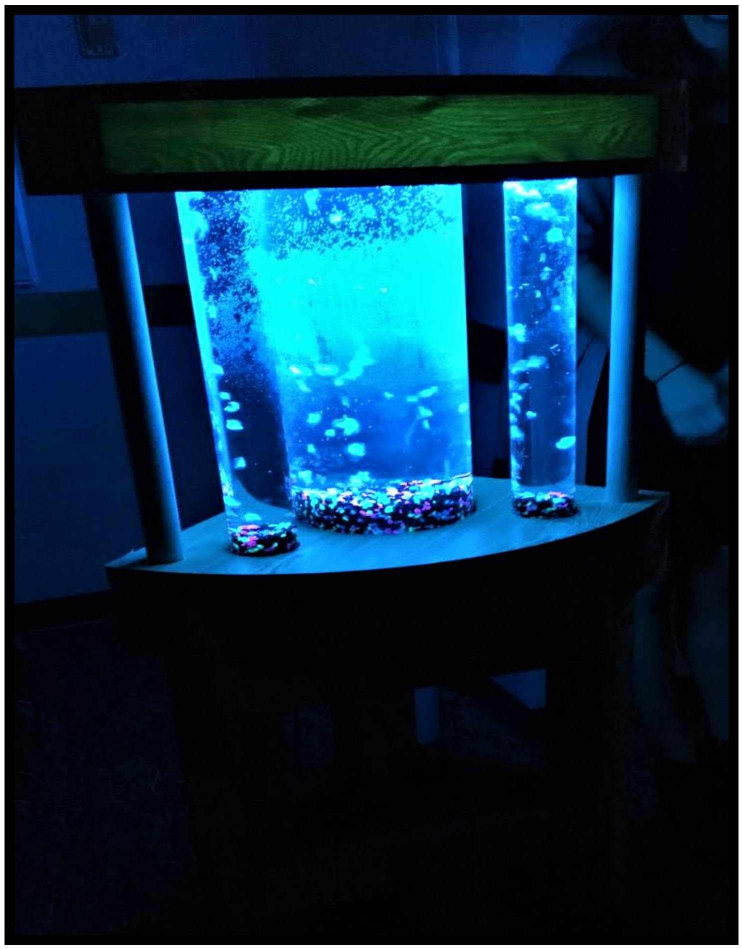
GEEN 2400 Engineering for Community

Final Report

The Sixth Sense



Members: *Rachel Sharpe, Sean Wilson, Beatriz Zepeda, Logan Onstott, Kendall McKay, Patrick Marlatt*

Supervisor: Dr. Malinda Zarske

University of Colorado-Boulder, College of Engineering and Applied Science

Abstract

Students are often influenced by their environment, that’s why thousands of multisensory spaces have been sprouting in schools throughout the country to provide a safe and soothing space for students with disabilities. Naturally, our client, Michelle Grayson, yearned for one in her Intensive Learning Program at Broomfield High School. However, multisensory spaces can cost anywhere from $5,000 to $15,000 dollars. Therefore, throughout the course of the semester our engineering team worked with Michelle and her students to ideate what components would be most fitting and cost effective. We landed on Bubble Tubes to facilitate relaxation and an LED Etch-A-Sketch to facilitate stimulation. Our process in developing the bubble tubes began with building a single tube. We ordered LEDS, acquired a large bubble tube, air pumps, a check valve, 3/16” tubing, and multi-colored, glow in the dark decorative rocks. The design was exciting, but unsatisfied with one bubble tube, we drew up our ideas for the best bubble tube display. We decided on a three legged, rounded corner stand, with built in space efficient electrical housing, and a total of three bubble tubes. To take a 32x32 RGB LED screen from an LED panel to an LED Etch-A-Sketch, we bought a microcontroller, two potentiometers, and a button. We converted the potentiometers’ mechanical rotation to the movement of lights in the x and y directions. Then we paired that with the capability to clear the screen with the touch of a button and implemented the whole system into a handheld wooden display. In the end, we were met with enthusiasm from our client who was ecstatic to gift her students with an escape from the everyday stresses of life.

