

GNG1103 F
Engineering Design

Temperature Gradient

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April 15, 2019

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Abstract

This report highlights our design process and how we came up with the idea of “Temperature Gradient.” By utilizing the design process, we were able to effectively meet the design criteria of bringing more attention to the equilibrium structure, and of creating more traffic flow through the STEM building’s main entrance. In creating multiple prototypes, the design was iterated until we came up with something that met the required time and budget constraints. Throughout this project, we learned and became familiar with: conducting research and benchmarking, understanding client needs, identifying problems, and generating concepts in order to come up with an effective and satisfactory solution.

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Introduction

Good building design should not only focus on the structural components and the function of the building, but it should consider how its interior environment inspires and appeals visually. In fact, art is a vibrant component of many buildings interior and exteriors and it humanizes any environment, making it more relevant to us as a society.

In March 2018, a group of two civil engineering students, Elliott Carrière and Marc Leblanc, and two visual arts students, Hannah Lacaille and Elizabeth Lebedev, were given the opportunity to produce prototypes for an interactive works of art to be placed in STEM, the newly constructed building in the University of Ottawa. These students came up with the idea of Equilibrium, that was built and installed for the opening of the building in September 2018.

In science, Equilibrium is a state of balance between two opposing forces, which is what this structure represents. As people walk up and down the staircase over which the sculpture hangs, the motion sensors detect the movement and send signals to a mini Computer, Arduino, connected to it, activating the sculpture.

The purpose of our design project was to improve Equilibrium, the existing art installation in STEM. Our original plan was to add new parts to the sculpture itself but due to many restrictions including not having access to it, we decided to increase the traffic volume to the location of the art piece and attract more people to use the stairs rather than the elevators. Due to several facts like the harsh weather in Ottawa and the bad cell service in the building, we decided to design our Temperature Gradient.

Temperature Gradient is a simple, and convenient way for viewers to pass by and readily know the temperature outside without the need of their cell phones or personal experience of leaving the comfort of the building. Along with the useful information it provides, Temperature Gradient perfectly complements equilibrium by bringing people to the area and yet not drawing too much attention away from the hanging structure. In fact, the lighting systems in both projects complement each other and bring the whole area together.

Furthermore, our project is intended to be used by anyone entering or leaving the STEM building from students to professors, or simply visitors of any age. Because, everyone can use and enjoy this informative art installation. Temperature gradient fully fulfills our design criteria

of interactivity and encouraging stair use, while being simple and meeting the time and budget constraints.

Client Needs

The fundamentals of this project circled around the principles of an aesthetic design, while incorporating technical and interactive aspects. The original equilibrium design incorporated LED lights that reacted to the kinetics of users upon the stairs, and changed their light intensity over the course of a day based on volume of usage.

Having a chance to meet with the client, they brought up a number of their concerns once asked about what they would like to have improved or added to the existing artwork. *Table 1: List of Client Needs and Interpretations* elaborates on what the client described of importance for the project. Upon revisiting, it was established, both by the development team and the client, that the main objective was to increase attraction and volume of traffic to Equilibrium.

Table 1: List of Client Needs and Interpretations

Need	Customer Statement	Interpretation of need/Design Criteria	Importance
1	Fix current design	Sensors on the stair had stopped working, thus propose a solution to fix the component thats failing (code or hardware)	2
2	Has to attract students attention	If any amendments done to the design need to be visually appealing, and not take away from the original aesthetic of Equilibrium	1
3	Has to be cost effective	Cannot spend over \$100 CAN	6
4	Encourage Stair use	Increase the usability or desirability of using the stairs	2
5	Do not alter hangin structure	Any modifications done to the hanging piece must only be coding related work, whereas physical components added are left only to surroundings.	7
6	It would be neat if the art related to a surrounding	Find a means in which to relate equilibrium to the surrounding environment, or concept related to engineering or science (environment, time)	4
7	Do not impede stair usage	Stair path cannot be obstructed by any new additions	3

8	Make it interactive	Make the piece function by reason or means of the user or surroundings	5
9	Additions are to be made seamless	Any new components added are to be similar in nature that of the current design	5

The list is ranked starting from 1 (most important) to determine interpreted need value. From the above list and the detailed meeting with the client, the following problem definition and problem statement was formed to guide the focus of the project. The problem definition is used to define what the interpreted overall need is of the client, and the statement is such as a reference to come back to during the design process, to ensure the right “questions” are being answered during conceptual design and prototyping.

Problem definition: “A need exists for an improved sculpture that attracts users’ attention to use the stairs with visual and audio appeals, the issues with the existing sculpture has to be fixed and it has to be safe for users.”

Problem Statement: “To build a new or update the current feature in the STEM staircase to attract people and encourage recurring usage at the staircase. They are to be interactive when people are using the stairs but appealing/attracting when idle to people passing by (as a mechanism of attraction).”

Now that a problem has been identified that has been confirmed to suffice the clients needs, further market investigation and benchmarking can be done to determine viable pathways in progression for this project.

Problem Identification, Research and Justification

The client meeting provided valuable information of what the needs were of us to produce a product that is enjoyable to the client. However, there is more to learn at the actual location in which the current art installation already exist. Thus further investigation of the site is to be done to hone the design criteria.

Combining the results of the client meeting and viewing the location, the lost of requirements ara as follows:

Functional Requirements:

- Components or interaction does not impede use of stairs
- Light and sound
- Sensors consistently interact with users of stairs
- At times of high traffic, the lights and sounds remain appealing to users

Non-functional Requirements:

- Aesthetic
- Lifespan
- Brightness
- Volume
- Safety: all wires/hardware must be secured

Constraints:

- Space/Location
- Cost (CAN \$)
- Dimensions (ft x ft)
- Level of traffic
- Anything directly on stairs should be waterproof

After the site investigation, it became prevalent that the nearby staircase was a viable canvas to conduct further work, as method to not physically modify the current artwork that is someone else's, but also attract user to the area of the work by subtle means. Further discussion with the client confirmed that the idea was accepted and encouraged, thus giving the project compete originality, and maintaining the beauty of the art install.

Benchmarking:

Moving forward with the stair focus, benchmarking could begin to establish possible methods of approach to a product. Ideas that were considered of focus were:

- Underside of the staircase.
- Wall next to staircase
- Railing.
- Additional attachment
- Archway for the doorway
- Piano stairs: they are interactive stairs installations that encourage people to use the stairs rather than the elevators.

Benchmarking revealed current standards of stair features that exist today. Examples of benchmarked items can be found in *Appendix A: Benchmarking Concepts* at the end of this report. *Table 2: Benchmarking Chart of Current Products* encloses relevant items discovered throughout the investigation of similar items that already exist to give a better idea of what our product should cost and target specifications

Table 2: Benchmarking Chart of Current Products

	Product 1	Product 2	Product 3
Product	PDS-4 Fixture	LED Strip Lights	12v RGB Waterproof Flexible LED Strip
Company	Klus Design/Gestalthaus	DotStone	USLED Supply
Voltage	120V AC to 12V or 24V	12V	12V
Mounting System	Steel/Plastic Bracket or Mounting Tape	3M Adhesive	None (Would require glue or an alternative adhesive)
Cost	Not Available	\$22.67 for 2m	\$85 for 5m
Connection Options	Male/Female/Wire	Direct to Outlet	Wire
Colour Options	White	RGB	RGB
Other Features	Casing	Waterproof, Sync to music	Waterproof

Considering the current market items that have just recently been discovered, and the previously perceived design criteria can be modified and concept generation can begin. *Table 3: Revised Design Criteria and Importance factors* summarizes the changes made to or requirements due to the focus of the design being set to the stairs, and their quantitative importance.

Table 3: Revised Design Criteria and Importance factors

Number	Client Need	Design Criteria	Importance Factor
1.	It has to attract students'/user attention.	Any addition must fit the current sculpture and be Attractive, appealing to passers	0.5
2.	Sensors and Arduino code need to be fixed.	The current code is bugged, either create new code or amend the current code.	0.25

3.	Increase visual and audio appeal for users.	Users of the stairs have the ability to interact with the light functions of illuminating features	0.5
4.	Make connections from the sculpture to the stairs.	Create a connection/interaction between stairs usage and the art sculpture	0.2
5.	Secure the sculpture and working parts.	Any added hardware needs to be secured safely in accordance with municipal by-laws.	0.2
6.	It has to be inexpensive.	Cannot cost more than \$100	0.2
7.	Relate to the environment and/or time of day.	Light changes based on certain criteria.	0.2

Table 3 will be used after conceptual design to evaluate concepts and select a viable choice to proceed.

