Northeastern University
College of Engineering

Cornerstone of Engineering I and II
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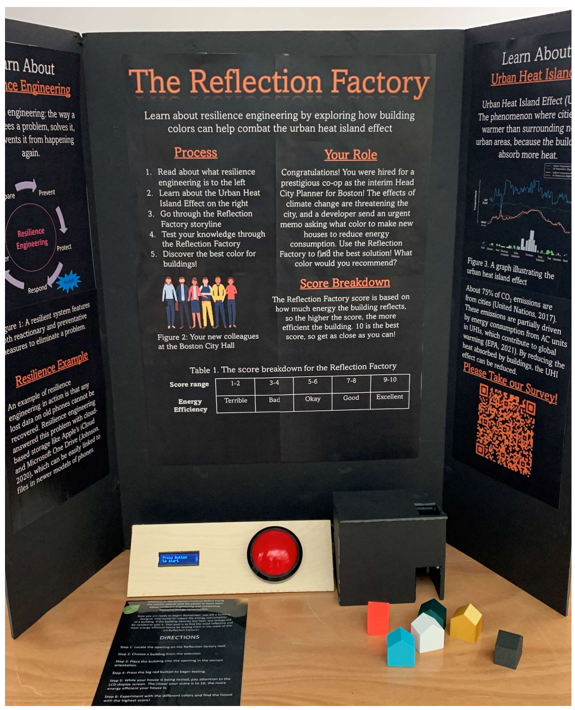
Museum of Modern Resilience Reflection Factory



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ABSTRACT

This project challenged our team to educate first-year non-engineering students about resilience engineering. We specifically choose to educate users on ways resilience engineering can reduce the urban heat island effect and reduce energy consumption. The project constraints included using an Arduino, reading two inputs, sending data to one output, creating a 3D printed or laser cut component, avoiding water, adhering to the universal design requirements, and spending less than $100. Our team had the self-imposed objectives of making the exhibit fun, autonomous, interactive, educational, and inclusive.

We met these goals by developing the Reflection Factory. The two-part exhibit was composed of a tri-fold poster board and an interactive learning box. The tri-fold board displayed informative text that teaches users the basics of resilience engineering and the urban heat island effect. The interactive learning box gives users an opportunity to test how much light different colors of buildings reflect, and it is controlled by a button on the control panel. The exhibit teaches users about combatting the urban heat island effect through resilience engineering in a fun and engaging way.

The Reflection Factory met the constraints of the project. It included an Arduino with inputs from a photoresistor and button and an output to an LCD. The houses users inserted into the interactive learning box were 3D printed, the exhibit was free from water, it cost less than $100 to construct, and it met all the universal design requirements. We used a user feedback form to determine if the exhibit met the qualitative project goals. We collected and analyzed this feedback to see if the average scores met our criteria for success. All users agreed or strongly agreed that the exhibit was autonomous, educational, inclusive, interactive, and fun, so the final exhibit met all the applicable design objectives.

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MATTHEW COUGHLIN

1.1 INTRODUCTION

PROBLEM STATEMENT

Our group began the project by crafting a problem statement. The problem we were given is to educate first-year non-engineering students on how to incorporate the ideas of resilience engineering into their lives. Specifically, we wanted to educate them on ways design and engineering resiliency is used to combat global warming and growing energy usage. Educating these students will give them knowledge of the core concepts of resilience engineering and ensure they understand the importance of finding solutions to the current issue of global warming.

There are many ways museum exhibits educate users. Specifically, we saw existing exhibits that taught users about topics by using user input to produce different results. These exhibits were educational through their user-dependent nature, and they were also autonomous since they ran on-demand and were tailored to the interests of the user.

Many cities are in hot climates and the rising temperatures are causing building designers to look for solutions to keep buildings cool. We explored some of the current solutions such as using air conditioning, central ventilation, adding shade, and reflecting light and solar energy away from buildings.

The goal of our project was to educate first-year non-engineering students about resilience engineering by sharing solutions to reduce energy use in buildings. Our project objectives include using an Arduino, creating an autonomous exhibit, integrating user input into the program, and giving feedback based on the inputs. The constraints for our project are that it must run and reset without any manual input, cost under $100, use a 3D printed part, and not include water. The overall function of our project is to be understandable for a first-year non-engineering student, so our project must not include too much technical or confusing information.

STAKEHOLDERS

The primary stakeholders in the project are first-year non-engineering students. They are the people who are coming to the museum exhibit to learn about resilience engineering. They want to learn about resilience engineering in a fun and engaging way. These users may also not have as much knowledge of engineering as students in the cornerstone class, so the exhibit needs to be designed to be easy-to-understand.

A second stakeholder is first-year engineering students. The exhibit is not designed for these users, but future engineers may be present at the expo and during in-class presentations as part of Stacked Cornerstone. These users have more knowledge of resilience engineering than most college students, so they may be able to interact with an exhibit that contains a lot of technical information. First-year engineering students should be able to interact with the exhibit without being bored, so the exhibit needs to be entertaining and fun.

Pertinent Topics in Engineering: Resilience Engineering

Resilience engineering describes creating designs so that they can adjust to any issues before they occur or so that they can easily respond once an issue arises [1]. There are many categories of resilience engineering, but our group choose to focus on design and engineering resilience. Design and engineering resilience is most concerned with finding ways to respond to hazards that can disturb systems.

Pertinent Topics in Engineering: Reflectivity, Solar Radiation, and the Greenhouse Effect

The primary way the Earth is heated is through solar radiation coming from the sun. The planet absorbs some of the radiation, and it reflects the rest back into space. Different materials and colors reflect different amounts of radiation. Light-colored, reflective, and smooth materials generally reflect more radiation that dark, opaque, and rough materials.

Some of the radiation that is reflected off the surface of the Earth towards space is reflected back to the surface by gasses in the atmosphere. This phenomenon is known as the greenhouse effect. The most prolific greenhouse gas is carbon dioxide, a common product of combustion.

Pertinent Topics in Engineering: The Urban Heat Island Effect

Cities tend to be hotter than the suburban environments surrounding them. The average temperature increase is one to seven degrees during the day and two to five degrees during the night [2]. This temperature difference is known as the urban heat island effect. It is mainly caused by the differences between the structures found in cities and the structures found in suburban settings. Buildings and roads tend to absorb more radiation, and consequently stay warmer, than fields, grass, trees, and houses [3].

Scope

This report described the process of creating a museum exhibit to educate first-year non-engineering students about resilience engineering. It describes the process our team used to design the exhibit, and it contains the technical documentation necessary to recreate the exhibit from scratch. The report is descriptive enough that most students, professionals, and professors can recreate an exhibit on their own.

ANTHONY ZAPPALA

1.2 INTRODUCTION

PROBLEM STATEMENT

As temperatures rise, society faces a slew of increasing problems, especially those relating to global warming. 2020 was the hottest year in recorded history and temperatures look to continue climbing as the world struggles to respond to global warming. To improve society's resilience to the problems of climate change and global warming, we must educate them on strategies that can be utilized to reduce energy use while maintaining function. We must educate first-year non-engineering students on how to incorporate the ideas of resilience engineering into their lives. Specifically, we want to educate them on ways design and engineering resiliency is used to combat global warming and growing energy usage. By educating these students, they gain knowledge of the core concepts of resilience engineering and understand the importance of finding solutions to the current issue of global warming.

There are many methods and mediums used throughout museums and other educational facilities that seek to educate its users. Specifically, we saw existing exhibits that taught users about certain issues or topics by relying on user inputs that would cause different results. These exhibits were educational through their user-dependent nature and were also autonomous, so the exhibit could run whenever a user decided to learn more. Specific to the issue of reducing energy usage to combat global warming, we found several solutions in the sector of maintaining building temperatures. Since many cities are in already hot climates, the rising temperatures are causing building designers to look for solutions to keep buildings cool. We explored some of the current solutions such as using air conditioning, central ventilation, shading buildings, and reflecting the light and solar energy projected onto buildings.

The goal of our project will be to educate first-year non-engineering students on the engineering design process and the mindset behind it as it relates to resilience. In addition, we have the goal of educating the students on specific solutions to reduce energy use in buildings. Our project objectives include utilizing Arduino, creating an autonomous exhibit, utilizing user inputs to run the program, and giving feedback based on the user inputs. The constraints for our project are that it must run and reset without any manual input from the project designers, cost under $100, utilize a 3D printed part, and not include water. The overall function of our project is to be understandable for a first-year non-engineering student, so our project must not include too much technical or confusing information.

STAKEHOLDERS

Clients

The stakeholders for our design include the intended clients who will be interacting with our museum exhibit. These users are first-year non-engineering college students. Since they are first-year college students, the exhibit needs to be engaging for students around the age of 18. Additionally, since they are non-engineering students, the exhibit cannot include any complex language that would only be taught in engineering classes. Any topics that are presented in the exhibit must be completely explained to target the intended user. Another client group within our main user group is non-engineering students who are still studying topics of renewable energy or greener alternatives for future use. Since our exhibit focuses on design for reduced energy consumption, this topic would apply to the focus of these clients and would offer information relevant to their field of study.

PERTINENT TOPICS IN ENGINEERING

Resiliency Engineering

Resilience engineering refers to engineering that makes a design able to respond before, during, or after any expected or unexpected changes [1]. In addition, there are several types of resilience engineering. For our project we focused on the sub-category of design and engineering. This category of resilience engineering is based on the development of design, systems, and infrastructure that respond to disruptive hazards. These hazards can be both man-made and natural.

Heat Transfer by Radiation

One way heat can transfer is through radiation. In our scenario, we are focusing on heat traveling via light rays from the sun. When the sun's rays hit an object on earth, the object absorbs some of the energy and the energy is absorbed as heat.

Color and Light

Any color that the human eye perceives is the wavelength or wavelengths of light that the object reflects. For example, a yellow object would absorb other frequencies of light except for yellow's frequency. A black object reflects almost no color since it is made of several colors mixed, so more light is absorbed into black objects. Inversely, a white object reflects most wavelengths of light and absorbs less light energy.

Urban Heat Island Effect

In cities a special phenomenon called the urban heat island effect causes the average temperature to be about 1-7 degrees hotter during the day and 2-5 degrees hotter at night [2]. This effect is caused by the high concentration of buildings absorbing and reemitting the sun's energy at a much higher rate than other areas [3].

SCOPE

This report covers the planning, design, development, testing, and feedback analysis of a museum exhibit that teachers first-year non-engineering students about resilience engineering. It covers everything from the physical build of the exhibit to the code and electronics that help it function.

NICHOLAS LAUX

1.3 INTRODUCTION

PROBLEM STATEMENT

Global temperatures have risen dramatically over the past few decades and have brought detrimental changes to the world. Recent history has seen 2020 recorded as the hottest year in history and global temperatures will continue to rise as the world struggles to combat global warming. To improve society's resilience to the problems of climate change and global warming, we must educate them on strategies that can be utilized to reduce energy use while maintaining function. In particular, we must educate first-year non-engineering students on how to incorporate the ideas of resilience engineering into their lives. Specifically, we want to educate them on ways design and engineering resiliency are used to combat global warming and growing energy usage. By educating these students, they gain knowledge of the core concepts of resilience engineering and understand the importance of finding solutions to the current issue of global warming.

There are many methods and mediums used throughout museums and other educational facilities that seek to educate its users. Specifically, we saw existing exhibits that taught users about certain issues or topics by relying on user inputs that would cause different results. These exhibits were educational through their user-dependent nature and were also autonomous, so the exhibit could run whenever a user decided to learn more. Specific to the issue of reducing energy usage to combat global warming, we found several solutions in the sector of maintaining building temperatures. Since many cities are already located in hot climates, the rising temperatures are causing building designers to look for solutions to keep buildings cool. We explored some of the current solutions such as using air conditioning, central ventilation, shading buildings, and reflecting the light and solar energy projected onto buildings.

The goal of our project will be to educate first-year non-engineering students on the engineering design process and the mindset behind it as it relates to resilience. In addition, we have the goal of educating the students on specific solutions to reduce energy use in buildings. Our project objectives include utilizing Arduino, creating an autonomous exhibit, utilizing user inputs to run the program, and giving feedback based on the user inputs. The constraints for our project are that it must run and reset without any manual input from the project designers, cost under $100, utilize a 3D printed part, and not include water. The overall function of our project is to be understandable for a first-year non-engineering student, so our project must not include too much technical or confusing information.

STAKEHOLDERS

Throughout the project at hand, there exists a range of people viewing our project in some capacity. Namely, our client and user will have the largest stake in viewing this project.

Client

Our client is our cornerstone professor, Professor Keyvani. She is coordinating the engineering exposition in which we must educate non engineering students on the topic of resilience engineering. She has administered many iterations of this assignment, including teaching resilience topics to users in middle schools as well.

User

Our users are the attendees of the Northeastern University Engineering Exposition in the Curry Student Center on December 5th, 2021. They are non-engineering students who are attending the exhibition to learn more about resilience engineering and sustainability engineering, the two topics that were being presented by the two classes there at that time. They are students who may have outside knowledge of other topics as they are university educated students but most likely not of engineering specific topics. They will be attracted to interactive and bright features and drawn in by interesting relevant topics. This project lends itself into that notion, through resilience engineering being introduced through a more familiar application of it.

Secondary Beneficiaries

The secondary beneficiaries of this project are future engineering students at Northeastern University who will view our project. Our project must serve as a guide for future students to use as an example and reference on what is required of them for the project once they are in Cornerstone of Engineering.

PERTINENT TOPICS IN ENGINEERING

Resilience Engineering

The most pertinent topic of engineering that is being showcased is resilience engineering. Resilience engineering describes the way a society sees a problem and reacts to it through engineered solutions. These solutions provide a society with more effective ways to fight the same problem if it occurs again. The prevention through solutions is the major part that defines resiliency. By creating things that can fight the problem themselves, a society will not have to worry about the problem again.

Engineering Software

Other engineering software is also heavily used throughout the scope of this project. Namely, AutoCAD, Solidworks, and Arduino with C++.

AutoCAD

AutoCAD is a software in which users can sketch 2D designs. AutoCAD is important to this project as the user display is a laser cut object that was developed in AutoCAD. The sketch contributing to this project in AutoCAD can be found in (Appendix C).

Solidworks

Solidworks is a software that allows users to sketch 3D models. Solidworks is important to this project as the houses that the user can use were 3D printed Solidworks models. The sketch contributing to this project in Solidworks can be found in (Appendix C).

Arduino and C++

Arduino components are different components that rely on inputs, outputs, wiring, and resistance. They are all interconnected to make one circuit and the circuit can be run through C++ code to connect the inputs and outputs. These components are useful as they are the buttons, motors, lights, photoresistors, and LCD screen that contribute to the overall museum experience. These components can be found in (E).

SCOPE

The main of the cycle that is being enunciated in this project is the engineering and design step. In the context of our issue, society, namely cities, must prevent the further release of CO_2 into the atmosphere. This coincides with the prevention aspect of the resiliency cycle. Through the change of building color or material, building temperatures would change less, resulting in fewer emissions being released through AC and heating units. For ourselves, the scope of the project also includes using a certain amount of arduino components, laser cut wood, 3D printing, and other engineering features to truly highlight the skills we have learned this semester.

JULIA RASMUSSEN

1.4 INTRODUCTION

PROBLEM STATEMENT

The overall aim of our project was to make a museum exhibit where first year non-engineering students could learn about resilience engineering. We decided to make a museum exhibit that focused on the urgency of the urban heat island effect, with an interactive component that demonstrated the usefulness of one solution to the urban heat island effect, changing the exterior of a building. For our project, we were given the constraints that our exhibit must have either a 3D printed or laser cut component, that it must include an Arduino with two inputs and at least one output, that it cost under $100, and that it could not contain water. It also had to fit on the tables in Curry that we presented our exhibition on. We also came up with further objectives that we decided our project should fulfill: that it be informative, engaging, cost-effective, inclusive, have solid visuals, and use any build time efficiently. We also decided to go for the two extra credit sections of the project, that it be auto-resetting and inclusive.

The overall function of our project was to have the users, in our case first year non-engineering students, learn about resilience engineering, and in particular how it relates to the urban heat island effect. We decided that the urban heat island effect was a topic in resiliency that would be the most relevant to our users, as they all live in a city, and would thus be able to introduce the concept of resiliency engineering well.

STAKEHOLDERS

The main stakeholders for our project were first year non-engineering students. These students most likely do not have a background in engineering, and thus don't understand resilience engineering and its importance in coming up with solutions to problems such as climate changes. Their goals most likely do not involve engineering, but as resilience engineering is useful in so many fields, it is still something that would be useful for them to learn about.

Other stakeholders for our project include our professor, Professor Keyvani, and fellow engineering students, such as our peers who are also doing projects on resiliency engineering. In this case, both of the stakeholders already have a firm understanding of resiliency engineering, and thus that part of the project is readily understandable. The only foreign concept to these stakeholders is the urban heat island effect.

The stakeholders in our project could also be defined as the people who live in cities. After all, our project is based off of the effect of climate change on cities, and more specifically, the urban heat island effect, whose greatest impact is on urban residents. And it is the people who live in cities who are the most affected by the urban heat island effect, as they are the ones who have to endure the heat within the city. Thus, given that the non-engineering students, our professor, and our peers all go to Northeastern, which itself is located within a city, all of our stakeholders are naturally invested in our topic.

Pertinent topics in engineering: Resilience Engineering

Of all the topics in engineering relevant to our project, perhaps the most important is resilience engineering. Resilience engineering is a type of engineering that tries to preemptively stop problems from happening, and thus is extremely useful in all sorts of fields, from agriculture to technology to urban planning.

Pertinent topics in engineering: The Engineering Design Process

Engineers follow a set of iterative steps designed to make the best possible solution to a problem called the engineering design process. The engineering design process starts off with defining the problem and then conducting research about it. Once a deep understanding of the problem has been reached, engineers brainstorm solutions to the problem, and then select a solution to move forward with, which they then build. After making the final design, they analyze the effectivity of the design, and then find ways to improve upon the design [4]. This cycle can then be repeated until there isn't much to improve on the design, at which point the design solves the problem well.

Pertinent topics in engineering: Duncker Diagram

Duncker diagrams help identify the core problem to solve. Though engineers may start out the problem definition phase with a pre-defined problem at hand, most of the time it is not the core problem. In order to get to that core problem, Duncker Diagrams start with the pre-defined problem, and the "obvious" solution to that problem, as well as what would need to happen in order to get to that solution. However, it also challenges the engineer to think about how to get to the desired state if it were made to be okay to not solve the problem directly. In this case, novel solutions that may not have been thought of by the engineer initially come up, and this process can be repeated to get new solutions.

Scope

The scope of this report will be a full description of our project from start to finish, following the steps outlined by the engineering design process. First we will present a brief overview of the topics relevant to our project in the introduction and background. Then, we will look at the upon how we actually did our project through methodology, as well as the individual contributions from each team member. We will then look at the final design of our project and the results of our project, in particular whether or not our project satisfies the objectives we laid out in the beginning of the project. We then will analyze the results we got and discuss our project overall and the further work that could be done on it.

TEAM FIVE

1.5 BACKGROUND

PROBLEM HISTORY

Increasing temperatures require many facets of human society to be resilient and adapt to the challenges of operating in a warmer world. The three hottest years on record, 2016, 2019, and 2020, have all occurred within the last five years [1], and temperatures will continue to rise in the future. These rising temperatures pose a serious threat to ecosystems, the environment, and the economy. One of the primary ways the world is responding to global warming is by reducing greenhouse gas emissions. We designed our exhibit to teach first-year non-engineering students about how resilience engineering can combat climate change by helping solve the urban heat island effect.