Table of Contents

List of Figures

1.0 Introduction

Broomfield High School in Boulder Valley School District has a distinct and exceptional feature called the Intensive Learning Program. This program is catered towards multi-leveled and multi-needs high school students with wide and diverse ranges of capabilities. The program had a small space in the school that they requested to be transformed into a sensory space for the students. Therefore, Michelle Grayson-Feldman, a head of the Intensive Learning Program at Broomfield High School, enlisted our project group to help design and create components for a sensory space for her students.

A sensory space is a room or space that has multiple components with many different functions and purposes, all providing relaxing stimulation of some sort. These can range from completely interactive to completely noninteractive depending on the need of the student. The goal is for the students to have a place to go during a busy school day and unwind and calm down when overstimulated. Most of the current sensory spaces that exist are extremely expensive and once installed are very difficult to remove. Our client had hoped for us to design components that featured lights, were soothing and relaxing, and had an interactive aspect for the students who were more inclined to fidget. The product needed to be safe and durable, for the safety of the students, as well as useful to all of the students with ranging differences in ability. Lastly, Michelle noted that it needed to be age appropriate, since many high school students are influenced by what others think about them.

Our design team proceeded to design and construct not one, but two products for Michelle that would fulfill her students' needs; a bubble tube display and an LED Etch-A-Sketch.

2.0 Design Requirements

From the beginning, our client was extremely excited about the idea of the project. As a team, we met with our client for the first time and conducted a brief interview. Our client, Michelle, proposed the project idea to us to design components for a sensory space for her students in the Intensive Learning Center at her school. She wanted something that had lights, was relaxing, and also had an interactive piece that would be able to stimulate her students. She told us about the types of students who would be using the space and that they had a wide variety of abilities. Michelle also informed us that only two students, each aided by a teacher, are allowed to use the space at a time due to the limited size and mild safety concerns.

There were multiple design requirements that we needed to meet in our design. The most important were that the components needed to be soothing and/or interactive. Additional constraints included that the components needed to be battery powered as the room lacked outlets. Finally, we had to be able to easily remove all components for the safety of students and to provide the capability for Michelle to transform the room if necessary. These requirements led to many different developments and iterations of our designs as the project progressed.

A second interview with our client and a few of the students led to the decision of our overall design and product. Michelle was extremely intrigued by the idea of bubble tubes which are quite common among other sensory spaces. As a team, we generated the idea of using a large LED screen in some way. When asking the students what they would like to see the LED screen used for, be it cascading lights or an interactive display, every single one voted for an LED Etch-A-Sketch.

In order to optimize both parts of our project, we analyzed a variety of parameters. One of the components we spent an extensive amount of time researching was how to power both of our products. They both could only be powered by batteries and electrical engineering was a field none of us were fluent in. Another aspect we considered was the safety of the design since students would be using the project every day. These different parameters and how we went about analyzing them set the tone for our design and project in its entirety.

2.1 Design Alternatives and Process

Bubble Tube Design Iterations

The bubble tubes were initially only going to be made up of one large acrylic tube with LED light strips, an air pump, a check valve to prevent water leakage, tubing to connect the air pump to the acrylic tube, and rocks in the acrylic tube to disperse the air bubbles. This initial idea was a rather basic one where the acrylic tube and air pump simply sat on the floor while the LED lights were wrapped around to illuminate the bubbles going through the tube. This singular tube idea had pros in the sense that the center of focus was just on the acrylic tube as well as it was an easy task to transport. However, this initial idea had the top of the acrylic tube wide open and the LED lights were not organized well. Thus, we needed to improve upon our initial idea in order to hide the top of the acrylic tube along with the unorganized LED lights.

Therefore, we came up with the design iteration to create a wooden box that could be placed on top of the acrylic tube to hide the open top of the acrylic tube as well as hide the unorganized LED light strips. The pros to this idea were that the project looked sleeker and more organized as well as the LED light strips illuminated the acrylic tube far better than before. The only cons to this alternative design were that now the project was top heavy and prone to tipping over and that there was now less surface area showing for the students to observe. We then needed to somehow create a way to prevent the project from tipping as well as maximize the viewing surface area.

In result, we decided to add two bubble tubes of smaller diameter and create a corner stand that holds all the tubes in place. The stand would be built out of framing wood and have wheels on the bottom to easily cart the tubes around. The pros of this iteration would be that the stand would make the tubes sturdy and not top heavy anymore and the two extra bubble tubes would make up for the surface area lost for covering the top of the tube. The only problems that are possible would be the wheels not wheeling correctly or the table being capable of still tipping. These would be things to check when testing how efficient the iteration is.