Concept Generation

Concept generation was initiated by each team member through individual brainstorming and idea sketching. In this step, team members reflected on the list of design criteria before creating their list of possible solutions. No judgement was allowed during this phase to encourage “out of the box” thinking.

Overall, team members put heavy emphasis on attracting traffic flow of users to the staircase, but not to distract from equilibrium. The reason for this being that our client is the original creator of equilibrium, and the tasked was set to get more attraction to the piece.

As stated earlier, Table 3 was used to establish how well the conceptual design fulfilled the design criteria. To quantitatively value a concept, the concept was given a number for each criteria based on how well it performed (1-poor, 2-moderate, 3-good). This value was then multiplied by the importance factor of the criteria to give a “performance” number. In the end, each performance number for the design criteria are summed up, resulting in a concepts total score. The total scores are then compared to one another, and the concept with the highest total score is selected to move forward with design, as it best answers the design criteria. A summary of the result, formatted in a design matrix, can be found in Table 4 below.

Table 4: Concept Design Selection Matrix

Design criteria	Importance factor	Piano Stairs	Stair Lighting	Seasonal changing	Doors	Interactive Stairs
1.	0.5	3	2	2	1	2
2.	0.25	1	1	1	1	3
3.	0.5	3	2	2	2	1
4.	0.2	1	2	2	1	2
5.	0.2	2	1	1	3	1
6.	0.2	1	2	2	1	1
7.	0.2	3	2	2	1	1
SUM		4.65	3.65	3.65	2.95	3.25
Design criteria	Importance factor	Dual purpose Stairs	Temp Gradient	Distraction	Trip sensors	
1.	0.5	1	3	1	2	
2.	0.25	2	2	2	2	
3.	0.5	1	3	1	3	
4.	0.2	2	2	2	2	
5.	0.2	2	3	3	1	
6.	0.2	2	3	1	1	
7.	0.1	3	3	1	1	
SUM		3.3	5.4	2.9	4.0	

As a result, the conceptual design to move forward with design is *Temperature Gradient*. For an exhaustive list of the concepts conceived and their selection tables, refer to *Appendix B: Conceptual Designs and Successful Concept*.

Metrics and Target Specifications

Given that the design approach has focused to the stairs, design specifications have to work with building code requirements. Building codes have been released to not only keep everyone safe but to also not “injure” the building in anyway. The specs will revolve around the staircase, the Arduino boards, the lights, the wires and the doorway.

For the design of the replica staircase: Using the building code guide of Ontario, the staircase must meet certain specifications. The riser height must be a minimum height of 4 inches and a maximum height of 7 inches. The stair tread has its own dimensions that must be satisfied. The depth of the stair tread must be 11 inches minimum and the width of the steps are usually around 36 inches. (Queen’s Printer of Ontario, 2018) Using this building code we will be able to visit STEM and record its measurements for the staircase and try to incorporate lights underneath.

Injuries resulting from falls on stairs caused around 50,000 visits to the Emergency room in Ontario in 2015. (Cowle) Research has shown that injuries from falls on the steps occur usually on the first three steps or the last three steps of a staircase and that’s without tripping hazards in the way. We spoke with the client briefly and he discussed that when Equilibrium was in the design stage and being built there were certain specifications that they had to meet in regards to their wiring and height requirements/placement of the sculpture in STEM. The client had mentioned specs that the sculpture being 2 meters out of reach and all of the wiring had to be contained in tiny boxes and secured on the wall. Since our design is on the stairs itself, any added features must be mounted in a hard case to avoid injury and destruction of material.

The Arduino board currently in use for Equilibrium is hidden under the staircase, and out of site from users. This method allows access for maintenance and protects it from undesired moving. The Arduino to be used for temperature Gradient will follow the same method of protection.

Planning and Scheduling

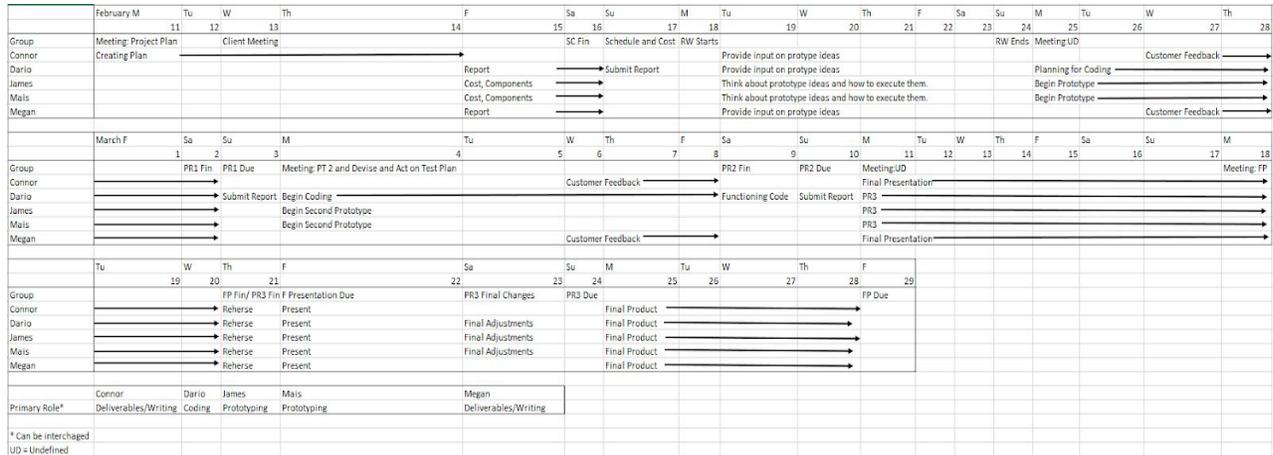


Figure 1: Process and Scheduling Chart for Development of Temperature Gradient

After our first client meeting and after making our final decision on what we wanted to do going forward, we were able to come up with a plan. The purpose of the plan was to streamline our design process, which allowed us to divide up work and ensure enough time was allocated to complete tasks. While this schedule was helpful in organizing what needed to be done, it was very rarely relied upon for actual work. Many individual roles within the group were interchanged, and there was a large amount of overlap in who covered what areas of the project.

Methodology

We followed a three-stage process in our methodology for creating our design, and each stage corresponded with a prototype. We began with multiple conceptual ideas, including plans for lights and sound. Our second stage was creating a physical, working concept that narrowed our focus to what we could reasonably accomplish in the timeframe. The purpose of the third and final stage was to bring everything together into a fully functional and representative third prototype and final product.

As previously mentioned, at the point where we began construction and planning of our first prototype, the finished product was still very much in the conceptual stage. We used this time to come up with multiple ideas and goals for the project, ranging in functionality and visual appeal. We wanted to ensure that none of our budget was used on parts of this prototype that would not physically contribute to the final project. Because of this, the first prototype did not contain any functioning parts, but allowed for reorganization and manipulation of pieces to provide a visual concept. Without having received any prior feedback, this made the most sense as it allowed the client to easily provide feedback and adjustments.

This prototype was made from 100% recycled or household materials and it contained two areas of focus: the front face of the steps, and the railing. We focused on these locations since they were the easiest places to apply our ideas without impeding the functionality of the staircase, and since the equilibrium structure could not be touched, we were confined to this. Creating a simple frame out of cardboard boxes allowed for the easy visualization of the workspace, and the railings made from sticks and string were simple and allowed for objects to be placed on the sides of the space.

