed on the counter for the race to start. The functional model could help the members to visualize this interaction. Here, the energy is used to move the gears, which rotates to start the race. The losses of energy could also be visualized, and they included heat and sound.

Also, the developed functional model enabled the team to define the specific interaction of processes and components in an engineer's pit race design. Then, the energy transformations that took place in the process were also established. Also, the outcome of each process, as well as how it affected the overall system was determined. It can, therefore, be concluded that the functional model is a visual aid enabling the establishment and improvement of interacting processes and components in the engineer's pit race design.

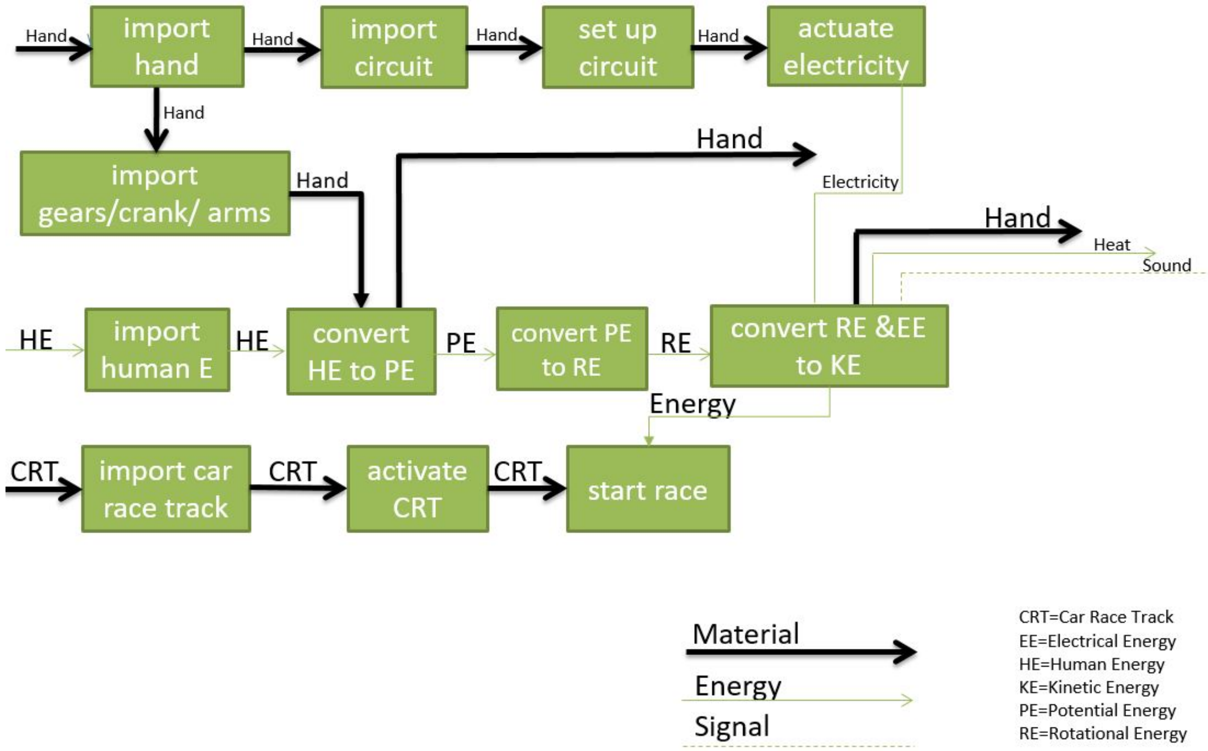

Figure 4: Function Decomposition of "An Engineer's Pit Race"

4 DESIGNS CONSIDERED

The initial designing phase of the project was difficult because of the amount of designs required from the group. The clients requested 100 ideas. The Wonder Factory wanted a large variety of ideas to pick from. For the beginnings of the design selections, our team used many different methods for creating designs. We incorporated the C-sketch, and the 4-1-2 methods. Throughout the process our group took inspiration from many things to help us come up with quality ideas. Eventually after coming up with many ideas together we went and each thought individually, and came up with the rest of the ideas individually. The engineering requirements were always kept in mind during design creation to help guide thinking. The pros and cons of the designs were decided based on the customer requirements.