Figure 1

LED Matrix Design Iterations

The LED Etch-A-Sketch didn't take as many iterations, but proved to still be just as difficult, if not more, than the bubble tubes. When we first came up with the idea to create an Etch-A-Sketch, we thought it would be an almost impossible task to accomplish. We initially used an 8x8 LED matrix, but we quickly found that the code is very difficult to figure out and applied on a broader scale. We also found that the code for the 8x8 LED matrix didn't transfer at all to a larger 32x32 LED matrix which we wanted to use in our final design. Therefore, we forgoed the testing on the 8x8 LED matrix and began work on the 32x32 LED matrix. This allowed us to devote more time to figuring out the 32x32 LED code that would create the panel into an Etch-A-Sketch.

We used Sparkfun's library of codes for a 32x32 LED matrix as well as the Hookup Guide they provide to get our screen up and running. After a few iterations of wiring the panel, we managed to get a sample code running. Once we had a sample code working, we decided to move onto the final design and iteration of our product, which would incorporate potentiometers and a button.

2.2 Description of Final Design

Etch-a-Sketch

Our final design of the the LED Etch-A-Sketch included our 32x32 LED panel, an Arduino Mega, 2 potentiometers, a button, multiple wires, and a battery to power everything.

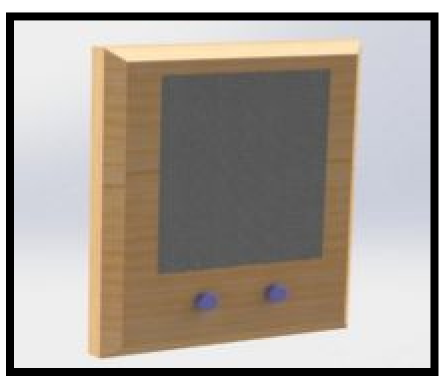


Figure 2

Initially, we hooked up a potentiometer to an individual LED light to make sure we understood the basics of using a potentiometer. We then wired the potentiometer directly to our Arduino Mega, allowing us to see the value that the potentiometer outputs. After hooking up a potentiometer to our Arduino Mega, we discussed our ideas with Dan Godrick, who is a mentor for students in the ITLL. Together we developed an algorithm to convert the range of numbers read from the potentiometer (0-1023) to a range the LED panel could understand (0-32). The code can be found in the third line of 'void.loop' of code in Figure 1 in the Appendix. We used this first potentiometer and the values that were read from it to create a single line in the x direction. Once we saw that making a single line was easy, we moved on to hooking up a second potentiometer. Using two, we created a second variable, allowing us to use one potentiometer to move the row and one to move the column (seen 'Serial.println' in Fig. 1 of Appendix). Finally, we used a button to clear the screen, similar to how shaking a normal etch-a-sketch clears the screen. When pressed, the button outputs a 0, and when unpressed, it outputs a 1. In the code (second-to-last line of code in Fg. 1), we wrote an if statement telling the Arduino that if the button is pressed, outputting a one, to clear the whole screen except the LED that was last turned on.

To create the final look of the Etch-A-Sketch, we created and designed a box for the panel, the button, and knobs to reside in. The box is easy to maneuver, and can either be held or could be attached to a wall with proper accessories. The box holds all of the electronics in a secure manner. We also decided to 3D print larger knobs that fit on the much smaller potentiometers so that the students could use the Etch-A-Sketch with ease.

Bubble Tubes

The dimensions for our sensory space had to be well thought out because our sensory space was merely 8 feet wide, with a small doorway. Additionally, we were working with a public high school, therefore our products had to be free of loose wires, sharp edges, and any additional safety hazards. Lastly, we had to be considerate of the tool and machinery we had to work with in our school's machine shop, so a well dimensioned drawings and CAD models were crucial in developing our full display.