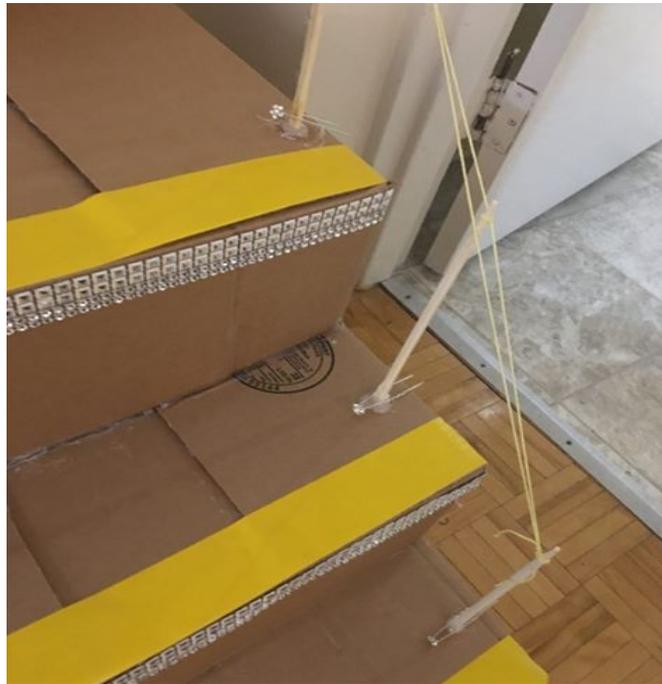


Figure 2: Prototype One - Low Fidelity, Zero Dollar

The prototype featured visual representations for three key concepts: light strips, sensors, and sound. The light feature was the first idea we implemented and was our focus from the start. This was represented by jewel strips, as seen in the figure. Ideas for the lighting were what colours the LEDs would be, as well as its specific placement underneath the step. Motion sensors already existed for equilibrium, so if they were to be included, it made the most sense to include them in a similar location, being the wall. It did not make sense to include a wall in this prototype since it would be bulky and resource heavy, so the bobby pins representing the sensors and the railing attachment points were sufficient for demonstration purposes. The bobby pins also served to represent where speakers could go in case we implemented sound. Our initial idea was to combine the lights, sensors, and sound to create a virtual piano that ran up the stairs and triggered as people used it. While this was a feasible idea, it was decided that in the interest of time, we would not include sound, and switch to a single, external sensor that would be located outside of the scope of the project that records the temperature and conveys it to the light strips. This is where we finalized the components and locations of Temperature Gradient.

The second prototype was a focused physical model. It contained 19 neopixels, an Arduino Uno board, multiple wires and a temperature sensor. Its success and failure criteria was based on whether the model worked. At the start of the second prototype the idea was to have two codes that would work with the different aspects of the stairs and then figure out a way to link them together. The first code was meant to use a temperature sensor and then based on what the temperature detected was, it would result in a certain colour of light being emitted from the neopixels. Warmer temperatures would result in reds, oranges and pinks being emitted and cooler temperatures would result in different shades of blues and violets to be emitted. The other code was designed to relay the motion detected by the motion sensors to activate the lights. The lights would turn on and emit the color of light they were supposed in accordance with the temperature and then with a certain time delay they would shut off after a predetermined time interval.

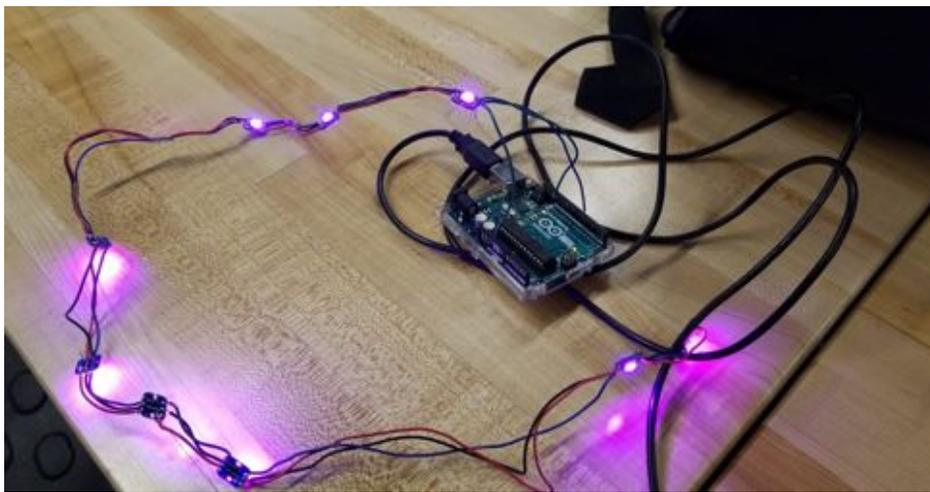


Figure 3: Prototype two - Focused, LED Lights and coding

In theory this was all relatively straight forward. Unfortunately, due to a time and budget constraint, this is where our group ran into a couple of issues with the design concept at this stage. The primary issue was that there was no simple way to connect the two codes. After sitting down with the client, the second code was completely scrapped. The improved design concept proposed that instead of the lights turning on and off when someone activated the sensor, the lights would remain on during the day and as the temperature increased or decreased during the day, the colour of the lights would change also to reflect on the temperature. The client, the engineers of *Equilibrium*, approved of the idea and the project was given the go ahead to continue. The client expressed interest in this new design concept as it still met with the client's needs and was still able to be paired with equilibrium without taking away from *Equilibrium's* unique aspects.

The temperature sensor is capable of detecting temperatures ranging from +129°C to -86°C. Hopefully Ottawa will never have to experience temperatures close to those extremes but regardless, the sensor is capable enough to withstand the temperatures in Ottawa. The code was designed to only reflect the colour spectrum that corresponds to the temperatures from +25°C to -25°C. This is a much more suitable range for the temperatures that Ottawa is exposed to. This prototype has the ability to emit 11 different colours

from the neopixels associating with 11 different temperature ranges. The figure on the right represents most of the colours that can be emitted from fondant to violet and 9 shades in between. The second prototype contained an Arduino Uno board, connected by usb cord to the computer to run the code. On the other end it contained multiple wires that were attached to each neopixel. The wires were soldered the the neopixels to connect the to make a long strand.

Fondant	1	25+	
Pomegranate	2	23	24
Lipstick	3	20	22
Shrimp	4	17	19
Sunshine	5	14	16
Saffron	6	11	13
Citron	7	8	10
Spring green	8	5	7
Grass green	9	3	5
Aspen	10	0	2
Sherbet	11	-0	-2
Cloud Blue	12	-3	-4
Aster	13	-5	-7
Denim	14	-8	-9
Bluebell	15	-10	-12
Wisteria	16	-13	-15
Violet	17	-16	-18
Plum	18	-19	-24
Black	19	-25	
Creme			

Figure 4: Temperature Scale Model Used for Temperature Gradient

The second prototype ultimately proved to be a success. It met all of the clients needs and withstood all of the growing pains throughout the design phase. The plan of action from this point it to hone and test any coding bugs, and the create a stair canvas for the light rail to sit. In addition, a protection method had be implemented for wiring and the LED lights, as they are currently exposed and non-rigid, supported by the wires alone.

Solution: Final Prototype

The final prototype combined the concept of the first prototype, and physical components of the second prototype to create the finished product. The staircase created used recycled wood, a 2x2 and a 4x2 to create two steps to model the stairs found in STEM. Other supplies to make the staircase included, yellow tape, black spray paint, and screws. As is noted in *Appendix C*, plans were drawn up on AutoCad for the schematics. The strip with the neopixels was inserted into vinyl tubing and reinforced with thin pieces of Balsa wood so that the neopixels would remain facing the proper way in the tubing, and to refrain the tubing from bending to original coiling at purchasing. The vinyl tubing was chosen for a couple of reasons. The first reason was that it kept the light more focused so that it refracted over more area on the stairs and secondly it helps protect the neopixels. The steps on the STEM staircase have a small overhang which allowed for the vinyl tubing to be placed underneath the steps so that it would reflect on the step below. The whole second prototype was implemented into this final design. The wiring with the neopixels was in the vinyl tubing and then the Arduino UNO sat just behind it, attached to a laptop and the temperature sensor. *Appendix C* contains photographs that document the smaller aspects of the finished prototype such as the vinyl tubing with the neopixels and the construction process of the staircase.

On design day the heat from someone's hand and a cooler with ice water provided the source for the temperature change. This allowed for the project to be displayed on design day. For the future, the temperature sensor would actually be outside or it would be connected to wifi. And the code would run without needing a laptop right beside it.

There was a great deal of testing completed. One test had to do with the temperature sensors and LED functionality with the correct colour response. This testing had to be done to ensure that the colour emitted directly corresponded to the correct temperature. Warmer temperatures resulted in reds, oranges and pinks and cooler temperatures corresponded to blues and violets. Colours that travel faster through the neopixels by signal are reds and pinks and colour that travel slower are the blues and purples.

The second test had to deal with the stairs strength testing. The prototype was designed to be a fully functioning and usable model so strength testing had to be completed on the staircase. The stairs tested successful in withstanding the weight of the team members. This signifies that they can support the load capacity of users without collapsing. The stairs were tested for weak points in the construction and none were found.