4.1 Compressed Air Organ

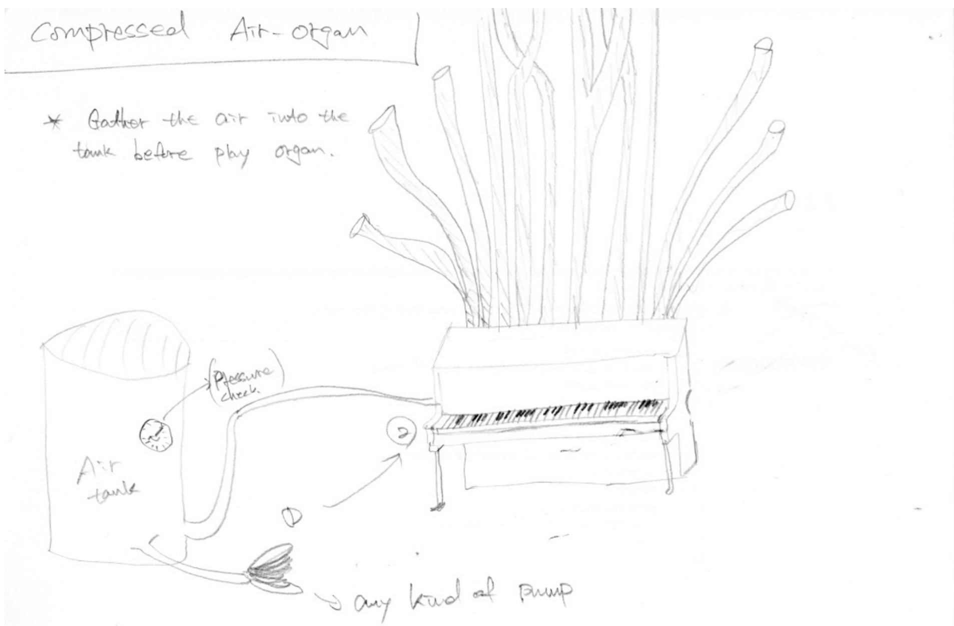

Figure 5: Compressed Air Organ Concept

The basic concept of this design is showing how air can make sound. Kids need to keep pressing air to play the organ while the kid play. In case there are more than two kids, another kid can compress the air for player.

Advantages

- Simple
- Safety
- Extremely Auditory

Disadvantages

- Not Very portable

4.2 Gear Powered Race

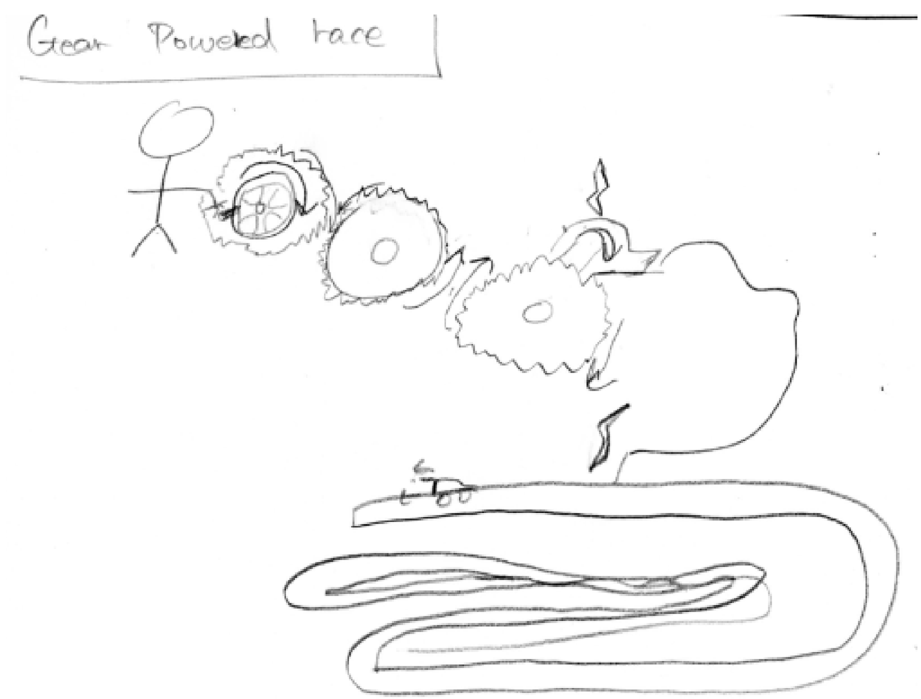

Figure 6: Gear Powered Race Concept

The concept of this design is how kids can generate power efficiently to race the car faster. In other words, if kids can generate more power by understanding how gears work, the racing car will go faster.