THE URBAN HEAT ISLAND EFFECT

One challenge that is worsened by global warming and contributing to greenhouse gas emissions is the urban heat island effect. The urban heat island effect is a phenomenon where the average temperatures in cities are about 1-7 degrees hotter during the day and 2-5 degrees hotter at night than in surrounding areas [2]. This occurs because structures commonly found in cities, including roadways and large buildings, absorb more heat than features in surrounding urban areas such as trees and open fields. Air conditioners are the most common way people respond to high temperatures in cities, but they also require a large amount of energy [3]. Rising temperatures worldwide will only worsen the urban heat island effect and increase the amount of energy used to power HVAC systems in cities. Some cities are responding to this challenge by making infrastructure and buildings absorb less heat. There are various modifications that can reduce the amount of heat that a structure absorbs, including replacing existing roofs with green roofs, changing the material or color of roadways, and painting the sides of buildings to lighter colors [2].

UNIVERSAL DESIGN REQUIREMENTS

The universal design requirements state that all exhibits must be equitable, flexible, intuitive, understandable, tolerant of errors, physically easy to use, and reasonably sized. The purpose of these guidelines is so that all potential users can interact with an exhibit, even if they have a disability or challenge that makes interacting with a traditional exhibit difficult. Museum exhibits can meet the universal design requirements in several ways. The simplest approach is designing every element of an exhibit with all users and these guidelines in mind. Text, audio, visual, interactive, and informative components of museum exhibits all contribute to whether the exhibit meets the universal design requirements.

EXISTING SOLUTIONS TO REDUCE ENERGY USE

There are several existing strategies to reduce energy usage in buildings through resilience engineering. Design choices about the size, location, and reflectiveness of windows and skylights can play a large role in how much solar radiation is absorbed by buildings and converted into heat [5].

Another approach to reduce the energy absorbed by buildings relies on applying special coatings to their exterior. These coatings work by reflecting most of the energy that a building would normally absorb. Researchers have developed several new types of “ultra-white” paint that reflects almost all of the radiation coming from the sun [6]. A special paint developed by researchers at Purdue reflects 98.1% of sunlight [7]. The same principal of using color to reduce the amount of energy absorbed can also be applied to roofs [8]. Unlike air conditioning and central cooling, these methods passively reduce the temperature of buildings through resilient design and engineering.

EXISTING SOLUTIONS FOR MUSEUM EXHIBITS

Many museum exhibits already exist which teach users about engineering concepts. The most successful exhibits all contain interactive elements, like buttons or touchscreens. The Arctic Adventure exhibit in the Museum of Science shows the importance of interactive elements. Figure 1 pictures users interacting with the exhibit.

Fig. 1. Interactive components in a museum exhibit, including touchscreens and GPS simulators [9]

The interactive elements keep users engaged and interested in the exhibit to ensure they learn the material presented [9]. Most exhibits also featured informative text that is easy enough to understand so that users do not struggle to grasp complex concepts. Exhibits also featured an order that users were supposed to follow. Having a predetermined course of interaction lets the exhibit designer specify what the user sees. This ensures the designer knows when to display information that is relevant to the user based on where they are in the exhibit.

1.6 METHODOLOGY

RESEARCH IN MUSEUM EXHIBIT DESIGN

Our team began designing the museum exhibit by researching resilience engineering, museum exhibit design, and the universal design requirements. Our search included journals, databases, and scholarly websites. We focused on learning about how engineers can respond to a problem in a resilient manner. Developing a thorough research base allowed us to understand the resilience cycle itself and design exhibits that effectively communicated the concepts we wanted users to understand. The next step in designing a museum exhibit was emphasizing with potential users. This exercise showed us that first-year non-engineering students wanted an exhibit that is easy to understand, interactive, and informative.

IDENTIFYING A TOPIC

Our team researched pressing issues in engineering to determine the topic of the exhibit. One issue that was frequently listed among the most important in the world was global warming. We choose to focus specifically on the urban heat island effect because it is a topic that is very important for anyone who lives in a city. Northeastern also has an urban campus, so we felt the urban heat island effect would be an impact of global warming that directly affects Northeastern students. After deciding to focus on the urban heat island effect, our group used a Dunker diagram to better understand the issue and several possible solutions. The Dunker diagram is included below in figure 2.

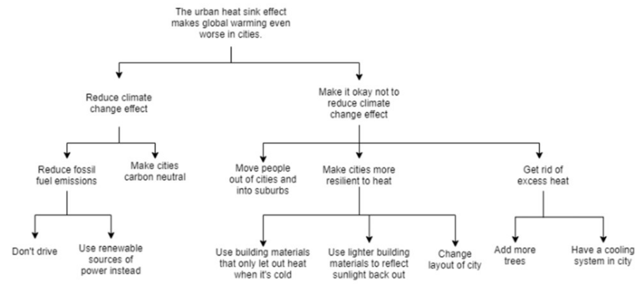

Fig. 2. A Dunker diagram to better understand the urban heat island effect

EXHIBIT DESIGN

Our group continued the engineering design process by brainstorming different exhibits that could teach users about the urban heat island effect. We used ideation techniques, including brainstorming and random word prompts, to come up with inspiration for the exhibits. The sources for inspiration are included in appendix B. Each member of our group took two ideas and created an informal napkin sketch showing their concept. Figure 3 shows a napkin sketch by Matthew Coughlin.

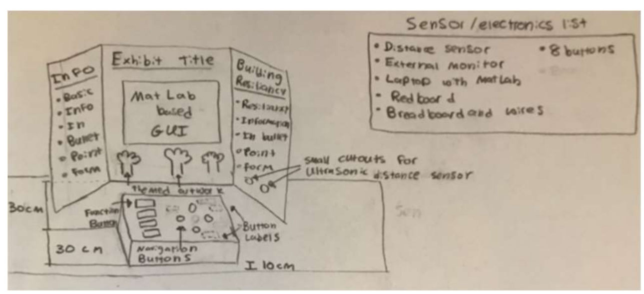

Fig. 3.A sketch of a possible museum exhibit by Matthew Coughlin

We began choosing a design by identifying the criteria all exhibits had to meet. The relative importance of each criterion is summarized in appendix B. We then took the napkin sketches of the museum exhibit and ranked how well they met various criteria. We compiled the results in a KTDA chart to objectively determine which design met the criteria of the project the best. The KTDA chart is included in appendix B. Figure 4 shows the design with the highest score.

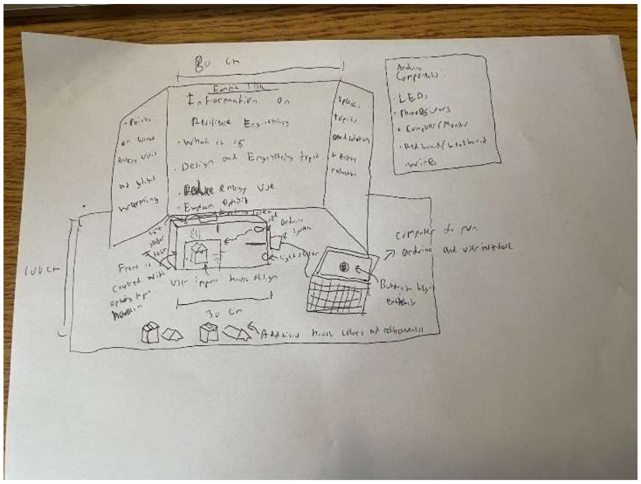

Fig. 4. The napkin sketch our final design is modeled after

The design involved a light shining on different colored houses. A photoresistor reads the amount of light that was reflected to report to the user how much energy the building would absorb. Other exhibits also included features that we wanted to integrate into the final design. We decided to replace the GUI with a button and an LCD based on a different sketch. The final exhibit also included a mechanism for automatically ejecting the houses from inside the interactive learning box that was incorporated from another design.

PROTOTYPING

We began the process of prototyping the design by creating Solidworks and AutoCAD drawings of various components of the exhibit. The control panel was composed of laser cut pieces of wood. A fully dimensioned drawing of the control panel is included in appendix C. The next element we designed were the houses that the user placed into the interactive learning box. The houses were all the exact same shape, but they were printed out of different colored filaments. Figure 5 shows an image of all the houses.

Fig. 5. A photo showing the 3D printed houses made from various colors of filament

Each house was the exact same size so that the only difference in between them was color. A detailed isometric view and drawing of the houses is included in appendix C. The next element we designed was the reflection factory interactive learning box. The box was shaped so that the house could easily fit in and be ejected once the user is done interacting with the exhibit. Figure 6 shows an isometric view of the interactive box.

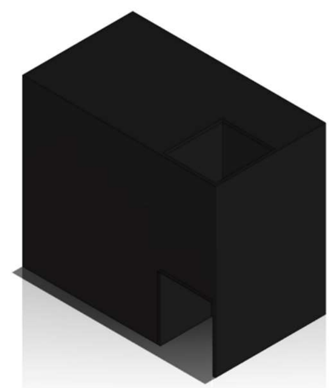

Fig. 6. An isometric view of the interactive learning box.

A detailed multiview of the box is included in appendix C. We constructed the box from black foam board. A 3D printed stand secured the motor that ejected the houses from the interactive learning box in place. The dimensions of the stand and a drawing showing how it fits into the interactive learning box are included in appendix C.

We concluded the design portion of the project by creating a poster board and writing Arduino code to control the exhibit electronics. We wrote the Arduino code last so that the exhibit could evolve during the construction phase. The code used in the project is included in appendix E.

Internal Testing

We engaged in rigorous testing of the exhibit to ensure it worked correctly. Our first proof-of-concept test confirmed that shining light on different colors would produce different amounts of reflected light. Figure 7 shows the setup for the test.

Fig. 7. A proof-of-concept test to see if a photoresistor could detect meaningful variation in the amount of light reflected by colored objects

The test was successful. The second proof-of-concept test explored whether a motor was strong enough to eject houses from the exhibit. Figure 8 shows the setup for the test.

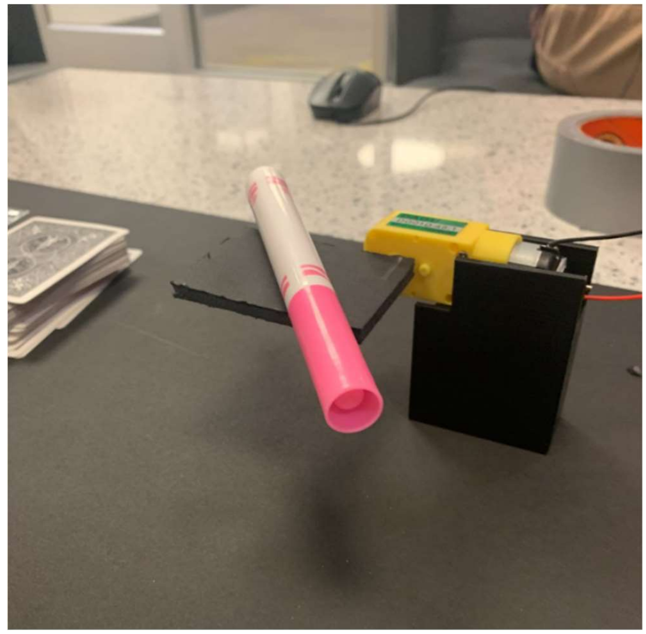

Fig. 8. A proof-of-concept test to confirm a motor could automatically reset the exhibit

A marker replaced the houses in this test because a marker is about the same weight as a house. The test also passed successfully. Our group tested the final exhibit to confirm that it was fully functional. We did these tests by pretending to be users interacting with the Reflection Factory. An image of a simulated interaction is included in figure 9.

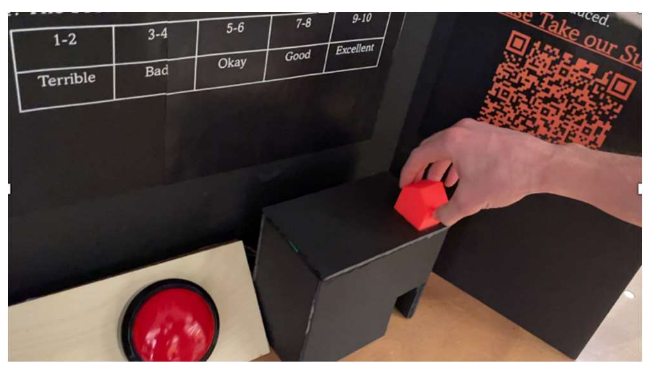

Fig. 9. Exhibit designers interacting with the Reflection Factory to confirm it works

The exhibit worked in all of the simulated interactions.

Collecting Feedback

Our group collected feedback from users to determine if the exhibit met the project criteria. Users completed a short survey that included both open ended responses and Likert scales. A photo of the survey given to users is included in figure 10.

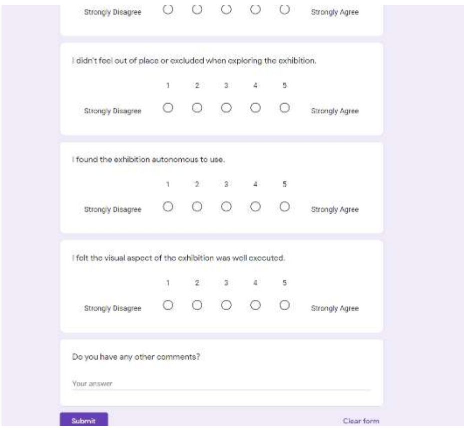

Fig. 10. An image of the survey given to users

The Likert scales gave users an opportunity to rate how well the exhibit met the subjective requirements of the project. Our group determined what scores would indicate the exhibit met the project criteria before we evaluated any user feedback. The methodology for evaluating the success or failure of the project on each subjective criteria is included in appendix D. For most criteria, a four or above indicated the exhibit met the requirement. Open-ended questions also gave users an opportunity to write larger responses. We used this qualitative data to determine how the design could be improved.

Users had two opportunities to provide feedback: other future engineers in the Stacked Cornerstone class evaluated a prototype of the design during an in-class presentation, and first-year non-engineering students reviewed the design at the Cornerstone Museum exhibit expo. We aggregate all feedback to evaluate the project.

Individual Contribution: Matthew Coughlin

My individual contributions to the project began with research. I found ten sources during milestone one which covered museum exhibit design, resilience engineering, and the urban heat island effect. These sources were important since they helped the group learn about the best way to design our project.

For milestone two, I designed two museum exhibits. Figures 11 and 12 show the exhibit designs.

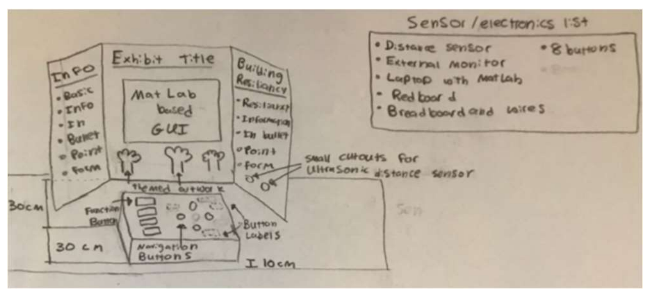

Fig. 11. One of my possible museum exhibit designs

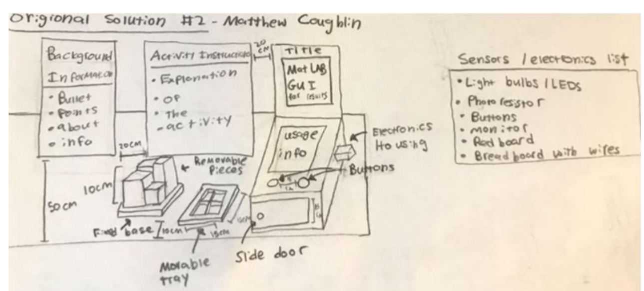

Fig 12. My second museum exhibit design

Both of my exhibits included a MatLAB GUI, an interactive component, and an informative poster board. Our final design included an interactive component and a poster board. One of the designs involved a light shining on multicolored buildings, and a photoresistor reading how much light was absorbed or reflected. This is the same general idea that we used in the final exhibit, but the exhibit involved single-colored houses instead of several buildings. I learned from our decision to simplify the buildings down to a single house that it is very important that museum exhibits only focus on teaching users one concept at a time. Our team felt that allowing users to change both building location and color would confuse users too much. The other design featured an interactive quiz that interacted with the MatLAB GUI. Our team moved away from this idea due to concerns about making it compliant with the universal design requirements. The accessibility issues we noted caused the design to score poorly in our decision analysis in appendix B. Our decision to move away from the design emphasized for me that no matter how fun or interesting a design may be, by far the most important criteria is that the design meets the requirements and objectives of the project.

I included a MATLAB GUI in both of my drawings. We did not end up using the GUI, but our team replaced it with an LCD. Including the LCD allowed us to simplify the exhibit without losing any functionality, since we did not need to use a full GUI to display simple text to users. This change reminded me that is important to not overcomplicate projects.

In milestone three, my primary contribution was helping construct a prototype of the exhibit. Prototyping the design was important since it allowed our team to see what the final exhibit should look like. Milestone three reinforced my belief that the museum of modern resilience is really a team project since we all helped construct an exhibit prototype from cardboard.

I was the project manager for milestone four, when we built most of the electronics for the exhibit. Figure 13 shows the exhibit at the end of milestone four.

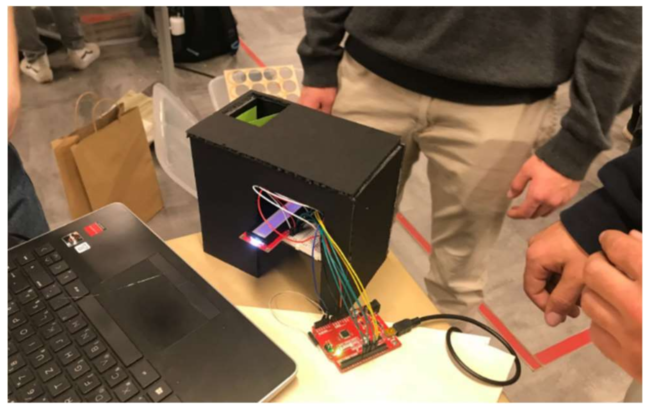

Fig. 13. An image of the electronics for our museum exhibit.

My largest contribution in milestone four was organizing our team and keeping the project moving along. I took responsibility for delegating tasks and making sure we were on track to meet all the requirements in the Gannt chart. The Gannt chart we used for the project is included in appendix H.

In the final milestones, I helped our team finish constructing the exhibit and present the results to the class. These milestones reminded me that carful time management is extremely important. We were able to finish our exhibit, presentation, and final report by dividing up the tasks and making incremental progress on them over the course of many days. Helping our team stay on track to complete the project in time was one of my largest contributions to the group.

Individual Contribution: Anthony Zappala

My individual contributions began with the research phase of the project. I researched ten sources to learn more about successful museum exhibits, resiliency engineering, and current methods of combatting energy consumption.
During milestone one, I served as project manager and analyzed these sources to help create a user image.
During milestone two, I created two sketches of possible exhibit ideas that reflected the ideas of our group and the research I had done on successful museum exhibits.
Figures 14 and 15 show my two sketches.

