MUSE 1: Interactive Water Table Project Report

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Executive Summary

The purpose of this project was to design and construct an interactive water feature to be installed on a vacant outdoor area of land at The Muse, a non-profit children's S.T.E.A.M. (Science, Technology, Engineering, Arts, Math) museum located in Knoxville, Tennessee. In order to effectively utilize this vacant area of land, our group designed a water feature that allows children to learn about water flow and movement. This feature facilitates creative learning and self discovery through various activities while incorporating the themes and geographical elements of the Tennessee River. This feature will provide a safe and interactive learning environment for children that requires critical thinking and problem solving skills, as well as provide an aesthetic outdoor display that is reliable and maintainable.

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Problem Statement

Design and construct an interactive water feature to be installed on a vacant outdoor area of land at The Muse, a non-profit children's S.T.E.A.M. (Science, Technology, Engineering, Arts, Math) museum located in Knoxville, Tennessee.

Review of Last Semester

Statement of Root Cause(s) of Problem

At the beginning of this semester the patio area at The Muse consisted of a large concrete patio surrounded by grass, trees, and other greenery. There were no exhibits in this area, only a few small store-bought water tables and benches for crafts. The Muse wanted an interactive exhibit in this area.

What We Did: Fall Semester

Last semester, we began by researching existing water exhibits, safety requirements of water exhibits, pool regulations, and height and weight ranges for children ages 2 through 12. Using this research, we then created a functions and requirements document. This document outlined our agreement with the Muse to create the exhibit and what the expectations were for this exhibit.

To meet the requirements outlined, we brainstormed what features we would like to include in our exhibit. These features needed to demonstrate the learning concepts outlined in the functions and requirements document. We had a variety of options to choose from, but we eventually narrowed it down to a sunsphere water vortex, a boat racing ramp, a build your own dam section, and a lock and dam section. These features were chosen because of their feasibility to execute and the value of the learning opportunity for the children. We also thought that these features would be fun and engaging for the desired age range.

After the features were selected, we designed the tables that would hold the water and support the features. While modeling the design in Solidworks, we considered what materials we would use. Using a concept matrix, we choose wood lined with plexiglass. The concept matrix clearly showed that wood lined with plexiglass was the best option, because it is strong, water tight, and easy to assemble. Using the chosen materials, we designed the tables in Solidworks to show every piece of wood and plexiglass, which prepared us for the construction portion of the next semester.

After designing the tables and features, we chose a pump that would provide the circulation of water in the exhibit. Using volumetric flow rates, we compared several different pumps. We chose an above-ground pool pump with a 1500 gallon/hour capacity. Finally, we created a bill of materials that included everything we planned to purchase in the spring semester.