Advantages

- Simple
- Visual
- Project Into Role Easily

Disadvantages

- Not as Portable as others

4.3 Popsicle Stick House

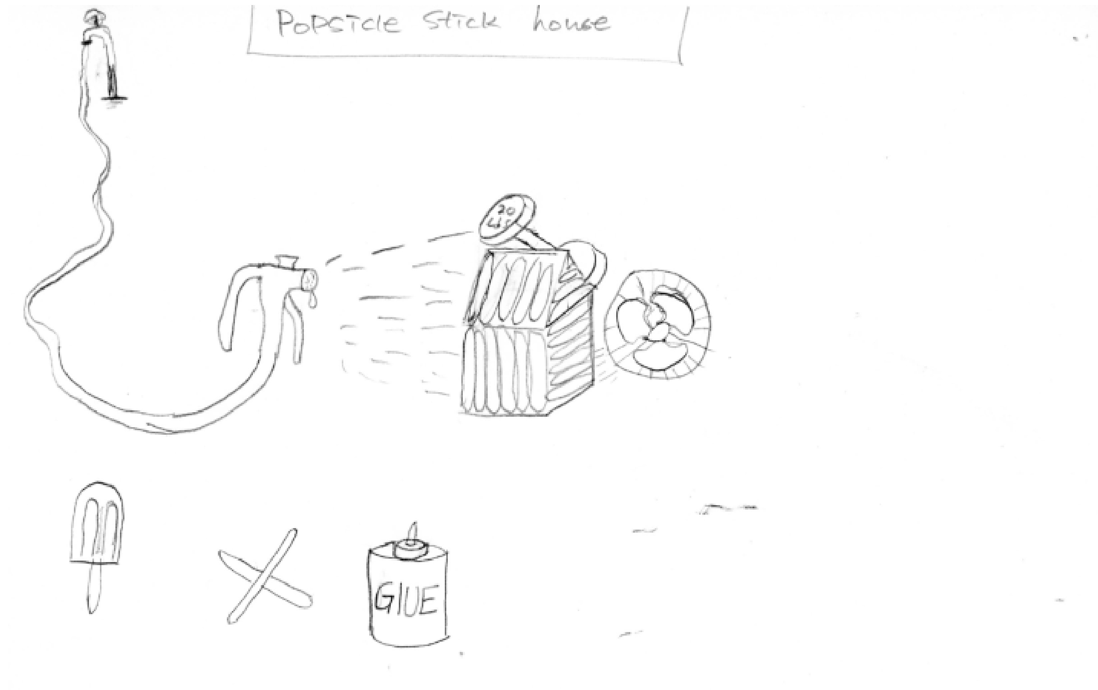

Figure 7: Popsicle Stick House Concept

This design asked kids to come up with their own design for a house that could withstand weight, water and air effects. The kids would get glue or some other form of adhesive and popsicle sticks for creating their homes. Depending on how well their houses did their name would be recorded and they would get a picture of themselves with the house they designed and built.

Advantages

- Project Into Role
- Safety

Disadvantages

- No Auditory element

4.4 Music Water Cups

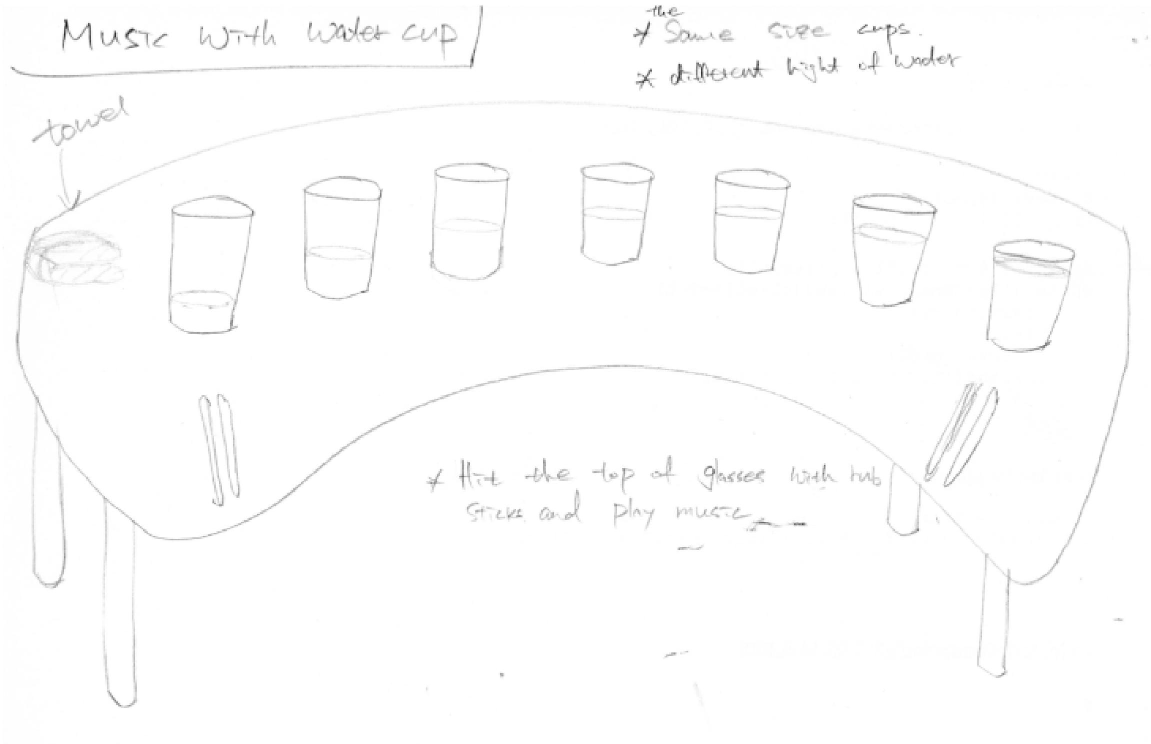

Figure 8: Music Water Cups Concept

This design will teach kids that the water filled in the cup can change its vibration frequency. Also, each cup has its own sound so that kids can play any music they want. There is measure line on the cup so kids can adjust the sound they want.