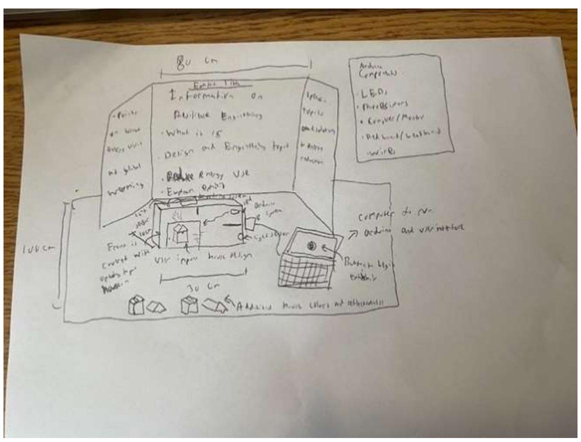

Fig. 14. One of my possible exhibit sketches.

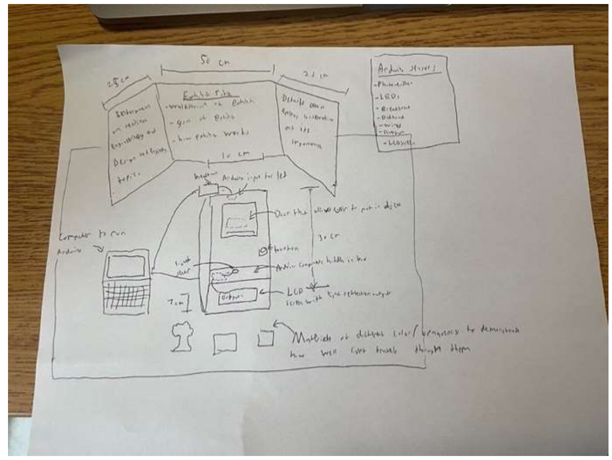

Fig. 15. My second exhibit sketch.

My exhibits were like the final design, but they included a MATLAB GUI which we did not end up including. My sketches are shown in appendix G in the photo log.
For milestone three, I helped create a cardboard mock-up of the final exhibit at the time. While I put my individual time and effort into this milestone, the overall prototype was largely a group effort to create and assemble.
During milestone four, I was responsible for making detailed AutoCAD diagrams of the control panel and creating a laser cutting AutoCAD sketch to cut the pieces for the control panel. The detailed sketch can be found in appendix C.

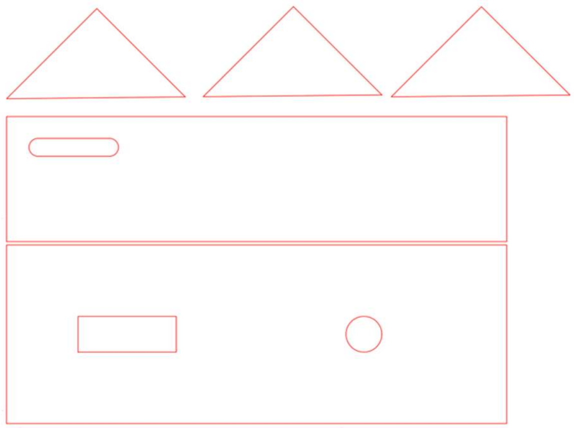

Fig. 16. The AutoCAD laser cut file for the control panel parts.

I also was tasked with creating a solidworks design for the small houses used in the exhibit. A detailed image of the Solidworks design can be found in Appendix C.

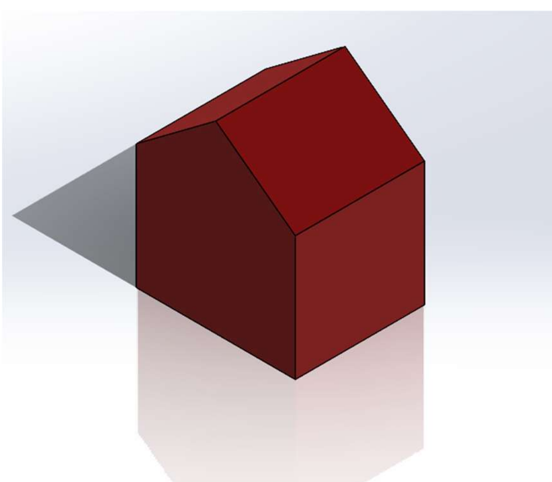

Fig. 17. An isometric view of the houses designed to fit into the interactive learning box

In the final milestones, I assisted in the construction of our final exhibit and the rigorous testing we went through to ensure consistency. It was also my responsibility to laser cut the wood and assemble the control panel and 3D print the six houses. After receiving feedback from the in-class exhibit showcase, I created a laminated handout with directions for our exhibit that was placed by the control panel.

Fig. 18. An image of a handout placed by the reflection factory control panel.

Individual Contribution: Nick Laux

My contributions to this project include both tasks broken up between members of our group, and tasks that were delegated specifically to me. In the beginning, our team was tasked with finding 40 sources on resiliency and the urban heat island effect. We divided the sources into four and I located sources to write ten annotated bibliographies. I also helped consolidate the 40 sources and identify the other deliverables for the first memo.

The second memo was my project manager week. As project manager, I read through the assignment with my group as we formulated deliverables. I made sure that each member of the group was okay with their workload and made sure that the load was as equal as possible. As for other contributions, I helped research two current market solutions of successful museum exhibits. This, along with the two each that each group member did, gave us a good footing moving forward. I also helped create 2 solutions of my own to showcase modern engineering resiliency in the real world. These solutions included flowcharts that showed the user interaction with the exhibit ideas. The two designs that I created are visible in figures 19 and 20 below.

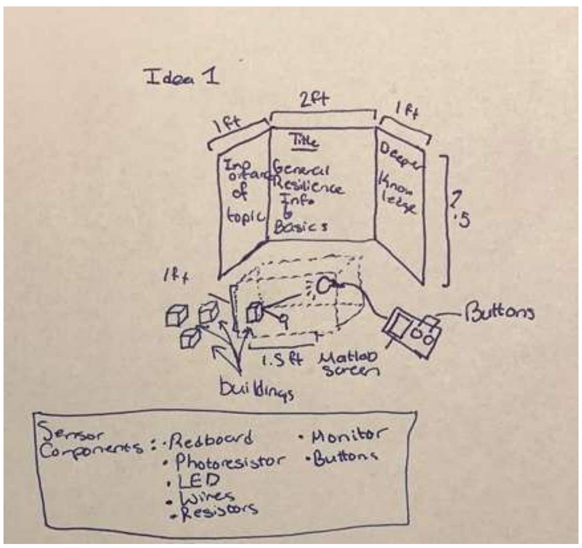

Fig. 19. My first possible museum exhibit sketch

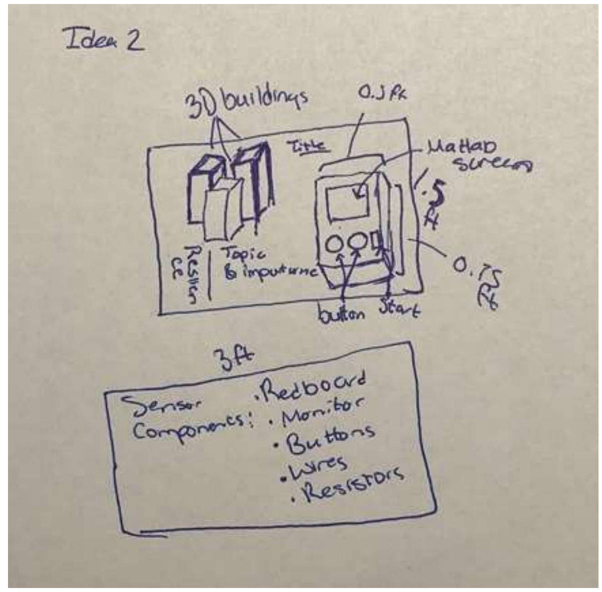

Fig. 20. My second museum exhibit sketch

In the third milestone, I assisted in helping make and update the KDTA chart as well as the potential problems chart to submit in the third week. Other members of the group and I met in the engineering center at Northeastern to build a scale model of the Reflection Factory. The KDTA and problems charts can be found in Appendix B and the building of the scale model can be found in Appendix G.

Over the 4th week on, I went back to research more sources and create a comprehensive model of the teaching components of resiliency and the urban heat island effect. I also wrote the interactive portion on the draft posterboard. The figure below shows the posterboard. The left panel shows the resilence engineering teaching, the right panel teaches the urban heat island effect, and the middle holds the interactive content of the draft shown to the class prior to the engineering expo.

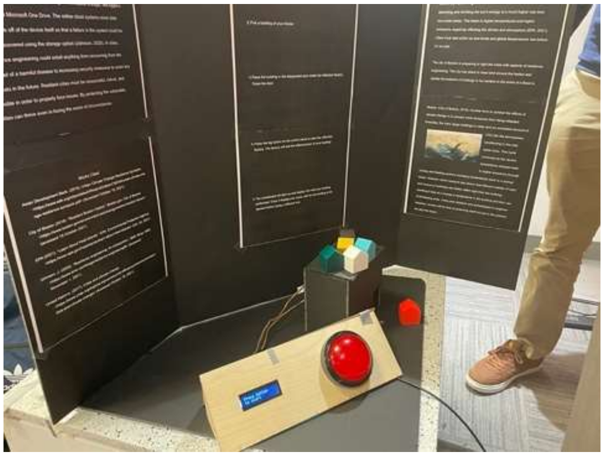

Fig. 21. The first draft of the educational posterboard, before it was updated for aesthetic purposes.

The group and I also spent time in the engineering center building the Reflection Factory box. Lastly, I helped with determining the evaluation of our goals, summarized in a chart. The evaluative chart can be found in Appendix D. Images of our group can be found in Appendix G.

INDIVIDUAL CONTRIBUTION: JULIA RASMUSSEN

I was involved with the project from the beginning to the end. During the first week of the project, I researched climate change and various resilience engineering solutions to the urban environment in the face of rising temperatures. I also did a needs assessment for the project using a Duncker diagram to find possible solutions to our problem. For the second week of the project, I found two museum exhibits from the Museum of Science and made a fishbone diagram that analyzed the aspects of all the preexisting museum exhibits my team had found that made them work well. I also drew two possible designs for the museum exhibit, shown in Figure 22 and Figure 23, as well as the flow charts for how each design would actually function.

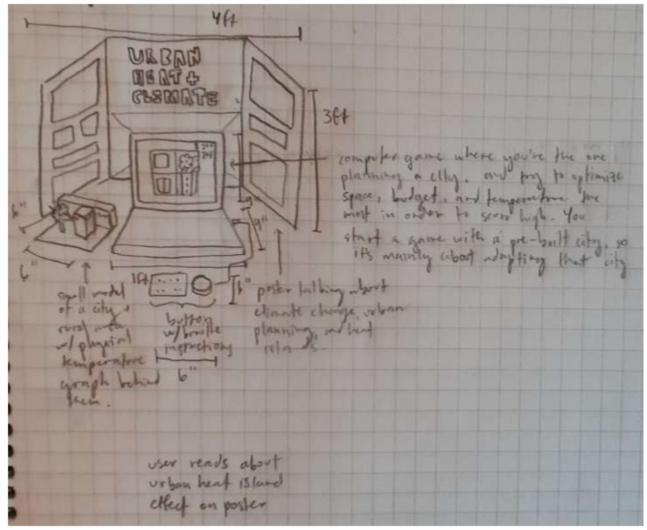

Fig. 22. A sketch of a possible museum exhibit designed by Julia Rasmussen.

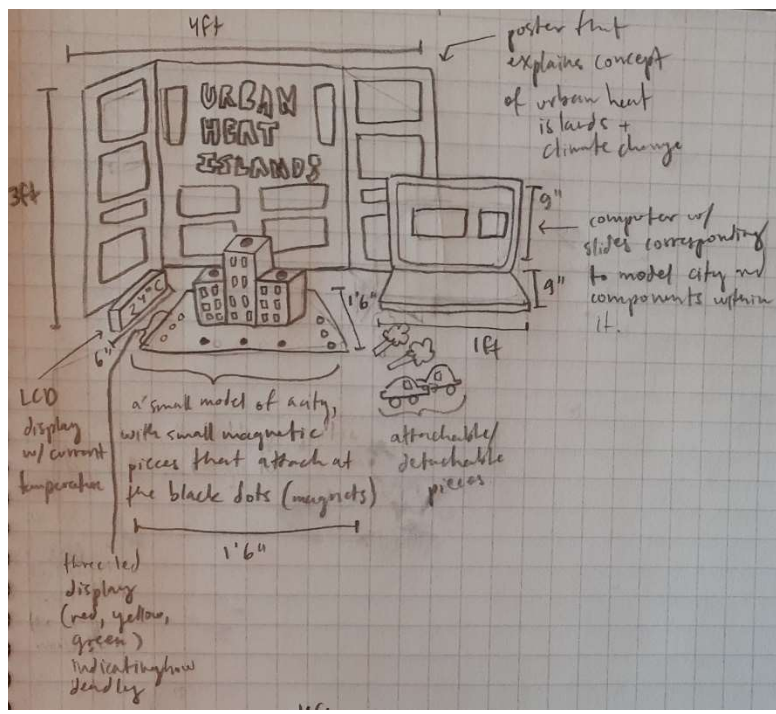

Fig. 23. A sketch of another possible museum exhibit designed by Julia Rasmussen.

These designs are slightly different from the design we ended up going with. The first design, Figure 22, is of a computer simulation that would allow the user to model their own city, and see how different strategies in mitigating the effect of climate change would affect the temperature within the city. There's also a 3D model that shows the urban heat island effect visually. The second design, shown in Figure 23, is a small model of a city, where the user can add magnetic attachables to the model in order to change the temperature of the city, and learn about heat mitigation strategies that way. Then, for the third memo, I worked on the rank order and KTDA diagrams in order to identify the objectives for our projects, and which of the designs met those objectives the best. I also started the wiring for the Arduino, and figured out some of code with Matt. This was also the week that I was the project manager, and thus I emailed our mentor and set up a meeting to check in with her about our project. I then presented our progress for the project in class in a Town Hall presentation. For the fourth module, our team started working on the prototype of the exhibit. I worked further on the Arduino proof of concept, along with the wiring diagram on for the Arduino using TinkerCAD. The final wiring diagram can be found in appendix F.

For the final few modules, our team brought together everything that we had worked on individually and built the exhibit entirely. I helped with the construction of the reflection factory, and rewired the electronics with materials borrowed from FYELIC, so that I wouldn't have to keep rewiring it (as I had to use the same board for in-class assignments), and could simply keep the wiring as it was. I also helped print the poster.

1.7 FINAL DESIGN

The final design includes a poster board, an interactive learning box, and a control panel. The final design is pictured in figure 24.

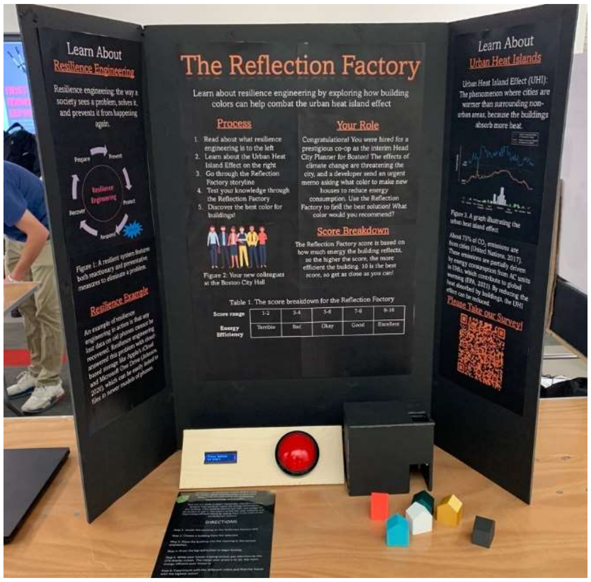

Fig. 24. A photo showing the overall museum exhibit.

FLOW OF USER INTERACTION

The user begins their interaction with the reflection factory by reading the poster board. They then use the reflection factory interactive learning box to see how color impacts the amount of light absorbed or reflected. A flowchart showing the user's interaction with the exhibit in detail is included in figure 25.

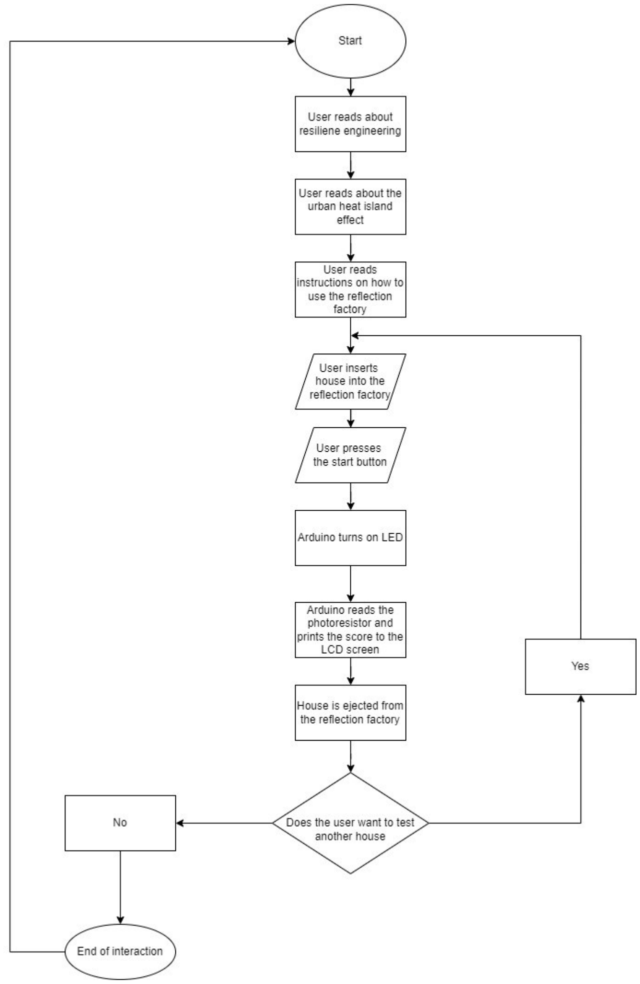

Fig. 25. A flowchart describing the user's interaction with the exhibit.

POSTER BOARD

The poster is broken into three different sections. Figure 26 shows the visuals included in the poster board.

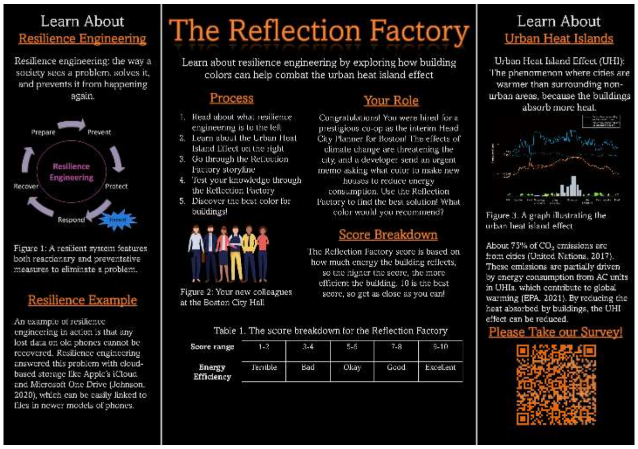

Fig. 26. A graphical rendering of the poster board component of the Reflection Factory

The left flap contains information about resilience engineering and provides examples of resilience engineering in other contexts. The right flap provides information about the urban heat island effects. The main flap is dedicated to instructing users on how to use the reflection factory box. It also provides context for the scores output by the reflection factory.

A handout with instructions on how to interact with the box part of the reflection factory instructed users on how to insert houses and interpret their scores. An image of the handout is included in figure 27.