Final Design

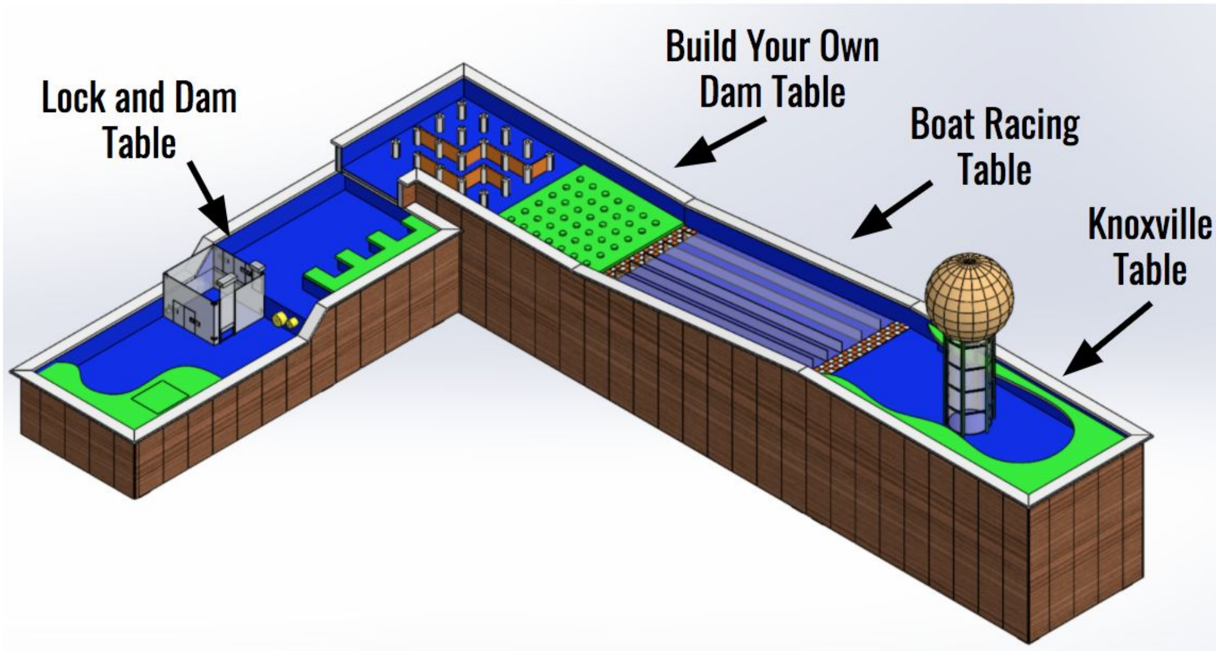

Figure 1. Final Solidworks model of water exhibit

Construction Plan

Base Construction

Before construction could begin, our design plan and bill of materials had to be reviewed. This was done to ensure that the bill of materials was accurate and that our design could be successfully executed. We then created a plan for when certain items needed to be purchased. For the construction of the wood table base, we purchased all of our wood from Home Depot on March 1st. For the 2x4s, we had Home Depot cut them to the lengths specified in our Solidworks design. We preassembled framing that went around the bottom of the 4x4 posts in order to determine where the 4x4 posts would be installed. After marking the locations of the posts, the post bases were installed using a hammer drill. We used removable anchor screws so that the exhibit could be removed if needed. The posts were then attached to the bases, and the wood structure of the table was built off of the posts. This was done according to the Solidworks drawings. As we built, we discovered that 2x4s were sometimes needed in slightly different locations than what we designed. Also, we shortened the ramp table by two feet to allow for a greater slope. These revisions were all easily done and did not impact the integrity of the design.

Figure 2. Wood Base Structure

After the base structure was built, the water trough area was installed using 2x10s and exterior plywood. Both of these materials were purchased from Home Depot. After the plywood was installed, decoration platforms were made using extra plywood and 2x4s.

Figure 3. Final Wood Structure

While the tables were being constructed, we purchased pre-cut plexiglass from ePlastics. The measurements sent to ePlastics were based on the Solidworks design. When the plexiglass came in, however, we had to make some adjustments to the sizes, as our structure did not match the Solidworks structure perfectly in dimensions. These adjustments were made using a small angle grinder with an 80 grit flap disk wheel and by using a jigsaw with a blade specifically for plexiglass. Also, holes needed to be added for the hose attachments and various other reasons. This was done using the ICS lab, the Art and Architecture lab, and using a hole saw. Once the plexiglass was cut to the correct size, we attached it to our wooden table using Iron Grip adhesive. We lined the entire inside of the table with plexiglass and sealed it using a silicone sealant. We then painted Flex Seal overtop of the sealant to ensure our table would not leak.

Figure 4. Wood Structure Lined with Plexiglass

The next step in our construction plan was to add exterior plywood siding to the structure. We chose siding that is frequently used in constructing outdoor sheds, and we painted it a natural brown color. Before installing the siding, we created an access door for the pump. The access door and siding were then installed. This left exposed sharp edges on the top side of the table. To make the sharp edges of the table more child friendly, we attached PVC trim to the top of the table using PVC screws. We also painted our decoration platforms and sealed them with Flex Seal. To finish construction, the features were then installed.

Feature Construction

1. Sunsphere Vortex Fountain

This Sunsphere Vortex Fountain (**Figure 5**) consists of a 10” diameter and 24” long hollow, acrylic cylinder that was attached to a plexiglass base using Weld-On, an adhesive that binds plexiglass to plexiglass. This structure sat on a stand designed to have the appearance of the sunsphere base. It was created by welding round aluminum rods to an aluminum plate. The holes in the aluminum plate were water-jet cut and the plexiglass tube was set on top of the baseplate. Underneath this structure, there is a seperate pump, which is used to create a water vortex in the acrylic cylinder. A gold disco ball sits on top of the aluminum structure. The height of the stand is taller than the cylinder so that the water has room to flow over the edge without touching the disco ball. The feature is attached on the top and bottom of the table using washers and nuts threaded on to the vertical aluminum rods.

Figure 5. Sunsphere vortex fountain

2. Boat Racing Ramp

The boat racing ramp feature (**Figure 6**) includes three racing lanes, separated by plexiglass. The lane dividers were cut in the ICS lab, then blowtorched to ensure no sharp edges. The lane dividers were attached to the table using Weld-On adhesive. To keep these pieces vertical, brackets were designed using extra pieces of blue plexiglass. This was also attached using Weld-On adhesive. Boats for racing were purchased from Amazon.