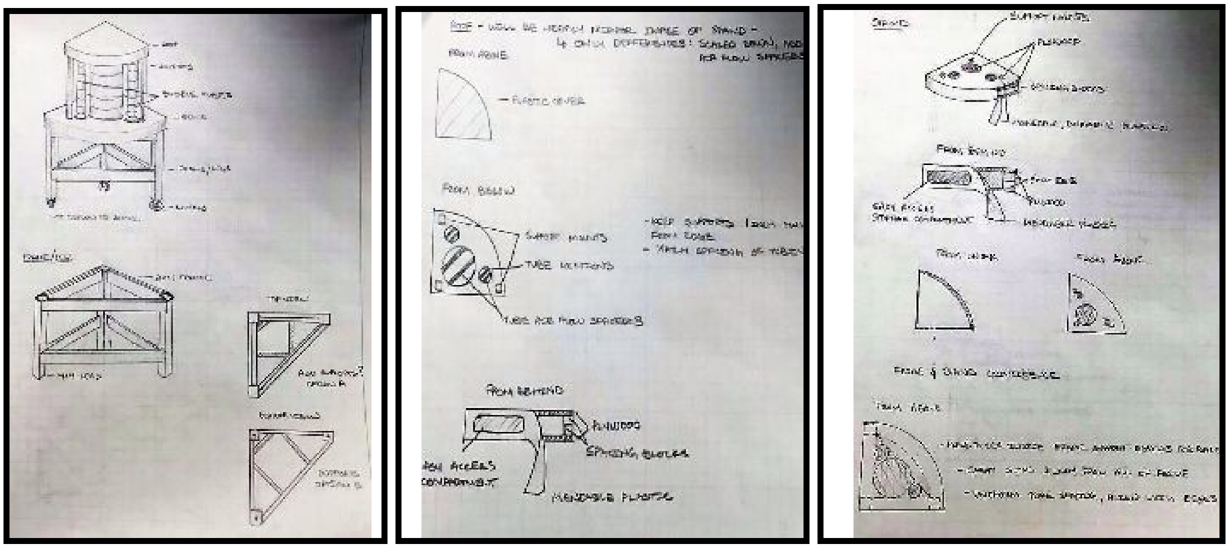


Figure 3

To accommodate the small room, we decided on a corner display table. The table would roll easily, fit through the door, and fill up our 12x8 space while still small enough to leave the room spacious for two users. Our initial designs favored a larger tabletop than roof (as shown in figure 3) but due to our financial constraints and compact space in our school's machine shop, it made the most sense to shrink the table top to match the size of the display's room. However, this had its consequences, which we encountered after completion of the display. With the initial plan of a larger base frame, balance was not an issue, but with the new design plan for a smaller base frame, top heaviness was weighing in as a serious concern. Upon testing our constructed design, we immediately went back to the drawing board and planned for a way to restore balance. Our best option was to add another wheel that would support our table without jeopardizing the table's aesthetics. Therefore, we added a wheel in the center of the outside of the front leg support. This significantly relieved the weight on the back end of the table, allowing us to meet our primary safety constraint.

We originally planned on covering the upper and lower electrical housing with thin acrylic, but this was ruled out financially. Our next idea was to wrap it with canvas, which was not as well thought out as the acrylic and later on ruled out, because we would have to wrap the entire housing components rather than cover individual sections. This was problematic since we needed to put the table together from the inside of the housing components, one step at a time. Our last good option was to cover it with some type of wallpaper, we ended up using contact paper with a wood grain print. This was not ideal since contact paper is much less durable than acrylic or canvas, but we all deemed it durable enough, and it led to another dilemma we did not foresee; LED's shine through paper. At first, we thought that glowing contact paper could take away from the light directed into the tubes, but it turned out to be a pleasing low glow that brought the entire design together.

3.0 Testing

Our project consisted of two critical components that stood as the foundation for our two project components, the 32x32 RGB LED Matrix Panel utilized for the Etch-a-sketch, and the bubble tube structure for the LED bubble display. Both critical components were initially tested at a user testing client meeting with our client Michelle as well as some of her students, at Broomfield high school. We started the testing process with explaining how we expected the prototypes to progress as well as explaining the apparatus that we would be testing during that meeting. We set up the bubble tube prototype and walked our clients through the final design progression that would be happening in the upcoming weeks. The prototype utilized the same motor that was incorporated into our final design, however, differed in the acrylic structure as well as wooden base that was ultimately implemented. We then discussed the critical component, the LED matrix, as we had a scaled version that was running a basic code to show the visual of what an interactive electrical component could be. We further tested the matrix by uploading the code numerous times to exhibit different visual properties such as color and input values, to show and experiment with the potential capabilities of the design. We walked away from our first user testing session with a great deal of positive feedback and constructive criticism to move forward into our next iteration phase.

