CMF Design

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1 Problem Formulation

1.1 Introduction

The foundation of a problem must be strongly set in order to understand it. The Problem Formulation Section endeavors to describe the reasons why this team is undertaking the task of solving this problem.

1.2 Background

For the Fall 2020 Semester at Humboldt State University, as a continuation of the partnership that Humboldt State University's Engineering Design Class has with Six Rivers Charter High School in Arcata, California, the Fall 2020 Engineering Design Class will be creating solutions for the safe return of students and teachers to classes.

The principal of Six Rivers Charter High School (referred to as SRCHS henceforth), Ron Perry, has tasked this class of intrepid designers with designing different apparatuses to complete the challenge. In the past, the Engineering Design course has created many useful tools that serve several different learning purposes at SRCHS. This semester will be no different, except in that there will be minimal in-person interaction with the client, the client's constituents, and the designers.

There are four areas of concern that Mr. Perry has highlighted as needing solutions at SRCHS. These are: the outdoor science lab; the indoor science lab; the theatre department; and teacher's desks/podiums/lecterns.

This team will be working on solving the problem of how to create a safe, contained space for teachers when they return to school.

CMF Design, this team, consists of three members: Carolyn Heredia, Marlin Gast, and Franziska Daumberger. The first initial of each teammate's name was the inspiration for the name of the team. These students are all studying Environmental Resources Engineering and are all transfer students from different California Community Colleges. They all have a passion for engineering solutions to fix the environmental issues of this era.

Figure 1.2: Google Maps satellite view of SRCHS

1.3 Objective Statement

The objective of CMF Design is to engineer a solution for the safe return of students and teachers to the SRCHS campus.

Figure 1.3: Black Box Model

2 Problem Analysis and Literature Review

2.1 Introduction

In order to most efficiently solve the problem at hand, the team must fully understand it.

2.2 Problem Analysis

The purpose of the problem analysis is to identify the client's criteria and design constraints. The problem analysis will cover specifications, considerations, usage, and production volume.

2.2.1 Specifications

The Specifications of this project are features that must be implemented in the design in order to have a good process. The following four specifications will be considered in this design project: cost, ease of use, level of aid of instruction, and level of COVID safety. This design will provide long term use for the teachers at any school that decides to implement it.

2.2.2 Considerations

The client's production capabilities must be considered, this applies to dimensions of barriers and other materials that must be cut to size. Given the clients available laser cutter the barrier size limit for materials such as acrylic is 32x20 inches.

2.2.3 Criteria

1. Must be replicable by students.
2. Must be able to protect teachers from COVID-19 transmission effectively in a variety of situations.
3. Must be within a reasonable price range.
4. Must not impair the learning environment.

2.2.4 Constraints

1. Any individual solid barriers must be equal to or smaller than 32x20inches.
2. Needs to effectively block particulate from having a direct path between individuals.
3. Needs to be under $150 per unit.
4. Cannot block sound or vision to an impractical amount

2.2.5 Usage:

The final design of the COVID-19 safe teacher workstation will be considered for schoolwide use at Six Rivers Charter High School. If successful, the Workstation will be used to help aid in the return of classes to an in-person environment.

2.2.6 Production Volume:

One prototype will be created in order to demonstrate its functions and serve as an example to replicate if the client chooses to.

2.3 Literature Review

2.3.1 Introduction

The literature review section endeavors to find any and all relevant existing literature on the subject at hand, so as to make informed decisions on materials and methods. In this section, CMF Design researched barrier materials, potential rolling methods, potential framing materials, communication through barriers, and various existing measures that other establishments have taken, as well as CDC guidelines.

2.3.2 Barriers

There are many clear barrier options, including glass, acrylic plexiglass, and polycarbonate.

2.3.2.1 Acrylic Plexiglass

Acrylic plexiglass is the least expensive type of clear barrier. Compared to glass, acrylic is ten times more impact resistant. Acrylic is very clear making it easy to see through and practical in applications that require a barrier that does not impede view. It is less scratch resistant than glass but more scratch resistant that polycarbonate. Being UV resistant, acrylic is a good option for outdoor use. Acrylic is easy to custom cut and the edges are easily polished, for custom applications this is very helpful as it is generally less expensive to buy bulk sheets compared to ordering many already cut individual sheets. There are some factors regarding acrylic that can be negatives in certain situations; when compared to polycarbonate it is more rigid and therefore prone to cracks and chips when it comes in contact with forces such as being leaned on (Lexan vs Plexiglass). Acrylic is also prone to melting and burning at very high temperatures, in certain situations this may cause a fire hazard. When cleaned if the wrong chemicals are used acrylic can lose clarity, this makes cleaning more involved.

2.3.2.2 Glass

Glass has some great barrier characteristics but can also be very dangerous when subjected to situations that exceed its structural limits. Glass is extremely rigid; many times, this is a good characteristic. When properly framed and supported glass does not bow in and out due to airflow and pressure, less ridged polycarbonate under certain conditions can have that issue. Of the three options glass is by far the most scratch resistant, many metals will not even scratch glass. Polycarbonate and Acrylic however are relatively easily scratched when frequently come in contact with. Of the three options glass is the least impact resistant, when an impact occurs glass can shatter and create many dangerous shards that will cut and puncture skin. Glass has very good longevity in terms of clarity; acrylic and Polycarbonate over time can take on a yellow

tint. Glass is very easy to clean; it is chemical resistant to any type of cleaner and will not lose clarity or scratch in the cleaning process.