Figure 6. Boat racing ramp feature

3. Build Your Own Dam (BYOD)

For the Build Your Own Dam feature (**Figure 7**), Lego baseplates were purchased and attached to the table using Weld-On cement adhesive. Using MegaBloks, children will be able to create dams by building walls and other structures on the baseplates. We provided some MegaBloks, and the Muse has more that will be used in the exhibit. For other water manipulation, we developed a 3D printed pylon that along with plexiglass slides can be used to create dams in the water. The pylons were designed in SolidWorks and 3D printed in the Maker Lab in the Dougherty Engineering Building. After the pylons were printed, we had the bottom hole threaded, so they could be screwed onto bolts on the table. The bolts were installed under the table, and a rubber washer, metal washer, and hex nut were installed on the top of the table to keep the bolts in place. The pylons were then carefully twisted onto the bolts. After installing the pylons, the distances between slots were measured to determine the best length for the plexiglass slides. The plexiglass slides were cut in the ICS lab and blowtorched, so the edges would not be sharp. We also provided The Muse with a few extra pylons, just in case any of the existing ones were damaged.

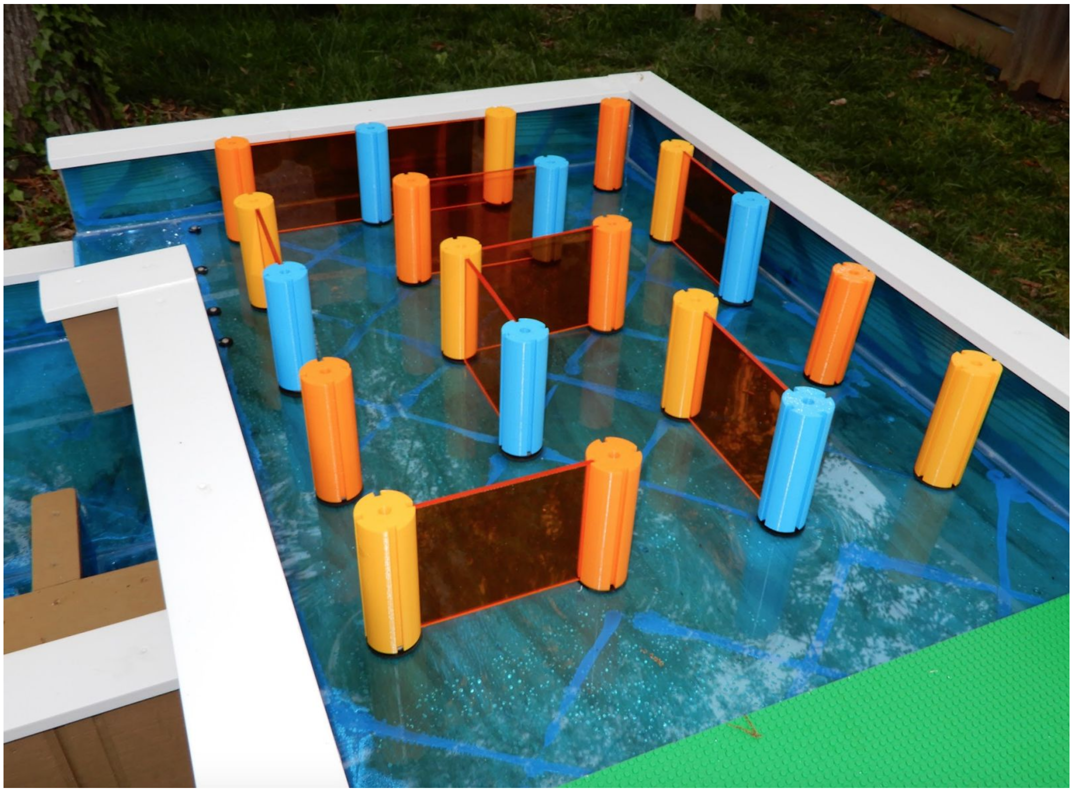

Figure 7. Build Your Own Dam feature

4. Boat Loading

The boat loading dock (**Figure 8**) was constructed using 2x4 wood pieces, plexiglass, and plywood. The 2x4 pieces support the plywood from underneath, and they were screwed directly into the table. Any exposed wood was covered with the plexiglass.

Figure 8. Boat Loading feature

5. Lock and Dam

The Lock and Dam feature (**Figure 9**) was constructed using a thicker, ½" clear plexiglass and attached using Weld-On adhesive. The four sides of the feature were cut using the water jet cutter in the UT Maker Lab. Two slots were machined in the sides to allow for the amber plexiglass to slide and create openings. Plexiglass was then cut to fit into each slot. Plexiglass doors were also cut and attached to the lock feature using brackets and Weld-On adhesive. While the lock is in use, water will continuously flow around the lock on the right side.