The finished product passed all of the tests and the prototype could be labelled a success. The client was very happy with the finished product and it met all of their desired needs.

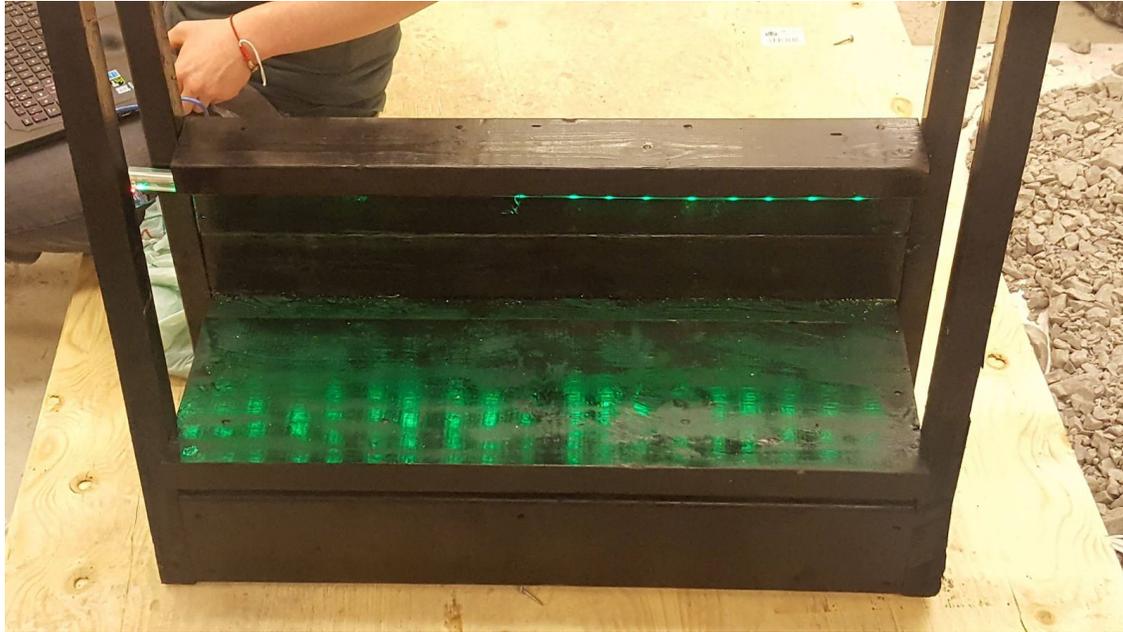


Figure 5: Final Prototype After Construction

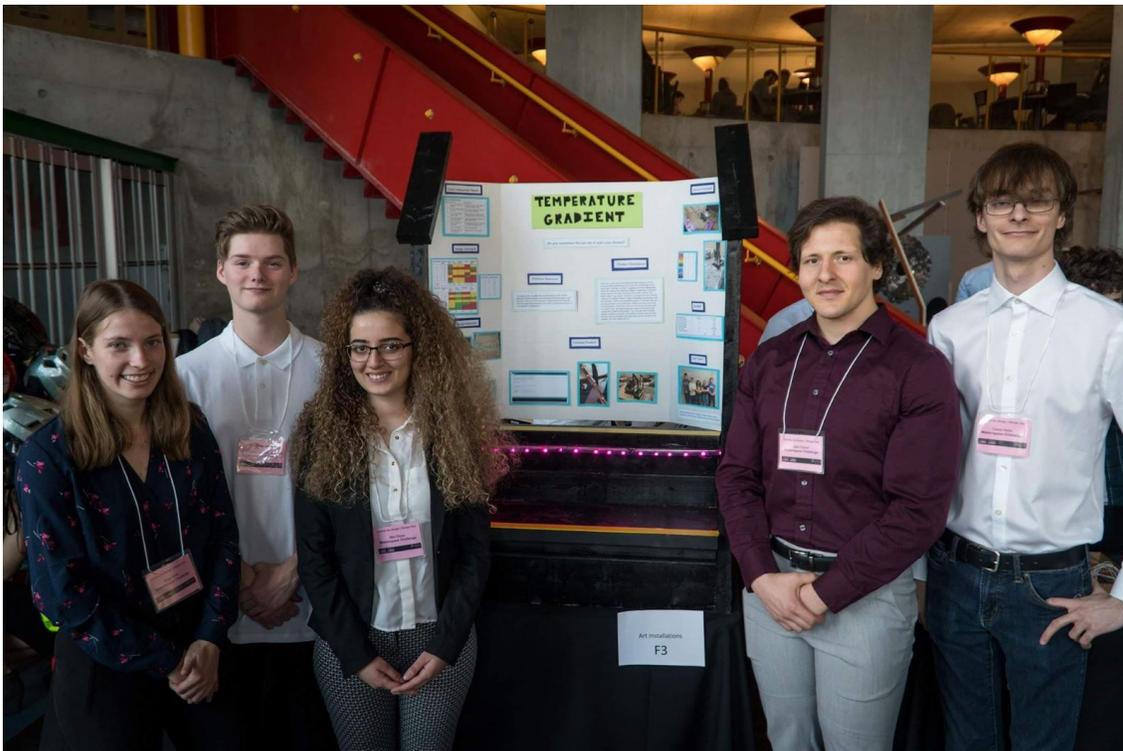


Figure 6: Final Prototype and Design Team F3 on Design Day

Cost Analysis and Materials

As stated earlier in *Table 1*, the budget of the project was constrained to \$100 CAD. This meant that a comparison, validation, and purchasing of all materials has to be stringent to ensure keeping below budget. The use of recycled material and donations were heavily used in the production phase as to save on expenses. *Table 5* supplies a *bill of materials* (BOM) and details total cost of each production phase.

Table 5: BOM List and Cost Summary

Material	Quantity	Cost (CAD)	Acquired Location	Model
Cardboard Boxes	x6	Recycled	Household Material	Prototype 1
Jewel Strips	x3	Recycled	Household Material	
Bobby Pins	x6	Recycled	Household Material	
Wooden Dowels	x6	Recycled	Household Material	
String	x2	Recycled	Household Material	
Total Prototype Cost: \$0.00 CAD				
Arduino Board	x1	27.00	MakerLab	Prototype 2
Bread Board	x1	5.00	Makerlab	
Neopixels	x19	Donated	MakerLab	
Temperature Sensor	x1	7.00	MakerLab	
Total Prototype Cost: \$39.00 CAD				
Recycled Wood		Donated	Structures Lab	Prototype 3
Nails		Donated	Structures Lab	
10 foot 2x4	x2	9.94	Home Depot	
8 foot 2x2	x2	5.35	Home Depot	
Clear Vinyl Tubing	x1	13.01	Home Depot	
Black Spray Paint	x3	15.45	Home Depot	
Total Prototype Cost: \$43.75 CAD				
Total Overall Cost: \$82.75 CAD				

The total cost of the project came to be \$82.75 CAD, within the \$100 CAD budget. In hindsight as a learning lesson, a fair number of dollars (\$30.74, or 30.74%) of the total budget was spent on the model stairs, which was more supplementary to the project when compared to the light components. A better balance of budgeting and time could have been exercised to allow more money to be put towards the functional parts of the design. However, the final result was still under budget and functioned accordingly.

Lessons Learned: Recommendations

Throughout this project, the team ran into some constraints, both on “everyday life” aspects, compliance, and legal aspects.

Starting with the most obvious, the main constraints that the team ran into were time, money, materials and manpower. When the project was obtained back in September, team members were convinced that with over two months to complete everything, there was plenty of time. Nonetheless, it was amazing how fast time flew. Moreover, there was a budget limit of one hundred dollars. As a group, quite a bit of time was spent finding way to optimize the materials to be used with the fixed funding. It is easy to say that it was preferred that the lighting were to be built out of manufactured LED strips, and have 60 per meter. However, this option was not realistic knowing that inexpensive materials could do just as good of a job, thus learning frugality. Materials also somewhat tie into money as the team ran into a lack of materials due to the spending cap. Materials got expensive and as such the contingency of the budget get spent early on. For the final prototype, strength test for the light tube was refrained from being done as the money wasn't available to replace certain aspects of the light rail, and risk for design day increased. Lastly, for a group of five people with five other classes to juggle, it was amazing to see how each member was able to accomplish a large amount of work altogether. However, it would have been nice to have more manpower/womanpower so that tasks could be delegated evenly amongst people rather than heavily focused on availability and willingness to work.