Fig. 27. An image of a handout placed by the reflection factory control panel.

INTERACTIVE LEARNING BOX

The interactive learning box is controlled by a control panel. An image of the control panel is included in figure 28.

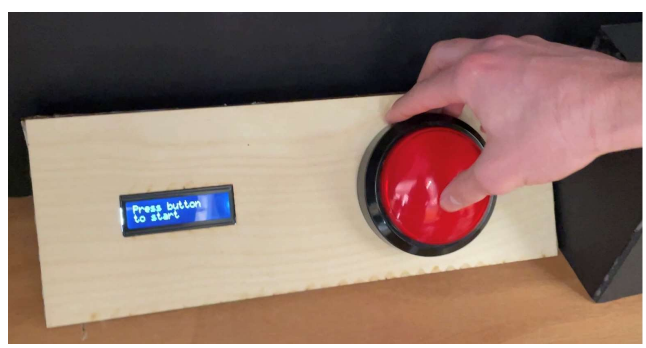

Fig. 28. The control panel for the exhibit in use

A more detailed drawing is included in appendix C. The large button starts a test in the interactive learning box. The result is printed on the screen on the control panel. The score is calculated by turning on an LED pointed at the side of a colored house inserted into the reflection factory. A wiring diagram for the electrical components can be found in appendix F. The Arduino reads the amount of light reflected and calculates the score based on how much light is reflected relative to the minimum and maximum amounts of light it is possible to reflect. A flowchart showing the path the Arduino code follows is shown in figure 29.

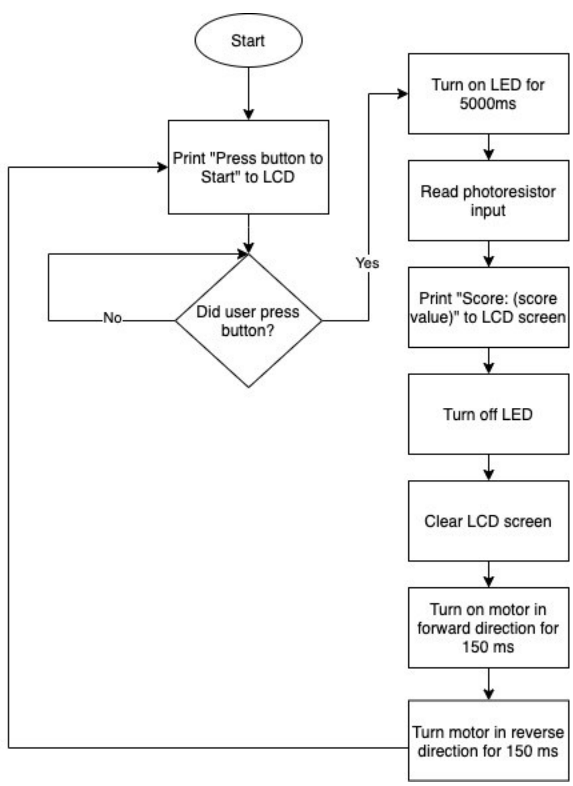

Fig. 29. A flowchart showing the flow of the Arduino code in the reflection factory.

The full Arduino code is included in appendix E. The houses the user inserts into the interactive learning box are specially designed to fit into the box. An isometric view of the houses is included in figure 30.

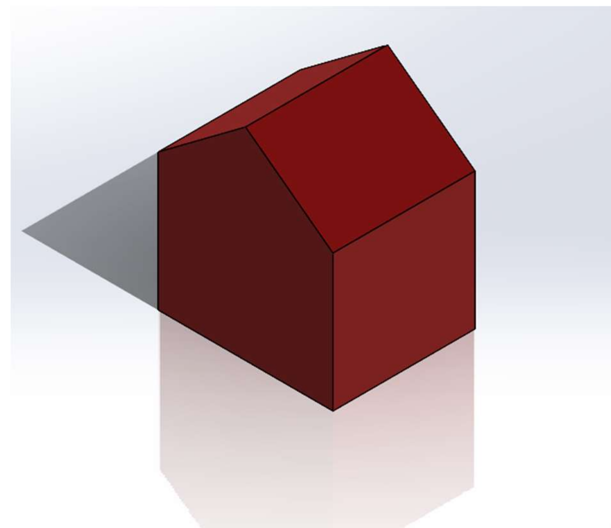

Fig. 30. An isometric view of the houses designed to fit into the interactive learning box

All the houses are identical in geometry, but they are made from different colored 3D printer filaments. A technical drawing showing the exact dimensions of the house is included in appendix C. The interaction with the reflection factory ends when the house is ejected from the testing chamber. This is done by a motor held in a special 3D printed holder. Figure 32 shows an isometric view of the motor holder.

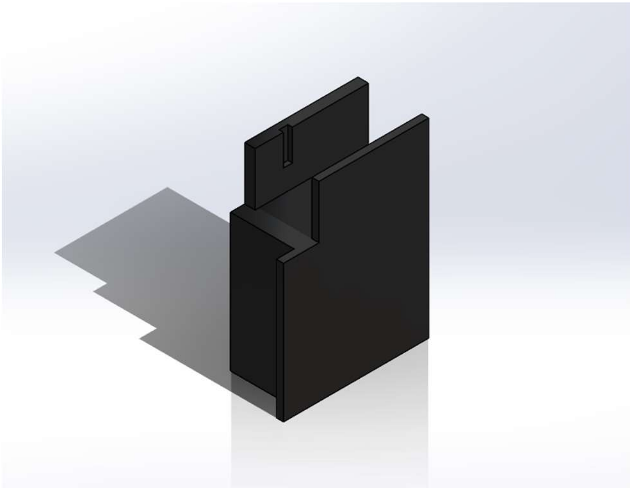

Fig. 31. A picture of the holder for the motor that ejects houses from the reflection factory.

A technical drawing of the motor holder is available in appendix C. The motor ejects a house by lowering the floor and allowing the house to fall out of the interactive learning box. The motor then raises up the floor. This action pushes the house out of the door in the front of the box. The materials used to create the reflection factory box are summarized in a bill of materials included in appendix K.

1.8 RESULTS

Physical Specifications

The poster board used for the exhibit measured 3’-0” by 4’-0”. The reflection factory and control panel fit in a 2’-0” by 1’-0” area, and we also had a laminated piece of 8 ½” by 11” paper with instructions on how to use the reflection factory. There was no water used in the construction or operation of the reflection factory. All of the wiring ended up fitting within the control panel and reflection factory, with the exception of the wires running from the control panel to the reflection factory, connecting the two.

Electrical Components

The reflection factory had two inputs. The first input was the large red button that was used to start the exhibit loop when the user was ready. The second input was the photoresistor which read the amount of light reflected off the selected building. The reflection factory had one output. The output was the LCD screen on the control panel which displayed text telling the user to “Press button to start” and their score which was a number 1-10 corresponding to the amount of light detected by the photoresistor. The Reflection Factory included five main Arduino components. These components were the LCD screen, white LED, photoresistor, gearbox motor, a breadboard, and a Redboard.

Laser Cutting and 3D Printing

The reflection factory used a total of seven 3D-printed parts. Six of these parts were the small houses of colors white, galaxy black, cyan, forest green, orange, and gold, which were placed into the reflection factory exhibit. The final 3D-printed part was the custom motor holder mount where the Arduino motor was held in place in the reflection factory.

The reflection factory also used laser cut parts in the control panel. The top, sides, and back of the control panel were made from laser cut wood parts designed in AutoCAD.

Cost and Build Efficiency

The overall project budget was set at $100. The final cost of the reflection factory exhibit amounted to $17.83 Appendix I. The total time spent building the exhibit was 358 hours.

Survey Data

Users who came to the exhibit had the opportunity to provide feedback by completing a short survey. The survey consisted of several questions about the exhibit’s performance where users responded on a Likert scale of 1-5, where a score of 1 was “Strongly disagree” and a score of 5 was “Strongly Agree”. It also included open-ended questions where users could provide general feedback on the exhibit and give any specific comments.

A total of 17 users responded to the questionnaire and provided feedback data, and a detailed summary of the questions and user responses is included in appendix D. Users generally agreed or strongly agreed with the questions posed in the survey, which focused on their experience in the exhibit, and included prompts like "I understand the urban heat island effect after having gone through the exhibition" and "I found the exhibition autonomous to use." No users disagreed or strongly disagreed with any prompt, and the average score across all prompts was 4.74 out of 5. When asked if the reflection factory exhibit was informative, engaging, and had appealing visuals, the average score was 4.52, 4.76, and 4.71 (with a standard deviation of 0.72, 0.56, and 0.59), respectively. As our initial threshold for meeting each criterium was a score of 4, all of the subjective criteria for our exhibit were well within the limit of being met. Additionally, the average score for the inclusivity and autonomy of the exhibit was 4.94 and 4.76 (with a standard deviation of 0.24 and 0.44), respectively. Thus, our goals of inclusivity and autonomy were also met.

Open-Ended Responses

Responses to the open-ended questions were generally consistent with the Likert scores. Several users from the presentation during the cornerstone class asked for more information about what the scores from the LCD meant. A standard response generally asked us to "include high score best, low score worst. Some sort of scale on trifold would make understanding problem better." Our group modified the exhibit in between presenting the prototype to the cornerstone class and presenting the exhibit at the museum expo by adding an additional sheet of instructions by the control panel, as well as by adding a descriptive word such as "good" that showed up next to the score on the LCD. After implementing these changes, no users at the first-year museum exhibit expo asked for additional clarification of the LCD scores.

1.9 DISCUSSION/ANALYSIS

FEEDBACK DATA

Based on our survey findings after the first showing and engineering exhibit, we feel that we were successful in each requirement and were able to adapt to fix any inconsistencies. As for being informative, engaging, inclusive, autonomous, and visually appealing, we had averages above 4.5 on a 5-point scale. We had originally intended for a score above 4 to be considered successful and had far surpassed that goal. As for the longer response types, prior to the final engineering exposition, we had received feedback regarding changing the meaning of the reflection factory score. The original scoring system was a number from one to ten. The number has no indication of what it had meant and did not suit the users well. Users had responded that the scores were hard to understand and that they did not provide value as is. Our group noticed the feedback and worked to create a better scoring system. We labeled the scores with meaning, from terrible to excellent, and the user had to aim for an excellent score (8-10). We had also written on the posterboard, and the instruction sheet the meaning behind the scores and improved the storyline to better the user's experience. The feedback received at the expo elucidates our improvement in this category.

OBJECTIVE CRITERIA

The design met all of the objective criteria. First, it cost less than $100 to construct. A table summarizing project expenditures is included in appendix I. The Arduino also had the required two inputs and one output: it received input from a photoresistor measuring the reflectiveness of a house, it received input from a button the user pressed to begin testing houses, and it sent output to an LCD screen that informed users of their score.

The project criteria also called for a laser cut or 3D printed component. The houses that users inserted into the interactive learning box were 3D printed, and the control panel was laser cut. The final objective requirements stated that the exhibit needed to be portable and free from water. Our exhibit was portable since we were able to bring it to and from the first-year non-engineering student expo without any issues. It also did not use any water.

SUBJECTIVE CRITERIA

Our team used the results of the survey to evaluate whether the exhibit met the subjective criteria. One criteria required that the exhibit was engaging. 94% of users agreed or strongly agreed that the exhibit was engaging, and no users disagreed. The project also required that the exhibit was informative. 88% of users agreed or strongly agreed that they learned about the urban heat island effect from the exhibit, and no users disagreed. A full summary of relevant survey data from users is included in appendix I.

EXTRA CREDIT

The project also contained opportunities to earn extra credit by making the exhibit inclusive and autonomous. The exhibit featured several accessibility and inclusivity features to meet universal design requirements. Images on the poster contained figures with many different identities. A picture of the relevant section of the poster board is included in figure 32.

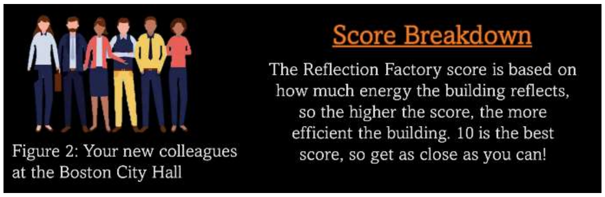

Fig. 32. An image of the poster board that shows inclusive figures.

We included these images to make sure the exhibit was inclusive. 100% of users agreed that the exhibit did not make them feel excluded or out of place. The exhibit was also autonomous. Houses inserted into the reflection factory were automatically ejected from the exhibit. 100% of users agreed or strongly agreed that the exhibit was autonomous to use. All these metrics exceed our predetermined thresholds for stating the project met the objectives of engagingness, informativeness, inclusivity, and autonomy. An overview of our thresholds for feedback analysis is included in appendix D.

1.10 CONCLUSION

Our group designed a museum exhibit to educate first-year non-engineering students about resilience engineering and the urban heat island effect. The final design included a poster board with panels explaining resilience engineering, the urban heat island effect, and how to use the interactive learning component of the exhibit. It also had an interactive learning box where users inserted houses of a variety of colors to discover how much energy they absorbed.

We followed the engineering design process throughout the project. This meant researching the problem, brainstorming solutions, prototyping the exhibit, collecting user feedback, and revising the design. The design met all the project criteria, including coming in under budget, using the required parts, being informative, being engaging, and having high-quality visuals. We also met the goals of creating an inclusive and auto-resetting exhibit, and the overall average user-given score for the subjective criteria within our project was 4.74 (see appendix D), much greater than our target of 4.

Lessons and Key Takeaways

Overall, our group was satisfied with our final exhibit. We could have made the exhibit better by making the internal wiring more secure and possibly soldering the components together. This would have made it more difficult for them to come undone. We could also have improved the auto-resetting portion of our project by making the houses return to a known location instead of just being ejected. This would have made it more difficult to lose houses. Our final suggestion for future improvement is to make the houses out of different kinds of plastic. All the houses were made from PLA, but different materials may have different levels of reflectivity. It would enhance the experience of our users if they could learn about how both color and material choice contribute to the urban heat island effect.

1.11 RECOMMENDATIONS

Our main recommendation for any further work on this project or any like it would be to make the exhibit more polished. After all, all the components in the exhibit are functional, and the exhibit ended up meeting all the design criteria we originally made it for. Thus, a lot of the exhibit could be improved simply by adding to the visual presentation, by soldering the electrical components together, either painting or finishing the wood of the control panel, and perhaps recutting the foam board of the reflection factory (or changing the material to laser cut pieces).

Another feature that could be useful to add could be to make the exhibit more accessible to people with visual impairments. Because our exhibit currently relies on the user to read instructions given both on the poster board and on a sheet next to the control panel in order to use the reflection factory, it is not currently accessible to people who are visually impaired. In order to make it more inclusive, a future project could include an audio station next to the reflection factory and control panel consisting of headphones, an mp3 player, and a button with which to start the audio. This audio station could have a voice over that reads the information on the poster board to the user, as well as a voice over that explains how to use the reflection factory. In addition, braille could be put on the houses in order to describe the color of each house, a tactile map of the layout of the exhibit could be 3d printed, and the control panel could be wired to the audio station in order to say the score that each house got. In order to make sure that it is useable, it would also be useful for a visually impaired person to test it out and determine whether or not enough information is given through the audio and tactile aspect of the exhibit.

Future work could also include a more in-depth exploration of various strategies used to combat the urban heat island effect. While our exhibit only focused on the use of paint to reduce the heat of buildings, more research could be done about other cooling strategies, such as green roofs and the introduction of trees to urban spaces. This information could support an entirely new exhibit that runs parallel to our own. It would supplements the learning from our exhibit, and the user would understand the impact of the urban heat island effect and the strategies that can be used to overcome it better than if they were to only have gone to one of the exhibits. Overall, we were very happy with how our exhibit turned out, and believe that it would only get better with the implementation of these recommendations.

MATTHEW COUGHLIN

1.12 LESSONS LEARNED

CONTRIBUTIONS

My individual contributions to the project began with research. I found ten sources during milestone one which covered museum exhibit design, resilience engineering, and the urban heat island effect. For milestone two, I designed two museum exhibits. Our final design included an interactive component and a poster board similar to the ones I described in my design.

In milestone three, I mainly helped our team by assisting with the construction of the museum exhibit. Prototyping the design was important since it allowed our team to see what the final exhibit should look like.

I was the project manager for milestone four, when we built most of the electronics for the exhibit. My largest contribution in milestone four was organizing our team and keeping the project moving along. I took responsibility for delegating tasks and making sure we were on track to meet all the requirements in the Gannt chart. The Gannt chart we used for the project is included in appendix H.

Milestone five required our group to finish constructing the project and to present it at the expo. My main job was making sure that the motor that reset the exhibit worked. This was a challenging task because the houses fit tightly in the slot and sometimes got stuck. The final solution integrated several of my ideas with those suggested by my groupmates; specifically, adjusting the amount of time the motor moved, adding a peg to control where the motor stops, and fixing an interior wall inside the interactive learning box

I contributed to milestone six by working on the final presentation and final report. My main contributions in the final report include the methodology and final design sections. I also made the first sections in our PowerPoint presentation that covered the final project design and how it met certain criteria.

RESOURCES

Our group completed the project significantly under budget: we spent less than $20 of the $100 we were allocated. Appendix I shows the budget in more detail. I learned about resource management while working on this project. I now appreciate that it is important to carefully budget a project before it begins because there is always the chance of unexpected expenses. In our case, we spent an extra $3 in printing dollars due to issues with the Snell library copy machines.

I also gained new experience managing time. I spent almost 100 hours working on the project, and this reinforced my belief in carefully budgeting time. Appendix J breaks down exactly how long my team members and I worked on each task. It was only possible to get the project done because I worked on the assignment a little bit each day. I plan to take an incremental, balanced approach to managing my time in group projects going forward.

REFLECTIONS ON LEARNING

The entire project helped me learn more about the engineering design process. This was the first project that I followed the engineering design process through from start to finish, and I plan to use the process going forward. One of the main takeaways I had was that the process is extremely collaborative. My focus from milestones one to four was designing the interactive learning box, but I relied on the contributions of my teammates to get the electronics working. We collaborated on the project and completed it successfully because of each other's contributions.

Being the project manager reinforced my belief that it is important to have one point person leading a group. Managing the team took a lot of time: I spent most of milestone four working on project manager tasks such as the Gannt chart, the hours log, and the memo. I also learned that one of the most important tasks for a project manager is making sure the group meets the expectations of the assignment. One of my primary tasks was reviewing the assignment description to confirm that we were not wasting any time and effort.

The largest takeaway I have from this project is that the engineering design process is a cycle of constant refinement. We went through several iterations of the mechanism that removed houses from the interactive learning box before finding one that worked. I redesigned the entire system several times in the week before the exhibit expo. The experience of having several designs fail before finding one that worked reminded me it is important to constantly refining and improving work.

Reflections on Working in a Team

Our team worked extremely well together. I believe that we did an excellent job distributing the workload so that no one person had too much work and no one was contributing too little. Constructing the museum exhibit was such a big project that no one person could construct it alone. The reason we completed the exhibit successfully is that we worked together and shared responsibility.

The importance of teamwork was most prominently on display when we ran into issues with the electronics, interactive learning box, and poster board. I noticed our team was always ready to lend a hand when other people were having trouble on their assigned tasks. Frequently, a new pair of eyes was enough to solve the issue.

Collaboration also made all my team members easy to work with. It was simple to be the project manager since we all were already on the same page about most expectations. I believe my group members would also agree that it was easy to be the project manager for me and the rest of the team.

