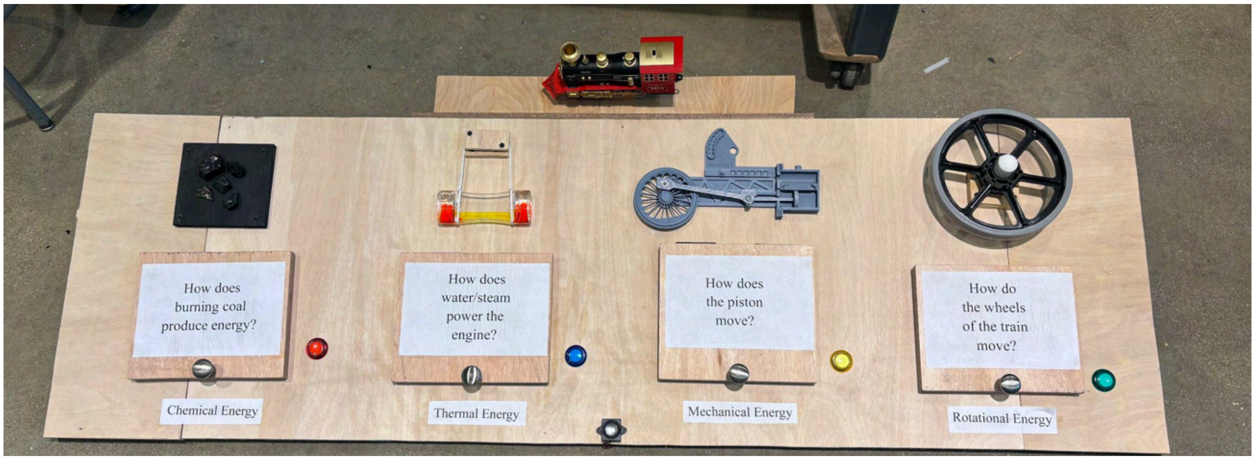
Final Design Report:
STEAM - See-Touch-Engage-Activate-Move



Prepared for:
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June 13, 2025

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Table of Contents

List of Figures

Executive Summary

Project Problem

In collaboration with the Wilmette Historical Museum, we identified a need for an engaging, accessible exhibit to teach visitors about steam engine mechanics. Existing displays often fail to captivate multi-generational audiences, relying on static models or text-heavy panels that overlook hands-on learning opportunities.

Project Requirements

Our goal was to create an interactive exhibit that:

- Makes STEM concepts intuitive through tactile and auditory experiences
- Accommodates visitors of all ages and abilities
- Requires minimal maintenance by museum staff
- Stays within a $150 budget

Research and Development

We interviewed museum director Rachel Ramirez and Keith Boyd about what they were both envisioning for the museum exhibit: hands-on STEM education with accessible wording. We researched user interactions with exhibits and tested 8 prototype concepts. Testing revealed that users were heavily drawn to the touch board stating that it was enjoyable to play with the objects while learning new concepts.

Design Summary

Our final design, STEAM, is a stand-alone exhibit that combines:

- The original model steam engine as the center-piece of the exhibit, displayed under a plexiglass case for its protection
- A model train engine to contextualize the steam engine's usage
- A hands-on touchboard where users can manipulate textured coal, a piston mechanism, a water chamber, and a grooved flywheel to explore mechanics
- An interactive flip board that teaches visitors about the process of a steam engine with question and answer boards on hinges
- Audio enhancements with button-triggered audio to enhance accessibility by reading out the text and adding depth by including engine sounds
- A modular frame of a wooden base that can be easily assembled by museum staff or an external company that has access to blueprints

This design improves upon traditional exhibits by making invisible physics tangible. Future upgrades could integrate lights as well as an additional AR application viewable on user's phones.

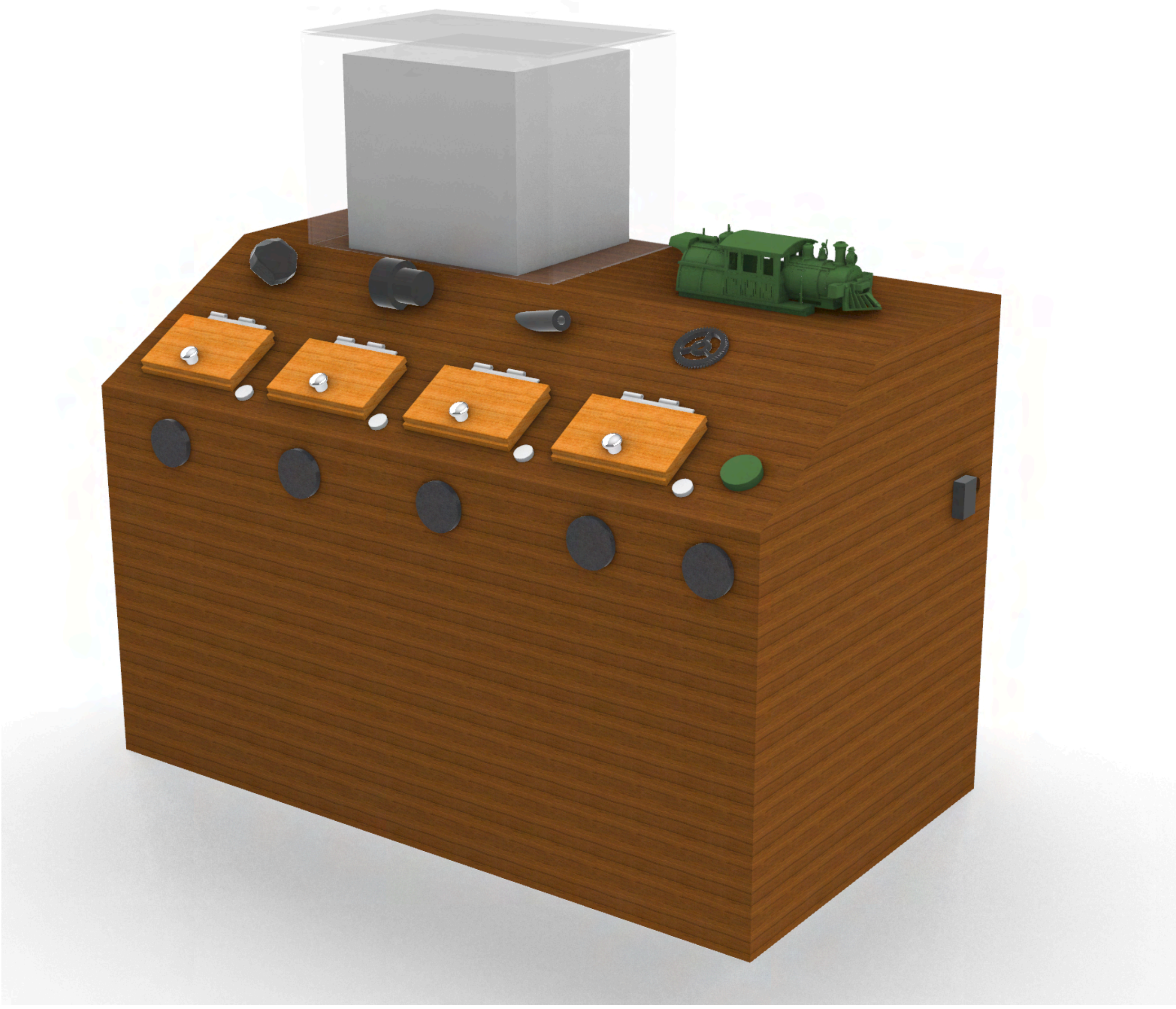

Figure 1. Final design created with CAD and rendered with accurate textures and sizes.

I. Introduction

Successful museum exhibits have three main aspects that signify an exhibit that will hold the attention of visitors of all ages. Museum exhibits should have interactive elements, be clear and understandable to people of all ages, and contain a storyline that guides the visitor through the exhibit. Our project partners Rachel Ramirez and Keith Boyd have indicated the need for a museum exhibit for a 20th century steam engine at the Wilmette historical museum. They envisioned an exhibit that would capture the attention of a diverse group of users, be accessible to smaller children and disabled users, and also keep the original steam engine at the center of the exhibit design. Though the steam engine is not currently functioning, our project partners still desired that it would take a main role in our exhibit design and be directly connected to a storyline that we created through the exhibit.

To fulfill these goals, our team has built the See-Touch-Engage-Activate-Move (STEAM) exhibit. The touchboard component consists of pieces that directly represent parts of the original steam engine that can be pressed tactically by users of all ages to create a more immersive, tactile, and engaging experience. The flip board portion of the exhibit contains the majority of the educational and storyline oriented portion of the exhibit. The flip board will consist of 4 panels that each discuss the functions of the respective touchboard elements above them. The exhibit also contains a sound system. When the visitor presses the button beside each flip board, they'll hear both a narration of the educational content and corresponding steam engine sound effects that bring the concepts to life. This improves accessibility and engages younger audiences. Finally, our design has a model steam engine train with a moving piston and wheels, sound, and steam.

This report includes an overview of the STEAM project, including the problem, the design process, and our final solution. This report is organized into the following sections:

- Users and Requirements: Explains the major users of the project, relevant details of each group, and their interactions with the project.
- Design Concept and Rationale: Overview of the design and an explanation of each component which includes the testing and research necessary for each component.
- Future Development: A description of further prototype development, alternative designs, and project maintenance.
- Conclusion: A summary of the project and its fulfilled requirements

II. Users and Requirements

Main Users of the Design

Visitors of Museum

- Students of varying ages from elementary to high school
- Parents and families
- Seniors

Staff at Wilmette Historical Museum

- Volunteers
- Full time employees

Project Partners

- Rachel Ramirez
- Keith Boyd

Major Requirements

Easily Maintained by Staff: Maintenance time per month should be less than an hour per month. Maintenance would include replacing batteries ensuring security of objects.

Sustainable & Maintainable Design : Expected lifespan before major repairs should be more than 5 years. Replacements should all be commercially available. However, some parts may be 3D printed and not as readily available.

Engaging to the public: We expect the average interaction time per visitor to be more than 3 minutes as they read the exhibit label, touch objects, flip boards, and listen to audio.

Accessible to visitors of all ages and ability level: Museum exhibits should be ADA compliant especially in terms of height with a maximum accessible height of 40”. The speakers will provide readings of the flipboards to increase accessibility.

Must fit within exhibit confines: As measured from observation, maximum dimensions of the space is 10’4” wide with 9’ of height. The exhibit should fit in these confines.

III. Design Concept and Rationale

The STEAM exhibit (Fig. 2) is composed of a base assembly, combined flipboard/touchboard interface, static train model display, display of the model steam engine, and arduino-powered audio system. The purpose of this system is to effectively show how a basic steam engine works and the energy transformation that allows a steam engine to power a train through an interactive and multisensory exhibit. Further details of each component are provided in the following sections.

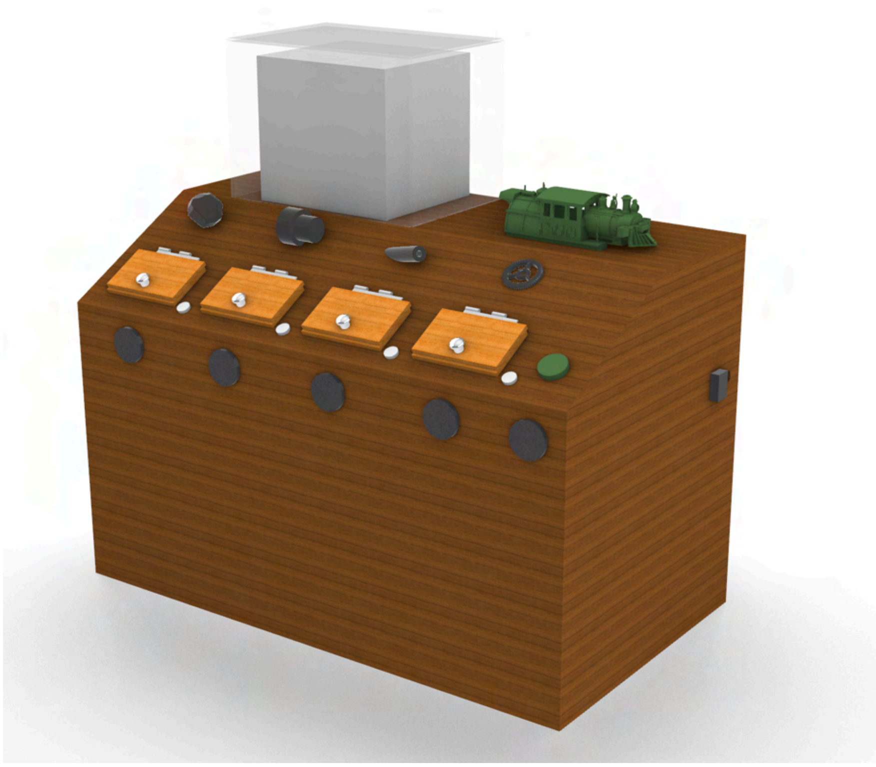

Fig. 2. Computerized model of STEAM exhibit

Base Assembly

Description

The base (Fig. 3) serves as the structural platform for the exhibit, supporting all interactive and display elements. The entire exhibit is 64” wide. The lowest height in the front is 33” while the platform height is 42.62”. The depth of the entire exhibit is 35.72”, broken down into 17.72” by the forward facing panel and 18” by the platform. The entire base will be constructed of wood with a finish that matches the other exhibits in the museum.

Fig. 3. Base of exhibit with dimensioned top (middle) and side (right) views.

Overall Design Rationale

The base prioritizes accessibility by using specific heights that allow the average elementary school-aged children to comfortably interact with the touch board and flipboard components. It also complies with ADA guidelines for visitors in wheelchairs. However, it is not too low for taller adults to still interact with the exhibit and utilizes the space above the base for more information that cannot explicitly be interacted with. It also focuses on museum continuity and doesn’t stick out too much where it blocks or interferes with other exhibits and allows the museum to stay with a color/text/material scheme.

Flipboard interface

Description

The flipboard interface (Fig. 4) consists of four pairs of hinged wooden panels. Each flipboard panel measures 10” wide by 6” long and is constructed from wood. Each flipboard features a question on top relating to both a part of the steam engine and a state of energy (part of the transformation of energy). Underneath reveals a few sentences that answer the above question. The panels are connected by a singular hinge that allows them to lay flat when closed and fully open when a user wants to read underneath. The top panel contains a knob so that the user can easily flip up the panel.

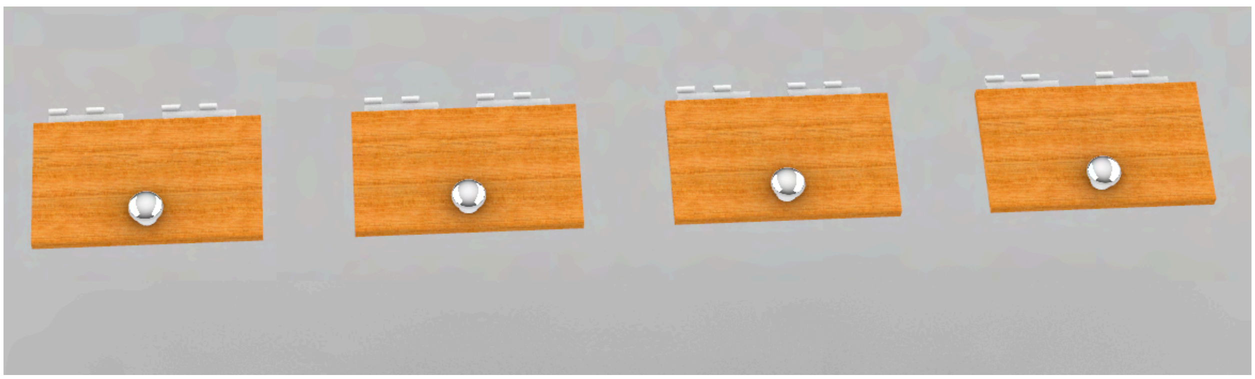

Fig. 4. Flipboard interface.