Dealing with compliance constraints specific to the public environment was not that difficult, because they were mainly common sense constraints. First, working with general public meant to preserve their wellbeing. The team had also to be aware of some codes that apply to public stairs, such as the *Ontario Building Code* and *National Building Code of Canada*. However, since the product has a goal of attraction and has nothing to do with the the building of stairs, the team hasn't found any legal regulation that should be applied to Temperature Gradient. Obviously, for the safety of users, the wires and all electrical components need to be properly soldered and protected, as to avoid any risks of injury and damage.

Due to legal reason and intellectual property, the trademark *Arduino*® will be indicated on the product, since it was the main electronic component used in the operation of the Temperature Gradient, and the basis of the code was also picked on *Arduino*® official website.

Conclusion

In conclusion, the development of Temperature Gradient came out a success. A plan was set out from the beginning to orchestrate the order of events that would come before the project. Constant iteration, timeline planning, feedback evaluating, and other necessary managerial tasks relating to the project are the reason Temperature Gradient came to completion with satisfaction. However, they did not come along with their own lessons.

Through the trials and tribulations of this project, tasks of working in the real world were more than just a reality, but a lesson. Learning to deal with a real client, and not an imaginary criteria sheet, forced the development of real empathy and care when designing the final project. By virtue of this, team members are more willing to learn to adapt for a common goal within a group setting, through means such as conflict management. When the effort and stress put into a project is real and whole hearted, the taste of success afterwards is much warmer and satisfying, knowing someone real will get to enjoy the fruits of the labour.

Although, being that people are dynamic, so can be the product. Future development of Temperature Gradient starts from basic improvements, such as higher durability or stronger materials. Furthermore, the original concept consisted of wireless temperature sensors, so including wireless or bluetooth function can be added to improve further the design, as currently its wired directly to the arduino board. Other modes of improvement and advancement include; adding human interaction elements, integrating Equilibrium with Temperature Gradient to work in sync, and adding more sensors to highlight weather patterns, continuing the weather theme.

As a result, the entire group is very proud of the final product and had minimal issues that in hindsight would be changed. The group worked well together to overcome hurdles and came out with a completed and functioning product under budget, that the client truly enjoyed. Thus, the process of creating Temperature Gradient is deemed a success.

References

Cowle, S. (2016). Injuries from Falls on Stairs in Ontario. *Ontario Injury Compass, Issue 14, December 2016*. Toronto: Parachute. Retrieved from <http://www.oninjuryresources.ca/downloads/compass/compass-2016-12-falls-on-stairs.pdf>

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Appendix A: Benchmarking Concepts



Figure A1: Light installs to the side of the stairs



Figure A2: Light feature subtly hidden beneath the handrail of a staircase



Figure A3: Archway light installation, possibly able to be conducted around the doorway leading to staircase

Appendix B: Conceptual Designs and Successful Concept

Table 4: Concept Design Selection Matrix

Design criteria	Importance factor	Piano Stairs	Stair Lighting	Seasonal changing	Doors	Interactive Stairs
1.	0.5	3	2	2	1	2
2.	0.25	1	1	1	1	3
3.	0.5	3	2	2	2	1
4.	0.2	1	2	2	1	2
5.	0.2	2	1	1	3	1
6.	0.2	1	2	2	1	1
7.	0.2	3	2	2	1	1
SUM		4.65	3.65	3.65	2.95	3.25
Design criteria	Importance factor	Dual purpose Stairs	Temp Gradient	Distraction	Trip sensors	
1.	0.5	1	3	1	2	
2.	0.25	2	2	2	2	
3.	0.5	1	3	1	3	
4.	0.2	2	2	2	2	
5.	0.2	2	3	3	1	
6.	0.2	2	3	1	1	
7.	0.1	3	3	1	1	
SUM		3.3	5.4	2.9	4.0	