Going forward, I will always try to work with a team when completing large projects. Having group members is incredibly valuable and absolutely increased the quality of our final product in this project.

ANTHONY ZAPPALA

1.13 LESSONS LEARNED

Contributions

One of my main contributions to the final design was the design of the small testing houses used in our exhibit. I designed the house in SolidWorks and was responsible for coordinating printing the gold, white, and black houses. Another one of my main contributions was the development and build of the exhibit control panel. I designed the structure of the control panel, and created the laser cut design on AutoCAD. I was also responsible for purchasing the wood and setting up a consultation to get the design laser cut. Once the design was laser cut, I sanded down the interior hole for the LCD screen and made sure it had a snug fit in the panel. I also constructed the panel and attached the large button. For the final exhibit, I was responsible for creating the exhibit handout that guided users on how to use our exhibit's interactive features. I wrote the instructions and made the handout aesthetically pleasing on Microsoft Word software. I also was responsible for laminating the final handout. In the main box of the exhibit, I was responsible for developing a way to house the LED and photoresistor to get light readings off the houses. As a group member, I also contributed to the overall build of the exhibit, such as building the final reflection factory box and putting together the physical electronics of the exhibit.

Resources

Our group successfully met our budget of $30 we defined for ourselves, spending only $17. I personally spent $5 on the wood for laser cutting the control panel [Appendix I]. I devoted an average of 10 hours a week for this project, depending on the phase of the project. Further breakdown of hours spent can be found in the hours log in Appendix J. This project has shown me that proper foresight and planning is extremely important when it comes to resource management. The more detailed planning that occurs in the beginning planning stages of a project, the less unexpected costs will occur later. Additionally, leaving a buffer for additional expenses is important in case any unforeseen circumstances arise. I now have a greater skill of budget planning and mapping for projects that has grown because of this project. Before, I thought little about the cost and did not plan out what I needed to spend money on. However, I have gained the skills of organizing future costs and planning where I need to spend money.

Reflections on Learning

I learned a lot from this project about teamwork, management, dividing time, and planning. In terms of physical skills, I improved my AutoCAD skills while developing a laser-cutting file for the control panel and my Solidworks skills while designing the houses for 3D-printing. I also gained a greater understanding of Arduino electronic elements, especially the motor and motor driver. After experimenting with these components and the corresponding code throughout our project, I now feel confident working with these features in the future. The most beneficial things I learned throughout this project are my improved teamwork skills and skills with design software like AutoCAD and Solidworks.

Reflections on Working in a Team

My team working skills were greatly improved by this project. We overcame several challenges, beginning with schedule conflicts and times to meet. I also developed my brainstorming and determining skills as we devised several options for a project and worked as a team to decide on the project, we felt was best. I also learned how to properly divide work to get past a deadline and allocate time for any unforeseen issues with design or construction. One aspect of teamwork I still need to improve on is giving constructive feedback when I disagree with an idea. I typically avoid saying much since I do not want to sound rude to another teammate. However, it is important for me to be able to share my opinions in a respectful and constructive manner.

I would describe my leadership style as a group leader rather than a manager. As a group leader, I am still heavily involved in the project and its development. A more managerial style would focus more on assigning tasks than working on the project itself, but I was able to find a balance that allowed me to work on the project and oversee the other group members' work.

I feel that I can be managed effectively, since I am not afraid to voice my concerns even though there is a perceived gap in leadership.

As a team, we overcame adversity very well and collectively were able to solve every issue we came across. I found our team to also be very effective in dividing the work in an efficient and effective way that allowed us to push through any issues in our project.

My biggest asset to the team was my problem-solving skills in terms of finding ways around issues that came up during development and construction. Not everything always went as planned throughout our project, but I always felt confident in my ability to think critically and find a solution to the issue at hand.

If I could go back to the beginning of the semester again, I think I would have spent more time in the beginning planning and developing a more concise plan to avoid some of the issues that arose later. I would have also liked to add more features to our project, such as wiring the LED in the large button or adding an audio element with an Arduino buzzer.

NICK LAUX

1.14 LESSONS LEARNED

CONTRIBUTIONS

My contributions to this project include both tasks broken up between members of our group, and tasks that were delegated specifically to me. In the beginning, our team was tasked with finding 40 sources on resiliency and the urban heat island effect. We divided the sources into four and I located sources to write ten annotated bibliographies. I also helped consolidate the 40 sources and identify the other deliverables for the first memo. The second memo was my project manager week. As project manager, I read through the assignment with my group as we formulated deliverables. I made sure that each member of the group was okay with their workload and made sure that the load was as equal as possible. As for other contributions, I helped research two current market solutions of successful museum exhibits. This, along with the two each that each group member did, gave us a good footing moving forward. I also helped create 2 solutions of my own to showcase modern engineering resiliency in the real world. These solutions included flowcharts that showed the user interaction with the exhibit ideas.

The secon hald of the project focused on the actual creation of the exhibit. In the third milestone, I assisted in helping make and update the KDTA chart as well as the potential problems chart to submit in the third week. Other members of the group and I met in the engineering center at Northeastern to build a scale model of the Reflection Factory. Over the 4th week (first prototype build week), I went back to research more sources and create a comprehensive model of the teaching components of resiliency and the urban heat island effect. I also wrote the interactive portion on the draft posterboard. The group and I also spent time in the engineering center building the Reflection Factory box. Lastly, I helped with determining the evaluation of our goals, summarized in a chart.

RESOURCES

In terms of the budget, our group spent about 17% of the $100 budget, only about $17. In terms of my expenditures, I had used Northeastern printing dollars to print the first draft of the posterboard. I also used tape and other small pieces in the project, all. The final posterboard design was printed by another group member. The breakdown of the budget can be found in Appendix I. As for hours devoted to the project, my total hours amounted to well over 100. The breakdown of hours can be found in Appendix J. I am not surprised that this project took that many hours as it explored the entire engineering design process. It taught many lessons on time management which will be described in a later section.

REFLECTIONS ON LEARNING

Throughout the project experience, I have learned a lot through my own tasks and opportunities to manage a team. For the management role, I found that I am more of a collaborative leader than someone above the rest. Even in my week of managing, I still did an equal share of the work and learned more about my style. In helping my groupmates with their tasks, I learned even more about Arduino components including the motor piece and the functions that drive it as well as wiring pieces that were not a part of the kit itself. I feel a lot better working with all of the components of the project as I had to understand how each and everyone worked.

Reflections on Working in a Team

I have gained valuable experience from being a part of an engineering team. The experience was truly a great experience and being able to divide work between four people allowed us to efficiently create and showcase our exhibit. I am very happy that our team was able to plan out our exhibit and come out with a solution that had components that each member valued.

I feel that our team was best at dividing work and listening to each other; if any group member had outside conflicts, we were sure to adjust the workload. The group was more than willing to make up the work the next week essentially equalizing our efforts. We were also successful at working to our strengths. Personally, I have a lot of experience doing research and writing reports. I was tasked with doing the final research and writing that went towards the posterboard and believe that the role brought more out of me than if I were to perform another.

Even facing adversity, our team made sure that each of our tasks came out to be a product of all of us four. All four members spent some time helping others, from fixing the coding and motor, to poster design, and picking up pieces that helped the group. If there is anything I wish occurred differently, it is that we should have spent more time planning out the project itself. Some of the planning issues are due to assignment objectives not being visible, though even we could have planned to incorporate more into our exhibit to make it even better for our user. Overall, our team was successful in working together and had left me with valuable lessons that I hope to share with future engineering groups.

JULIA RASMUSSEN

1.15 LESSONS LEARNED

CONTRIBUTIONS

I was involved with the project from the beginning to the end. During the first week of the project, I researched climate change and various resilience engineering solutions to the urban environment in the face of rising temperatures. I also did a needs assessment for the project using a Duncker diagram to find possible solutions to our problem. For the second week of the project, I found two museum exhibits from the Museum of Science and made a fishbone diagram that analyzed the aspects of all the preexisting museum exhibits my team had found that made them work well. I also drew two possible designs for the museum exhibit, as well as the flow charts for how each design would actually function. Then, for the third memo, I worked on the rank order and KTDA diagrams in order to identify the objectives for our projects, and which of the designs met those objectives the best. I also started the wiring for the Arduino, and figured out some of code with Matt. This was also the week that I was the project manager, and thus emailed our mentor and set up a meeting to check in with her about our project. I then presented our progress for the project in class in a Town Hall presentation. For the fourth module, our team started working on the prototype of the exhibit. I worked further on the Arduino proof of concept, along with the wiring diagram on for the Arduino using TinkerCAD.

RESOURCES

Our group ended up well under our $100 budget, only spending $17 of it in total. This was due to how well we used the resources already available to us through FYELIC, Northeastern, and the assets that our team already owned. I personally provided the black foam core poster board for the exhibit and I also printed the color tabloid pages for the poster. Like most of my teammates, I spent about 100 hours on this project, which can be seen in the hours log in appendix J. I believe we used all of our resources in a very efficient manner, and we were able to pool together our resources both in terms of supplies and time in order to get the project done.

REFLECTIONS ON LEARNING

Over the course of this project, I personally learned more about resiliency engineering, the urban heat island effect, how to effectively work together as a group, and how to go from start to finish in an engineering project. Overall, I am extremely glad I did this project as the topic of our exhibit, the urban heat island effect and methods on how to combat it, is directly applicable to me as someone who has lived in a city for most of their life. By knowing more about topics surrounding urban resiliency I can be a more informed citizen of the city I live in, and understand the policy behind various governmental projects that aim to reduce the effect of climate change. Additionally, resilience engineering is a topic that is important not just as a future engineer, but also when looking at my own life. I can use resilience engineering principles jn order to become a more productive individual and make sure that I plan ahead for any accidents that may occur in work or life. It is also important for me to know how to work in a group for any future projects, and now that I know more about the engineering design cycle, I can apply that to any future projects as well.

This semester was also the first time I've formally learned Arduino, and the first time I have ever done such a large project with Arduino. Thus, I learned a lot about how to use both Arduinos and TinkerCAD, and feel comfortable enough with both that I am confident I could use both in future projects.

Reflections on Working in a Team

Overall, I learned a lot about how to work in a team effectively throughout the course of this project. I’ve worked a lot with groups on group projects in the past, but it is always difficult to ensure that the right balance of work is struck, that is, that everyone has enough to do, but no one is doing too much or too little. Often, the burden of getting a part of the project done will inevitably fall onto a single team member, and as the project progresses, that same team member will end up getting swamped with work. This didn’t really happen for this project; while some team members inevitably did slightly more or less work each week, overall, we had a pretty even distribution of the work, and traded off the responsibility of getting everything done by changing the project manager each week. We worked around each of our individual schedules by having team members contribute whenever they could, and were able to schedule meetings that everyone could go to basically every week of the project.

I hope to use the team management strategies that worked well for our team in future group projects, so that those can go as smoothly as this project did. In particular, sitting down with the whole team and making sure that everyone is on the same page regarding the project at the very beginning is something I intend to do again. Laying out the groundwork and expectations early on through our team contract helped us avoid any conflicts and ensured that we all knew the expectations for the project going in.

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AUTHOR BIOGRAPHIES

Matthew Coughlin was born in Sharon, Massachusetts in 2003, where he has lived his entire life. He graduated from Sharon High School in Sharon, Massachusetts Summa Cum Laude in 2021, and he is currently pursuing a B.S in mechanical engineering at Northeastern University in Boston, Massachusetts.

He currently works part-time as a technical director for the Sharon High School Theatre Company and does occasional freelance audio-visual work. His primary research interest is in neurovascular network-on-a-chip technology and characterizing microfluidic pumps.

Mr. Coughlin is an active member of several Northeastern clubs, including HEAT, SGA, and AeroNU. Between clubs and a few entrepreneurial endeavors, he enjoys hiking in the summer and skiing in the winter.

Anthony J. Zappala was born in Norfolk, Massachusetts, in 2002. He graduated from King Philip High School in 2021. He is currently studying for a B.S. in Chemical Engineering at Northeastern University.

He is currently a research assistant in the Koppes lab at Northeastern University and is pursuing a PEAK fellowship in 2022.

Mr. Zappala is a member of the Northeastern Chemical Engineering Car club and American Institute of Chemical Engineers.

Nick Laux was born in Hackensack, New Jersey in 2002 and had moved to Rockaway, New Jersey ever since. He graduated from Morris Hills High School's Magnet Program for Math and Science in 2021.
He is currently a freshman at Northeastern University studying Chemical Engineering. Some of his prior research includes studies on the Economics of Healthcare Systems around the World, The Environmental Impacts of Factory Farming, and The Analysis of Blue Light Blocking Mechanisms on Teen Sleep Quality.

Mr. Laux is an active member of Northeastern University's Chapter of The American Institute of Chemical Engineers as well as its Italian Club

Julia Rasmussen was born in Cambridge, Massachusetts, in 2003. She went to Cambridge Rindge and Latin her first two years of high school, and then moved to Worcester her junior year. She graduated from the Massachusetts Academy of Math and Science in 2021, where she took classes at the Worcester Polytechnic Institute her senior year.
She is currently a freshman at Northeastern University pursuing a B.S.E.E. in electrical engineering and music with a concentration in music technology. Her past research includes modelling of exomoons using Python.

Ms. Rasmussen an active member of Northeastern's student run musical theater company, NU Stage, Art Blanche, and Northeastern's aerospace club, AeroNU.

APPENDICES

APPENDIX A – TEAM CONTRACT

DL-1 TEAM FANTASTIC FIVES (Team 5) CONTRACT

TEAM INFORMATION AND CONTACT INFORMATION
Team name: Fantastic Fives!

Anthony Zappala: 508-530-8842; zappala.a@northeastern.edu
Julia Rasmussen: 508-860-3758; rasmussen.j@northeastern.edu
Matt Coughlin: 781-817-9712; coughlin.ma@northeastern.edu
Nick Laux: 862-309-4078; laux.n@northeastern.edu

Communication
Our main form of communication will be through text messages in a group chat that we have already made. More detail about expectations and policies surrounding this group chat are provided below. We will also meet up in person once a week on Wednesdays.

TEAM ENVIRONMENT

Respect
In our team, respect covers many areas of team behavior. First and foremost, we will respect each other's identities and opinions. When every member of the group feels comfortable meeting and sharing ideas, our group can work more effectively and maintain a positive and supportive environment. Furthermore, we agree to respect each other's ideas and thoughts. Even if we may not agree completely with an idea, the group will have a discussion and work out a solution in a friendly and positive manner. Respect will also cover areas of each other's time and outside commitments. We as a team understand that each member has their own time commitments outside of Cornerstone, and we will understand when personal issues take precedence as long as communication is maintained.

Based on our team responses to *12 Angry Men*, we all want to be group members who are confident in our decisions and want to think logically about problems and their solutions. We want to avoid being like the jurors who did not show respect to others based on personal prejudice or stubbornness. We all want to be like jurors 8 and 11 and act as responsible and respectful members of the group, and we made sure our plans for respect reflected this,

Fairness
We will listen to everyone and make sure that we always take everyone's opinion into account. Additionally, over the course of the project, we will try to make sure that

everyone is responsible for an equal portion of the project and does not feel left behind or like they are doing the project on their own. The Project Manager is mainly responsible for these equal portions of the project. They will be the ones who are dividing the work. Especially around scheduling meetings, fairness will be taken into account. We will work around everyone's schedule to make sure that the meeting times work for the group.

Based on our team responses to *12 Angry Men,* we all want to be group members who are fair to each other throughout the project. In the movie, the jurors often interrupted each other and were not fair in their considerations of each other. Regardless of our backgrounds, we want to harbor an environment where every member is treated fairly.

Commitment

Our team will prioritize maintaining commitments. We will communicate with each other frequently. Choosing goals, deadlines, and meeting times will be a collaborative effort, and all members of the team will agree that the expectations we set for each other are reasonable and attainable. This ensures that all team members are making a fair and reasonable commitment to the group.

We acknowledge and expect that each of us will be unable to meet certain commitments throughout the year. The main reasons will be changes in circumstances between when the team agreed to a commitment and a deadline. Our team will operate under the assumption that no one breaks a commitment intentionally. Anyone unable to maintain a commitment will share that they need an extension with the rest of the group as soon as practical. The group will be as accommodating as possible. If occasional inability to maintain commitments becomes a chronic issue for one or more members of the group, the other group members will work with the person to make accommodations and ensure that the member still completes their fair share of the work.

Based on our team responses to *12 Angry Men*, we all admired Juror #8 and his commitment to finding out the truth behind the case, even when he was the only one who believed the boy could be not guilty. In a similar way, our team would like to not jump to any preemptive conclusions and be committed to searching for the best possible solution to a given problem.

Transparency

Transparency is of utmost importance within our group. The project manager is responsible for delegating responsibilities equally and letting people know of their exact responsibilities. It is of each group member to communicate to the group should any changes or discrepancies arise with the responsibilities listed of them. Even if a member cannot complete all of their required tasks, it is better to bring it up to the group for the responsibilities to be covered. It is known that there are many situations that could arise and affect a particular group member, and that is okay. It is important, though, that these situations are communicated to the group to signal that a member needs help.

Our group chose to emphasize the importance of clear and up-front communication because a lack of transparency negatively impacted the jury in *12 Angry Men*. Juror #3, the last juror to change his vote to acquittal, was not transparent about his motives for fighting so strongly for a guilty verdict. He was motivated by his experience with his son instead of the facts of the case. This was critical information that would have allowed the other jurors to more clearly discuss the case from the beginning. We are prioritizing communication so our group works efficiently from the start of our projects and does not repeat the mistakes of *12 Angry Men*.

Inclusion
As a team, we will strive to include everyone's unique perspectives and work through any conflicts we may have in a respectful and understanding manner. If any conflict does arise, the project manager will be responsible for resolving them. The principle of everyone's opinion being included in the conversation from our commitment to fairness also applies here. In addition, we will be open to everyone's ideas and respect the fact that each group member can bring in unique and innovative thoughts.

In *12 Angry Men*, several of the jurors were talked over and left with little speaking time or influence on the verdict. In our responses, we all talked about how we wanted to avoid acting like juror #3 since his actions of being loud and yelling over people often left many jury members out of the discussion. We will not follow in these footsteps and ensure that every team member is included in the discussion and project.

POLICIES FOR PROCEDURE VIOLATIONS

Our group will strive to be understanding; however, if problems arise or deadlines are not met, there will be consequences.

Meeting Attendance
Group members are expected to arrive on time and stay for the full duration of all meetings. If a group member can communicate any last-minute emergency or valid reason to miss meeting time or show late, that is fine, unless it becomes a recurring problem. If a team member is late to a meeting consistently (more than 5 minutes late, more than twice), or skips a meeting without adequate reason, the team will communicate with the member in question. The members will be required to explain what happened and develop a detailed plan to ensure they are on time for future meetings. If a team member had a sudden scheduling conflict and was not able to communicate, the group might slightly change the meeting time to accommodate. If the lateness or no-show is on purpose and/or does not have valid reasoning, we will discuss it as a team and take further action as needed.

If a team member is late once (5 minutes, by accident) they can bring drinks or snacks to the next meeting and there will not be any further action.