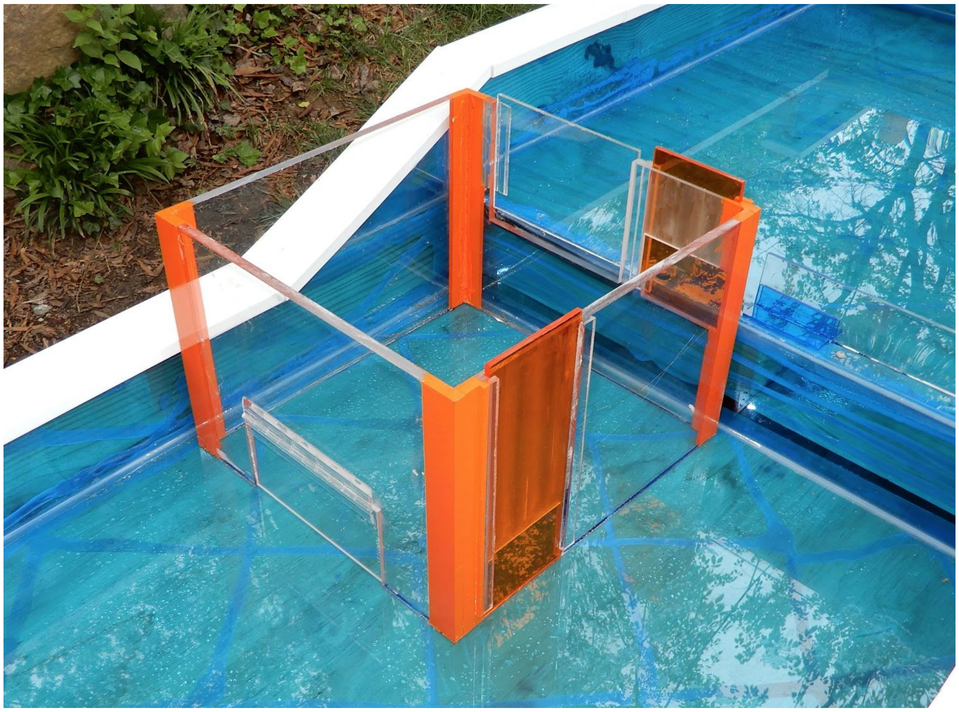

Figure 9. Lock and Dam feature

Appearance of Final Design

Figure 10. Completed Interactive Water Feature

Cost

The approximate final cost of our project was $3,500. This is the total cost, including structural materials, features, and tools purchased. This was very close to the cost we estimated last semester, which was $3,320.52. We were over budget by about $200 due to unforeseen expenses, such as a high shipping cost for the plexiglass. In our initial cost estimate last semester we did not account for enough unexpected costs, specifically costs of tools. Also, we were not aware of everything that we would need this semester. We faced a learning curve that prevented us from having complete knowledge of all needed materials.

Lessons Learned

Throughout the course of the semester, many valuable lessons were learned. First, we learned that building dimensions do not always match designed dimensions. We didn't allow for the expansion and contraction of the wood and plexiglass when we chose the materials. We ran into issues with having to recut materials, because we did not plan for anything to be different from our SolidWorks model. In reflection, it would have been best to build the wood structure first and order the plexiglass afterwards. Then, accurate dimensions could be used and less on-site revisions would have to be made.

We also learned a lot about construction. Before this project we had very limited knowledge on woodworking and power tools. We learned how to use a lot of different tools including, but not limited to, drills, circular saws, hole saws, chop saws, and grinders. Having a successful building day was largely dependent on how prepared we were with the necessary tooling and materials. We also learned that it is very important to schedule time for delays. This semester, rain was a huge obstacle in our construction. It was impossible to seal anything in the rain, and we also ran into some flooding problems around the patio.

We also learned that sealing plexiglass to be waterproof is more difficult than it sounds. If we were to be given an opportunity to do this again, we would build a small model using the materials we chose, to test the difficulty of assembly. Throughout the process of building, we continued to receive suggestions about different ways to make the table watertight. One suggestion had been to use rubber paint or a roofing/pool liner like Duro-Last. These options would produce zero joints, which would ensure that the table was completely watertight. This points back to the lesson learned that it is important to do thorough and careful research in the design phase of any project and to gather as much outside advice and insight as possible before making the final design selection. Unfortunately, in our case, this information came too late and was therefore not a design consideration. Lastly, we learned the importance of working as a team and dividing tasks according to each individual's strengths because with a project as large as this, it is impossible to complete without constant communication and support from one another.