Advantages

- Simple
- Auditory

Disadvantages

- Not many users at once

4.5 Dam To Generate Power

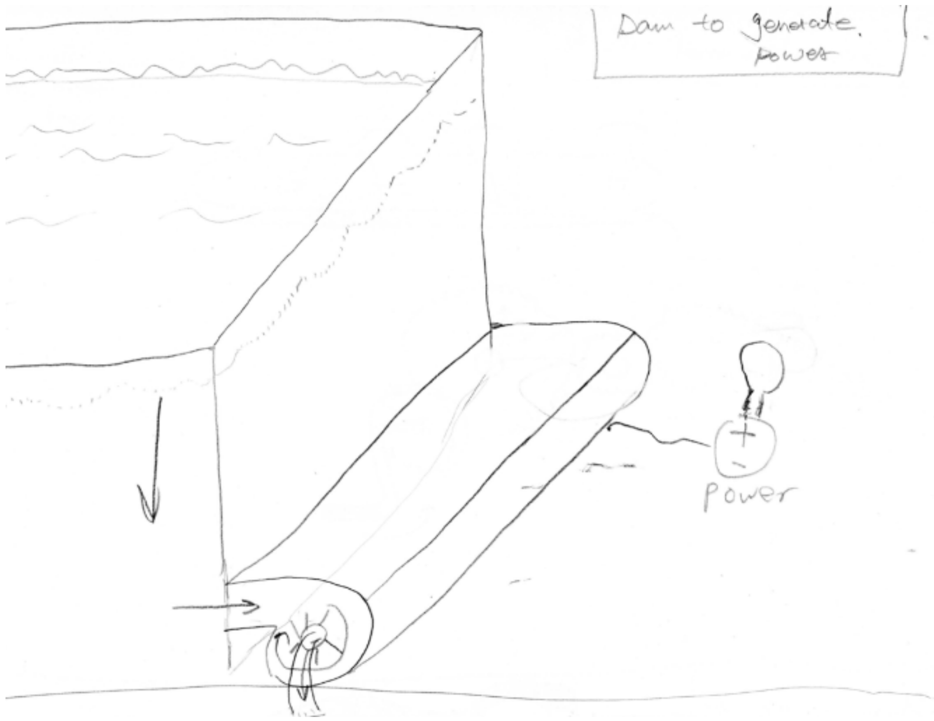

Figure 9: Dam to Generate Power Concept

This design was meant to show the kids how water from dams produce electricity. Using a big clear container full of water and a small hydro generator near the bottom of it, the machine would let water through the generator and produce electricity. The kids would be able to fill as it drained and see what happened if they add more or less water.