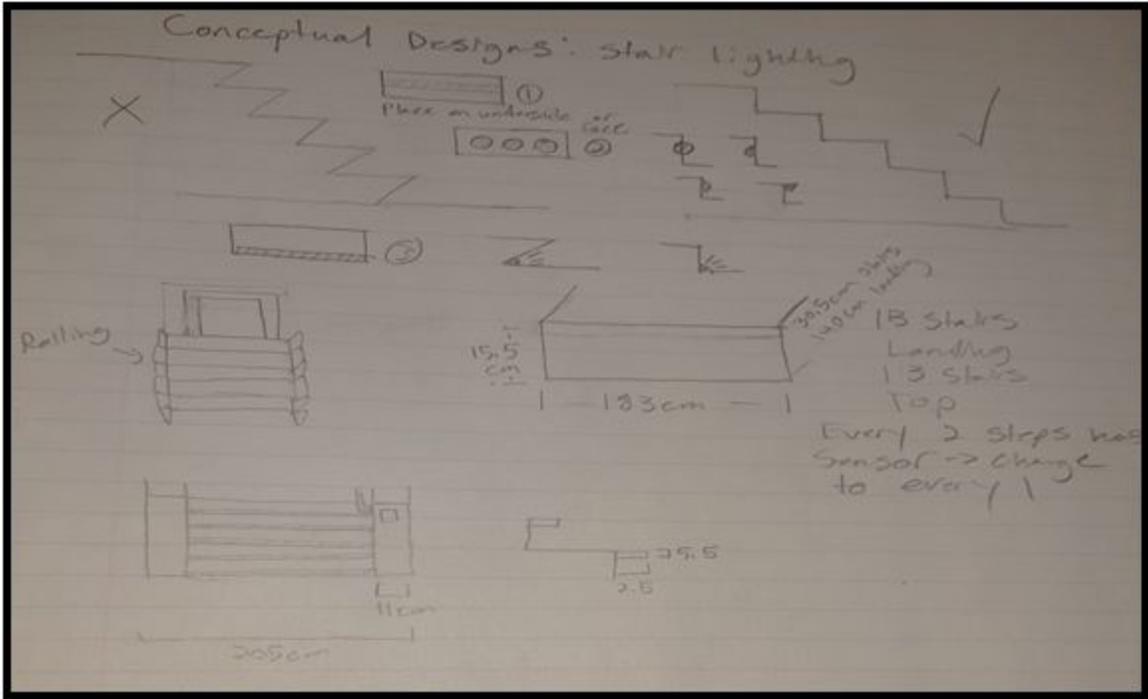


Figure B1: Stair Lighting Concept

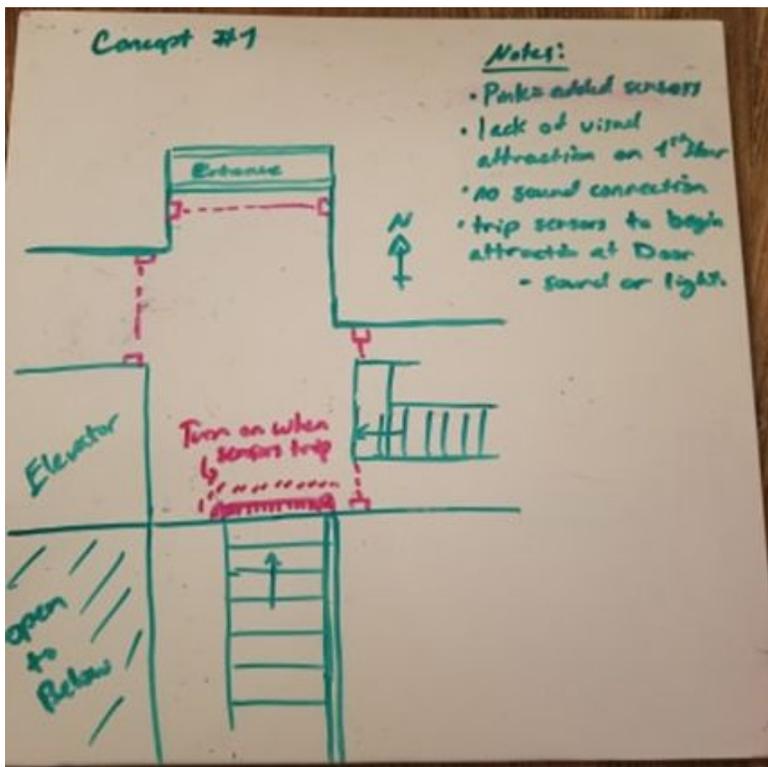


Figure B2: Trip Sensors Concept

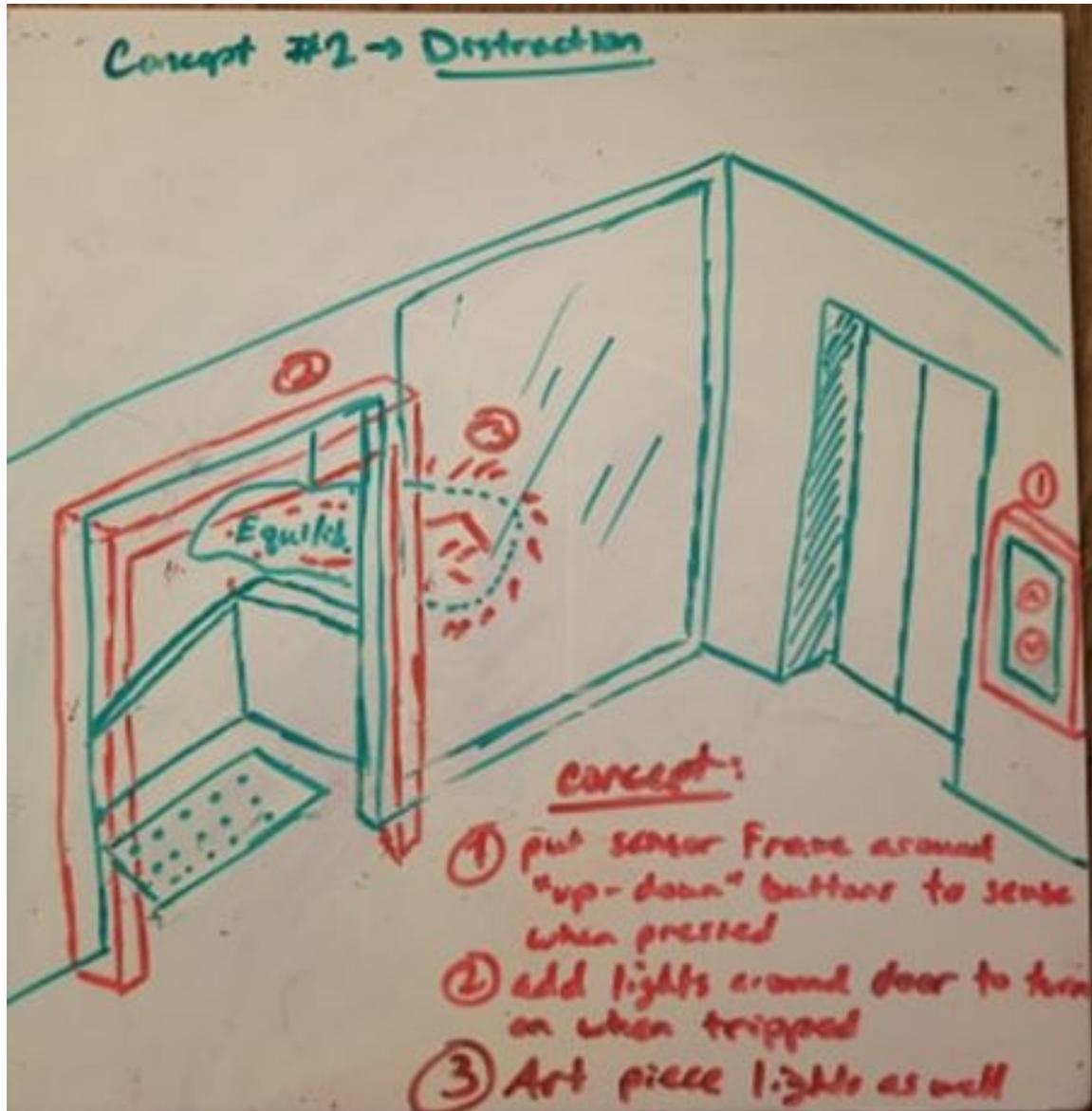


Figure B3: Distraction Concept

Concept #3: Temp Gradient.