Schedule with Milestones

#	Task Name	Duration	Start	Finish
1	*Review and Revise*	2w	1/14/18	1/28/18
2	Review and Revise Design	1w	1/14/18	1/21/18
3	Review and Revise BOM	1w	1/21/18	1/28/18
4	Review and Revise Gantt Chart	1w	1/21/18	1/28/18
5	*Materials*	4w	1/28/18	2/25/18
6	Procure Non-Structural Materials	2w	1/28/18	2/11/18
7	Procure Structural Materials	3w	1/28/18	2/18/18
8	*Fabricate Parts*	5w	2/11/18	3/11/18
9	Non-Structural Features	5w	2/11/18	3/11/18
10	Structural Pieces in Perkins	4w	2/18/18	3/11/18
11	*Assemble Prototype*	5w	3/18/18	4/15/18
12	Pour Concrete and set in structure at MUSE	2w	3/18/18	4/1/18
13	Attach trough to structrual pieces	1w	4/1/18	4/8/18
14	Attach features and decorations	1w	4/8/18	4/15/18
15	*Testing*	10w	2/11/18	4/22/18
16	Create Testing Plan	1w	2/11/18	2/18/18
17	Test Non-Structural Features	2w	2/18/18	3/11/18
18	Test Structural Features	9w	2/18/18	4/22/18
19	*Presentation*	12w	2/11/18	5/4/18
20	Collect photos of project	10w	2/11/18	4/15/18
21	Outline PowerPoint presentation	1w	3/11/18	3/18/18
22	Interview MUSE employees and children about water	1w	4/15/18	4/15/18
23	Practice Presentation	1w	4/22/18	4/29/18
24	Give Presentation	1d	5/4/18	5/4/18
25	*Written Report*	8w	3/11/18	5/4/18
26	Outline Written Report	1w	3/11/18	3/18/18
27	Start writing introductory stuff	1w	3/18/18	3/25/18
28	Finish Remainder of Report	6w	3/25/18	5/4/18
29	Submit Report	1d	5/6/18	5/4/18
30	*Senior Design Poster*	8w	3/11/18	4/26/18
31	Outline Poster and its contents	1w	3/11/18	3/18/18
32	Create Poster	1w	4/12/18	4/17/18
33	Practice Presentation	1w	4/17/18	4/26/18
34	Give Poster Presentation	1d	4/26/18	4/26/18

Table 1. Predicted Schedule for the Spring 2018 Semester

#	Task Name	Start	Finish
1	*Review and Revise*	1/14/18	1/28/18
2	Review and Revise Design	1/14/18	1/21/18
3	Review and Revise BOM	1/21/18	1/28/18
4	Review and Revise Gantt Chart	1/21/18	1/28/18
5	*Materials*	1/28/18	5/4/18
6	Procure Non-Structural Materials	1/28/18	5/4/18
7	Procure Structural Materials	1/28/18	3/18/18
8	*Fabricate Parts*	2/11/18	4/29/18
9	Non-Structural Features	2/11/18	4/29/18
10	Structural Pieces in Plumbing Services	3/4/18	3/11/18
11	*Assemble Prototype*	3/23/18	4/15/18
12	Structural Assembly at the Muse	3/23/18	3/25/18
13	Attach trough to structrual pieces	4/1/18	4/8/18
14	Install Plexiglas	4/8/18	4/15/18
15	Attach features and decorations	4/22/18	4/23/18
16	*Testing*	2/11/18	4/22/18
17	Create Testing Plan	2/11/18	2/18/18
18	Test Non-Structural Features	4/1/18	4/22/18
19	Test Structural Features	2/18/18	4/22/18
20	*Presentation*	3/23/18	5/8/18
21	Collect photos of project	3/23/18	4/15/18
23	Outline PowerPoint presentation	4/29/18	4/30/18
24	Practice Presentation	5/5/18	5/7/18
25	Give Presentation	5/8/18	5/8/18
26	*Written Report*	4/1/18	5/8/18
27	Start writing introductory stuff	4/1/18	4/15/18
28	Finish Remainder of Report	4/1/18	5/6/18
29	Submit Report	5/8/18	5/8/18
30	*Senior Design Poster*	4/8/18	4/26/18
31	Outline Poster and its contents	4/8/18	4/17/18
32	Create Poster	4/12/18	4/17/18
33	Practice Presentation	4/17/18	4/26/18
34	Give Poster Presentation	4/26/18	4/26/18

Table 2. Actual Schedule for Spring 2018 Semester