Advantages

- Simple
- Visual
- Multiple Users

Disadvantages

- Not Very Portable
- No Auditory Element

4.6 Plane In a box

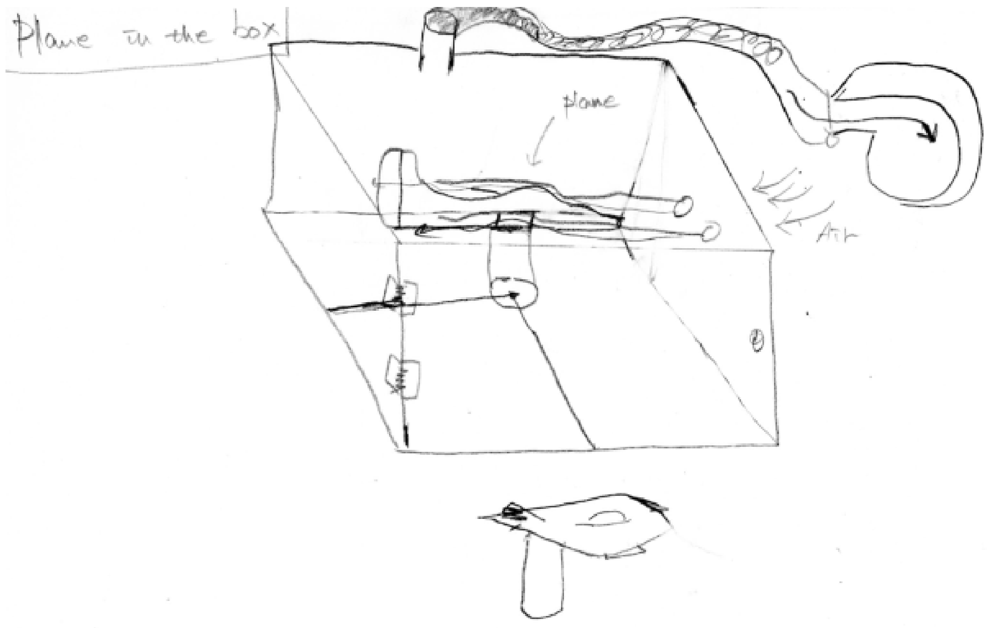

Figure 10: Plane in a Box Conept

This design is showing the force 'Lift' by wings in flowing air. The box would have some smoke lines that would flow over winds of some premade aircraft and if the kids wanted to they could design some of their own and see how the lines flow over their aircraft.

Advantages

- Visually Great

Disadvantages

- Not Very Simple and may be too complex

4.7 Gear Puzzle

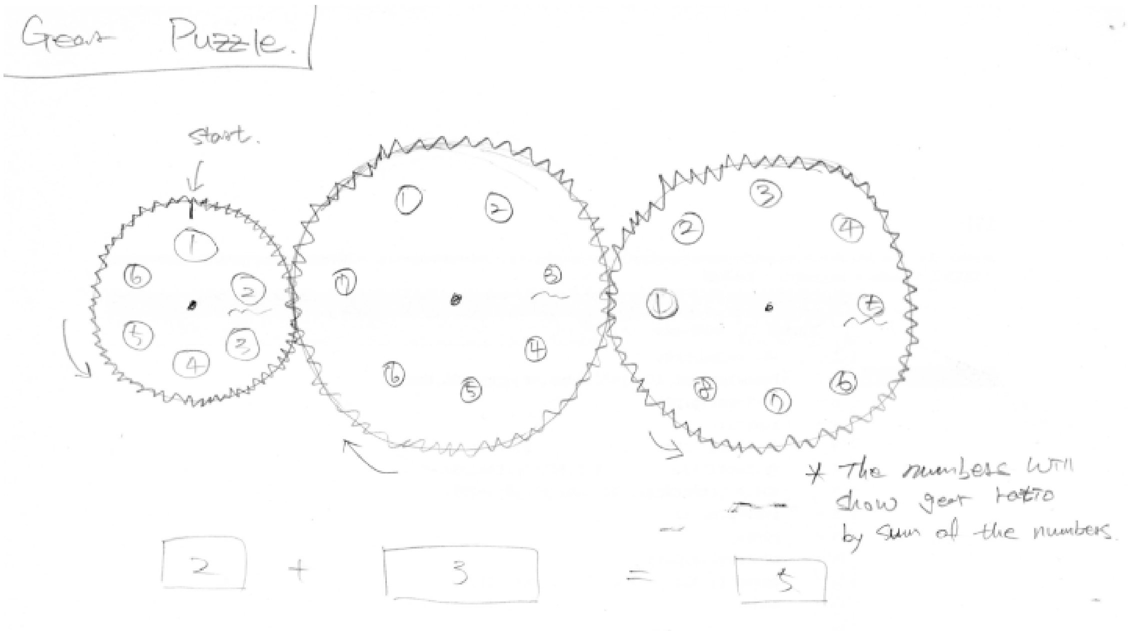

Figure 11: Gear Puzzle Concept

This design will be useful device to understand gear ratio. Basically, there is numbers on the gears, and it will show what final gear indicates a number. Kids are, also, able to change size of gear and it will help kids understand ratio more.