Not Communicating
Each member of the team is expected to engage in team communications (over text or in-person). If a team member does not respond to a text message directed at them for over 4 hours, a secondary reminder text will be sent to remind the member to respond to the chat. If the team member does not respond after an additional 2 hours, then the team member will have to bring a snack for everyone to the next meeting. Additionally, the group will talk with this member about the importance of communication and how this issue can be resolved so it does not repeat itself. If this issue of not communicating persists, the team will communicate with the member and reserves the right to call them in lieu of texting for any matters. Continued and repeated failure to communicate with other members of the team, if it becomes a chronic and serious issue severely impeding the operation of the group, may result in the dismissal of a member once all other corrective actions have failed.

If a team member makes clear there are certain times that they will be busy, they will be exempt, within reason, from the above rules. The group expects all members of the team to share all times they are busy at least a day in advance unless doing so is not possible.

Mutual Respect
Team members are expected to treat each other fairly, respectfully, kindly, and professionally at all times. Any member who feels that they have been treated poorly should immediately address the issue with the group. These situations will be dealt with on a case-by-case basis. Any issues of serious disrespect, including first-time issues, may result in the temporary suspension of a member or the member's removal from the group.

Overtaking the Project or Not Completing Enough Work
If the team feels like the project is being taken over by a single team member, we will communicate with them and try to make sure that the work is redistributed throughout the team over the course of the next team meeting. Conversely, if the team feels like a team member is not doing enough work, we will also communicate with them and then redistribute the workload. Everyone on the team should maintain a rough log of the amount of time they spend working on the project, and be prepared to share this log if there are any issues with work distribution. A difference of more than 3 hours per week between members, excluding the project manager who is expected to do slightly more work, is considered an issue.

In both situations, the group will reassess the situation one week after the initial complaint was made. At this meeting, all members will share if they feel the situation has been resolved. If anyone feels the workload remains unfair, the project manager and the rest of the group will rebalance the workload again.

If a member continues to overtake the project or does not do enough work a subsequent time, they may be given mandatory time off or required to complete additional work. In situations that are serious and recurring, the group may pursue more extreme action, culminating in the removal of the member from the group.

Poor or Substandard Work
All group members are expected to uphold the group's expectation for high-quality work. If a member submits poor or substandard work, the group will work to identify why the work did not meet standards.

1. Scenario one: the member misunderstood directions but made a good-faith attempt to complete the work
   In this situation, the group will strive to learn how the directions were confusing and take action to ensure directions are clearer in the future. The member will also be encouraged to communicate frequently and ask questions in the event of disagreement.

2. Scenario two: the member shows little effort but submits work on time
   Submitting work on time does not guarantee it is a satisfactory contribution to the project. In this situation, the project manager will clarify the expectations and provide more clear guidance for what constitutes high-quality work. The member may also be asked to redo any substandard work on top of their other responsibilities.

3. Scenario three: the member does not try at all, and instead blows off the work or clearly puts no effort into a part of the project
   In this scenario, the group will have a discussion as to what happened and clarify with the member that they are part of a group and must meet the group's expectations. The member may be asked to attend a one-on-one meeting with the project manager or submit detailed plans for other work in the immediate future. Displaying a lack of regard for the project is very serious. The group may take further action, including removing a member from the group, if the quality of work and lack of effort becomes a serious and recurring issue.

In each scenario, communication is the best solution. We will talk to the team members to identify what occurred and how we can help them perform better for the next deadline. However, these issues may persist. If a team member accrues more than four scenarios 1, two situations 2, or one scenario 3 issue, the team, and project manager reserve the right to make additional changes. These include requiring the team member to complete additional work or submit work for more frequent check-ins. Overall, if these issues persist and the team member does not show signs of improvement, the team will discuss potentially taking further action. In the event of severe and chronic issues, the team reserves the right to take actions including dismissal of the team member.

We plan to have meetings every Wednesday. Each team member is responsible for bringing up any issues that they may have with the project at the beginning of each meeting, so that these can be resolved in a timely and efficient manner, and not impede on the project.

Signed,

APPENDIX B - DECISION ANALYSIS

Table 1. A summary of our most important goals using the rank order technique.

Goals	Cost-effective	Auto-resets	Informative	Engaging	Inclusive	3D/laser cut part	Build Efficiency	Autonomy	Visual	No Water	Arduino	Total
Cost Effective		1/2	0	0	1/2	0	1/2	0	0	0	0	1.5
Auto-resets	1/2		0	0	1	0	1	1/2	0	0	0	3
Informative	1	1		1/2	1	1	1	1	1	1	1	9.5
Engaging	1	1	1/2		1	1/2	1	1	1	1	1	9
Inclusive	1/2	0	0	1/2		0	1	0	1/2	0	0	2.5
3D/laser cut part	1	1	0	1/2	1		1	1	1/2	0	1/2	6.5
Build Efficiency	1/2	0	0	0	0	0		0	1	0	1/2	2
Autonomy	0	1/2	0	0	1	0	1		0	0	1	3.5
Visual	1	1	0	0	1/2	1/2	0	1		0	1/2	4.5
No Water	1	1	0	0	1	1	1	1	1		1	8
Arduino	1	1	0	0	1	1/2	1/2	1	1/2	0		5.5

Table 2: An analysis of our existing solutions using the KDTA technique.

Alternative solutions/goals		Sketch 1		Sketch 2		Sketch 3		Sketch 4		Sketch 5		Sketch 6		Sketch 7		Sketch 8	
Musts	Informative	Go		Go		Go		Go		Go		Go		Go		Go	
	3D printing / laser cutting	Go		Go		Go		No Go		Go		Go		Go		Go	
	Engaging	Go		Go		Go		Go		Go		Go		Go		Go	
	No water	Go		Go		Go		Go		Go		Go		Go		Go	
Wants	Weight (0-10)	Rating Scale 0-10	Score= W*R	Rating	Score	Rating	Score			Rating	Score	Rating	Score	Rating Scale 0-10	Score= W*R	Rating	Score
Auto-resets	6	6	42	3	21	8	56			5	35	9	63	8	48	4	24
Cost-effective	3	9	36	5	20	7	35			7	28	6	24	4	12	4	12
Inclusive	5	4	20	8	40	4	20			8	40	5	25	8	40	6	30
Build Efficiency	4	5	20	6	24	6	24			4	20	3	15	3	12	6	24
Autonomy	7	6	42	6	42	6	42			4	28	6	42	6	42	2	14
Visual	9	6	54	8	72	8	72			6	54	4	36	6	54	5	45
Arduino	10	6	60	5	50	6	60			5	50	7	70	4	40	8	80
Total		**274**		**269**		**309**				**255**		**275**		**248**		**229**	

Table 3: An analysis of potential problems and solutions to those problems using the KT Problem analysis technique.

Potential Problem	Possible Causes	Preventative Action
1. User cannot see buildings	a) Blindness	Place brail on surfaces for user and have audio accompaniment.
	b) Color Blindess	
2. User does not understand how interactive component functions	a) Unaware of project	Make project easy to understand language wise, possibly translations.
	b) Does not understand English	
3) User leaves house inside factory after leaving	a) In a rush	Have exhibit reset after set time or explain to new user how to reset to keep exhibit completely autonomous.
	b) Purposefully leaves exhibit during presentation	

APPENDIX C - FINAL AUTOCAD/SOLIDWORKS DRAWINGS

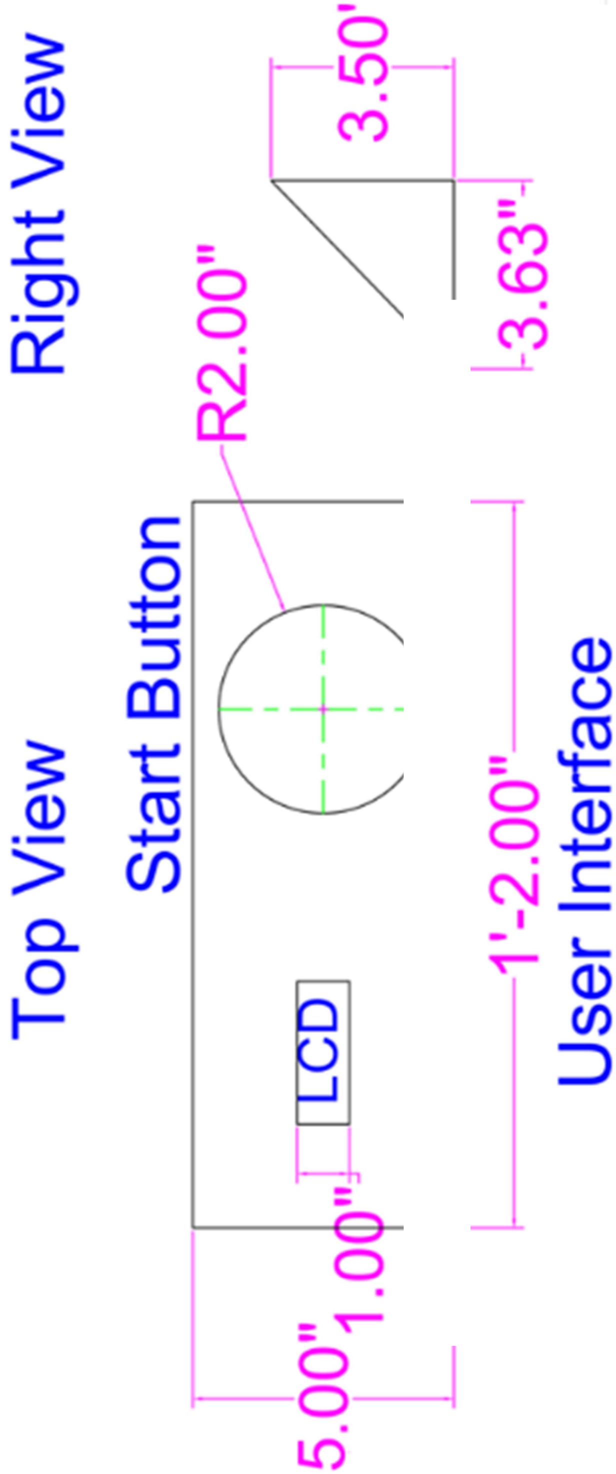


Fig. 33. An AutoCAD drawing of the control panel for the exhibit

Fig. 34. A dimensioned multiview of the interactive learning box

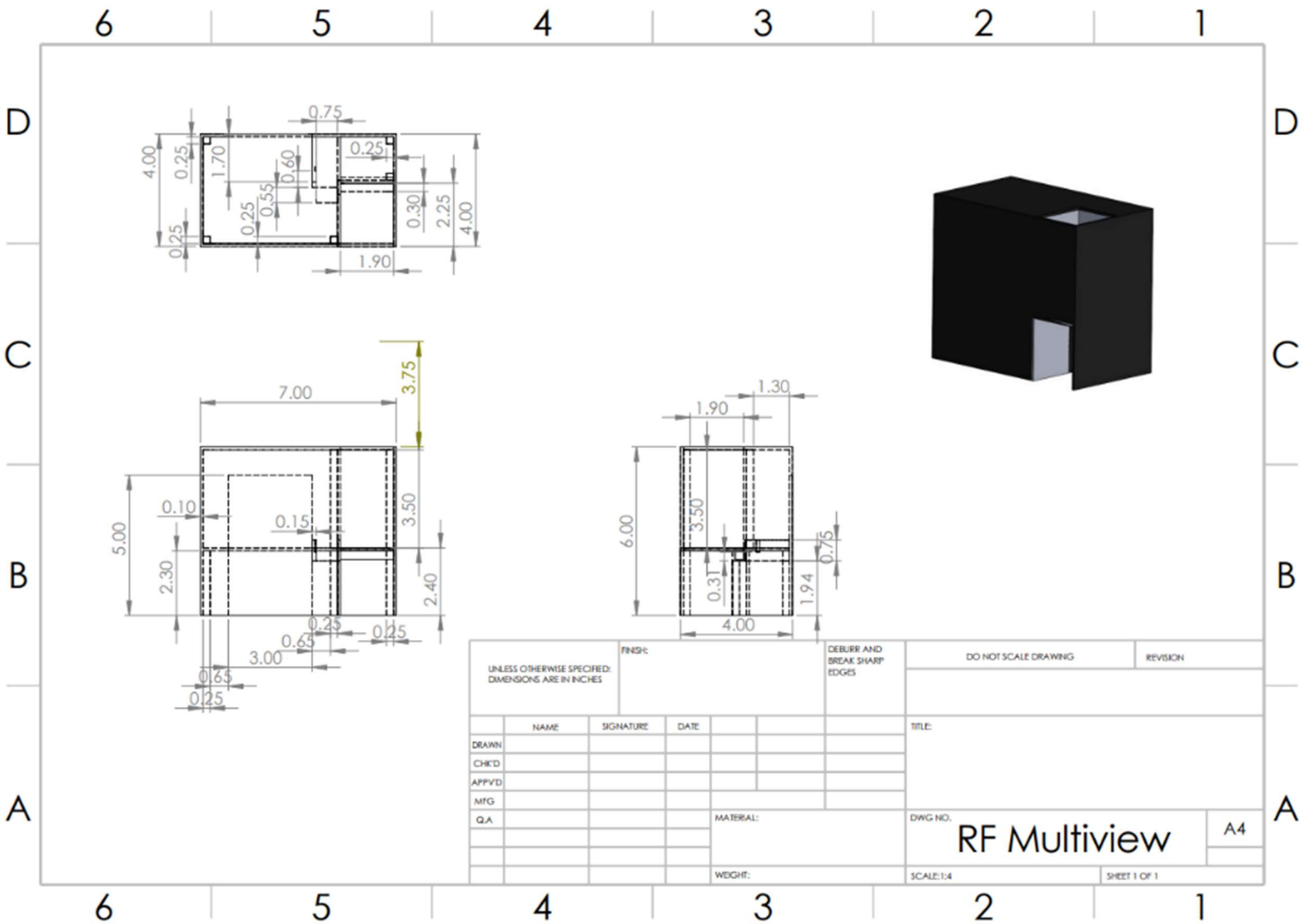


Fig. 35. A dimensioned multiview of a house

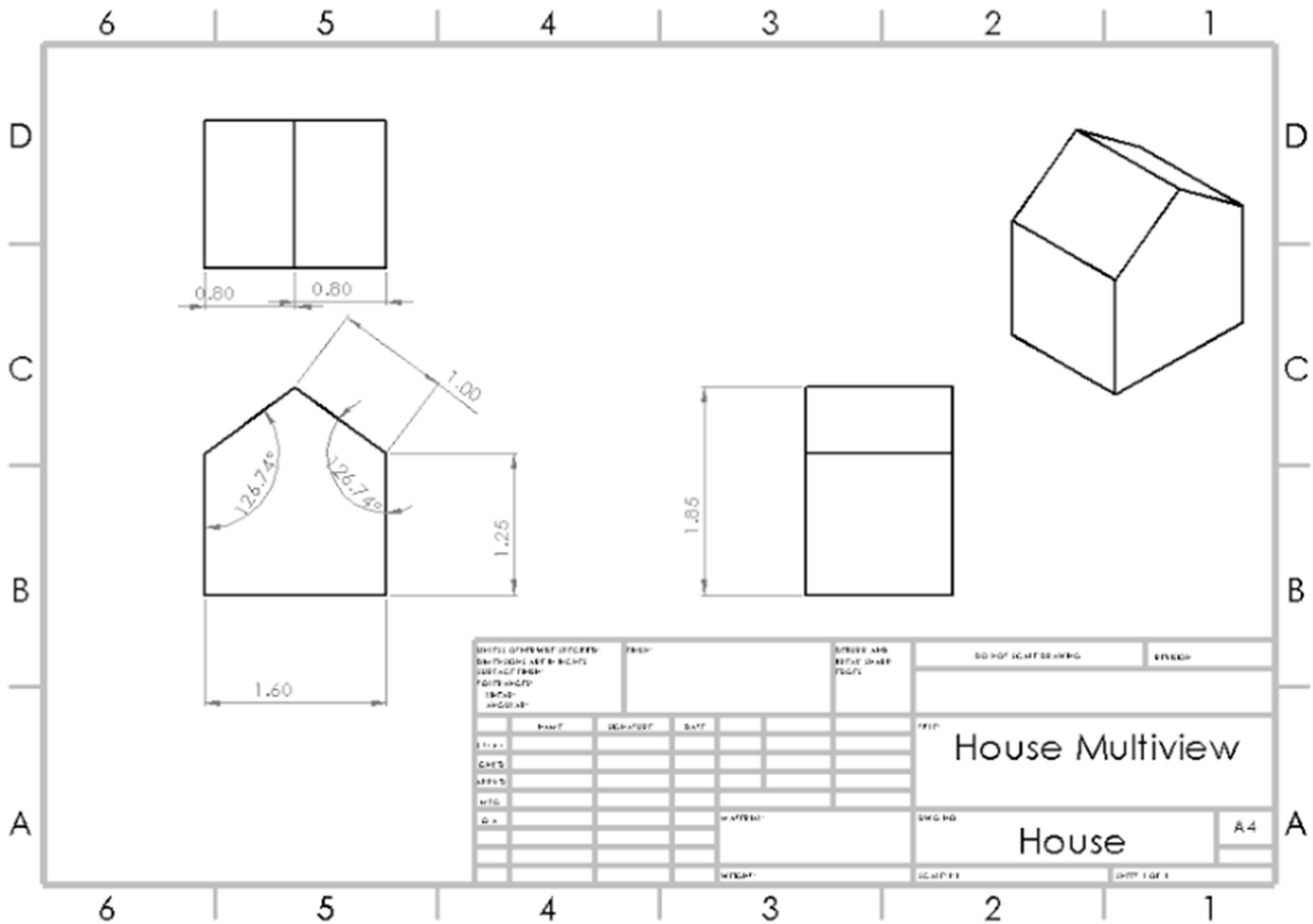
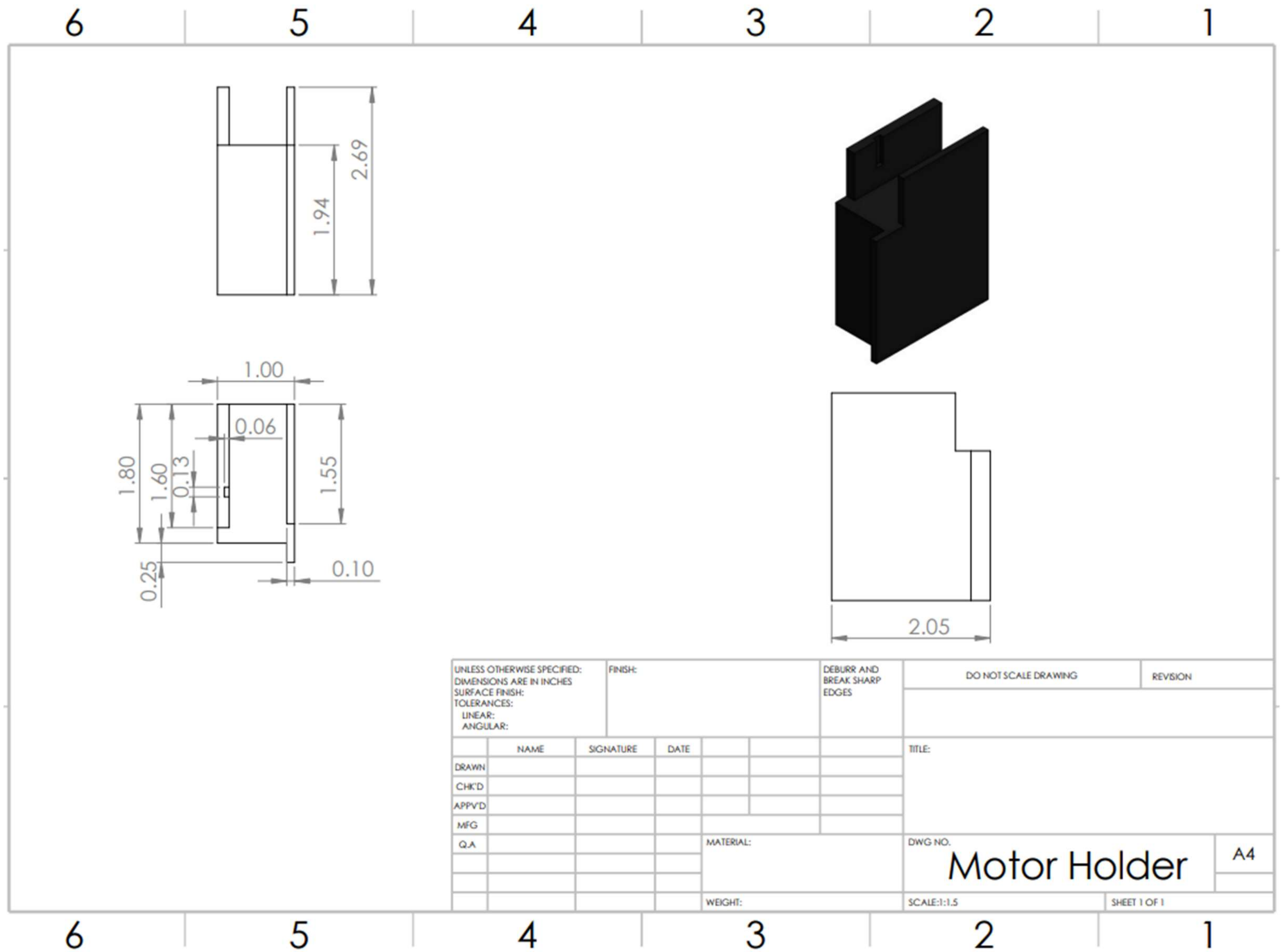