Overall Design Rationale

Using a flipboard as the primary method of education allows users to consider what they may already know about the steam engine and sparks curiosity before revealing the actual answers. Additionally, giving information through an interactive medium increases a user’s engagement with the material, which is important when targeting such a wide age range. It also subsequently increases the likelihood they may learn and remember something new. The information itself is designed to be understood by children with approximately a 3rd grade education, but doesn’t fully compromise more complex topics such as thermal to mechanical energy transfer and conservation of angular momentum. The wood and hinge design ensures durability where users can open and close the flip boards repeatedly with little wear or need for replacement, while the knobs increase ease of use and intuitively indicate that the boards are meant to be touched and flipped open, if that wasn’t already clear.

Touchboard Interface

Description

The touch board (Fig. 5) is mounted directly above the flipboard and contains four individual components representing a different part of the steam engine. The four components are coal, a water chamber, a piston, and a wheel. Each component is of a different material (plastic or metal) and texture and is securely attached to the base so that each piece can be touched without coming free. Each piece varies in size but they are each roughly 5-7” wide and 4-5” tall.

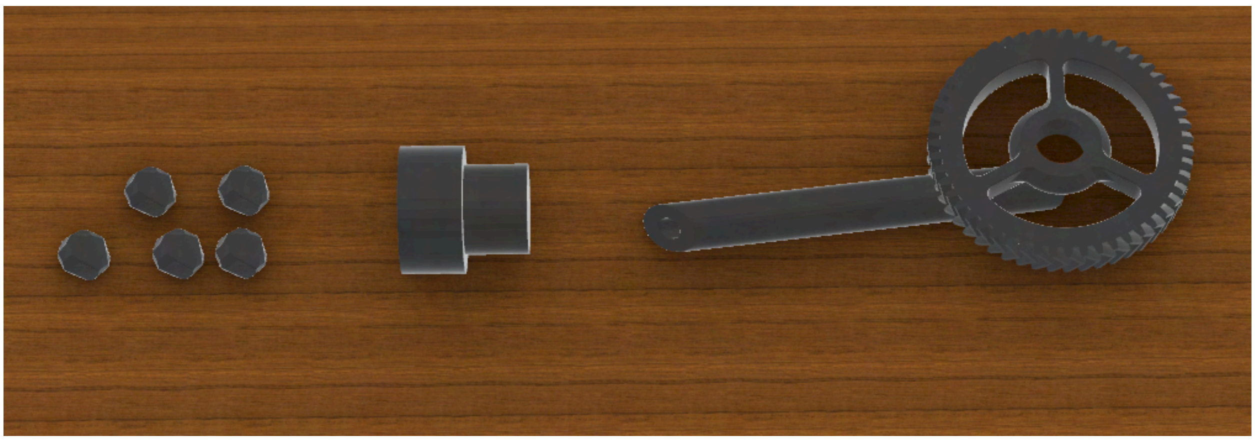

Fig. 5. Touchboard interface

Overall Design Rationale

The touch board is designed as an interactive element to make the exhibit more fun and engaging and also to activate users’ tactile senses. The placement directly above the flip boards links the tactile experience with informational content, reinforcing learning of new content/ideas. Specific pieces were chosen with safety and durability in mind because of the high use they are intended to have.

Static train model and model steam engine display

Description

Sitting on the platform of the base is the original model steam engine and a static train model (Fig. 6). The original model sits on the left and is fully encased by plexiglass for protection. Adjacent to the steam engine is the train model. This train emits steam and plays sound when turned on. Users are able to turn on the model train by pressing a button on the right hand side of the flipboard interface.

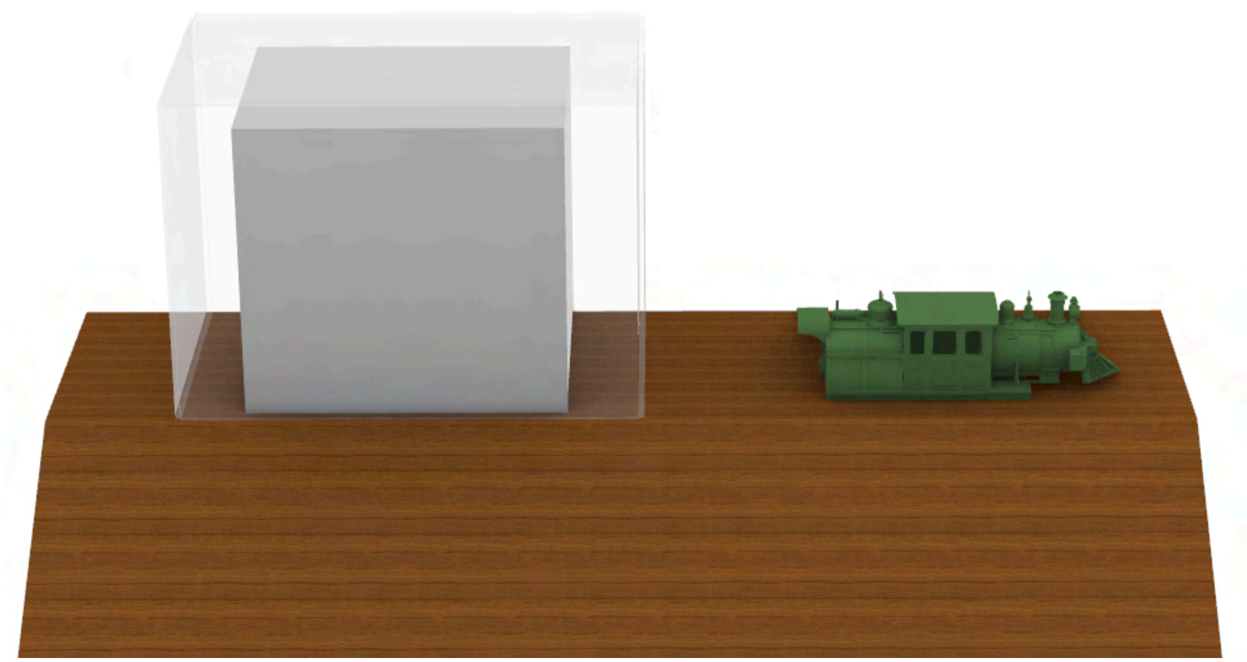

Fig. 6. Steam engine model (cube used as placeholder with correct spatial dimensions) and static train model

Overall Design Rationale
This section anchors the exhibit visually and conceptually. It naturally integrates the actual model steam engine into the exhibit, which itself is focused on using more interactive components. It is placed on the left of the exhibit because it is the part of the exhibit that stands out the most and naturally attracts museum visitors to the exhibit. The model train is an exciting way to consider how the parts of the steam engine can work together to power a locomotive, one of the themes of the exhibit and central to how the transfer of energy is described. The sound and steam that it emits is an engaging component of the exhibit, especially for younger visitors.

Arduino-powered audio system

Description
An Arduino microcontroller is programmed to play audio summaries of the text on the flip boards as well as related soundbites via connected push-buttons. Each flipboard has its own button, and there is one additional button and speaker at the end which activates the static train that sits above on the platform and train audio plays on the speaker below. The system is mounted within the base, with speakers wired to the front of the exhibit, with a 9V battery mounted on the side of the exhibit to power the buttons. A portable charger powers the Arduino MKR Zero used for this exhibit.

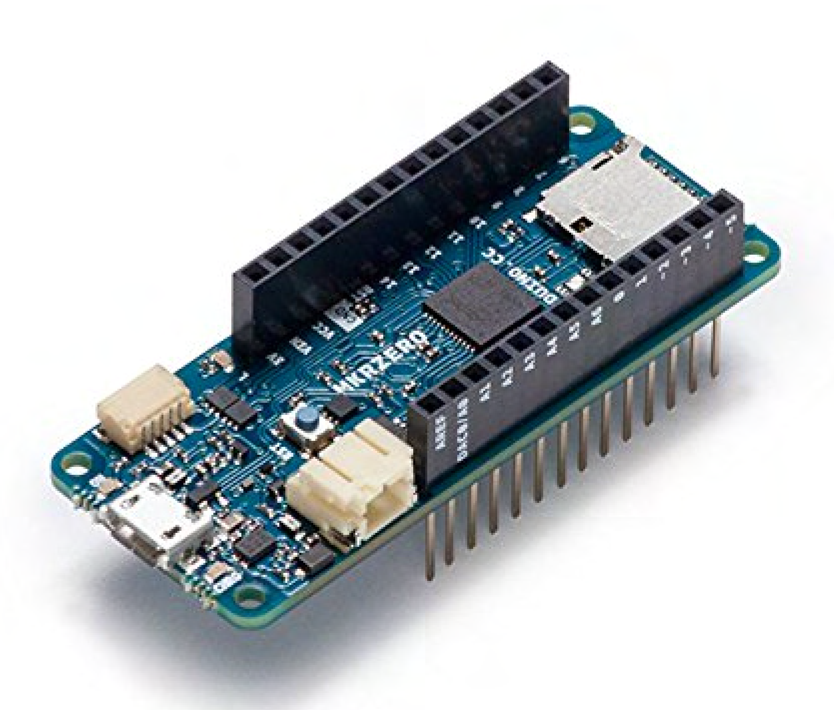

Fig. 7. Arduino MKR Zero used in this exhibit.

Overall Design Rationale

The Arduino powered audio system provides a cost-effective, customizable solution for interactive audio. The audio is another way that the exhibit utilizes multisensory learning. Additionally, it provides an accessible alternative for users who have visual impairments or young visitors who may struggle to read the material. The use of a portable charger efficiently powers the system and its placement on the side of the exhibit is out of the way of users but easy for museum staff to replace when necessary.

IV. Limitations and Next Steps

While each element of our design underwent user testing to ensure it met the design requirements, time and budget limitations prevented any extensive performance testing. Durability was considered when selecting materials, but the long-term performance and amount of maintenance is a bit unknown. Given more time, resources, and testing, various expansions of the STEAM exhibit can be taken to make a more engaging and functional exhibit.

Developing more interactive components

While the current design is centered on interactivity, budget and time constraints limited the number of components used. One component that could be added to the design is lighting. Lighting can be used to draw attention to the exhibit. It could also be used to highlight specific parts of the actual model. For example, if we attached LED lighting to the actual model, a user could push a button selecting a component. The light in that component would turn on and highlight where it is on the actual model. This would also be a clever way to incorporate the model as an active part of the exhibit and not just on display, while creating a way for users to learn more about the specifics of the model and not just the general steam engine. The concern for lighting would be damaging the model steam engine, which in its current state is very fragile. It also requires more power than currently used so a new electrical system would be necessary.

Another electronic component could be connecting the sound system to the flipboards. Instead of having a button next to the panels, sound could be activated by simply flipping up the panel. This would make the exhibit more cohesive connecting the tactile elements with the audio elements. It also may be more intuitive as a button (unless labeled) may be confusing for some visitors. However, this would be technically challenging and potentially become a high-maintenance component of the design.

Finally, multimedia elements could be added. One example would be to add an AR application that users can open on their phone. It would bring up a model steam engine that users could interact with and look at both individual components and how the system works together. While a unique feature, it could have some accessibility concerns for people not familiar with the technology or those without smartphones. An alternative form of multimedia are screens that could be added to play motion graphics or a video to better illustrate the concepts we attempt to teach. This may be more engaging for users than straight audio or reading the content.

Improving Accessibility

STEAM utilizes accessible height standards and has audio alternatives for those with vision impairment or reading disabilities. However, given that the museum has visitors of all ages including young children, it may be too tall. In a future iteration, a fold down step stool could be added so that people of all heights and ages can interact with the exhibit.

V. Conclusion

To summarize, our design meets the demands of our users: the visitors of the Wilmette historical museum. The exhibit provides an interactive and immersive experience for the users while also providing an important educational experience that is enhanced through a storyline that maintains relevance and depth.

Looking ahead, we have clear next steps to further refine our design. In the short term, we planned to conduct mechanical tests on our touchboard elements to assess durability and wear over time as we want to ensure a robust user experience. For long-term development, we aim to integrate more complex lighting and sound systems to further user engagement with the exhibit. Additionally, continuously improving accessibility remains a top priority, and we will actively work on improving our design to meet the highest standards.

Appendix A:
Secondary Research Summary

The Wilmette Historical Museum: Overview and Exhibits

The Wilmette Historical Museum is located in Wilmette, Illinois, a Chicago suburb with a current population of about 27,000. Situated next to the Wilmette Police Department, the museum frequently collaborates with them on community events. General admission is free, with operations sustained by donations managed by the Wilmette Historical Society. It is open from 1 to 4:30 PM daily, except for Fridays and Saturdays. These limited hours reflect the museum's small size and the brief time visitors typically spend in each exhibit.

Currently, the museum has six permanent exhibits, with a new temporary exhibit scheduled to open this May. In addition to indoor exhibits, the museum also offers walking tours of its grounds and the nearby historical cemetery. The staff includes three main members: Rachel Ramirez, the director, David Pratt, the curator, and Diane Grauer, the Sunday coordinator. Volunteers handle the remaining work

Established in 1951 by the Village of Wilmette, the museum is jointly operated by both the Village and the Wilmette Historical Society, a non-profit organization that has strong community ties and support. A 2004 restoration and renovation project expanded exhibit space as well as behind-the-scenes areas for meetings, administrative offices, storage rooms, and research facilities. This renovation also ensures plenty of space for future exhibits.

The current exhibits include

- Lost Wilmette: Focuses on historic buildings in Wilmette, highlighting ones that have been demolished and those currently being preserved.
- From Settlement to Suburb: Provides information and artifacts from original Wilmette settlers.
- Native Americans on the North Shore: Features information and artifacts related to Native communities in Wilmette.
- Wilmette Stories: Shares stories of individuals important to Wilmette's history in various fields and areas.
- Local Legends: Provides information about celebrities who have lived in Wilmette
- Historic Gross Point Jail: An old, refurbished sheriff's office turned into an interactive jail cell exhibit designed to engage children and attract families to the museum.

Understanding Steam Engines

A steam engine operates by converting the thermal energy from steam into mechanical energy. At its core, a steam engine consists of a boiler, cylinder, piston, piston rod, and flywheel. Water is heated within the boiler, usually by burning coal, wood, oil, or natural gas, creating steam. Once hot enough, the pressure increases which pushes steam down a channel into the cylinder. This increases the pressure even more, pushing against the piston. The motion of the piston caused by the steam is a transfer of energy from thermal to mechanical. The piston is connected to a flywheel using a rod that converts the side to side motion into rotational motion. A flywheel is designed to continue smooth and steady rotation despite the fluctuations in instantaneous velocity as the piston moves back and forth. It does this by storing some of the energy as potential energy and then releasing it again when the piston slows. As the wheel spins, the valve allowing steam into the cylinder changes position so that the force against the piston changes direction, allowing it to move back and forth. After the steam expands and loses energy, it is either released or condensed back into water and returned to the boiler to be heated again. Early steam engines often released used steam directly into the atmosphere, but more advanced engines recycle the steam to improve efficiency.

In steam engine locomotives, the concept doesn't change. The primary difference is the larger size of the heat box (boiler), also known as the superheater. This component generates significant heat, directly heating the water into steam and also heating the internal pipes themselves. This process increases steam pressure and total energy an engine can provide.

Steam Engine Models in Museums

Typically, museums do not display models of steam engines because they can often acquire actual, no-longer-in-use steam engines through donations. The common idea of a model steam engine usually refers to a hand-sized model train that is electrically powered and doesn't actually produce steam. It's important to distinguish between two main types of steam engines:

- Locomotive engines: Used in trains, these are characterized by their vertical cylinders, which provide power while being contained within a smaller, more compact area.
- Stationary steam engines: Used for driving mills, factories, and power generation, these are distinguished by horizontal cylinders.

Existing museum displays of full-scale steam engines, such as the Tower Bridge engine and the Newcomen engine (both stationary types), are generally non-interactive. They are typically presented for viewing from a distance, accompanied by a sign describing their history. While some museums might allow visitors to tour the passenger cars of a locomotive, access to the engine itself is usually not allowed. For example, the National Railway Museum York has a display where parts of a locomotive steam engine are cut away to reveal its internal workings. While "cutaway" exhibits such as this offer insights into mechanics and are more engaging than static displays, they are still not fully interactive. This suggests a need for an exhibit that allows visitors to actively engage with the principles of steam engine operation, addressing the current limitations of passive viewing or partial demonstrations. Designing an interactive exhibit around a model steam engine offers a unique opportunity to demonstrate its workings in a hands-on manner that might not be feasible with a full-sized, historic engine.