Advantages

- Portable
- Tactile

Disadvantages

- Not Very simple

4.8 Gear Powered lights

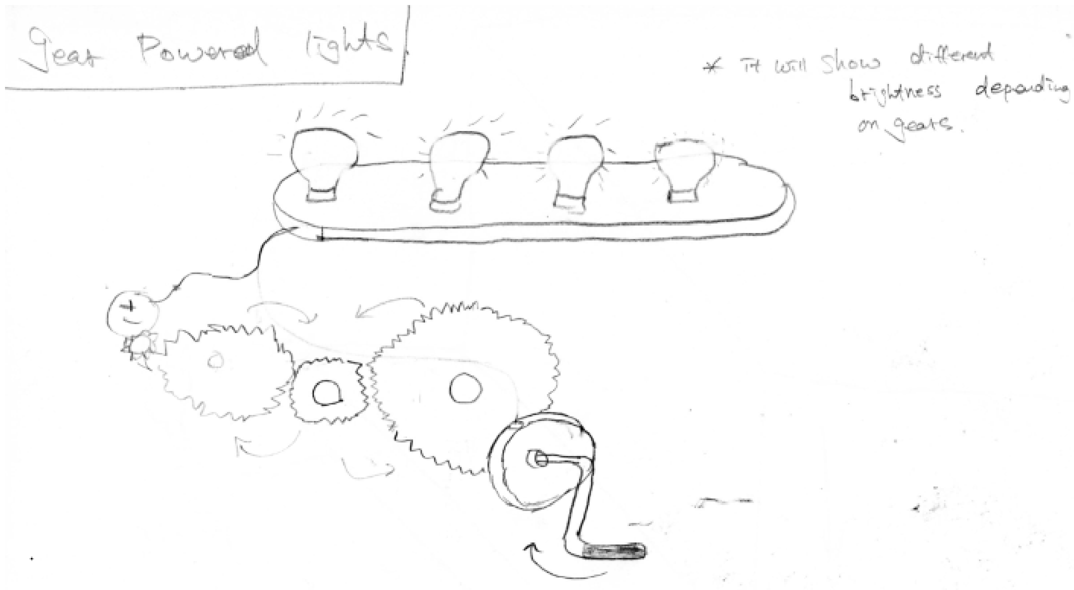

Figure 12: Gear Powered Lights Concept

This design is similar with gear powered race but this will show how much power generated directly with 4 bulbs. Kids can change size and order of gears, then they will figure out highest efficiency of gears. The faster they turn the crank the more lights that will turn on.

Advantages

- Simple
- Visual

Disadvantages

- Not as Safe as other ideas

4.9 Bridge Design and Build

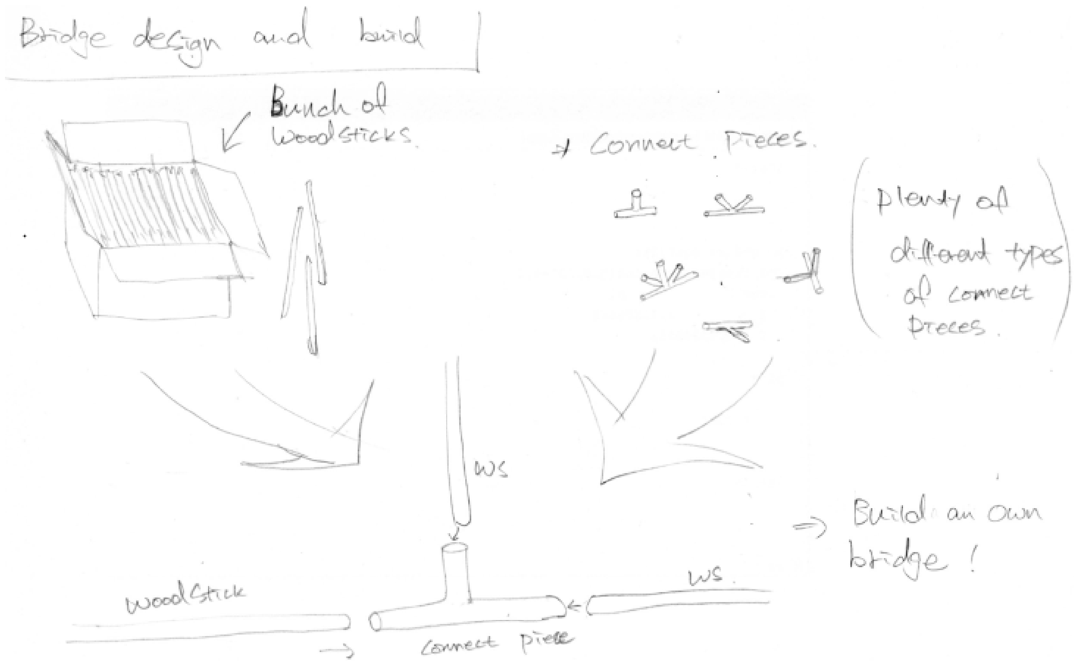

Figure 13: Bridge Design and Build Concept

Building bridge design will help kids to understand the theory of weight and the distribution of it. There are bunch of wood sticks and different shape of connecting pieces. By building their own bridge with these components, they will get which shape will be strongest.