Fig. 40. A dimensioned multiview of the motor holder



APPENDIX D – PRODUCT TESTING RESULTS

Table 1. A description of the methodology to gather and analyze user feedback

Requirements	**Method**	**Data**	**Corresponding Reasoning**	**Analysis**
Informative	Google Form Question to user	1-5 rating	Likert scale useful to quantify qualitative data	Was the average greater than four
Engaging	Google Form Question to user	1-5 rating	Likert scale useful to quantify qualitative data	Was the average greater than four
3D print/Laser cut	Looking at exhibit	Yes or No answer	There either is/ isn't a cut part	N/A
No water	Looking at exhibit	Yes or No	There either is or isn't water	N/A
Autoresets	Testing exhibit	Yes or No answer	The exhibit either can/cannot reset	N/A
Cost Effective	Comparing to budget	Money used, Budget	We are comparing the percentage of the budget used	Is the expenditures under 40% of the total budget
Inclusive	Google Form Question to user	1-5 rating	Likert scale useful to quantify qualitative data	Was the average greater than four
Build Efficiency	Looking back to building days	Materials List, Personal experience, time spent building	Able to make educated conclusion based on data	Qualitative Analysis on materials and time spent
Autonomy	Google Form Question to user	1-5 rating	Likert scale useful to quantify qualitative data	Was the average greater than four
Visual	Google Form Question to user	1-5 rating	Likert scale useful to quantify qualitative data	Was the average greater than four
Arduino	Looking at exhibit	Yes or No answer	There either is/isn't Arduino	N/A

Table 2. Summary of scores from the feedback form, with the average and standard

Summary	Average	Standard Deviation	1	2	3	4	5
Informative	4.53	0.72	0	0	2	4	11
Engaging	4.76	0.56	0	0	1	2	14
Inclusivity	4.94	0.24	0	0	0	1	16
Autonomy	4.76	0.44	0	0	0	4	13
Visuals	4.71	0.59	0	0	1	3	13

APPENDIX E – CODE USED IN PROJECT

Code used to control the Arduino:

```
#include <LiquidCrystal.h>  // the library for the LCD controller

int sensorPin = A0;    // select the input pin for the potentiometer
int ledPin = 3;      // select the pin for the LED
int sensorValue = 0;  // variable to store the value coming from the sensor
int buttonPin = 6; // set button pin value to 6

// motor driver pins
int PWMAPin = 2;
int AIN1Pin = 4;
int AIN2Pin = A1;

// create a new LCD control object
LiquidCrystal lcd(13, 12, 11, 10, 9, 8);

void setup()
{
  // declare the ledPin as an output and buttonPin as an input
  pinMode(buttonPin, INPUT_PULLUP);
  pinMode(ledPin, OUTPUT);

  //set motor driver pins as output
  pinMode(AIN1Pin, OUTPUT);
  pinMode(AIN2Pin, OUTPUT);
  pinMode(PWMAPin, OUTPUT);

  // get serial and lcd set up
  Serial.begin(9600);
  lcd.begin(16, 2);

  // print start screen
  lcd.print("Press button");
  lcd.setCursor(0, 1);
  lcd.print("to start");
}

void loop() {
  // if button is pressed, turn led on
  int buttonState = digitalRead(buttonPin);
  if(buttonState==HIGH)
  {
    digitalWrite(ledPin, HIGH);
    delay(1000);

    // read the value from the sensor:
    sensorValue = analogRead(sensorPin);
    Serial.println(sensorValue);  // print the value to serial for debugging
    // set the LCD cursor back to the start position and clear the screen
    lcd.home();
```

```
lcd.clear();
// print score: on the first line
lcd.print("Score: ");
// move the cursor to the second line
lcd.setCursor(0, 1);
// convert the photoresistor reading into a score
byte mappedReading = constrain(map(sensorValue, 375, 800, 1, 10), 1, 10);
// each score range corresponds to a different level of reflectivity
// these adjectives help interpret the scores for the users.
// higher numbers are better.
String adjective;
if (mappedReading <= 2) {
  adjective = "(terrible)";
} else if (mappedReading <= 4) {
  adjective = "(bad)";
} else if (mappedReading <= 6) {
  adjective = "(okay)";
} else if (mappedReading <= 8) {
  adjective = "(good)";
} else if (mappedReading <= 10) {
  adjective = "(excellent)";
}
// print out the score with the adjective
lcd.print(String(mappedReading) + " " + adjective);
// leave the score on the screen
delay(4000);
// turn off the led
digitalWrite(ledPin, LOW);

// turns the motor
// running the motor and powering the LCD at the same time take too much power
// clear the LCD so it does not flicker when the motor turns
lcd.clear();

// drive forward by pulling DIR_A High
// and DIR_B low, while writing a full 255 to PWM to
// control speed
digitalWrite(AIN1Pin, HIGH);
digitalWrite(AIN2Pin, LOW);
analogWrite(PWMAPin, 150);

// let the motor coast backwards by waiting
delay(350);

// Brake the motor by pulling both direction pins to
// the same state (in this case LOW). PWM doesn't matter
// in a brake situation, but set as 0.
digitalWrite(AIN1Pin, LOW);
digitalWrite(AIN2Pin, LOW);
analogWrite(PWMAPin, 0);

// wait while the house drops out
delay(750);
```

```
    // change direction to reverse by flipping the states
    // of the direction pins from their forward state
    digitalWrite(AIN1Pin, LOW);
    digitalWrite(AIN2Pin, HIGH);
    analogWrite(PWMAPin, 150);

    // wait for the motor to go up
    delay(400);

    // brake the motor now that the floor has returned to being upright
    digitalWrite(AIN1Pin, LOW);
    digitalWrite(AIN2Pin, LOW);
    analogWrite(PWMAPin, 0);

    // print start screen again
    lcd.home();
    lcd.clear();  // clear the LCD
    // print the text
    lcd.print("Press button");
    lcd.setCursor(0, 1);
    lcd.print("to start");
  }
}
```