Enhancing Museum Interactivity and Accessibility

Museums can incorporate interactivity through various methods to engage visitors' senses. This includes the strategic use of lighting and audio systems, or more complete solutions like Augmented

Reality (AR) and Virtual Reality (VR). Museums can also include motion in typically static exhibits to capture visitors' attention for longer periods of time.

Large blocks of text can often be overwhelming and unengaging, thus museums can break up information. A touch screen kiosk can also be an effective tool, allowing visitors to access further information if they choose. These kiosks can display images for context, as well as Fig.s that illustrate relationships. Users can click on specific parts of the kiosk to gain more detailed information. Additional possible interactive components for future exhibits could include integrating interactivity directly into walls and floors, and utilizing projections with smart glasses.

Another crucial aspect of modern exhibition design is accessibility (Fig. 7). While legal obligations often focus on architectural access (e.g., ADA compliance), a more comprehensive approach involves "accessibility-first" design.

Fig. 7. Image showing an exhibit set to an accessible height

This means integrating inclusive experiences from the initial design phase, possibly including features like haptic/touch smart tours. The audience should be viewed not just as a target, but as an integral part of the museum experience. This approach fosters motivation for learning through:

- Interest
- Relevance
- Expectations
- Sociability (how much people talk about the museum after they leave)

Museums possess institutional credibility, allowing them to innovate in how they present information. Examples of interactive showcases can involve:

- Adjustable lighting
- Dynamic audio systems
- Touchscreen kiosks for effective text display
- AR/VR technologies
- Potential for incorporating interactivity into walls and floors
- Projections with smart glasses

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Appendix B:
Interview Summary

Introduction

The model steam engine was made by Keith Boyd's great grandfather Joseph Trimble Watson Boyd. As described by Keith, Joseph Boyed enjoyed building objects and built the steam engine as a way to pass the time. After passing it down through the family, Keith has now decided to donate it to the Wilmette Historical Museum for more people to enjoy.

Methods

We conducted this 35 minute interview via zoom in a mostly question and answer format. Both Keith Boyd and Rachel Ramirez were present, with Keith providing clarity on the steam engine and the history behind it and Rachel answering questions about goals for the exhibit and the actual museum space. Both DTC teams working on this project asked questions and participated in the interview.

Results

Information given by Keith Boyd and Rachel Ramirez

- Rachel described the audience as typically older residents of Wilmette and the surrounding local areas, but children and families also come to the museum. The level of comprehension should be low enough that kids can understand and engage with the exhibit.
- The steam engine works with a smoke stack that simulates exhaust. Keith emphasized how because of this, it requires maintenance and proper knowledge to handle safely.
- Rachel expressed how the museum includes all of their exhibits have something to do with Wilmette's history. They have many artifacts that people simply look at and read a short paragraph. Most displays there are constructed with a wood base and a plexiglass cover. The steam engine is an opportunity for the museum to have an interactive experience.
- The space available to display the steam engine is very large. It will be placed in an old fire bay that is connected to the Wilmette Historical Museum. There are large doors that one can enter the room from. There are outlets in the floor that power normal machines and can also be used to power the steam engine.
- Staff usually do not assist in explanations of the physical exhibits. They usually introduce the entire museum at the desk and describe where each display is located. If a school group comes in, staff will provide a little more guidance. There are tours provided to groups like the local boy/girl scouts.
- In terms of information to include in the exhibit, Keith indicated that a little history about the actual model-maker would be important, and tie the model into local history. Keith has pictures and descriptions of family history. Some examples are a picture of the house his great grandfather

lived in as well as information about his father's family history. His father's side has continued to stay in the Evanston and Wilmette area as the family expanded.

- Additionally, it should explain the inner workings of a steam engine and the physics/chemistry behind the process of using the steam engine (especially the energy conversion) to produce electricity.
- Rachel mentioned that visitors only need to engage with the exhibit for a couple minutes for it to be successful, but that it should try to spur conversation as they are leaving and create some excitement or buzz.

Discussion

Throughout the interview, it became clear that both Rachel and Keith mainly wanted us to focus on incorporating interactivity. They said that they would focus on synthesizing information and that we should focus on how to display the steam engine. To display the engine, Rachel and Keith recommended plexiglass or other materials that would create a box as we want to focus on preventing visitors from touching the engine. However, because we would want to cover the entire engine, we will need to Fig. out a way to dissipate the steam from the working engine. We will also need easy access for staff to be able to unplug or emergency stop the engine. In further consideration of the staff, we must produce a clear plan for training them for safety of the engine and staff. We should thoroughly understand where things may go wrong and exactly how we can, first, prevent, then if needed, resolve the issue. Preventative measures may include oiling the machine and generally making it easy to access for maintenance. We may also want to include quizzes in the exhibit to keep visitors engaged and additionally to accurately collect feedback on exactly how much visitors learned.

Appendix C:
Observation Summary

Introduction

The Wilmette Historical Museum has preserved the town's heritage for over 70 years through exhibits about local and broader U.S. history. Recently, Keith Boyd, a long time resident of Wilmette, has decided to donate an artifact that has been passed down through generations of his family: a model steam engine. Crafted by his great-grandfather, the steam engine carries generations of family history but requires minor restoration to showcase its original fine craftsmanship. As a small-town institution, the museum depends on donations from visitors and support from the community to fulfill its mission of capturing the heart and soul of Wilmette. Rachel Ramirez is the director of the Wilmette Historical Museum and has worked in this position for more than two years. She has 10+ years of experience in collection curation. For this new exhibit with the steam engine, she is hoping to incorporate more STEM ideas. To gather information for our project, we utilized multiple research methods, including an online interview, an in-person observation, and follow-up communication.

Methods

On March 22, 2025, three team members visited the Wilmette Historical Museum in person to better assess the spatial and logistical requirements for our proposed steam engine exhibit. The visit began with a discussion with Rachel who led a tour of the initially proposed area. During this walkthrough, we identified crucial constraints such as the proximity of delicate artwork and limited floor space. These constraints raised concerns about potential risks to visitor interaction. After collaborative discussion with the other touring team and Rachel, we identified alternative spaces to compare advantages. After Rachel ended the tour, we conducted independent layouts of potential ideas by returning to the firebay. We defined the ideal and potential space using tape measures to assess its suitability for housing both the engine and interactive elements. These findings will help inform the mockups, prototypes, and eventually our final design to ensure that the exhibit meets both conservation and educational goals.

Research

For each exhibit we noticed that items that visitors were not allowed to touch were kept in display cases that could only be viewed. (Fig. 8)

Fig. 9. Picture of an exhibit showcasing historical artifacts.

On the contrary, items that visitors were allowed to touch were still on pedestals, but did not have a display case (Fig. 9). These items were also explicitly displayed with text asking visitors to touch them.

Fig. 10. Exhibit of historical bricks used in paving.

There are 4 floors of the Wilmette Historical Museum. It appears that the firebay is on the ground floor because we had to take stairs down to it. The first floor has hardwood flooring and consists of the collections, with one of the collections being renovated and constructed. The second floor is mainly used as a meeting space to host history, among other lectures, or events and fundraisers, such as concerts. The style of the area is a large open room with copious amounts of natural light. There are no exhibits in this room, but there is artwork along the walls that gets rotated periodically throughout the room. Our project partner has mentioned that it would be possible to build an exhibit, but it would have to be portable so that it could be removed for events. The entrance area holds our project partner's office and research room. The Fire Bay area consists of carpet flooring with outlets every 16-18 inches (Fig. 10) and is located 16' 8" to the left of the staircase, 19' past the stairs and 3' to the firebay doors.

Fig.10. Measurement of how far apart the outlets are in the firebay. Note the carpet flooring.

Rachel plans on moving the Native American history exhibit to a different area. The steam engine exhibit would then be placed in the newly available space. This chosen location presents a significant spatial constraint: a large painting, visible in Fig. 11, will remain high on the wall, extending from the stairwell to the back wall. After thorough in person discussion, Rachel proposed alternative areas such as the corner of the Fire Bay area, near the doors.

Fig. 11. Current exhibit showing Native American history and artifacts.

There are interactive elements in the room such as a TV and a touchscreen (Fig. 12) with a map of Wilmette where visitors can find places and learn the history of events/people at specific locations.

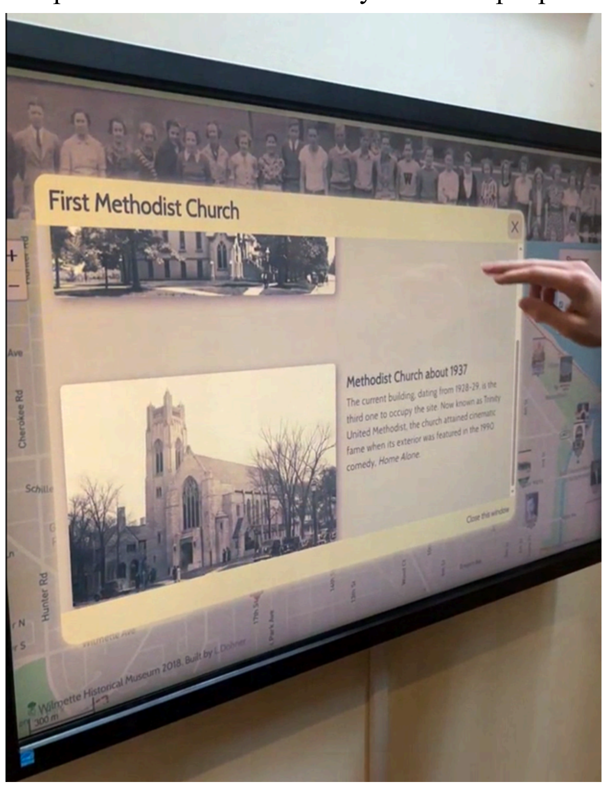

Fig. 13. A current exhibit that is interactive via touchscreen.

The basement has concrete floorings and holds the jail cell, which is a drawing factor for many children and families to the museum.

Discussion

Our assessment helped provide more concrete information on three primary considerations that we had identified from ideation: space constraints, visitor engagement needs, and historical preservation requirements. The firebay location offers high visibility, but presents challenges with delicate artifacts and foot traffic patterns as the stairs are nearby. If we decide on using the firebay, we should shift to the part of the wall that is closer to the back doors and away from the stairs. Alternative spaces provide more room, but less natural visitor flow.

Our main concern with the firebay area is the painting that the engine would be right under. If Keith and Rachel still wanted the engine to actively run, it would blast steam onto the painting. Additionally, the steam, any exhaust particles, or just the heat could activate the ceiling sprinkler system which could be damaging to the other exhibits and the building itself. Not to mention, the museum does not have active filtration systems and instead relies on air purifiers in the corners of the room. Rachel acknowledged these issues, and while it still remains her and Keith's desire to run the actual model, she said that we could design fake steam outputs or run scheduled demonstrations of the model, potentially outside or at least with the fire doors open.

Appendix D:
Model Steam Engine Observations

Introduction

On May 1, 2025, Team 2 conducted an observation and interview session with Kim Hoffman, Design Education and Strategic Initiatives Lead, Segal Design Institute Associate Clinical Professor as well as the lead on the project to repair the model steam engine. Our primary goal was to observe the current state and operational potential of a model steam engine, and worked to figure out if it would work for an interactive museum exhibit. We aimed to get some early ideas about how it functions, its physical shape, and practical things to consider for putting it on display and letting people interact with it, especially regarding safety and getting visitors engaged.

Methods

This observation involved a hands-on assessment of the model steam engine (Fig. 14). Kim gave us a live demonstration after explaining what her team had been fixing on the engine. The model comes with an AC plug (Fig. 15), which she plugged into the wall before pressing the "on" switch on the controller. We hoped this demonstration would help us understand its heating process, steam generation, and mechanical movement. Discussions with Kim also gave us context on previous attempts to restore the engine and insights into its historical use and design. Key areas of observation included:

- Physical condition: Assessment of its size, visible components, and any obvious signs of wear or damage.
- Operational performance: Time taken to heat up, presence and location of steam leaks, and the freedom of movement of mechanical parts.
- Pressure generation: Examination of the pressure gauge and perceived steam pressure output.
- Safety considerations: Evaluation of surface temperature during operation and uncontrolled steam release points.
- Maintenance and filling: Investigation into water intake and drainage mechanisms.
- Exhibit potential: Discussion on visitor interaction levels (touch/no-touch), fragility of parts, and opportunities for storytelling based on its exposed components.

Fig. 14. Model steam engine

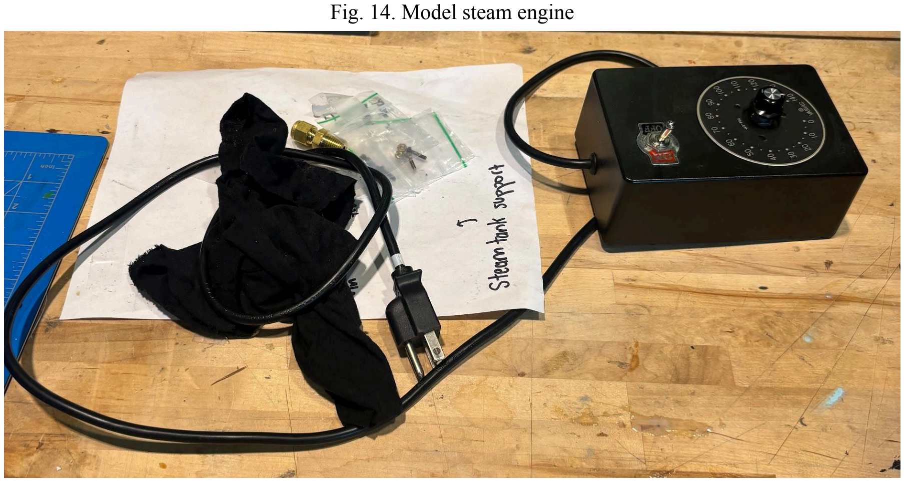

Fig. 15. AC wall plug that comes with the model steam engine

Research

Our main observation was that the steam engine is much smaller than we had initially thought. It takes a while to fully heat up and, once operating, leaks in a lot of places. It seems unlikely that it will be fully fixed by the end of the quarter. The parts move, but not very freely, suggesting a lot of work involving disassembly and lubrication might be needed. The water chamber doesn't build enough pressure, which could be related to the leaks or a broken pressure gauge. The pressure gauge itself was broken and loose, and while vaguely fixed, it didn't seem to work, leaving uncertainty about whether it's the gauge or a lack of pressure.

The team lead by Kim is hesitant to fully replace original parts, preferring to balance preservation of the original object and working functionality. This brings up thinking about different ways to approach making our own models. Our team member Rachel noted safety and logistics concerns, perhaps relating to draining the engine. Some potential safety concerns include the fact that the engine itself gets relatively warm to the touch and that the steam comes out of random places, not just the whistle. The team is not sure how the engine was filled in the past, with no other hole found besides a tiny one at the top. We also considered if there's a con to running it for long periods or a maximum number of hours it can run. The longest it's been run was around 10 minutes before it was unplugged due to all the leaks; the team is not sure what the true longest run time might be.

On the positive side, its exposed parts make it easy to tell a story about how it works. Our team member Rachel questioned whether it should be something guests can just use, not touch, or if it needs to be behind plexiglass, especially since lots of parts can be broken pretty easily if people get their hands all over it. Kim thinks it's a good human-centered design project to think about how to display it. She was involved more as a tinkerer than an expert and maintains a running Google Doc with everything done to try to fix it, approaching it from a museum-goer's perspective, not an expert's.

Discussion

The current state of the model steam engine presents significant challenges for its intended use as an interactive exhibit. Its small size, extensive leaks, and limited, stiff movement indicate that a fully operational display of the original object is probably not feasible in the short term. The lack of proper pressure buildup and a working gauge further complicate attempts to demonstrate its mechanics accurately. Safety concerns are also prominent, with the engine getting hot and leaking steam unexpectedly. These issues underscore the need for careful consideration of how to best represent steam engine principles within a museum setting.