Advantages

- Make the kids feel smart
- Project themselves into the role of civil engineer

Disadvantages

- No Auditory Element

4.10 Moment Machine

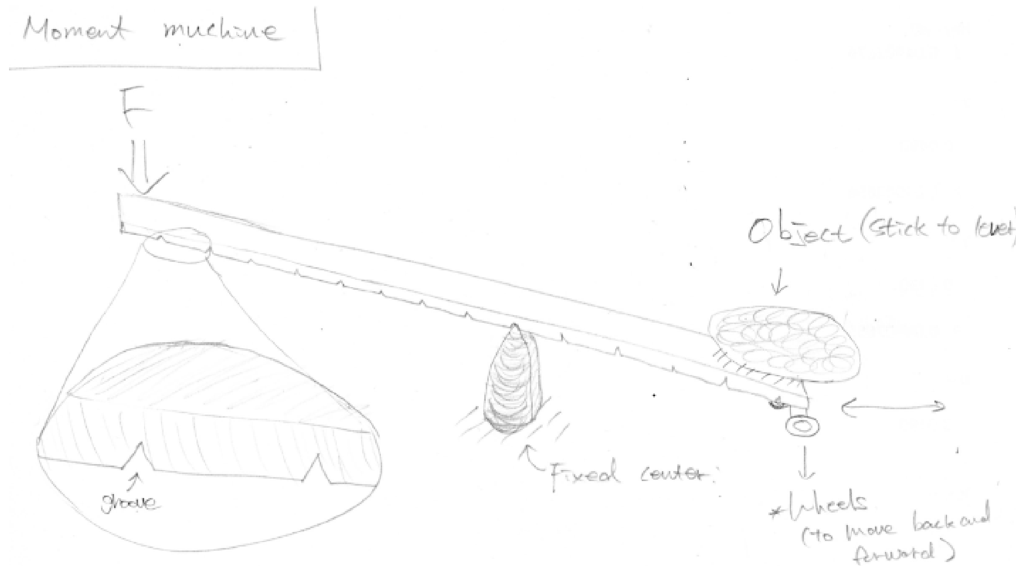

Figure 14: Moment Machine Concept

This design is lever basically. Kids can move the wood plate back and forward to experience that which distance between center and object is easy to lift.

Advantages

- Simple
- Tactile

Disadvantages

- Not Many Users

5 DESIGN SELECTED

Although the team developed 100 ideas, only 20 of the ideas were further evaluated. The team used a Pugh Chart to determine which ideas met most of the CRs. The team decided to critique the top four ideas and instead of choosing one of the four, the team created a new design.

5.1 Rationale for Design Selection

The team used a Pugh Chart to evaluate 20 designs that the team developed, which can be seen in Appendix B. The Pugh Chart uses a datum (an average idea) to compare the other ideas against it. Each idea was given a +1, 0, and -1 based on if the idea met the CR better, the same, or worse, respectively relative to the datum. The team assessed how many +1s, 0s, and -1s and total sum each design idea received. The team then took the top four ideas from the Pugh Chart and further evaluated each idea's strengths and weaknesses.

The team decided to create a new idea based on the strengths of these ideas that would meet all the CRs better than the datum. The new design developed is what the team is calling "an engineer's pit race". In this design, the users are counted down to start the race. Each user must determine which gears and crank arms they want to use based on how much power they want, how difficult the crank will be to turn the power generator, and which gears will mesh with each other. The users will then complete an electric circuit "puzzle" which will allow power to be transmitted from the generator to the racetrack. The users will finish by operating a racecar and competing against the other users to get to the finish line first.

This new design concept will meet all the CRs in the following ways:

- A setup that allows the client to disassemble the design for transport, without being bulky or having too many parts, will meet the portability requirement.
- Careful steps will be taken to make sure the design is safe to operate by not having any sharp edges, exposed electric components, or exposed crush or hinge points.
- The new design will allow at least two "players" to use it to compete against each other and this design could potentially have more than two players or teams. This satisfies the "multi-user" requirement.
- With this design, all the participants will be able to use their senses of touch, sight, and hearing while operating or observing this concept which will meet the tactile, auditory, and visual requirements.
- The users will be able to project themselves into the roles of the project through feeling like a manufacturer, engineer, and even a remote-controlled racecar driver while operating this concept.
- Lastly, this design will be simple enough to operate while also providing an exciting, interactive learning experience.

6 REFERENCES

[1] S. Oman, “Project Descriptions”, from *ME-476C Mechanical Engineering Design I.* Northern Arizona University. Available from Blackboard [Accessed 9/30/16].

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

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

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

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

[6] T. Jansen. *Strandbeest* [Online]. Available: http://www.strandbeest.com

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

7 APPENDICES

7.1 Appendix A – Client Approvals

NORTHERN ARIZONA UNIVERSITY

David Rankin <dl555@nau.edu>

ME 476C Sect 2 - The Wonder Factory Stem Display B - Team 15

Jackee Alston <thewonderfactoryflagstaff@gmail.com> Fri, Sep 30, 2016 at 10:21 AM
To: David Rankin <dl555@nau.edu>
Cc: Ali Alkhaiyat <aa3363@nau.edu>, Yongseok Park <yp68@nau.edu>, Juan Shields <js2762@nau.edu>

Hi David,

This looks great to me. Thanks! Keep up the good work!