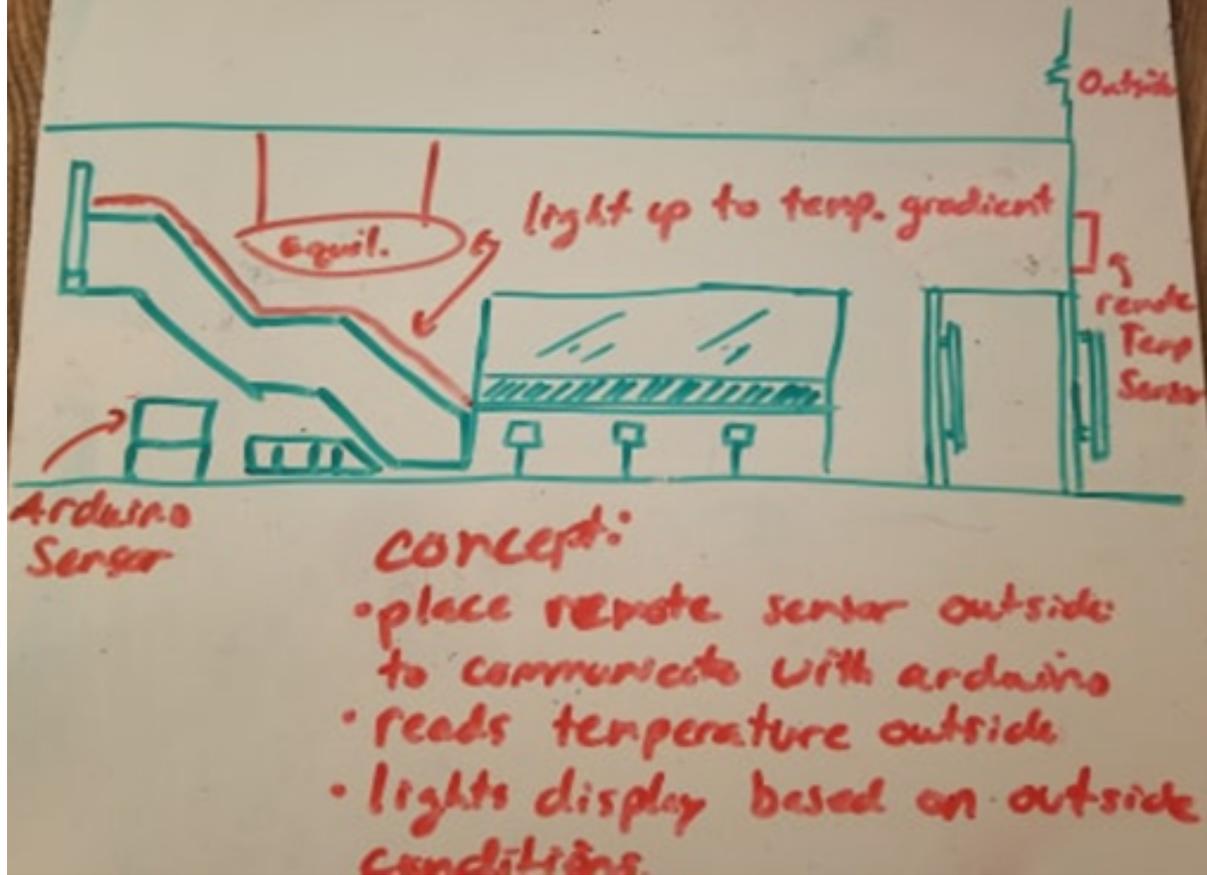


Figure B4: Temperature Sensors Concept

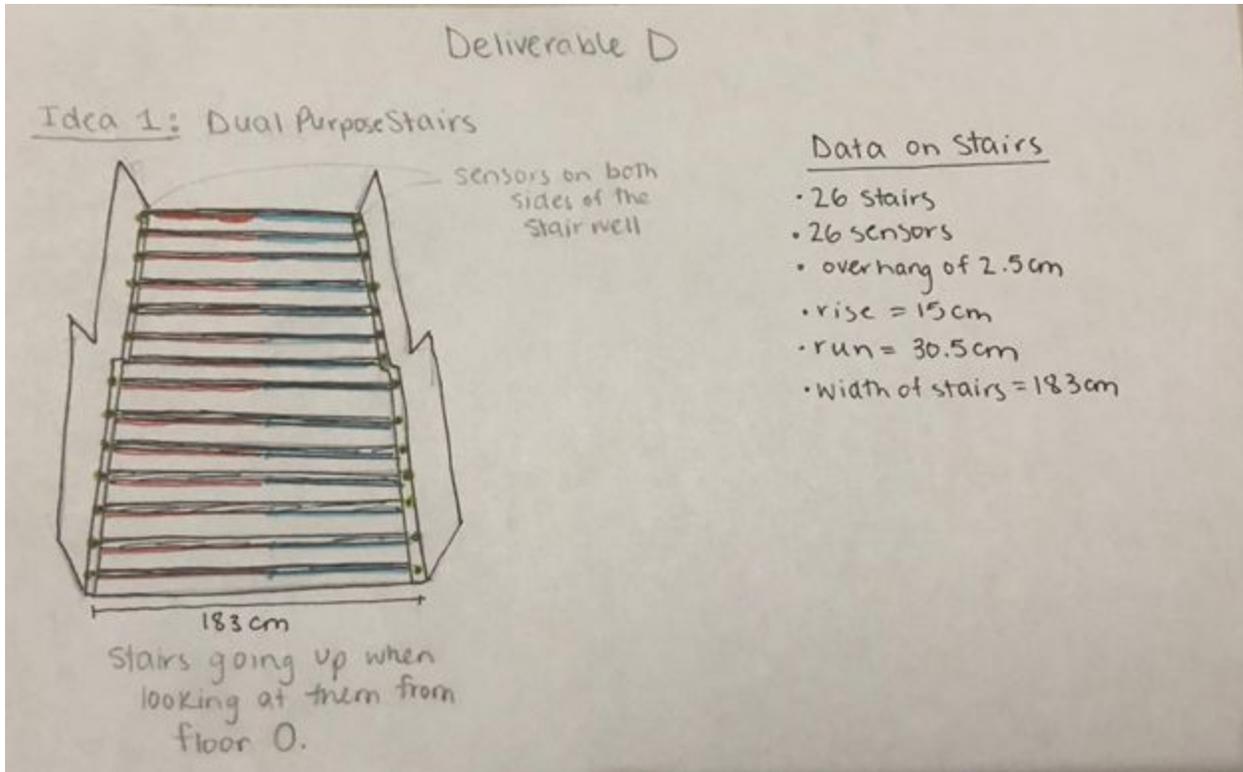


Figure B5: Dual Purpose Stairs

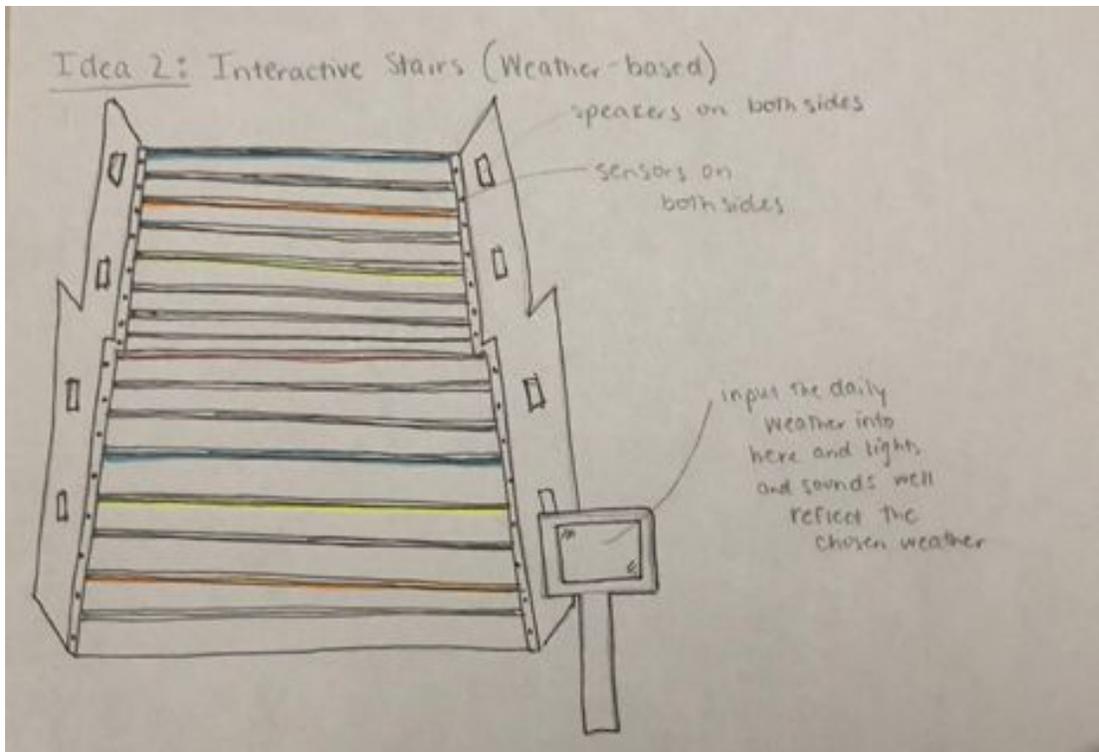
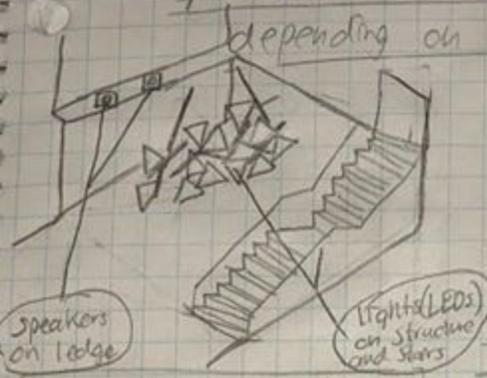


Figure B6: Interactive Stairs

Idea 1: Lights/sound changing on depending on time of day



Speakers on ledge

Lights/LEDs on structure and stairs

8:30am - 6:00pm busy hours

6:00pm - 8:30pm night hours

sound

- low/no sound during busy hours to avoid messy sounds
- simple sounds and small duration to allow for a large amount of users
- Night hours more complex sound functions
- long durations for single users to enjoy

Lights

- low light changes/microactions during busy hours
- simple light patterns/functions that are fast allowing for effective interaction with a heavy load of users.
- More complex light functions while usage is less.
- Light displays more complex for night hours

Idea 2: Lights/sound changing depending on season

<u>Winter</u>	<u>Summer</u>	<u>Fall</u>	<u>Spring</u>
<p><u>sound:</u></p> <ul style="list-style-type: none"> - cold "depressing" sounds - minor keys/chords - Not too loud to represent to a quietness of winter 	<p><u>Sound:</u></p> <ul style="list-style-type: none"> - "happy" warm sounds - major keys/chords 	<p><u>sound:</u></p> <ul style="list-style-type: none"> - calming sounds - ambient sounds 	<p><u>sound:</u></p> <ul style="list-style-type: none"> - sounds of water/rain
<p><u>Lights:</u></p> <ul style="list-style-type: none"> - "cold" colours - blue/white/purple - to reflect winter landscape 	<p><u>Lights:</u></p> <ul style="list-style-type: none"> - bright colours - yellow/red/green - represent the brightness of the sun and the colorful environment 	<p><u>Lights:</u></p> <ul style="list-style-type: none"> - red/green/yellow/orange to display trees changing 	<p><u>Lights:</u></p> <ul style="list-style-type: none"> - bright greens - to represent new growth of plants - Blue to represent water and rain