APPENDIX F – WIRE DIAGRAMS FOR SPARKFUN BOARD

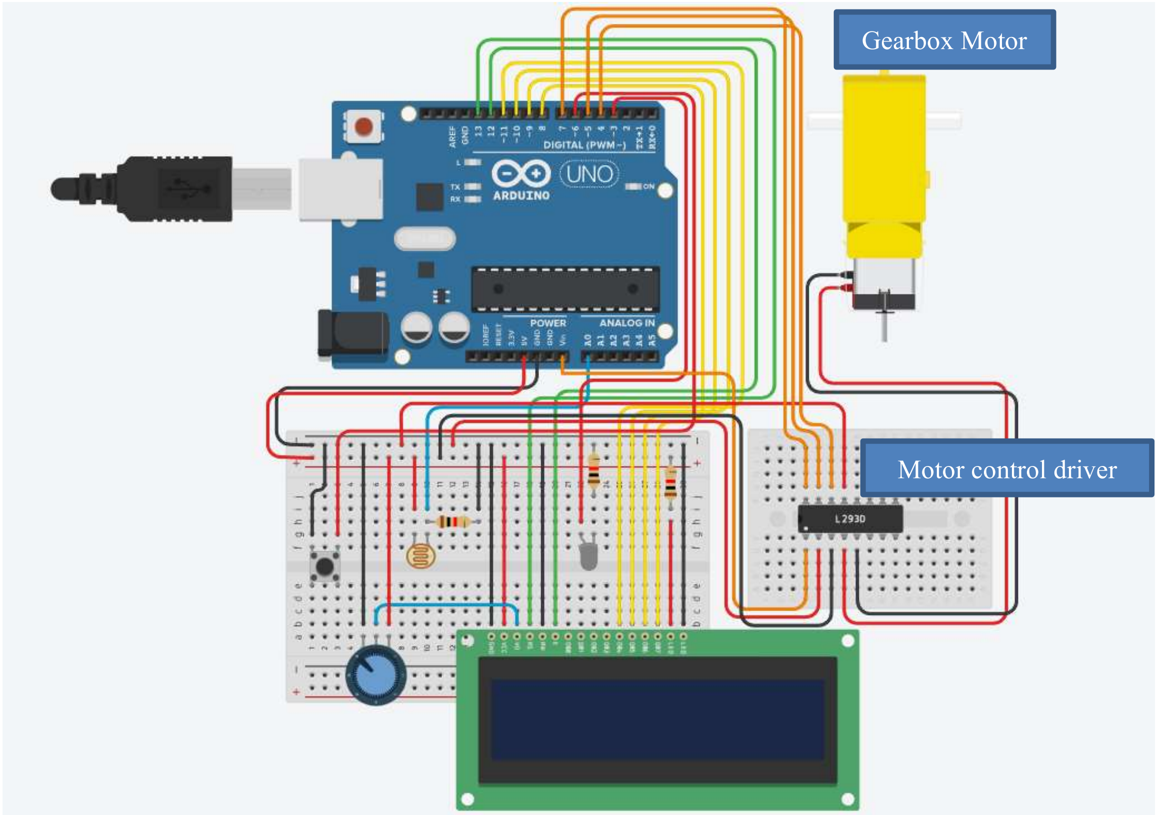


Fig. 41. A wiring diagram showing the electronics used in the exhibit

APPENDIX G – PHOTO LOG

Fig. 42. A first prototype of the museum exhibit

Fig. 43. An image of prototype houses

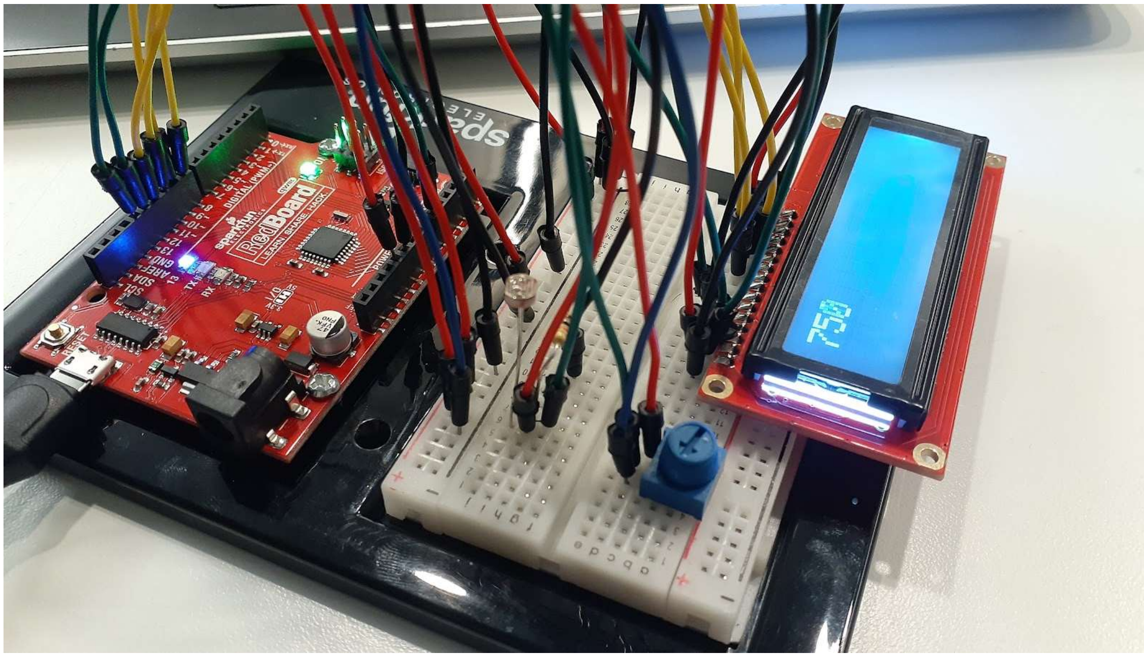


Fig. 44. The electronics before the motor controller was added

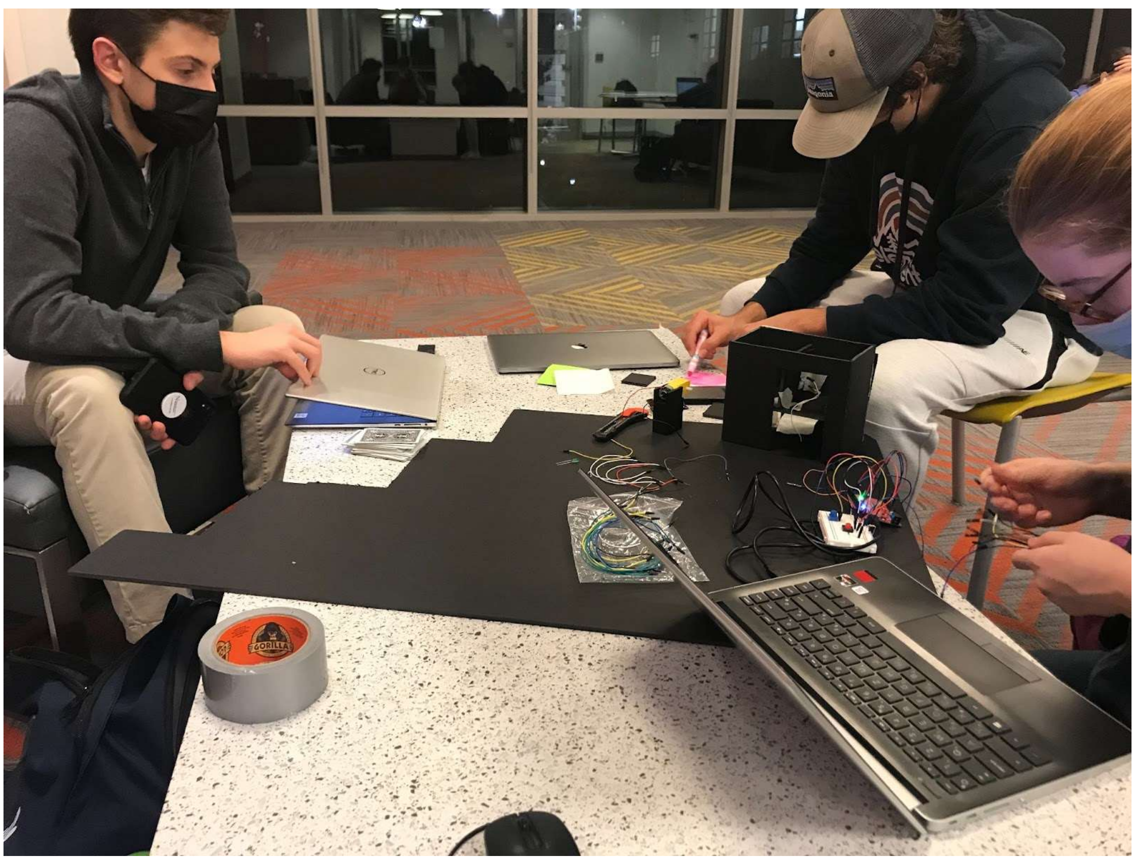


Fig. 45. Members of our group constructing the project

Fig. 46. Construction of the final museum exhibit in FYELIC

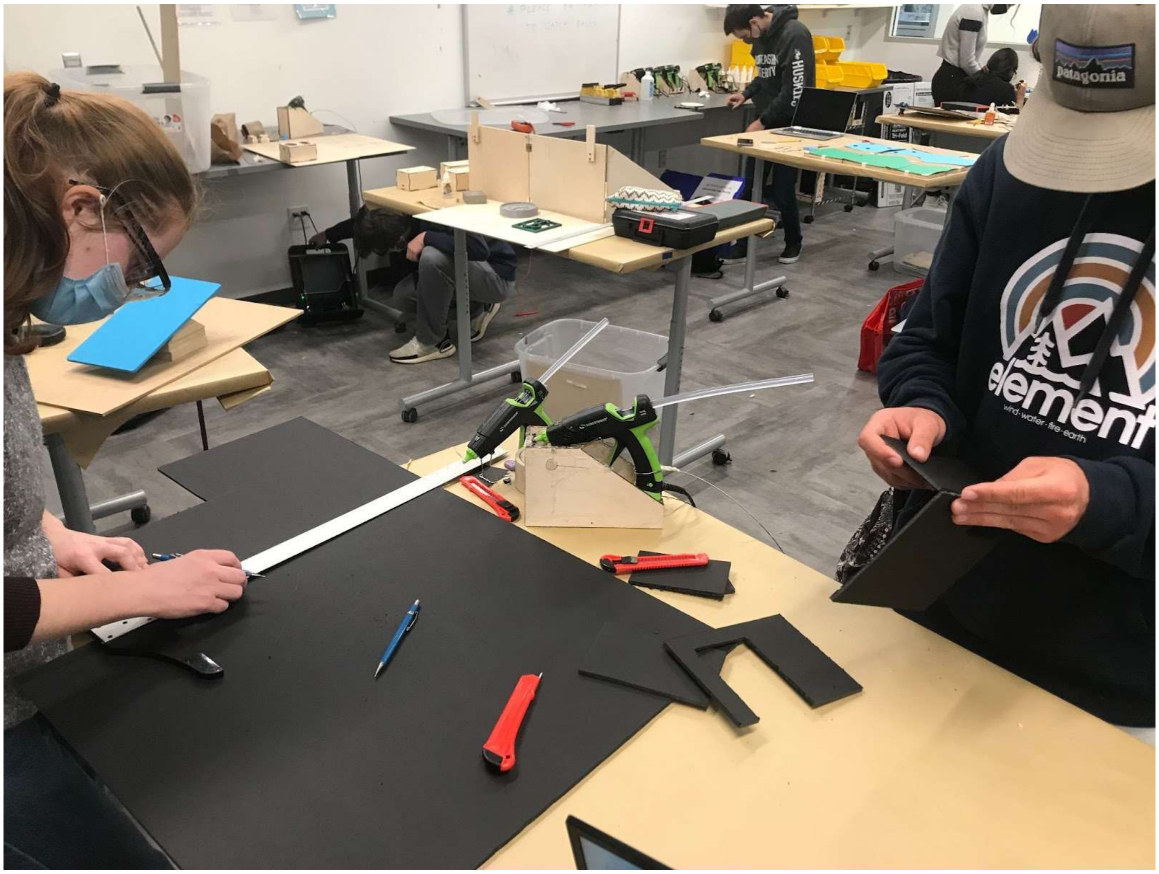


Fig. 47. Construction of the interactive learning box in FYELIC

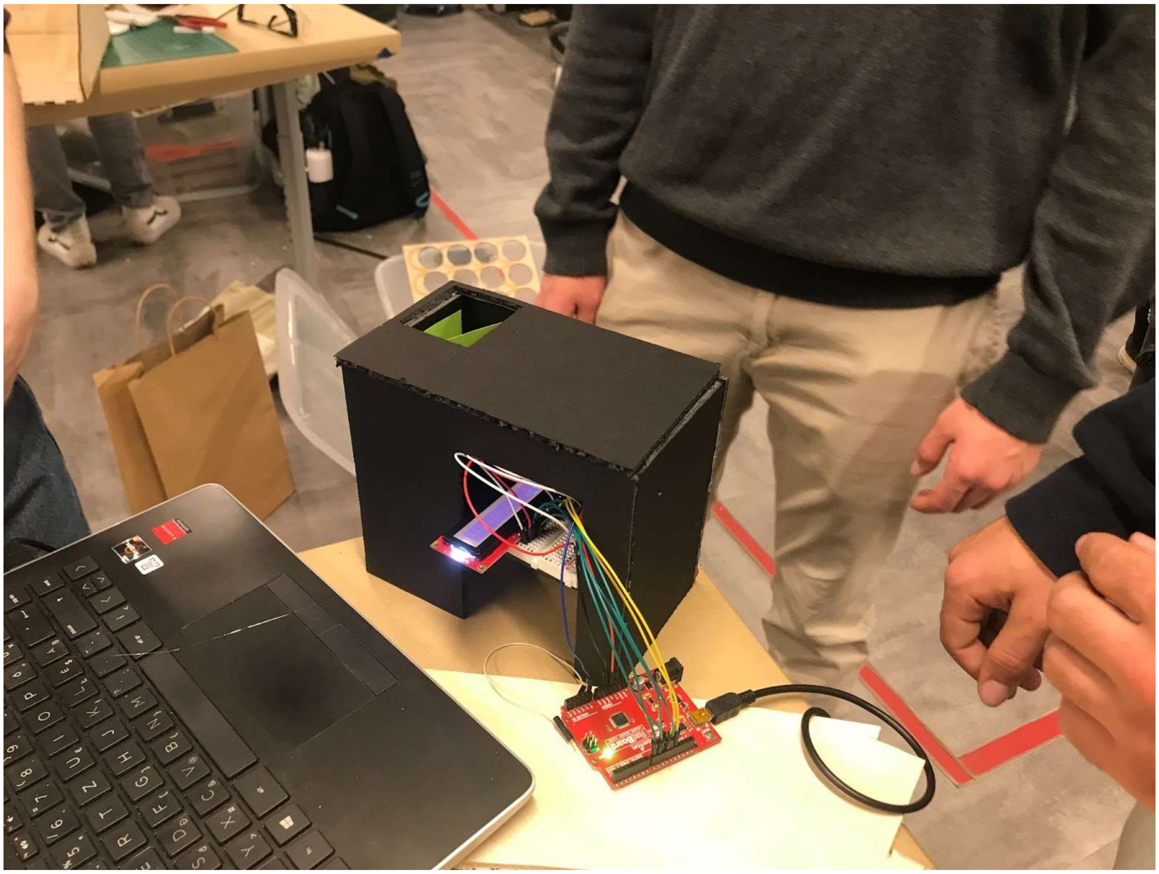


Fig. 48. A proof-of-concept test of the light reflection

Fig. 49. A proof-of-concept test of the automatically resetting portion of the exhibit

Fig. 50. The final control panel being assembled

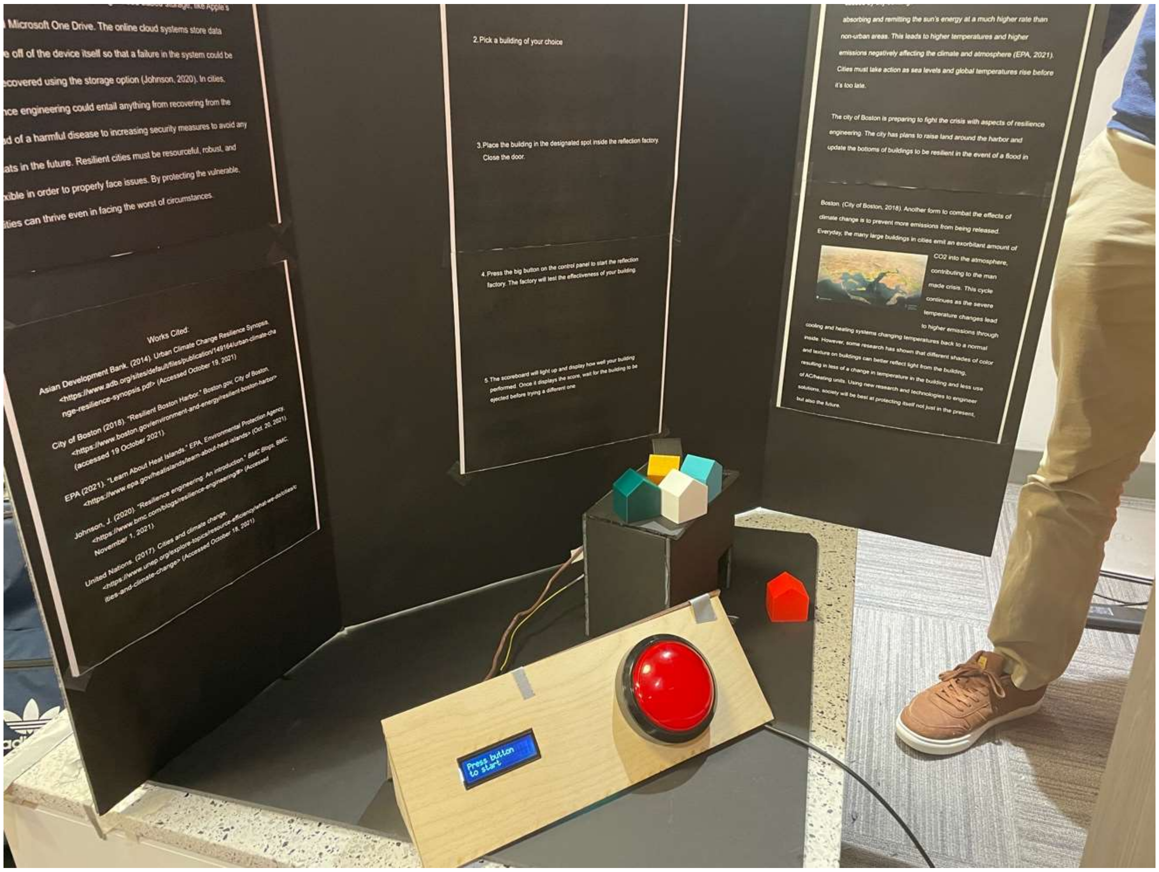


Fig. 51. The final museum exhibit

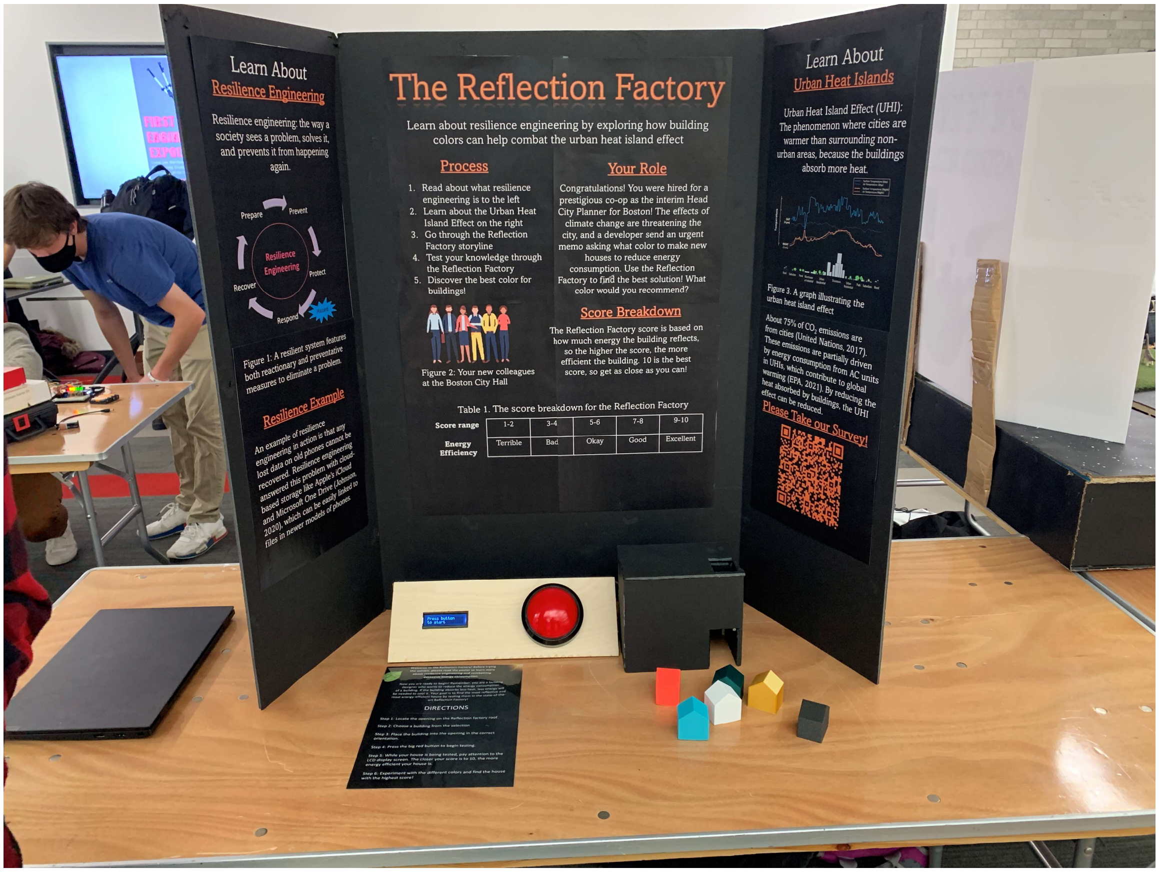


Fig. 52. The final museum exhibit at the first-year expo

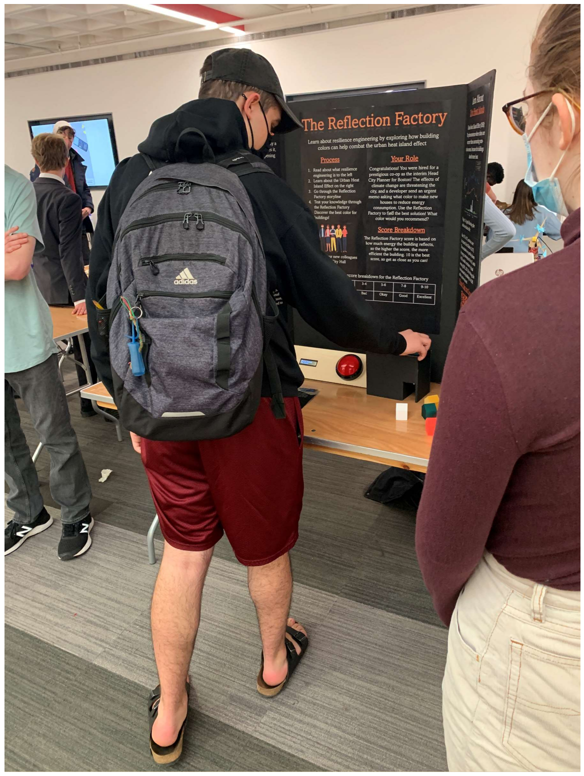
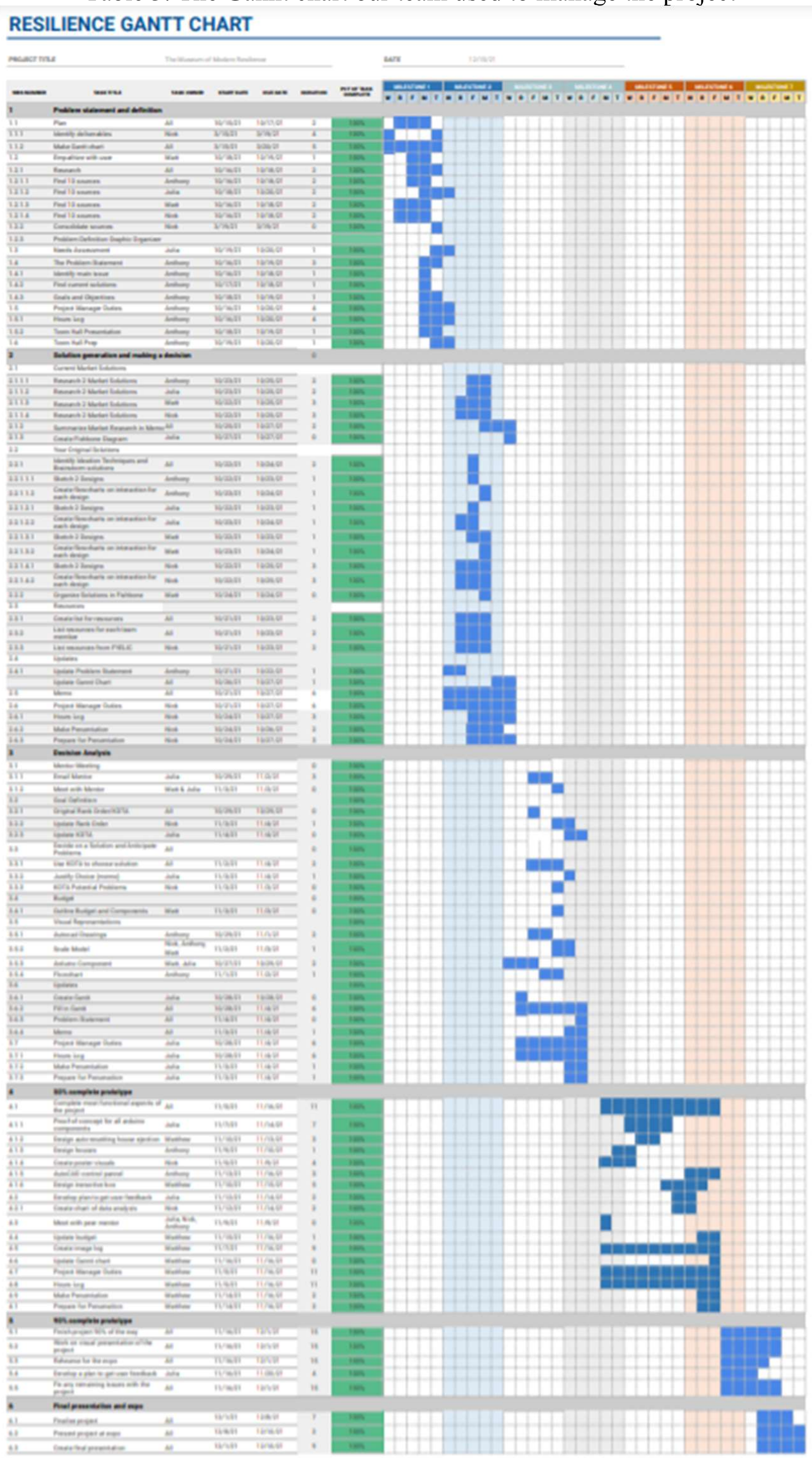


Fig. 53. Users interacting with the exhibit at the first-year expo

APPENDIX H – FINAL GANNT CHART

Table 3. The Gannt chart our team used to manage the project



APPENDIX I – FINAL BUDGET

Table 4. The final budget for the project

Item	Unit Value	Units	Qty	Value	Cost	Source
Lenovo 14W	$350.00	ea	1	$350.00	$0.00	Owned
Wires	$0.10	ea	20	$2.00	$0.00	FYELIC
LCD	$18.95	ea	1	$18.95	$0.00	FYELIC
Breadboard	$4.95	ea	2	$9.90	$0.00	FYELIC
RedBoard	$19.95	ea	1	$19.95	$0.00	FYELIC
Resistors	$0.06	ea	3	$0.18	$0.00	FYELIC
RedBoard cable	$3.95	ea	1	$3.95	$0.00	FYELIC
Photoresistor	$1.50	ea	1	$1.50	$0.00	FYELIC
White LED	$0.14	ea	1	$0.14	$0.00	FYELIC
Foam Board	$7.60	ea	1	$7.60	$7.60	Blick Art Store
Poster Board	$10.39	ea	1	$10.39	$0.00	Owned
Printed Paper	$1.00	ea	6	$6.00	$6.00	Library Printer
Laminated paper	$1.00	ea	1	$1.00	$0.00	FYELIC
3D printed house	$6.75	ea	6	$40.50	$0.00	FYELIC
3D printed mount	$6.75	ea	1	$6.75	$0.00	FYELIC
Wood sheet	$4.23	ea	1	$4.23	$4.23	Campus Store
Hot Glue Gun	$13.99	ea	1	$13.99	$0.00	FYELIC
Large Button	$11.99	ea	1	$11.99	$0.00	Owned
Gearbox Motor	$4.95	ea	1	$4.95	$0.00	FYELIC
			Totals	$514.97	$17.83	

APPENDIX J – PROJECT HOURS LOG

Table 5. The detailed hours log for the project

	Matt Coughlin	Anthony Zappala	Nick Laux	Julia Rasmussen
Milestone 1				
Background research	3	3	3	3.5
Problem statement	2	1	1	0
Needs Assessment	0	0	1	1
Project Management	0	3	0	0
MS1 Totals	5	7	5	4.5
Milestone 2				

Exhibit research	4	4	4	4
Exhibit designs	3	2.5	3	2.5
Research FYELIC	1	0	0	0
Create fishbones	0	1	1	0
Update problem statement	0	0	0	1
Project Management	0	0	5	0
MS2 Totals	8	7.5	13	7.5
Milestone 3				
KTDA and decision analysis	2	2	2	2
AutoCAD drawings	0	4	0	1
Model	6	2	6	3
Mentor Meeting	1	1	1	1
Project manager responsibilities	0	0	0	5
MS3 Totals	9	9	9	12
Milestone 4				
AutoCAD Drawings	0	6	0	0
Solidworks creations	5	3	2	2
Construction	3	5	7	7
Poster board	1	0	4	1
Proof-of-concept	5	2	1	4
Electronics	0	0	0	7
Interactive learning box	5	2	1	3
Project manager responsibilities	5	0	0	0
MS4 Totals	24	27	24	24
Milestone 5				
Exhibit construction	8	8	9	8
Exhibit testing	2	4	2	2
Feedback collection	4	2	2	3
First-year expo	3	3	3	3
MS4 Totals	17	17	16	16

Milestone 6				
Create final presentation	5	5	5	5
Rehearse final presentation	2	2	2	2
Write final report	12	14	12	12
Edit final report	3	4	4	4
MS6 Total	22	25	23	23
Total Hours	89	92.5	90	87