As we progressed with the project, we most benefited from user and developmental testing in respect to the production of the bubble tubes as it was key to ensuring the bubble tubes were progressing towards optimal functionality. When the bubble tubes were in an initial design phase, we created a prototype to see how the air pump and check valve would function with an interaction of water in an adjoined container. We used a two-liter soda bottle and cut the top off to replicate an acrylic tube and proceeded to poke a hole in the bottom to insert the tubing that would attach to the air pump. We filled the tube up to about two inches with rocks found outside and then completely filled it with water. Next, we wrapped the two-liter with LED light strips that we were going to use with the final iteration to see how they would interact with the bubbles. In the end, we tested the finished prototype and came to the consensus that it worked exceptionally well for its current stage in development.

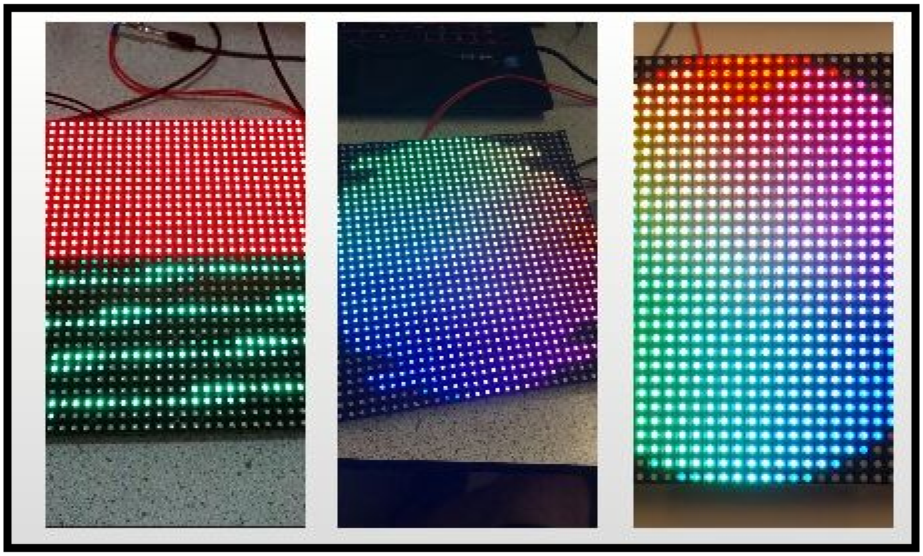


Figure 4

4.0 Analysis

4.1 Analysis of Etch-a-Sketch

Our user testing gave us a lot of useful information for the creation of our etch-a-sketch. We learned that an interactive, hands on product was an absolute must, and that calming colors like blues and purples for the LEDs would be more beneficial than reds or yellows. Though there were only three or four kids we surveyed, every one of them said that an etch-a-sketch sounded amazing. This pushed the idea initially, and helped us create what we did.

In addition to the LED panel analysis, we explored many options for the batteries. At first, we were using 9V rechargeable batteries that were to be hard wired to the LED panel. The week before expo, we found a far easier and efficient option, which is to use a portable phone charger. This just plugs into a USB splitter, then going to both the panel and the Arduino. Not only does the phone charger provide power for longer, but it also is very easily chargeable, since it just plugs into any USB to wall plug. We feel like we found the best option for power in our situation, and are excited to see how Michelle likes the ease of use.

4.2 Analysis of Bubble Tube Design

In the end, we opted to move forward with the design involving an orientation of one large bubble tube with two matching scaled tubes, as well as the wooden support stand with wheels. We combined all of the pros from the initial designs and combined them all into this final design. This iteration for our project allowed for the optimal level of positive aspects paired with the fewest amount of downfalls. As we went through each design we focused on the complications of each and worked to find ways in which to improve the design. This allowed us to come to the readiest and error free final design. The pros to our final design is the overall durability of the three acrylic tubes in the table and the maximized viewing surface area. The top and the base of the stand holding up the tubes can act as a storage area providing room to hide all the cords, LED light strips, and air pumps. The only complications that may arise are the same as stated before, the wheels need to work properly or the table having the capability of still tipping after manufacturing.