~ Jackee

On Wed, Sep 28, 2016 at 10:44 AM, David Rankin <dl555@nau.edu> wrote:
Hello Jackee,

We have put together your requirements along with our understandings of them and the relative weightings we thought were appropriate in the chart below. Would you be able to review them for approval, please? Feel free to make any adjustments that you deem necessary and we will make the changes.

#	Customer Requirements	Descriptions	Weight
1	Portable	Easy to move, setup, transport, etc.	5
2	Multiple users	Possible to have more than one user at a time	3
3	Project into role	User feels like an engineer, scientist, artist, etc.	4
4	Feel smart	Display allows user to learn from the experience	4
5	Tactile	Users are able to touch, move, and explore the display	3
6	Auditory	Display has integrated sounds for the user	2
7	Visual	Display is appealing and attracts visitors to use it	3
8	Simple	Not so complex that the user gets frustrated and quits	5
9	Safety	Anyone can use the display without injury	5

Scale is 0-5 with 5 being the highest importance. Please let me know if you have any questions or concern. I appreciate your assistance in this matter.

Figure 15: Client CRs and Weightings Approval Email

NORTHERN ARIZONA UNIVERSITY

David Rankin <dl555@nau.edu>

ME 476C Sect 2 - The Wonder Factory Stem Display B - Team 15

The Wonder Factory <thewonderfactoryflagstaff@gmail.com> Thu, Oct 27, 2016 at 8:58 AM
To: David Rankin <dl555@nau.edu>
Cc: Ali Alkhaiyat <aa3363@nau.edu>, Yongseok Park <yp68@nau.edu>, Juan Shields <js2762@nau.edu>

Great ideas presented today! Thank you! After talking with Steve, we both think you've picked one of the best ones. Another favorite of ours was the bubble organ. We're very impressed with all your ideas, though. Wonderful work!

As asked, here's the link to that race track: http://phoenix.craigslist.org/wvl/tag/5821876547.html.

Thanks again!

Jackee

Sent from my iPhone
[Quoted text hidden]

Figure 16: Client ERs Approval Email

7.2 Appendix B – Pugh Chart

Customer Requirements	air cannon	light shadow	smoke manipulation	mirror room	music with water cups	moment machine	clay car build and race	engineering puzzle	popsicle stick house	bridge design and build	gear powered race	compressed air organ	dam to generate power	plane in a box	treadmill candy machine	gear puzzle	gear powered lights	programming game	bicycle power video game	catapult game
Portable	0	-1	0	-1	0	-1	0	Datum	0	0	0	-1	-1	0	-1	1	0	0	-1	-1
Safety	-1	0	-1	0	0	-1	0		1	1	1	0	0	0	-1	0	0	0	0	-1
Mutiple Users	-1	0	-1	0	0	-1	1		0	1	1	1	1	1	0	1	0	0	0	1
Tactile	0	-1	1	-1	1	1	1		1	1	1	1	1	0	1	1	1	1	1	1
Auditory	1	-1	-1	-1	1	-1	-1		-1	-1	1	1	-1	0	-1	1	1	0	1	-1
Visual	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1
Project into role	0	-1	0	-1	0	1	1		1	1	1	1	1	1	-1	0	1	1	-1	0
Feel smart	0	1	-1	0	1	1	0		0	1	0	1	0	0	0	1	0	1	0	0
Simple	1	1	1	1	1	1	-1		1	1	1	1	1	0	1	0	1	-1	1	1
Positives	3	3	3	2	5	5	4		5	7	7	7	5	3	3	6	5	4	4	4
Negatives	2	4	4	4	0	4	2		1	1	0	1	2	0	4	0	0	1	2	3
Same	4	2	2	3	4	0	3		3	1	2	1	2	6	2	3	4	4	3	2
Total	1	-1	-1	-2	5	1	2	0	4	6	7	6	3	3	-1	6	5	3	2	1

Figure 17: Pugh Chart (20 Ideas)

Customer Requirements / **Design Ideas**	bridge design and build	gear powered race	compressed air organ	gear puzzle	New Design: An Engineer's Pit Race
Portable	0	0	-1	1	1
Safety	1	1	0	0	1
Mutiple Users	1	1	1	1	1
Tactile	1	1	1	1	1
Auditory	-1	1	1	1	1
Visual	1	1	1	1	1
Project into role	1	1	1	0	1
Feel smart	1	0	1	1	1
Simple	1	1	1	0	1
Positives	7	7	7	6	9
Negatives	1	0	1	0	0
Same	1	2	1	3	0
Total	**6**	**7**	**6**	**6**	**9**

Users are counted down to start the race. Each user must determine which gears/crank arms to install based on how much power they want, how difficult the generator will be to turn, and which gears will mesh. Then, the user must complete an electric circuit to transfer power to the racetrack where users will race each other.

Figure 18: Pugh Chart (Top 4 Ideas and New Design Concept)