Given the challenges of the original model, a more practical approach might be to build a separate, dedicated exhibit that expands upon the concepts introduced by the model steam engine. This new exhibit could feature robust, purpose-built interactive elements designed to clearly demonstrate steam engine principles without relying on the temperamental original. The original model itself could then be safely displayed under a plexiglass case (Fig. 16), protecting its fragile parts and addressing safety concerns while still allowing visitors to observe its historical form. In this scenario, the model would serve as an authentic centerpiece, an add-on that's still an integral part of a larger, more comprehensive and reliable interactive experience. This approach balances the desire to maintain the original object with the need for a truly engaging and safe exhibit. Kim's perspective on this being a "human-centered design project" reinforces this idea: it's about finding the best way to deliver educational engagement while respecting both the artifact's preservation and visitor safety. Understanding the maximum safe running time, while less critical for direct interaction with the original, would still be valuable for historical context.

Fig. 16. Example of how plexiglass cases are used in museum exhibitions.

Appendix E:

Ethics Statement and Action Plan

Project Summary: We are tasked with creating an engaging and interactive exhibit for a model steam engine at the Wilmette Historical Museum.

Ethical Concerns:

Factual Accuracy

We hold accountability for the displayed information to be correct. When people visit a museum, they take everything at face value and sources are typically not directly cited. Because of this, we should never change any of the information given to us about the history of the model or model maker to try and fit a narrative. Many visitors of a museum will want an exhibit to be authentic; they don't want to learn about fake news. However, what does authenticity mean in a historical museum?[7] Though perfect authenticity is not possible because of the environment that the display is in, museums should focus on representing "the past as we currently understand it". Additionally, when explaining the inner workings or history of the steam engine, we need to double fact check using a multitude of sources to make sure that every statement we make maintains factual accuracy. We can do this by determining the model of steam engine that Joseph Boyd modeled his replica after.

Accessibility

Plan: We will reference the ADA standards to ensure compliance throughout our exhibit. For example, the ADA requires that "if accessible routes through the building are temporarily blocked when exhibitions are installed…alternate routes must be created…".[1] We must ensure that the display of the steam engine does not block any entrance way whether specifically accessible or of other importance such as fire exits. In consideration of people who are blind or have low vision, we should consider preventing bumping hazards that may be created from objects "between 27 and 80 inches above the ground".[1] In addition to making the general museum accessible, we should also consider how to accommodate people with visual impairments or sensory disorders. Alternatives ways of displaying information such as using Braille, CD-Rom, and large print should be made available. In more specific terms of the steam engine, we may also consider a model of the model itself for tactile examination.[2] The Smithsonian also recommends mounting small items "at no higher than 1015 mm (40 in) above the floor"[2] to ensure visibility by all visitors. The top of table cases should be a maximum of 915 mm (36 in) above the finished floor".[2] While the museum itself does not have many size constraints for the exhibition, we should keep these minimum and maximum heights in consideration when designing the display.

Sustainability

Plan: Museums in general "can drive sustainability by choosing eco-certified vendors".[5] By demanding better through supply chains, vendors will listen to customers. While this display is to be permanent, we want to make sure that the materials we use are sustainably sourced and could be recycled or reused if necessary. Rachel recommended that we use plexiglass and wood as a way of encasing the model to prevent visitors from touching it. “Lots of plastics use plasticizers to make them flexible but these can evaporate over time and become a health hazard.”[3] Therefore, we should ensure that no harmful chemicals, specifically PVC,[6] are in the plexiglass or plastic-like material we choose. Sustainability also becomes especially important because certain parts may need to be replaced as part of the routine maintenance. Because we are dealing with a working model of the steam engine, we also need to make sure we are considering any possible pollution. For example, not burning anything in the exhibit, releasing steam without any other elements, or limiting the amount of steam that is produced. Releasing steam inside because it is water as a gas and may be hot enough to cause safety concerns. If the steam is directed outside, it can cause thermal pollution.[4] To fully integrate these goals into our design plan, we should write down more specific, measurable goals into a document and continue to reference it.[6]

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[5] J. Richardson, “Eco-Friendly Museum Practices: How Cultural Institutions Are Embracing Sustainability,” MuseumNext, Dec. 2024. https://www.museumnext.com/article/eco-friendly-museum-practices-how-cultural-institutions-are-embracing-sustainability/#:~:text=From%20exhibit%20materials%20to%20cleaning,Trade%2C%20FSC%2C%20or%20LEED. (accessed Apr. 17, 2025).

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Appendix F:
Project Definition

DTC 2 Section 13 Team 2

Project Name: STEAM See-Touch-Engage-Activate-Move

Project Partner: Rachel Ramirez from the Wilmette Historical Museum

Team members: Charmaine Guo, Lexi Rizzo, Mason Salma, Rachel Kludy

Date: May 18, 2025

Version: 3

Mission Statement

To design an interactive, immersive, accessible and educational exhibit of a 20th century steam engine for the Wilmette Historical Museum.

Project Deliverables

- *Presentation and poster during the DTC Final Presentation*
- *Final prototype*
- *Final report (digital copy)*

Design Constraints

- Must be educational and engaging for visitors
- Must be suitable for all ages to interact with
- Must display the antique steam engine and showcase how it works
- Must be able to be interacted with without supervision
- Must fit with the vision and purpose of the museum (include information about Wilmette, etc at the discretion of the end users)
- Must be constructed on a $150 budget (for the prototype)
- Must be developed within 10 week period

Users and Stakeholders

- Visitors of Museum
    - Students of varying ages from elementary to high school
    - Parents and families

        - Seniors
- Staff at Wilmette Historical Museum
    - Will need to maintain the exhibit
    - Will implement the model into the museum and experience user reaction.
- Project Partners
    - Rachel Ramirez
    - Keith Boyd

User(s) Profile

The exhibit's primary audience consists of museum visitors spanning all age groups who are interested in engaging with Wilmette's local history. The interactive steam engine exhibit will serve as a compelling focal point, sharing a unique story connecting Wilmette to Industrial Revolution-era technology.
Regarding museum operations, most staff members (excluding Director Rachel) are usually volunteers with limited time to master complex technical systems. This group also represents diverse age groups and physical capabilities, proving necessary that all maintenance procedures and interactive components be intuitively designed for easy operation.
Our project partners bring complementary perspectives to this initiative. Rachel Ramirez, while highly experienced in museum curation, has limited background in mechanical engineering. Similarly, donor Keith Boyd inherited the steam engine as a family heirloom without accompanying technical documentation. Lack of information initially made assessing its condition challenging. Both partners have emphasized their shared vision for an exhibit that prioritizes accessible STEM education about steam power principles, concise historical context through museum labels, and preservation of the artifact while maintaining its significance.

Illustrative User Scenario

As I enter the grand space of the Wilmette Historical Museum, I'm immediately struck by how the structure and architecture whisper its history - the soaring ceilings and sturdy wood floors are reminiscent of its previous life as a bustling town hall. As I climb the initial staircase, I pause to take in the vastness of the original firebay now occupied by exhibits rather than fire trucks.
There are not currently any guided tours for individual visitors like myself, so instead I grab a museum map and begin a self-guided exploration. Each exhibit greets me with intentionally arranged artifacts accompanied by clear, engaging labels that make Wilmette's history feel alive. These descriptions are both informative enough to satisfy my curiosity, yet short enough to keep me moving fluidly from one display to the next.
Following enthusiastic recommendations from both museum staff and online reviews, I make my way down to the basement to experience the famed Grosse Pointe jail. The stark cells and interpretive panels vividly illustrate early 20th century policing practices in our community.
Though my complete circuit of the museum takes just 40 minutes, the impact lingers far longer. My head buzzes with stories of Wilmette's past that I am already eager to share with friends and family. This compact yet powerful museum has transformed how I see our town.

Project Requirements - Needs Identification, Metrics, and Specifications

Needs	Metrics	Units	Ideal Value	Allowable Value	As-Built
Easily maintained by staff	Maintenance time per month	hours	< 1 hour	<3 hours	About 1 hour replacing the battery for the Arduino and making sure the objects are still secure
Sustainable & Maintainable Design	Expected lifespan before major repairs	years	>5	> 2	Untested
	Commercially available replacements	yes/no	All yes	80% yes	Yes (Amazon-sourced)
Must be engaging to public	Average interaction time per visitor	minutes	>3	>1	Untested
Accessible to visitors with impairments or disabilities	ADA compliance	Yes/No checklist	Yes for all checks	>80% yes	Height is ADA compliant. Specs: 33” minimum height, about 42” maximum height with a reach distance of 35” Reach distance is

					slightly too long, however, visitors should not touch items past 20”. Font size and type are yet to be determined
	Audio/visual/tactile feedback options	Count	>2	1	We plan on using the speakers to also record readings of the flip books.
Must fit within exhibit confines	Maximum dimensions	Inches	10’4” x 9’	Possibly other wider spaces	Yes, it will fit in the previously determined area.

Appendix G:

User Testing Summary

Introduction

The initial mock-up testing took place in Ford Motor Company Engineering Design Center where a total of four physical mockups and 4 mockup plans were tested by all four team members. In order to create effective mock-up prototypes, we iterated many ideas in a team meeting, sorted ideas in four categories: accessibility, interactivity, safety, and sustainability. We then combined our ideas to form eight multifaceted plans for our mock-ups that encompassed as many important facets and requirements as possible. Once our eight mockups had been determined and a mock-up plan had been created, we discussed the feasibility of turning our plans into physical mockups. After discussion, we determined that four out of the eight mock up plans could be feasibly turned into physical mock ups. After our observation and testing session of these four mock-ups and other four original mock-up plans, we had concrete data from our testers from ratings on a 1-5 scale, assessing interactivity, accessibility, information retained, and accuracy to the original steam engine. The identities of our testers encompassed Northwestern students aged 17-22 and family of Northwestern students aged 8-60.

Methods

To create our four physical mockups, we used multiple different approaches to best accurately represent our ideas and goals.

Physical Mock-up 1: Interactive Flipboard (version 1 and 2)

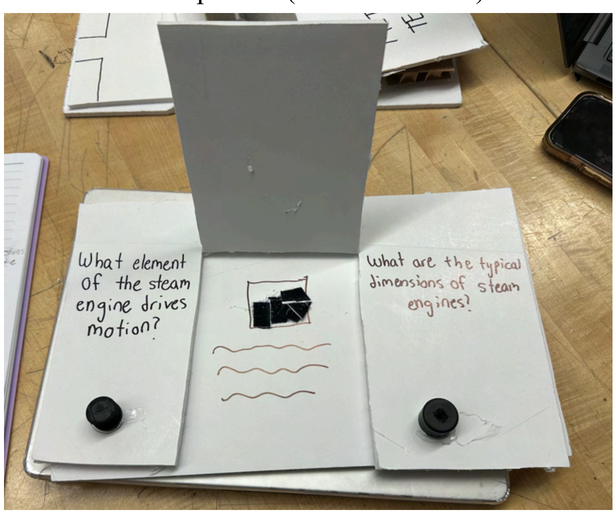

Fig. 17. Initial mock up of flip board made with foam core.

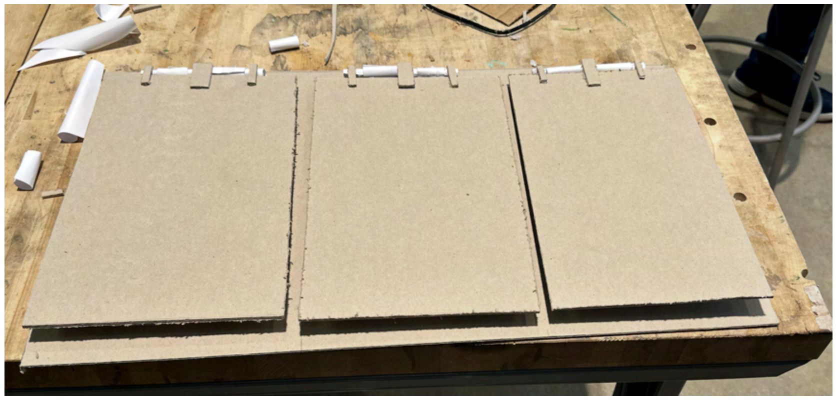

Fig. 18. Second version of flip board made with paper hinges and cardboard.

Testing Methodology: The first version of the flipboard design (on the left) was used for user testing, whereas the second was used for performance testing. The foam core flip board was presented to students at Slivka residential college where they filled a form that measured general interest, quality of information, engagement, and interactivity.

Physical Mock-up 2: Light Up Board with Buttons

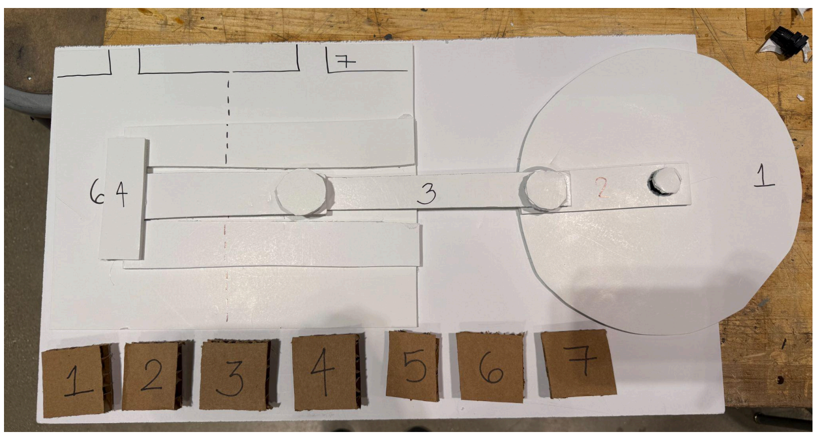

Fig. 19. Mock up of model piston and flywheel with “buttons” made from cardboard.

Testing Methodology: This mockup was used mainly for performance testing, to determine how to effectively portray a piston mechanism in a 2D format. To get the wheel and arm to move in the proper ways, multiple methodologies and materials were used in the shop. Valuable insight into necessary dimensions and pieces was provided through the creation of this physical board. The general design was also used for some user testing, through asking other unrelated (non-McCormick / Engineering) Northwestern students and family members about how the design engaged them. Friends and roommates were presented with the physical board to touch, turn the wheel, and press “buttons” on. Family members (Ages 40-45 and 15) were sent a video of the mechanism to give feedback on the design despite not being able to physically interact with it.

Physical Mock-up 3: Touch Board

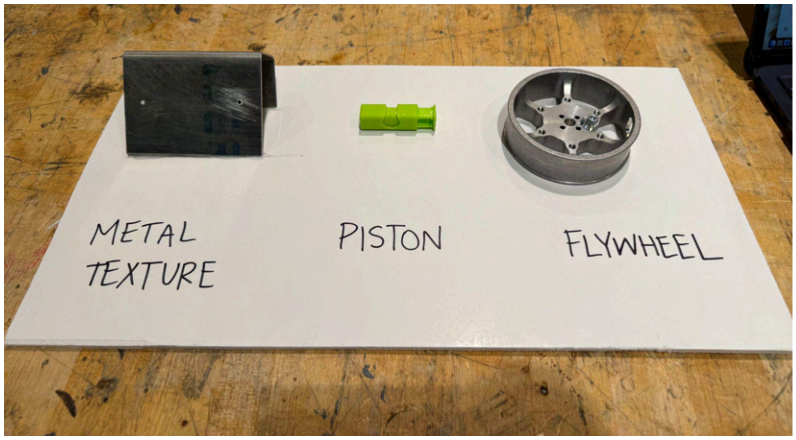

Fig. 20. Mock up of touch board made with foam core and various objects found in the shop.

Testing Methodology: This mockup was used for performance and user testing. Although the pieces used were not curated to effectively convey how a steam engine works mechanically, the concept of a “touch board” was tested against users of different age groups. By asking other Northwestern students and family members (Ages 40-45 and 15) about whether they would be interested in touching each piece and learning more about them, user feedback was gathered. Performance testing was done by roughly interacting with each element and seeing how it was able to maintain integrity and/or be tactically stimulating.