Figure B7: Seasonal Changing

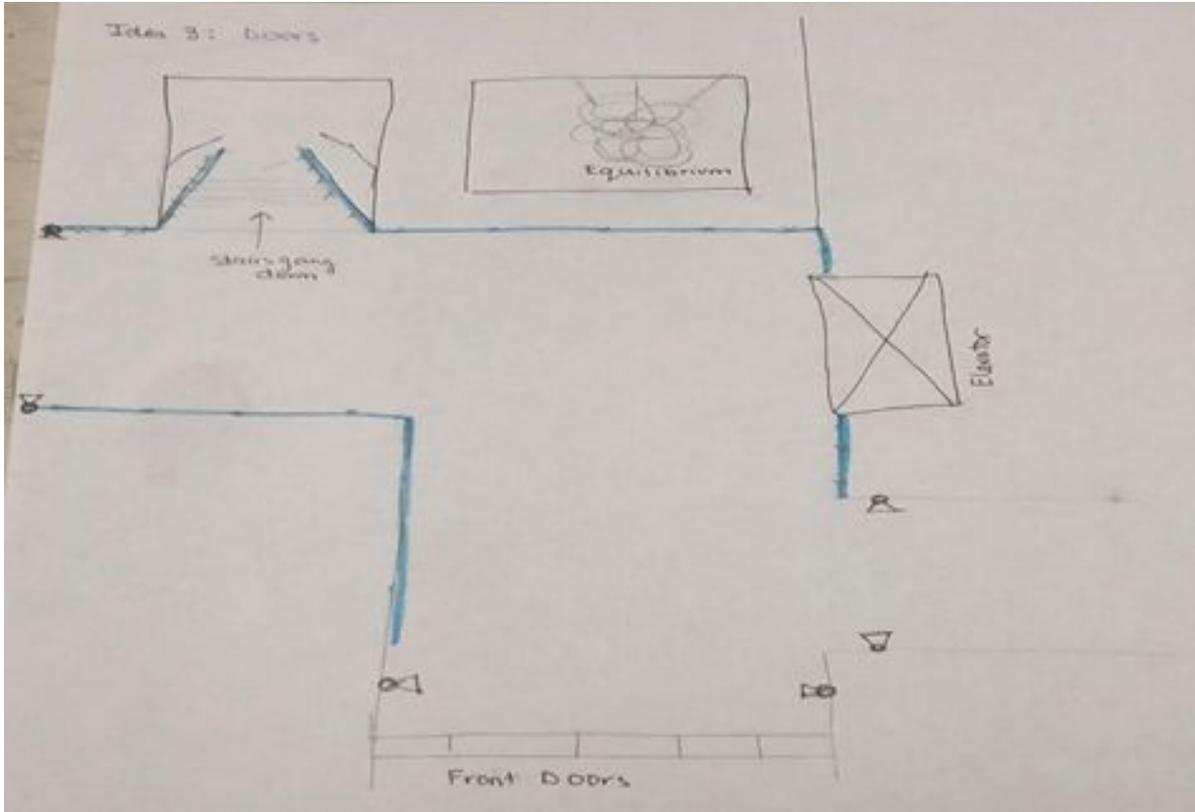


Figure B8: Doors

Appendix C: Prototype Diagrams

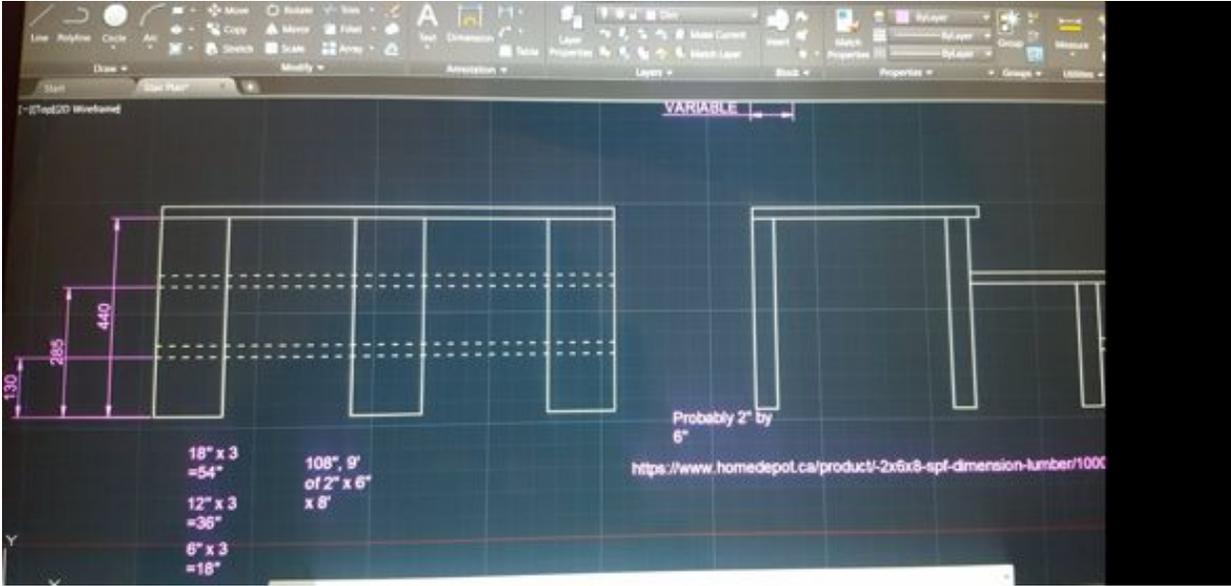


Figure C1: AutoCad Schematics of Stairs



Figure C2: Staircase During Construction



Figure C3: Neopixels in Vinyl Tubing

Appendix D: Meeting Minutes

January 31, 2019

- Worked on Deliverable C
- Spoke about benchmarking and creating our own ideas
- Discussed possible ideas (writing down even the ones that wouldn't necessarily work)
- Re-evaluated meeting times that are most convenient for everyone
 - Thursdays are scattered for everyone's schedules
 - Dario, Mais and Connor are done at 11:30
 - Megan is done at 1:00
 - James is finished at 2:30
 - People are waiting and live far from campus and can't go home for break
 - Meeting times were suggested and voted to have our new meeting time take place on Mondays before GNG lectures.
 - Deliverables are often due on Sundays so it gives us ample time to discuss planning for each week.
 - Everyone's scheduled to be on campus at that time, so no waiting around
 - Early in the week when everyone has rested from the weekend.

February 4, 2019

- Discussed Deliverable D
- Dario was elected as team leader
- Spoke about assignment #2, 2 people left to finish the first part before we can work on the second part of assignment.
- Worked on Deliverable D drawings
- Walked to STEM, got a measuring tape from Makerspace and measured parts of staircase, and door frames
- Split up to go work on individual designs at a later time

February 11, 2019

- Everyone was here
- Just submitted deliverable D last night, had to talk about where we went wrong (had to submit it at 11:59)
 - Online formatting on google docs (good thing to keep track of and to keep people on topic)
 - Having a deadline before the actual deadline (being done before Saturday night with a deadline of Sunday night)
 - Keeping in contact if you have something else come up
- Spoke about deliverable E (Cost and Scheduling)
 - Dividing group into a prototype group and deliverable group
- Decision time... Gradient Lighting will be our project
 - Dario will be in charge of prototyping
 - Connor is in charge of the gantt chart and the deliverable for this week
 - Mais, James and Megan will work on the first prototype (the three of us also live in Ottawa)
 - Dario will be treasurer (let him know about buying things and then he will be responsible for the receipts)
- On weeks with more writing, Megan will join Connor for the deliverable

February 27th, 2019

- Met with client to discuss overall idea and get feedback
- Project/design idea was well perceived and received the okay to proceed with minor changes
- The first prototype will be a set of stairs made out of cardboard and other scraps (Mais will work on that)
- Next meeting will be Saturday to work on handout (Connor, Dario, Megan and James)

March 2nd, 2019

- Dario, Connor, James and Megan met at site to finish prototyping plan and to discuss the plan for the upcoming week
- Will talk again during the lab for the second prototype

March 6, 2019

- Met with client during lab to update him on progress and plan for the next coming weeks
- Group discussed following subjects:
 - Decided to split the group into 2 groups
 - Megan and Dario will work on coding and lights prototype
 - Connor, Mais and James will work on stairs prototype
 - The goal is to submit the lights component for prototype 2 but in case we are delayed in getting the lights or the code doesn't work by sunday we are going to submit the finished product of the stairs for prototype 2 instead
 - No excuses for not being able to meet next
 - Next meeting will be Sunday March 10th at 10am
 - By splitting up this will make it easier to finish the project before design day without being stressed.
 - Dario bought arduino board, and temperature sensors
 - Found old wood to make stair frame and tools necessary

March 7th, 2019

- Megan and Dario worked on prototype 2
- Connor, Mais and James started the construction for the bridge
- TBD how all this goes

March 10th, 2019

- Mais, James and Connor worked on powerpoint presentation
 - Divided parts based on slides
- Megan finished deliverable G (coding) and worked on lights handout
- Dario in process of trying to find lights that work with the code and connect two different codes
- Meetings changed from Monday to sunday to complete the deliverables on a better scale

March 17th, 2019

- Deliverable H was due
- Dario went to makespace to find wood
- Megan and Dario went to home depot to buy vinyl tubing

March 27th, 2019

- Lab period was used to rehearse presentation
- Handed in deliverable I with our presentation
- Presented final project to class
- Megan signed out poster board from Makerspace and designed/worked on poster board

March 29th, 2019

- Design day
- Project was all ready for design day
- Deliverable J was submitted at 8 am