5.0 Conclusions

Our goal for this project was to build sensory space for Broomfield high school's intensive learning program students while simultaneously learning new techniques to implement arduino and electrical components into an engineering design. We as a team were able to not only create one functional component for the sensory room, but two. Through user testing, as well as a presentation at the University of Colorado's ITLL Engineering Expose, It was observed that people that came in contact with our project were able to distract themselves with the products and subsequently become entranced and allowed to relax. This surface observation allows us to deduce that our project will have a positive impact in helping the clients to relax during their stressful days as students. This project can be expanded to provide numerous other programs of this caliber with sensory room components like the bubble tubes. If this project could be mass manufactured as well as maintained to keep a feasible price, the idea and impact of a sensory space could have a prolonged and more prominent stance in the current intensive learning system. We would advise future engineers to further the project on a larger scale and to repolish the idea of the etch a sketch into a more robust and sturdy design.

6.0 Budget and Bill of Materials

One of the primary constraints for our project was cost. With each member able to contribute up to $75, the budget for the team was a grand total of $450. In doing some preliminary research on bubble tubes and LED displays we determined the average values for each component and aimed to develop products that substantially mitigated those. The budget for each component rounded out to what is provided below.

6.1 Bubble Tube Display

Item	***Cost***
35” Round 3/4” Plywood (tabletop)	$43.70
8’ Dowel (support columns)	$24.85
3 QTY 12’ 2x4’’ (frame)	$15.41
12’ 4x4’’ (legs)	$8.57
50 CT 3½’’ GRK Torque Lock Screws	$18.80
20 ct 2’’ Self-Drilling Wood Screws	$6.42
6’ Extruded 3/16’’ 2¾’’ Plastic Tube	$20
RC Waterproof LED Light Strip	$20

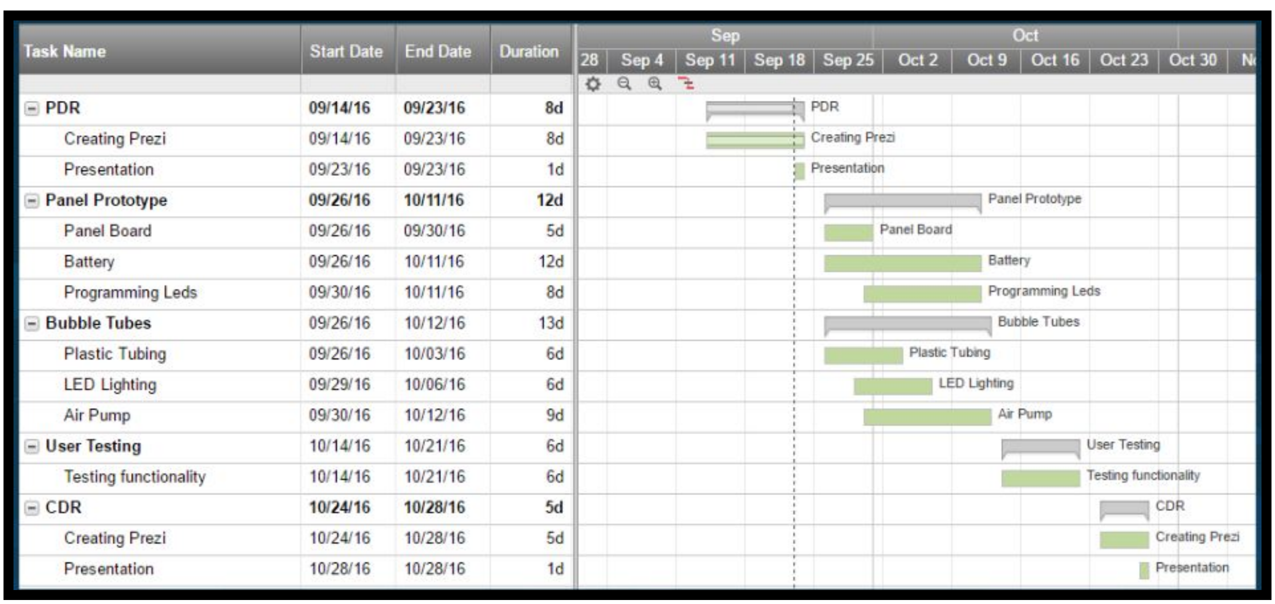
2 QTY 20 Gallon Air Pump	$40
3 QTY Check Valve	$8
3/16” Y tube joint	$2.14
10’ 3’16’’ Soft Plastic Tubing	$6
9’ Self Adhesive Contact Paper	$3.82
Acrylic Glue	$18.52
1x1’ 3/16’’ Black Acrylic Sheet	$6.47