Physical Mock-up 4: AR Model

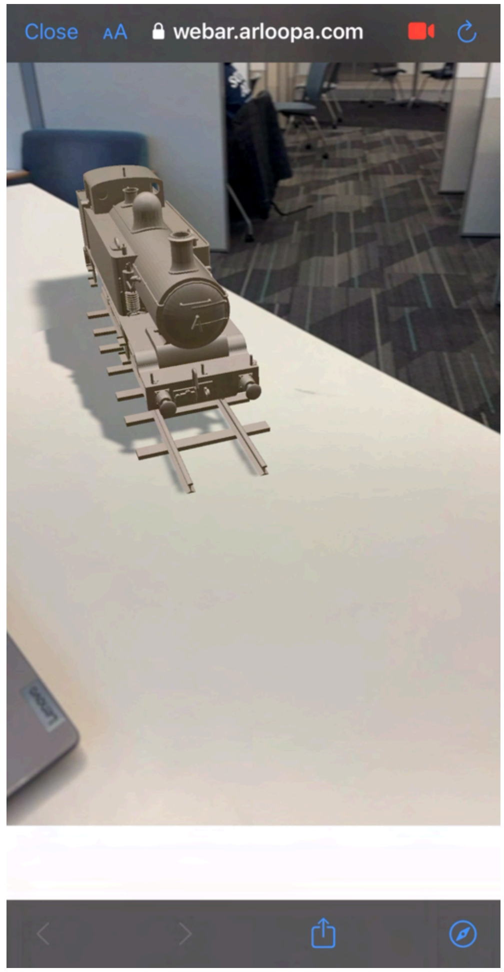

Fig. 21 Screenshot of what the AR model looks like when activated by a user.

Testing Methodology: This mock-up design was used for user testing. The software used to launch the AR was tested for performance. We conducted testing via google form with 7 participants aged 12-60 (including Northwestern students and family) to evaluate four key metrics:

1. Usability, measured through QR code scan success rates and interface intuitiveness.
2. Educational value, evaluated through participant self-reported learning gains.
3. Engagement, quantified by average interaction time compared to typical museum exhibits.
4. Technical performance, tested across iOS, Android, and tablet to determine if the ARLoopa Software was usable.

Physical Mock-up 5: Train-set

Fig. 22: A picture of how a toy locomotive steam engine can be used with a train. The image shows how the train can light up, blow "smoke", as well as make noises and be controlled from a distance.

Testing methodology: The model train set mock-up was evaluated through secondary research due to budget constraints. We analyzed 10 verified buyer reviews from Amazon with particular attention to age diversity and accessibility feedback regarding assembly difficulty and durability.

Physical Mock-up 6: TV/media Displaying Information

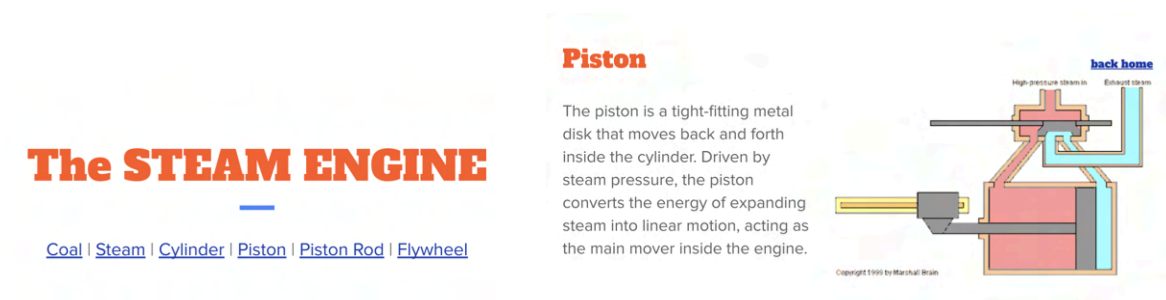

Fig. 23: Home Screen (left) with links to individual components and example page (right) that explains in more detail about what the component is and what its role in the creation of electricity with a motion graphic.

Testing Methodology: This mock-up design was used for user testing. Participants were able to access the presentation and without any prompting clicked through and read/watched the information. Full engagement only takes about 3 minutes. We then collected information on how much participants felt they learned, and which format/slide of information was the most interesting, informative, and engaging.

Physical Mock-up 7: Fog Machine

Fig. 24. 3 in 1 iron in an open position to show holes that the steam is generated from.

This mock-up utilized a household iron to generate a small, controlled amount of steam, simulating the steam expulsion from the model engine. The iron was carefully positioned to direct the steam from the model's exhaust point.

Testing Methodology: We focused on user engagement and feasibility. Informal user testing assessed if the visual representation of steam, produced by the iron, enhanced understanding of the engine's mechanics and served as a compelling visual element. Feasibility tests evaluated the practicality of using an iron for this purpose within an exhibit setting, considering factors like safety, consistency of output, and the scale of the effect. The primary goal was to determine if this simple, readily available method could effectively improve clarity and engagement with the steam engine's operation.

Physical Mock-up 8: Displaying model steam engine in plexiglass box

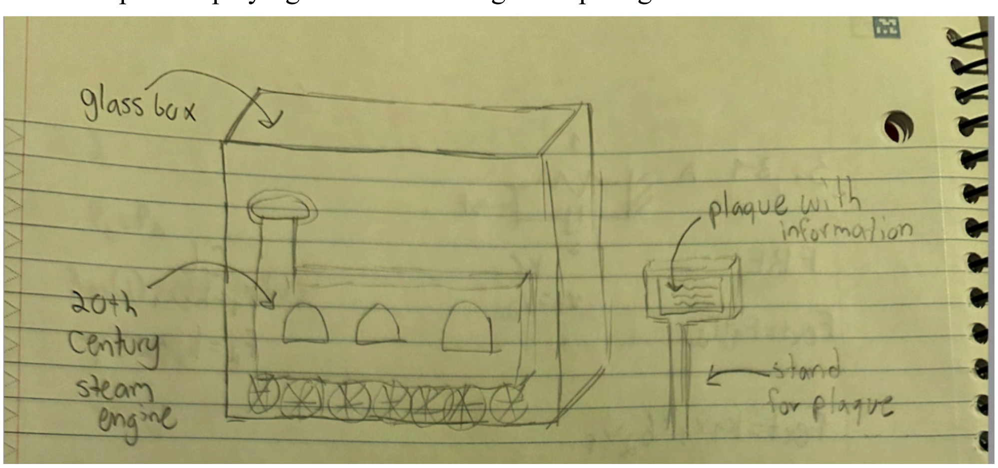

Fig. 25: Example exhibit of how we might use a plexiglass box to present the model steam engine. Adjacent is a plaque with information about the engine.

Testing methodology: While early assessments confirmed that a static plexiglass enclosure alone would fail to meet our core requirements for interactivity, education, and immersion, we recognized its essential role in artifact preservation and visitor safety. This led us to focus our testing on complementary interactive mock-ups that could work in conjunction with the protective casing to create a more engaging exhibit experience.

Results

Flipboard

The interactive flipboard first underwent performance testing, where the paper hinge device was tested for durability, ease of motion, and ease of use. The hinge device could only be used if the board was moved carefully and slowly; very quick movements broke the cardboard-paper hot glue seal 2 or 3 times. The hinge also allowed for some translational movement and rotational movement, which was not ideal. The translational movement was in the range of ± 1 cm and the rotational movement was about 5 degrees to either side. The range of motion was approximately 90 degrees, though it varied slightly for each panel depending on the length of the cardboard pieces holding the paper and panel together. The force required to move the panel was very low and the weight of the entire structure was approximately 0.5 lb.

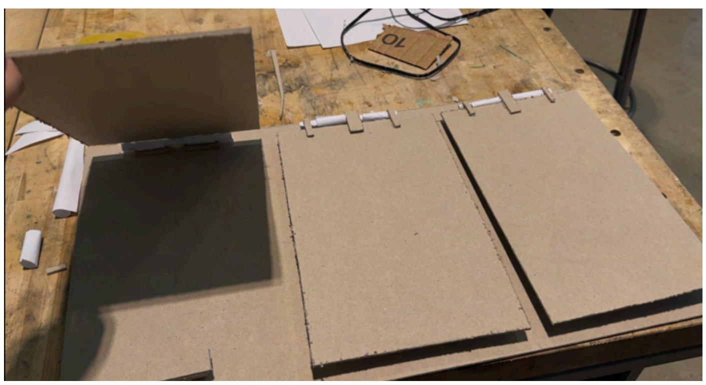

Fig. 26: Hinge performance testing of Panel 1

The interactive flipboard then underwent more building iterations to implement design features necessary for user testing. The selection of users were 14 students from Slivka Residential college aged 18-21 years old.

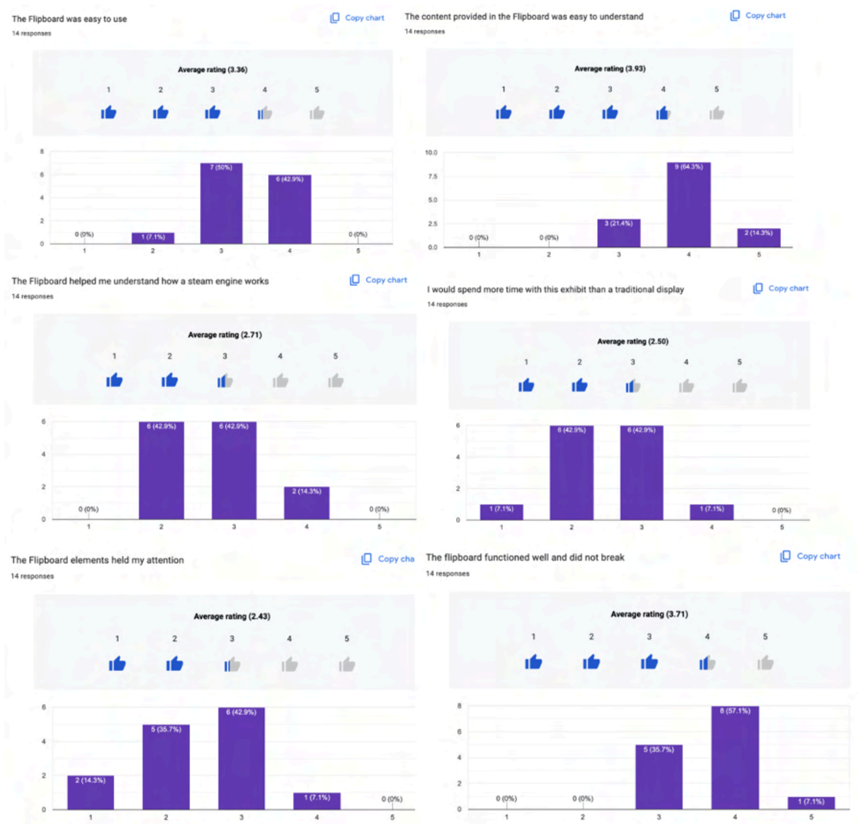

Fig. 27: Images of ratings on a 1-5 scale given by 14 residents of Slivka College based on ease of use, content, engagement, and durability.

As seen in the poll results, and seen in direct observation, the flipboard was quite easy to use and understand, though fragile at times. Where most user testers began to find issue was with the interactivity and overall learning experience. This in part is attributed to the slight lack of information in the mockup, as most time was spent designing the structure and mechanism for flipping, however, many users also noted the lack of interactivity and engagement the device offered.

Light Up Board with Buttons

For the Light Up Board with Buttons, both user and performance testing revealed that the model had faults with its usability. It was a struggle to convey the correct mechanism due to the 2D elements getting caught and not following predetermined paths. This impacted the users' ability to understand what the intended purpose of the mockup was. However, users across the board did express that having interactive buttons was stimulating and made them want to learn more about the mockup as a whole.

In addition to causing a lack of clarity, the construction of this mockup also caused problems during the process of manufacturing it. The materials chosen (foam core, various screws, and hot glue) made it difficult to portray the intended mechanism, and were not durable or smooth enough to properly accommodate the design.

Touch Board

Users had a more positive reaction to the touch board, stating that the pieces were "Interesting enough to want to touch or play with" (15y male). They liked the idea of getting to see pieces at a real-life or larger-than-life scale, and having the possibility of pressing buttons or levers even if they didn't connect to an obvious trigger. Multiple users commented on the "piston" model specifically, saying that they were drawn to it due to its springy mechanism and clicky feeling and sound. Some also expressed interest in touching the wheel due to it having different grooves and textures, but the least amount of users of all ages were interested in the piece of sheet metal, saying it was "boring" or "not as exciting" as the other two pieces on the board.

For performance testing, the pieces held up well in their ability to stick to the board even when roughly handling them. However, the piston mechanism did break after many users had pressed it repeatedly. Although the pieces used for this mockup were simply household items standing in for real parts, this did demonstrate a need for greater durability when creating items meant to be interacted with frequently or handled roughly.

AR Model

In the google form used to collect feedback, all questions were answered on a scale of 1 to 5 with 1 being least and 5 being most. The AR interface demonstrated strong usability, with 71% of respondents rating QR code activation. (Fig. 28.A) However, clear instructions were not provided as 71% of respondents also rated clarity 3 or lower. (Fig. 28.B)

Educational value scored well with 57% of users rating a 4 or higher when answering that the AR helped them understand how the steam engine worked. (Fig. 28.C) In addition, all users learned something new about STEM. (Fig. 28.D) Engagement metrics were very mixed as a few users answered they did not spend more time with this exhibit than they would with a traditional display while a few others said they did. (Fig. 28.E) The animations were engaging (Fig. 28.F) and users would typically recommend this AR feature to other museum visitors. (Fig. 28.G)

Generally, the software was not well received as the AR content failed to load in under 5 seconds for 57% of the users. (Fig. 28.H) The AR also glitched for 42% of users. (Fig. 28.I) One user also "didn't really see that [they were] supposed to tap at first so [they were] kinda confused". Another user said the video was slowed down and the text on the screen was flipped. Users said the most effective part of the AR experience was that it was 3D and visual and provided clarity.

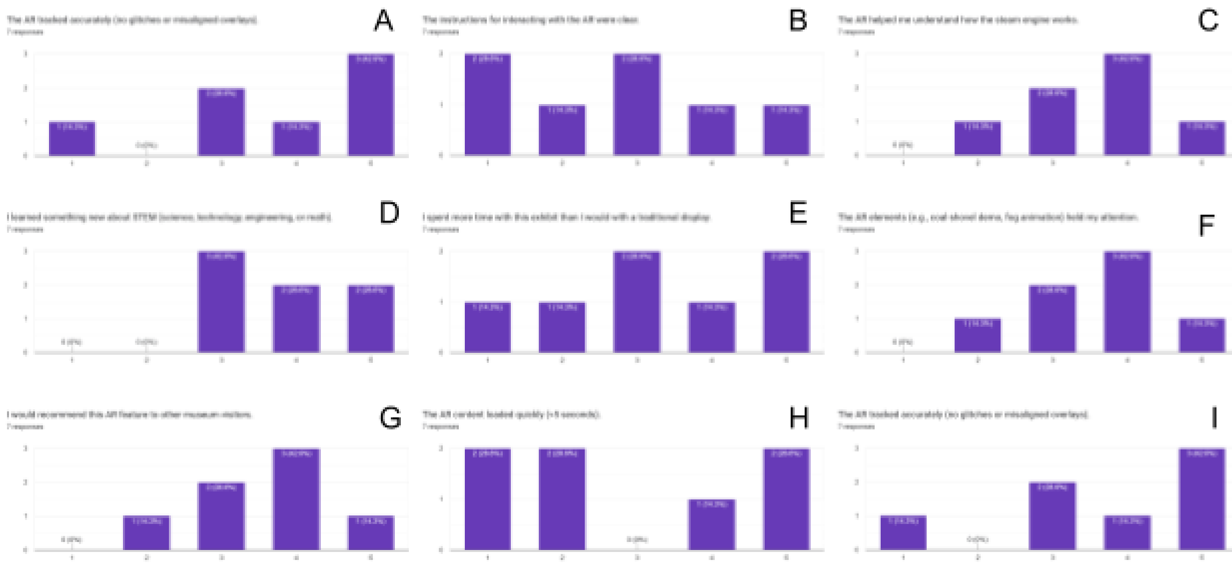

Fig. 28. Bar charts showing data from different questions answered by users.

Train Set

Analysis of the model train seat feedback revealed three critical operational factors: ease of assembly, long-term durability, and mechanical functionality.

A few users reported that the train was easy to assemble with one even noting that the entire setup took only ten minutes (Fig. 29.J). However, there was also confusion due to missing or unclear instructions. In one case, a user had to search online to Fig. out basic operations, such as how to activate the smoke function or use the remote control. (Fig. 29.A)

Durability emerged as another major issue among reviewers. Multiple customers described the train as fragile and cheap with some units breaking after just one use. (Fig. 29. C & F) Some reported that the train would fall off the track (Fig. 29.I) or that parts would arrive damaged or missing. Two reviewers noted that even after reordering due to missing parts, the second unit was still incomplete. (Fig 28.B & D)

Mechanical functionality received mixed responses. A few reviewers praised features like smoke, sound, and directional control, commenting that the train felt realistic and enjoyable to watch for young ages. (Fig. 29.G & H) However, others criticized the low volume of the sounds (Fig 28.E), frequent derailments, and malfunctioning components such as the remote or battery connections. In some cases, the train was not even able to stay on the track and operate properly. This issue was magnified when the train was used by young children.

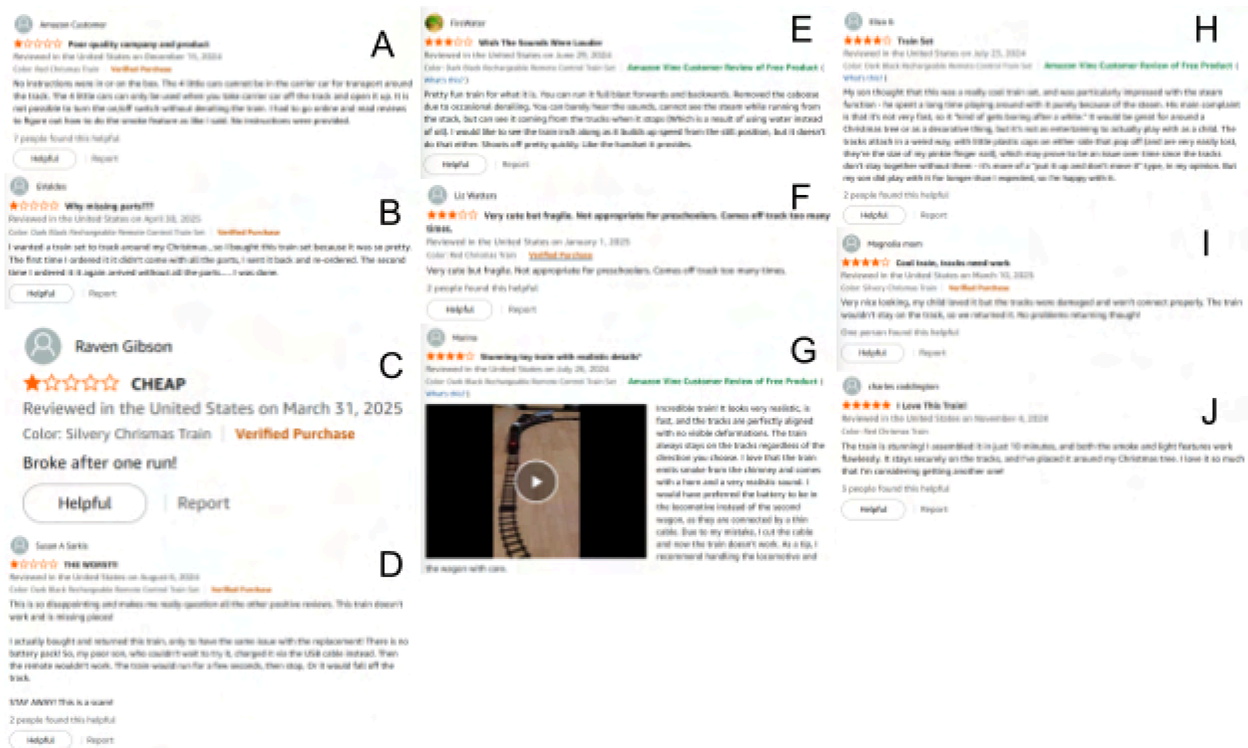

Fig. 29. Reviews from Amazon customers that bought the model train set.

TV/media Displaying Information

Users gave relatively positive feedback to the mockup. Examining the google form results, all but one user strongly agreed that they learned something about the steam engine, which is the main criteria that this mockup aims to do in terms of a larger exhibit. Additionally, despite never explicitly prompting people to go to every page, 75% of users indicated that they did anyways. Finally, when asked if they would recommend the presentation to other users, 87.5% responded with a 4/5 or higher indicating they agree with the statement.

Users were asked which slides they found most engaging. The most popular responses were the slides about steam and the piston. These two slides were the only ones with motion graphics, which may indicate that that feature was engaging to users. The only other slide that multiple users indicated it was among the most engaging was the flywheel, which utilized a video format instead of text. This may indicate that the video can be more engaging that straight text, but not as much as a motion graphic.

Users were also asked about which slides they found the most informative. The most popular responses were the slides about the piston rod and flywheel. These are the slides that get more into the physics of the steam engine and include terms such as work, mechanical energy, and potential energy. This may indicate that users want to learn more about the transfer of energy processes.

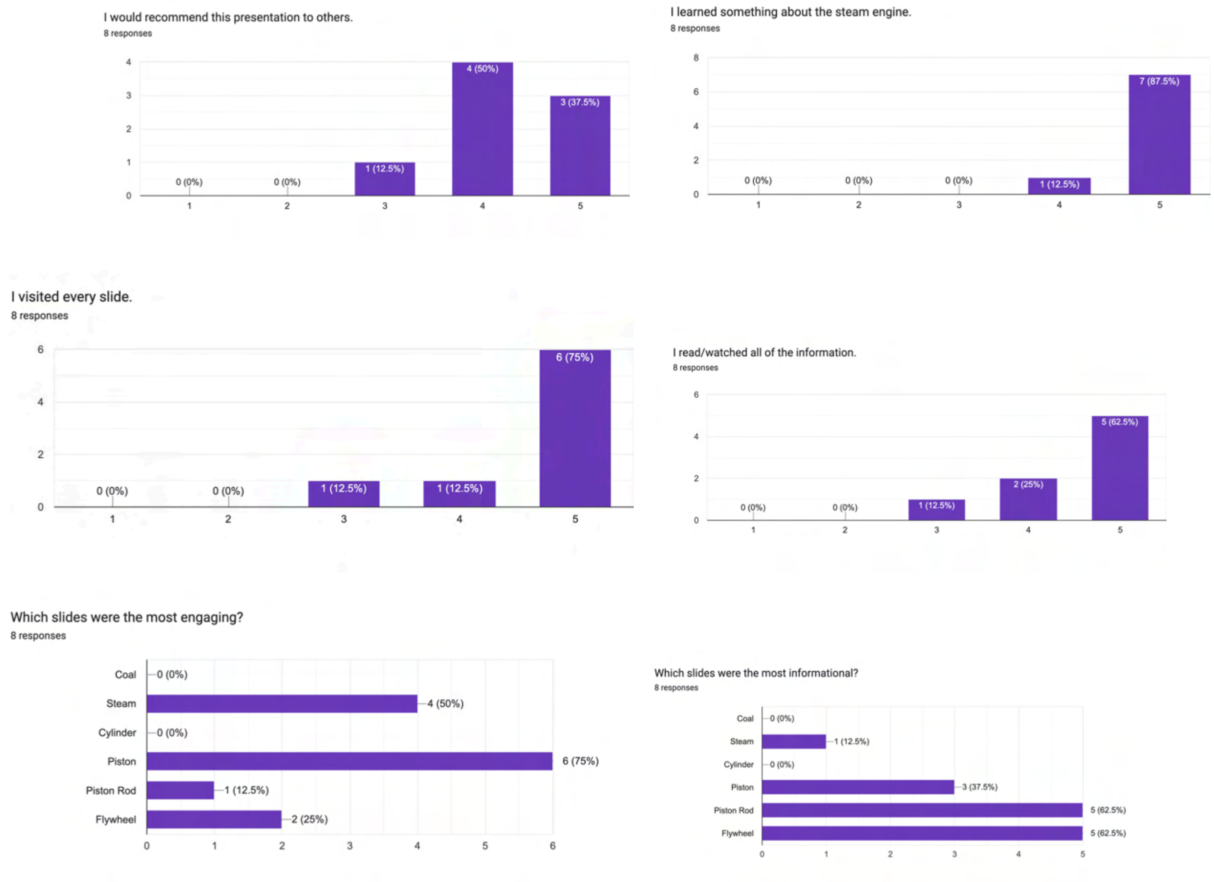

Fig. 30: User responses to questions about their interaction with mockup presentation

Discussion

The comprehensive testing of all mock-ups revealed critical insights that directly informed our final combined touchboard-flipboard design. While the AR model demonstrated strong educational potential (with 100% of users reporting new STEM learning), its technical instability (with 57% having experienced loading delays and 42% having encountered glitches) rendered it unsuitable for reliable museum implementation. Similarly, the model train set's fragility (50% of reviewers had missing or broken pieces) and the TV slideshow's passive nature (as most users preferred the slides with graphics and videos) failed to meet our core requirements for durability and engagement. These findings validated our decision to prioritize physical interactives that balance educational value with robust construction.

The flipboard and touchboard emerged as complementary solutions addressing distinct requirements. User testing showed the flipboard's 90-degree hinge mechanism, while requiring careful handling, successfully delivered information in an exploratory format that 71% of Slivka College testers found intuitive. Its fragility (±1 cm translational movement) was mitigated in our final design through reinforced mounting. Conversely, the touchboard's tactile elements proved universally engaging across age groups, with the spring-loaded piston being the most attractive part. This aligned perfectly with Rachel's emphasis on STEM engagement through direct manipulation, though we incorporated durability improvements after observing the piston mechanism fail under repeated use.

Our final design synthesis reflects these lessons. We plan on using the plexiglass case as a necessary protective shell while adding interactive elements to overcome its inherent lack of engagement. The mock-ups not chosen each contributed valuable lessons: the AR’s 3D visualization informed our touchboard’s emphasis on manipulable parts, the train set’s durability issues underscored material selection priorities, and the light up board inspired plans for future illuminated components embedded in the touch board (pending time constraints). By hybridizing the flipboard’s question-driven learning with the touchboard’s tactile exploration, we plan on creating a system that meets all specified requirements while remaining within budget and timeline constraints.

Appendix H:

Design Review Summary

Introduction

On May 16, 2025, our team presented a design review of our combined touchboard-flipboard exhibit for the Wilmette Historical Museum's steam engine display. This review was performed for an audience of Teams 13.1, 13.3, 13.4, and Professors Derrick and Kriegman. The team settled on this design because it addressed the core needs of durability, STEM education, and engagement of all ages. The design integrated the ease of use of the flipboard with the aspects of interactivity that the touch board and sound system offered.

Methods

For our design review, we created a comprehensive slideshow to communicate our steam engine exhibit's progress and validate our design direction. The presentation opened by reaffirming our mission statement to demonstrate how the current prototype fulfills the original requirements of accessibility, educational value, and durability within the $150 budget. We showcased detailed design sketches illustrated how the touch board and flipboard mockups would integrate spatially. This was accompanied by physical mockups of both elements (previously created by Rachel and Lexi) to demonstrate their combined functionality in a museum setting. A rough CAD outline of our design provided additional technical perspective on dimensions and structural relationships.

We also included proven reasoning based on user and performance testing, including survey responses that confirmed the touchboard's engagement value (particularly the piston and flywheel components) and the flipboard's effectiveness in conveying STEM concepts. We also presented a list of items with sourcing details, explaining material choices through the lens of cost, durability, and safety testing results. The presentation concluded with openly addressing primary concerns like hinge reliability and interactive balance where we invited the class to advise on solutions. During the 20-minute Q&A, feedback centered on how to structure the storyline of the flip boards and where we should focus our remaining time, which we documented for immediate iteration.

Research

The class and instructors provided targeted, constructive feedback to strengthen our exhibit design. These points primarily emphasized the need for clearer educational prioritization and accessibility refinements. Reviewers questioned the static train model's educational purpose, suggesting that we either justify its inclusion with explicit ties to STEM concepts or remove it to avoid confusion. Significant concerns were raised about the implementation of the interactive elements, particularly the poorly placed button which would likely not be accessible to users in wheelchairs and younger children. There was also concern about insufficient distinction between hands-on components and display-only elements. Feedback stressed that the flipboard's educational consent should be created first and the touch board objects chosen afterwards based on each board. Accessibility was also noted by multiple participants with one suggesting auto-triggering of audio with flipboard use as well as implementing specific heights of interactive elements. Durability concerns focused on reinforcing high-touch components like the coal attachment and flywheel mechanism. Lastly, reviewers advised prioritizing comprehensive blueprints over physical construction to align with our project partner's flexibility regarding deliverables. This input will be heavily considered as we move into our final prototyping phase, particularly in streamlining the interactive experience and tightening the educational storyline.

Discussion

Based on the feedback we received from both our project partners and our fellow DTC peers, we have decided to expend most of our energy on selecting relevant pieces for the flipboard and touch board and creating an engaging storyline that users will remember and find interesting and educational. Our first steps are to begin doing more research about the mechanics of a steam engine so we have a firmer understanding to then begin to create the information in the flipboard and select touch board pieces. We will also begin to code the sound system on the arduino as Rachel and Kieth described how it was important for us to work on technological aspects.

Appendix I:
Bill of Materials

Bill of Materials					
Item	**Description**	**Qty**	**Source**	**Unit Cost**	**Total Cost**
Arduino MKR Zero	Arduino MKR Zero Board [ABX00012] with SAMD21 Cortex-M0+, 32-Bit ARM MCU, Built-in SD Card Slot for Music Playback, 22 Digital I/O Pins, 12 PWM Outputs, 256KB Flash, 32KB SRAM, 3.3V Operating Voltage.	1	Amazon	31.20	34.40
Battery clips	2 Pack 9V Battery Clip Connector Hard Shell for Arduino Electronics, Student Experiment, STEM Projects, and Research (I-Type)	1	Amazon	3.97	4.38
Hinges	2-⅖” Long black butt hinges	1	Amazon	9.49	10.46
Knobs	Silver cabinet knobs with screw attachments	4	Shop	0	0
Fake coal	Christmas toy coal	1	Amazon	9.99	11.01
Piston	3D-printed steam locomotive engine, model created by mazaq1 on Thingiverse	1	Ford Design Center	0	0
SD Card	SanDisk 4GB Micro SD Memory Card w/SD Adapter	1	Amazon	8.47	9.34
Speakers	Speaker 3 Watt 8 Ohm Compatible with Arduino Motherboard, JST-PH2.0 Interface.	1	Amazon	7.99	8.80
Model train	Hot Bee Steam Locomotive Engine Train Toy with smoke, lights, and sounds, battery powered	1	Amazon	23.99	26.45
Batteries	4 AA Batteries for train, 1 9V	5	Shop	0	0

	Battery for Arduino				
Buttons	Colorful LED Light-up buttons with built-in 5V switches compatible with Arduino / Raspberry Pi	5	Amazon	11.88	13.10
Boiler Liquid Motion Bubbler	Bubbler fidget toy oil timer	1	Amazon	6.88	7.59
Breadboard	3 Set of Solderless Prototype Breadboard 830 tie Points Breadboard	1	Amazon	5.99	6.61
Solid Core Wires	22 Gauge Solid Core Tinned Copper Hook up Wire Kit, Black and White	1	Mechatronics	0	0
Plywood	¾ in, scrap wood approximately 2 sheets (4' x 3')	1	Shop	0	0
Spray Paint	Black spray paint for indoor use on wood	1	Shop	0	0
Portable charger	Portable Charger,10000 mAh Power Bank Travel Charger with USB-C(Input&Output),2.4A Fast Charging External Battery Pack Phone Charger Compatible with iPhone 16,Samsung,Android,Brilliant Black	1	Amazon	7.30	8.05
Audio Amplifier	5pcs LM386 Mono Audio Amplifier Module 20 Times AMP Solo 5V-12V 10K Adjustable	1	Amazon	6.99	7.71
Resistor	1K Ohm Resistor	4	Mechatronics	0	0
Solder	Tin Lead Solder With Rosin Core For Electrical Soldering	1	Mechatronics	0	0
Wheel	Smooth Grip Wheel 80A (gray)	1	Shop	0	0
Metal tube	Grooved metal tube, 1" long	1	Shop	0	0
Plastic cap	Threaded PVC plastic cap	1	Shop	0	0
USB to Micro-USB cable	USB to Micro-USB cable	1	Mechatronics	0	0
Total Cost including tax					140.71

Appendix J:

Instructions for Construction and Installation

Introduction

The STEAM exhibit contains four individual flip boards with content on different stages of the energy transfer/engine process, a touch board with corresponding components, a model locomotive with steam output, the real model steam engine, and audio elements that read the information and play sounds associated with different steam engine components.