6.3 LED Etch-A-Sketch

Item	***Cost***
9V Battery Pack	$21.99
MicroB USB Breakout	$1.95
USB Cable	$3.95
9V Battery Clips	$6.03
Wood and Screws	$8.23
Misc. (potentiometers, buttons, and wires from Tim)	~$10
Battery	$17
32x32 LED panel	$50
Arduino Mega	$50

7.0 Timeline

As good practice in setting a structural timeline for the progression of our project, our team started off with an initial Gantt Chart in order to keep ourselves motivated and productive with developmental and professional deadlines. As pictured below in figure 5 we broke up the development of our two project components to be evenly spaced out through the semester. There were numerous components of both designs that required their own attention in ensuring the optimal design and functionality in order to be best integrated into our final iteration of the project. As is common for engineering design projects, we as a team had to be flexible and responsive to several obstacles that resulted in a deviation from our initial timeline. There were instances in which sub-focuses of the project, namely the battery operations, were extended into other work periods, or in other cases where we were able to exceed expectations for a deadline. Working off of the estimated project timeline proved to be an excellent learning experience to show that taking into consideration obstacles regarding parts and client input, it is common to allow a responsive deviation in terms of project planning.



Task Name	Start Date	End Date	Duration
PDR	**09/14/16**	**09/23/16**	**8d**
Creating Prezi	09/14/16	09/23/16	8d
Presentation	09/23/16	09/23/16	1d
Panel Prototype	**09/26/16**	**10/11/16**	**12d**
Panel Board	09/26/16	09/30/16	5d
Battery	09/26/16	10/11/16	12d
Programming Leds	09/30/16	10/11/16	8d
Bubble Tubes	09/26/16	10/12/16	13d
Plastic Tubing	09/26/16	10/03/16	6d
LED Lighting	09/29/16	10/06/16	6d
Air Pump	09/30/16	10/12/16	9d
User Testing	10/14/16	10/21/16	6d
Testing functionality	10/14/16	10/21/16	6d
CDR	**10/24/16**	**10/28/16**	**5d**
Creating Prezi	10/24/16	10/28/16	5d
Presentation	10/28/16	10/28/16	1d

Figure 5

8.0 Appendix

```
#include <gamma.h>
#include <RGBmatrixPanel.h>

#include <Adafruit_GFX.h>
#include <gfxfont.h>


#define CLK 11  // MUST be on PORTB! (Use pin 11 on Mega)
#define OE  9
#define LAT 10
#define A   A0
#define B   A2
#define C   A1
#define D   A3
//int data = analogRead(A4);
//int mult = data/1023;
//int row = (mult*32)-1;
//int x = row;

RGBmatrixPanel matrix(A, B, C, D, CLK, LAT, OE, false);

void setup() {
Serial.begin(9600);

  matrix.begin();

  pinMode(12, INPUT_PULLUP);
  //cteates a virtual resistor for the button
}

void loop() {
  float xdata = analogRead(A4);
  float ydata = analogRead(A5);
  unsigned long row = (xdata/1023)*32;
  unsigned long column = (ydata/1023)*32;
  int x = row;
  int y = column;
  //defines variables

  Serial.println(row);
  matrix.drawPixel(x,y,matrix.Color333(5,0,7));
  //print the x value
  Serial.println(column);
  matrix.drawPixel(x,y,matrix.Color333(5,0,7));
  //prints y value
  int I0 = digitalRead(12);
  Serial.println(I0);
  if (I0 == LOW){
    matrix.fillScreen(matrix.Color333(0,0,0));
  }
  //read the button value. if it is 0, then clear screen except the final LED.
}
```

Figure 6