STEAM Exhibit Construction

Parts list

Parts	**Specification**	**Quantity**
Model Coal	From Amazon (see Bill of Materials)	5
Model Piston and Flywheel	3D printed PLA	1
Knobs	Chrome	4
Plywood	¾ in thick	2 sheets
Boiler Liquid Motion Bubbler	From Amazon (see Bill of Materials)	1
Toy Train	From Amazon (see Bill of Materials)	1
9V Battery	From Shop (see Bill of Materials)	1
Buttons	From Amazon (see Bill of Materials)	4
Arduino	From Amazon (see Bill of Materials)	1
Battery Clips	From Amazon (see Bill of Materials)	2
Speaker	From Amazon (see Bill of Materials)	1
Screws	½” wood screws, 1” wood screws	24, 12
Butt Hinge	2-⅜” long	8
Printed Material		
Steam Engine Model	Provided by Keith Boyd	1

Plexiglass	3/16”	case
Solid Core Wire	Black and White, approximately 25 ft in length	1 each
Resistors	1K Ohm	4
Solder	2 ft long	1
Wheel		
Double sided tape		3 ft
Electrical Tape		1 ft

Tools

- Soldering iron
- Fume extractor and smoke abs
- Six arms octopus helping hands for soldering

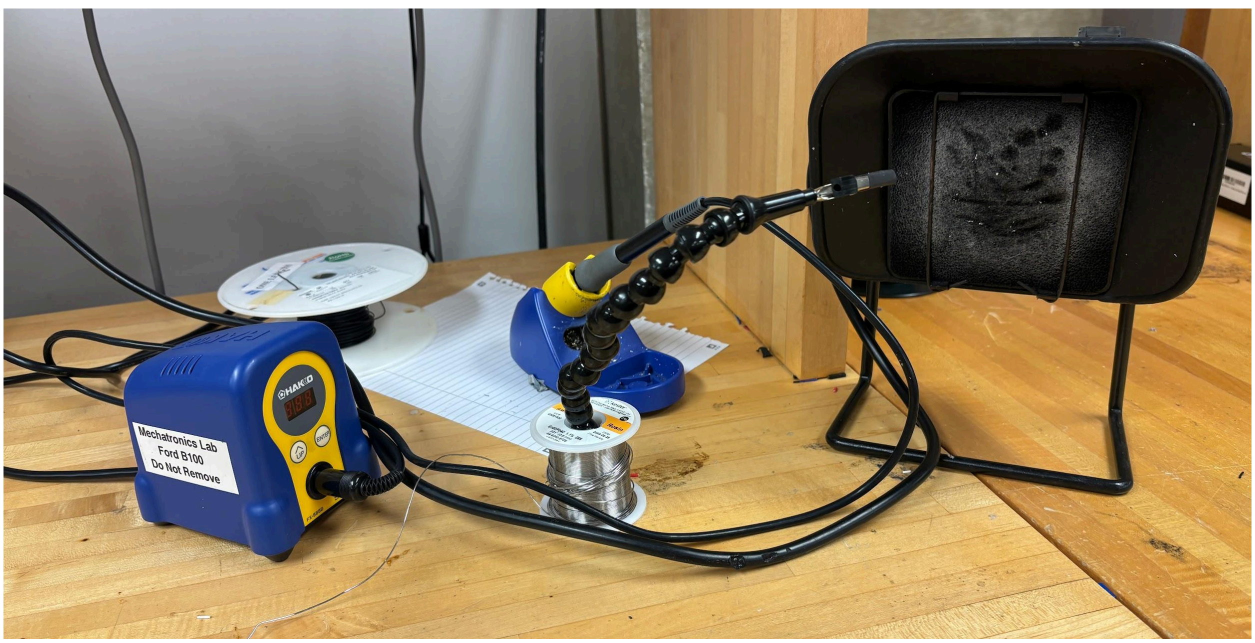

Fig. 31. Example soldering setup with soldering iron, helping hands, and fume extractor.

- Wire strippers/cutters 2 in 1
- Hot glue gun with hot glue sticks
- Vertical bandsaw
- Wood glue
- Arduino IDE Software downloadable here: https://www.arduino.cc/en/software/

Steps for construction

1. Access link to CAD file, text to print onto flip boards, and arduino code here.
    a. https://github.com/willowcharm6/STEAM
2. Cut the ¾" plywood to make a 64" x 20" rectangular mount
3. With the rest of the plywood, cut four identical pieces of dimensions 6" x 10"
4. Turning the flipboard pieces landscape, drill a hole in 5" from the left and 1" above the bottom
5. Then place the knobs into the hole and screw to secure. You should have four identical pieces that look like Fig 29.

Fig. 32. Flipboard piece with knob attached center-bottom

6. Flip over the wood so that the knob is face down and place a hinge at the upper left corner of the piece so that the axis of rotation sticks just off the top. Secure the hinge and screw in the wood screws in each of the three holes. Repeat with another hinge in the upper right corner. Repeat for each of the four pieces.
7. Carefully place the flipboard panels in their correct place on the mount. (Fig. 33)

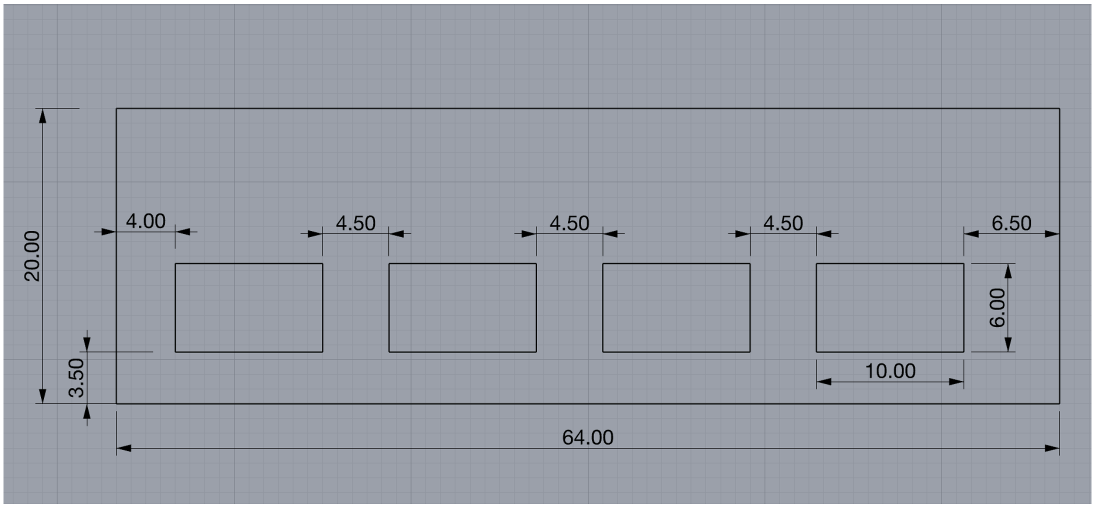

Fig. 33: Map of where to secure flipboard panels on mount

8. With the pieces in their correct places, open the hinge and flip up the board. Screw the bottom side into the mount using the wood screws.


Fig. 34: Hinges attached to flipboard and mount

9. Print out the text for the flipboards found in the github link from step 1.
10. Glue the printed questions on the panels above the knob and the related answers on the mount below the panels to create each component of the flipboard. States of energy can be glued onto the mount directly below the flipboard. From left to right it goes coal/chemical energy, water chamber/thermal energy, piston/mechanical energy, flywheel/rotational energy.
11. Cut and spray paint a 5” x 5” piece of wood black.
12. Glue on the coal pieces to the wood and then using the longer wood screws, attach to the mount directly above the flipboard.

Fig. 35: Coal touchpieces

13. Tie a string around the boiler piece. Using scrap wood, create a channel to put the string through and secure with screws as shown in Fig 36.

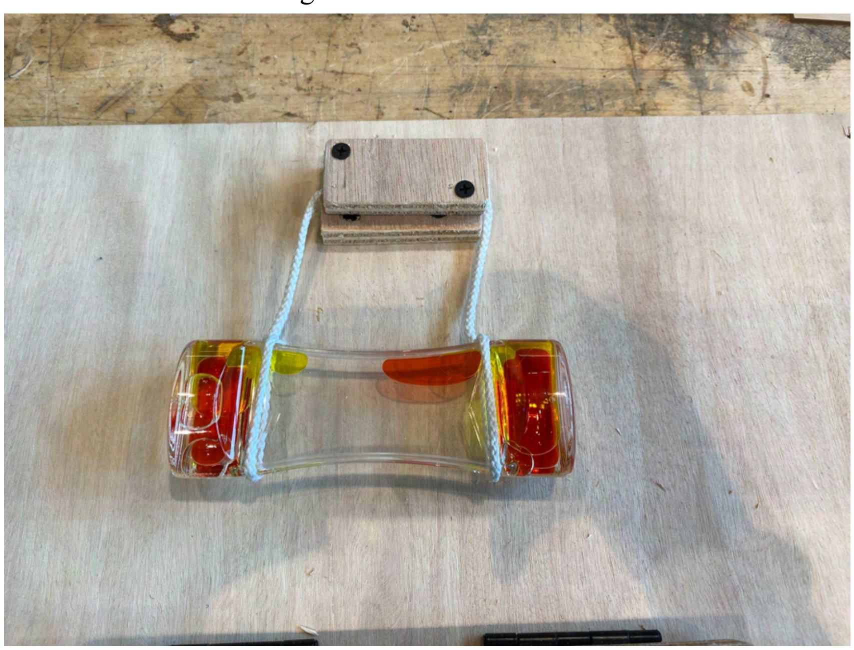

Fig. 36: Boiler piece connected to mount via string and wooden channel

14. 3D print the piston with tree supports using the file found in the github in step 1.
15. After printing, remove supports (Fig. 37) by hand or with pliers.

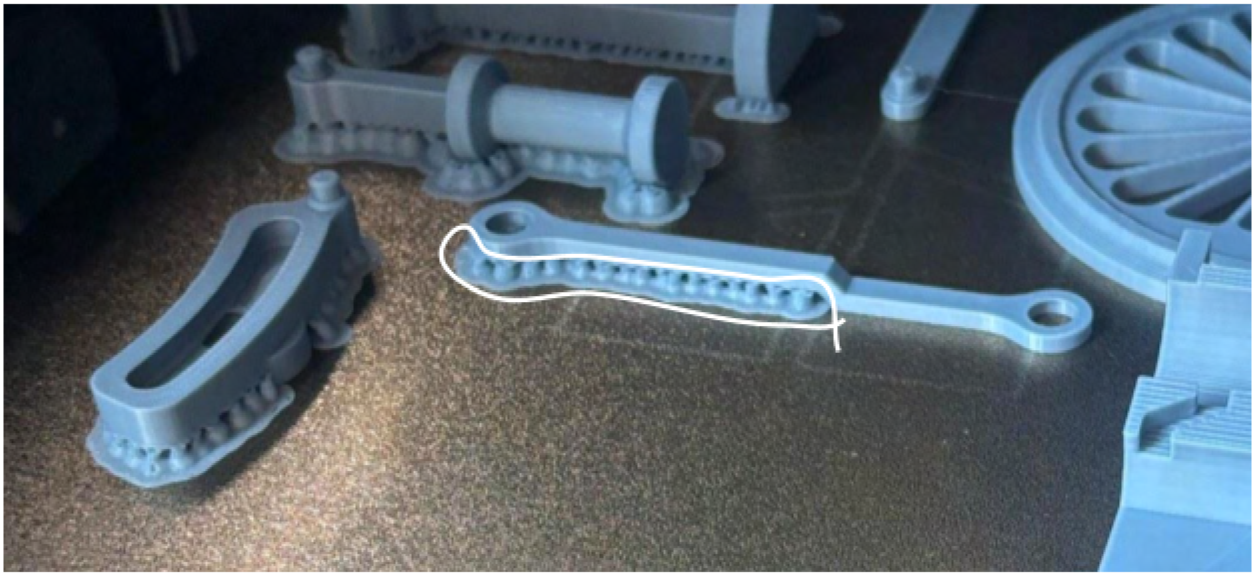

Fig. 37. Parts of piston after printing with supports circled in white.

16. Assemble the piston according to the creator's instructions via video found in the github.
17. Attach the piston in its designated space above the flip board describing how the piston moves via hot glue.
18. Glue the grooved metal cylinder to a piece of 3” x 3” piece of wood and screw the wood into the mount.

Fig. 38: Grooved cylinder attached to wood

19. Place the wheel over the cylinder and screw on the plastic cap.

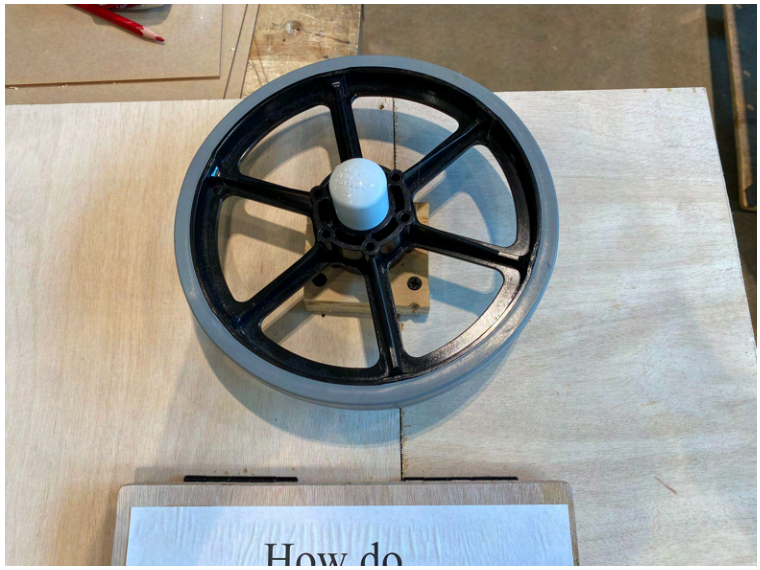

Fig. 39: Wheel touchpiece

20. Drill 4 holes in the mount to the right of the flipboard. Each hole should have a diameter of 3cm.

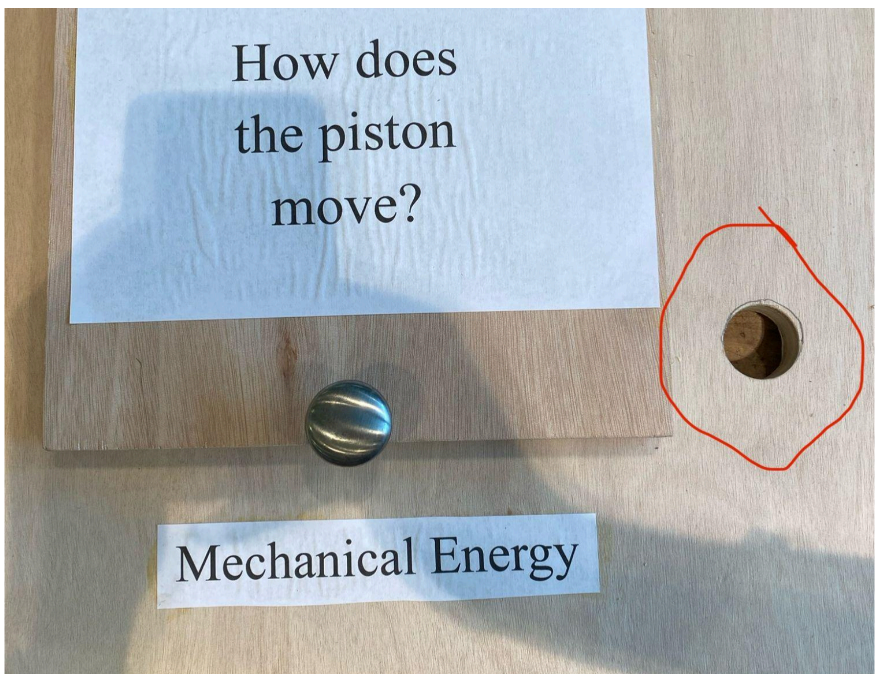

Fig. 40. Hole position for button in relation to touchboard

21. From both the black and white wire, cut two of each following lengths (you should have 16 total wires):
    a. 56” - corresponds to the red button placement
    b. 41” - corresponds to the blue button placement
    c. 27” - corresponds to the yellow button placement
    d. 14” - corresponds to green button placement
22. From both the black and white wire, cut 10”, this is for the battery.
23. Strip about ¼” of the insulation of each side of every length of wire.

24. For each button, solder a black wire to the negative terminal (Fig. 41) and another black wire of the same length to the negative terminal of the LED leg. Repeat with white for the positive terminal. The resulting arrangement should look like Fig. 42.

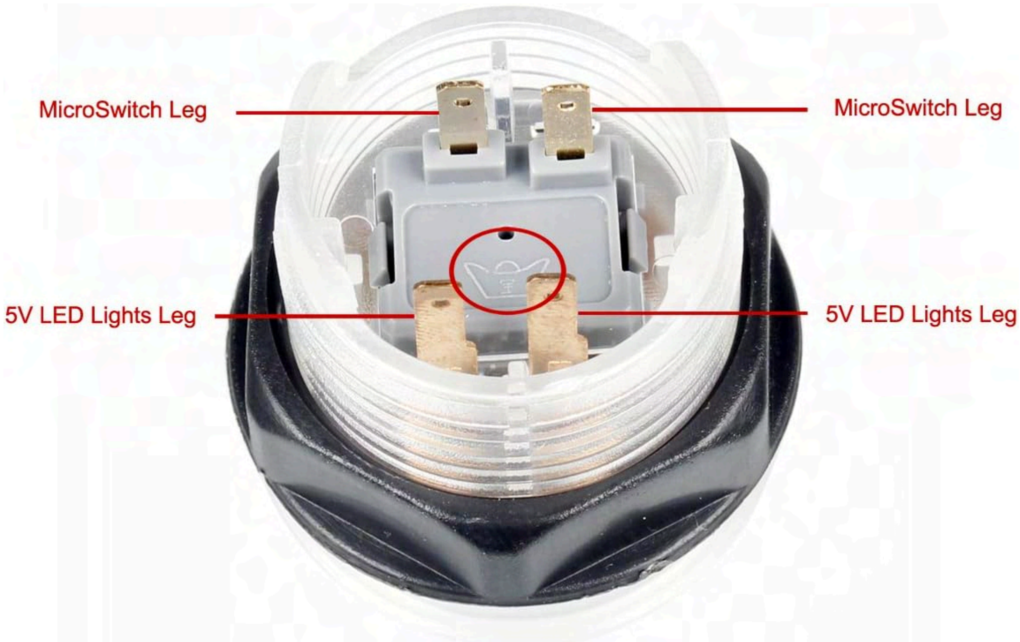

Fig. 41. Schematic pointing which legs are for the microswitch and which are for the LED.

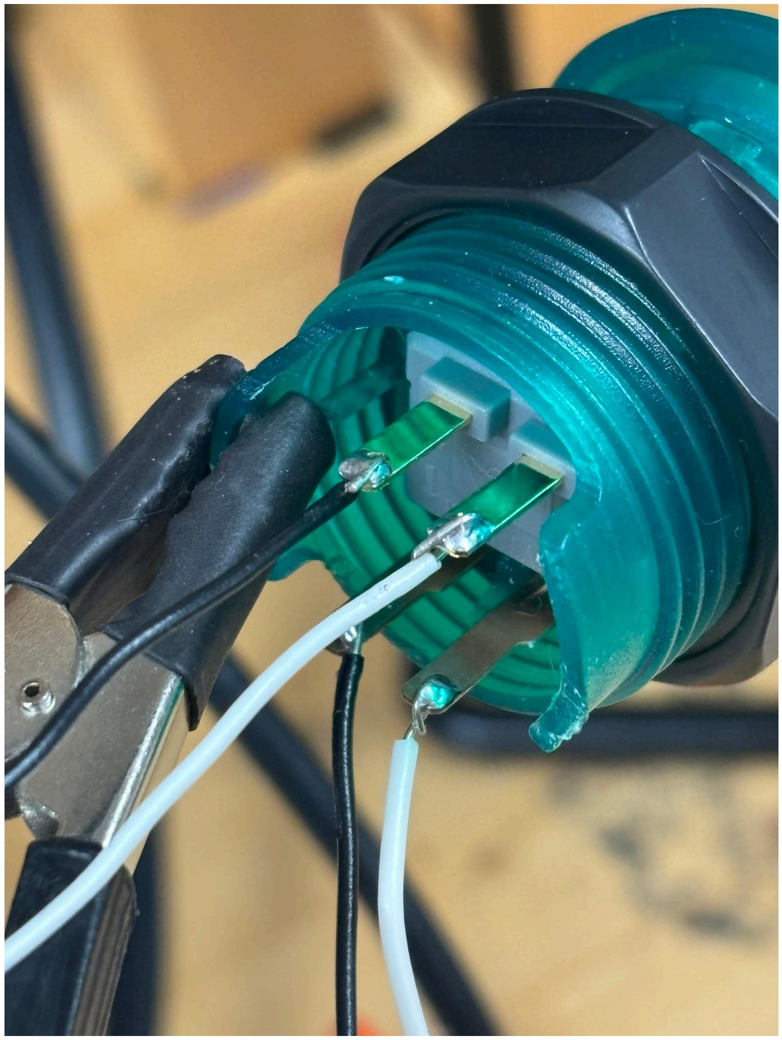

Fig. 42. Picture showing how the black and white wires are connected to the button and LED terminals.

25. Cut the plastic connectors off of the speakers. Pull apart the black and red wires and strip ¼" of each.
26. Matching black to black and red to white wires, solder the solid core wire onto the speaker wires.
27. Use electrical tape to cover the point of solder to prevent accidental shorting.
28. Place the buttons into their respective holes with the circuitry on the inside (Fig. 42). Note that the plastic nut is not attached to the button threads. (Optional: intertwine black and white wires for LED and micro switch for organization.)
    a. The red button should be placed next to chemical energy.
    b. The blue button should be placed next to thermal energy.
    c. The yellow button should be placed next to mechanical energy.
    d. The green button should be placed next to rotational energy.

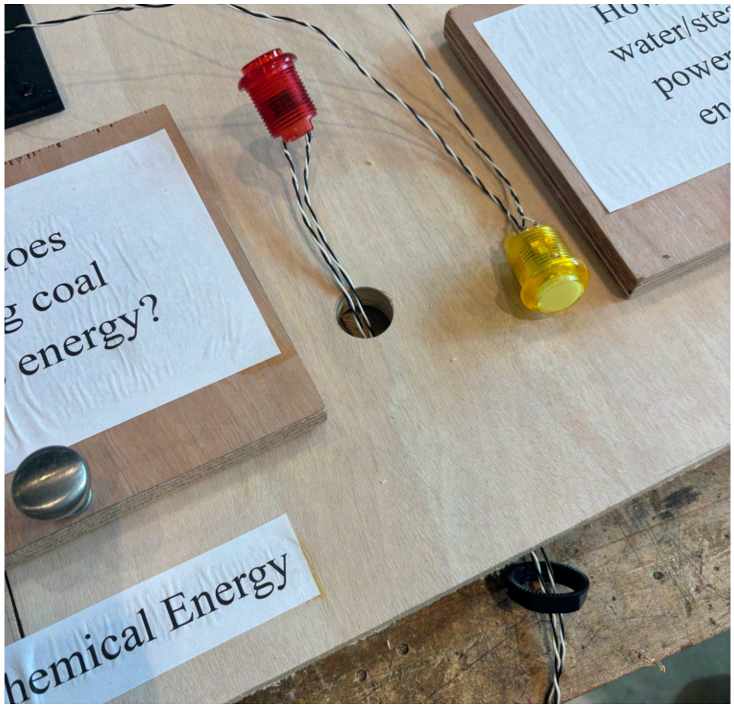

Fig. 43. Red button being inserted into its respective hole with circuitry on the inside.

29. Screw the plastic nut onto the button, noting that the flange should be upright.

Fig. 44. Plastic nut that comes with the button.

30. Upload audio files found in github onto the SD card using a laptop.
31. Download the Arduino IDE here.
32. After opening Arduino IDE, download the AudioZero library with description:
    "Allows playing audio files from an SD card. For Arduino Due only.
    With this library you can use the Arduino Due's DAC outputs to play audio files.
    The audio files must be in the raw .wav format."
33. Plug MKR Zero into a laptop with USB to Micro USB cable, making sure that it is detected by your laptop.
34. Insert SD card into the designated slot on the MKR Zero and flash the code by pressing the upload button.

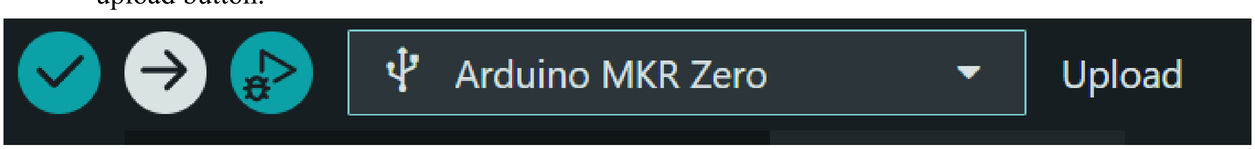

Fig. 45 The upload button is highlighted in a lighter blue. The laptop detects the Arduino MKR Zero in the COM port.

35. Cut smaller lengths of wire to use on the breadboard.
36. Assemble circuitry via this diagram. (White wire was used during assembly instead of red for power. The color of the wires connecting pins on the MKR Zero to the board does not matter.)

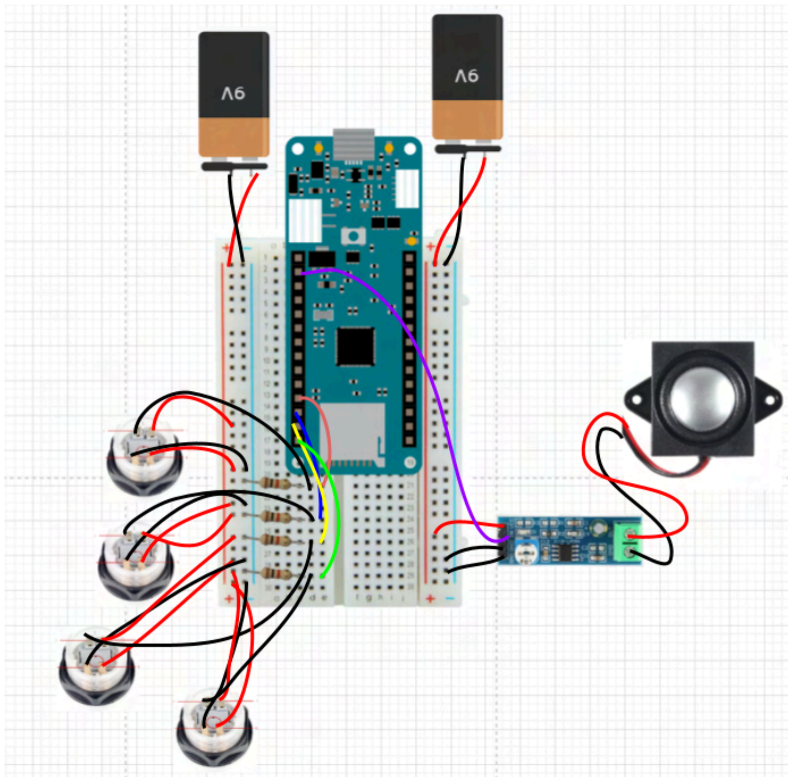

Fig. 46. Schematic of wiring diagram.

37. Build a base out of ¾" thick plywood to hold the mount and platform at correct heights as specified by Fig. 3
38. Cut holes in front of the base for speakers and place speakers into the respective holes with circuitry on the inside.
39. On the right side of the base, 1" hole. With double sided tape, secure the battery to the right of this hole and plug into the breadboard as directed by step 36.
40. With double sided tape, secure the portable charger to the left of this hole. With the USB to micro USB cable, plug the USB side into the portable charger and the micro USB side into the MKR Zero.
41. Cut 64" x 18" of the ¾" plywood
42. Place the plywood flat connecting to the base and mount.
43. Place the model steam engine on the left side of the platform.
44. Hot glue the model train onto a small 3" x 4" x 2" wood plywood block and hot glue the other side of the block to the right side of the platform.
45. Place plexiglass cover over the model steam engine
46. Secure exhibit to back wall to ensure it doesn't fall over
47. Done

Appendix K:

Instructions for Use

Visitors of the Wilmette Historical Museum should interact with the exhibit following the storyboard:

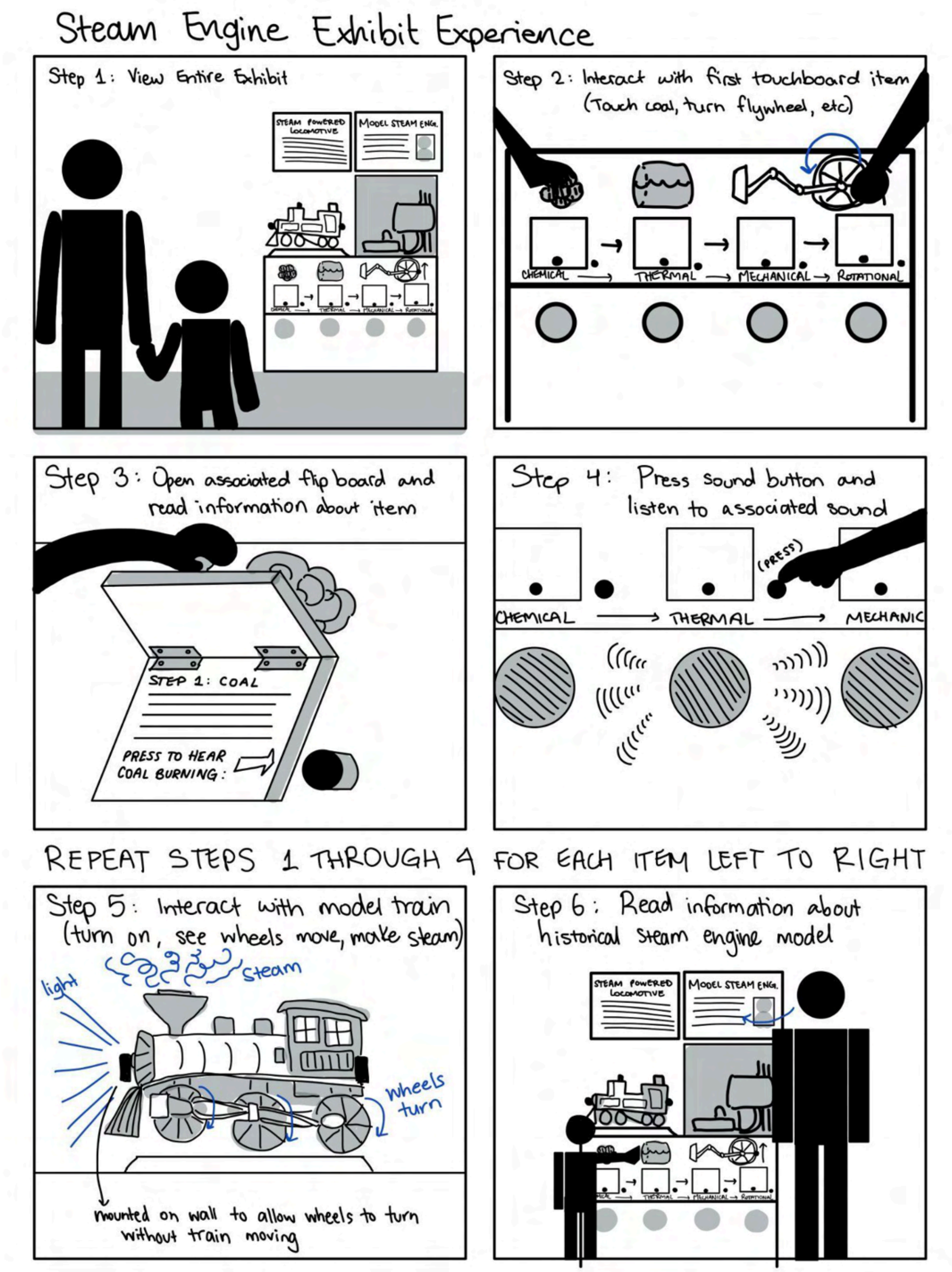

Fig. 46. Infographic detailing steps of STEAM exhibit usage.