2.3.2.3 Polycarbonate

Polycarbonate is a very strong compared to the other two materials. When a barrier against impacts or force is required polycarbonate is an excellent choice, considering its impact resistance is 250 times higher than glass (Lexan vs Plexiglass). Polycarbonate is very flexible; this means it can be bent into a rounded shape without cracking like acrylic. Unlike acrylic polycarbonate is very chemical resistant and not very flammable; it does however still melt at high temperatures (155C). Of the three options polycarbonate is generally the most expensive and very easy to scratch. When cleaning a very fine clean cloth must be used to avoid micro scratches.

2.3.3 Rolling Mechanisms

There are several different methods of rolling or sliding an object, either on a contained rail or allowing free motion. Rolling rails and sliders are a guided way of allowing horizontal or vertical movement; castors are a way to allow free motion in any direction on a horizontal plane.

2.3.3.1 Rolling Rails

Rolling rails use external guides to dictate the direction of travel of an object, the object being moves has roller attached to it that are positioned within the guides. The use of rollers provides smooth and controllable movement while dictating the objects path of motion. Rolling rails can provide a rigid frame for the object if it is positioned between two guides. Rolling rails often use bearings as rollers, since bearings create minimal friction they allow the rollers to maintain tight clearances overtime without wearing out (Choosing the Right.). rails have more moving parts than slider rails causing them to be more complicated and require occasional lubrication in some cases. Roller rails are more expensive than slider rails and generally must be purchased due to their complicated nature.

2.3.3.2 Sliders

Sliders follow the same concepts as roller rails but do not use rollers inside the guides; instead the object is the sliding surface. Sliders provide the same function as rollers but not as smooth, due to increased friction sliders must also have looser clearances and can wear out faster. Unlike rollers, sliders do not need maintenance and are less prone to failure. Sliders are inexpensive and can be easily made.

2.3.3.3 Castors

Castors are a wheel or multiple wheels attached to a base, which is mounted to the object that needs to be moved, generally multiple castors are used. Unlike sliders and roller castors only allow horizontal movement and do not restrict direction or range of motion. There are two types of castors, fixed and rotating; generally used in conjunction. Fixed castors allow the object to move only in a fixed direction forward and backwards. Rotational castors allow the wheel/wheels to turn which in turn allows the object to travel in any direction. Castors generally employ ball bearings to allow the wheels to turn, this results in very smooth function. Castors can be limited when they encounter objects or ridges along the surface they are rolling on. Depending on the size of the wheels, small things such as an extension cord or pencil will stop them from rolling.

2.3.4 Framing Materials

Three different materials were considered with which the frame of the barrier would be built: ABS pipe, PVC pipe, and wood.

2.3.4.1 ABS Pipe

ABS (Acrylonitrile butadiene styrene) is a rigid black plastic that can come in the form of a pipe, ABS pipe that has many pros for use as a barrier, it is easily cut to size with a hand size. It is also easy to put with together store-bought fittings that fit with little effort and are secure.

2.3.4.2 PVC Pipe

PVC (Polyvinyl chloride) is made of a synthetic plastic polymer and has good characteristics such as heat resistance and rigidity. It has the same build characteristics as ABS but the color is generally gray, it also makes a great option for a barrier frame. ABS and PVC are interchangeable, and usage depends on ease of access.

2.3.4.3 Wood

Wood is very versatile with its large range of available types and dimensions, it can also be cut to any size and put together with glue or fasteners. These attributes make it a great candidate for a barrier frame.

2.3.5 Barrier Effectiveness

Barriers of all materials can be an effective tool to be used against the transmission of a disease, there are however certain guidelines that must be followed in order for them to work properly. Acrylic, glass, polycarbonate, and any other barrier type must regularly be properly disinfected through cleaning (Cai Ru Gan). In order for a barrier to be cleaned effectively it must be non-porous, which glass, acrylic, and polycarbonate all are; making them excellent material options. According to the University of Washington a barrier must “create a distance of at least 6 feet for any indirect pathways” in order to be effective. Based on the average height of individuals in the United States the CDC recommends a minimum barrier height of 72 inches above the ground. This was established taking into consideration the tallest average people and an extra buffer added. According to the CDC barriers are not completely effective as standalone protection from viruses but rather the must be used alongside other safety measures; such as masks, hand sanitization, and distancing (University of Washington).

2.3.6 Communication Devices

According to the University of Washington communication can be impaired by barriers, which in turn reduces their effectiveness due to a tendency to talk around the shield. In order to avoid this issue, it is recommended that some sort of speak through device be used; such as a “no draft speak through device” or “an electronic communication device” (University of Washington).

2.3.7 Guidelines on the Return to School from Various Countries

This section describes the various different approaches that schools from around the world have taken to make sure that their students and teachers are safe when they return to school.

2.3.7.1 School Methods

The first topic that was looked at was the guidelines and practices that other schools, mostly k-12, have implemented. Very few universities have described what they have done or are doing.

A compilation of several different school systems from schools that had only a brief amount of time for which they were closed was created by the Learning Policy Institute, an American group. The document stated that, while some schools had barriers in place, most of the new precautions and installments had to do with handwashing and social distancing.
An article by the Asian Journal of Distance Education showed that during the H1N1 outbreak, reducing the number of students in classrooms, establishing stable groups of students, reducing the movement of students around the school premises, and increasing cleaning measures, as well as increasing ventilation if possible had shown to create some positive outcomes. This article also mentioned that during the H1N1 outbreak, there were some schools that used dividers attached to desks to minimize the spread of the disease.
The national Taiwan University of Science and technology put transparent dividers between students in the cafeteria. The issue that eating brings up is one that dividers could help with, but they are far from the only solution to the problem.
This information from schools shows that while there are various methods as to the re-introduction of children into schools, the method must both fit the school and conform to CDC guidelines. There is no one-size-fits all solution.

2.3.8 Guidelines on Physical Barriers from Retail and Service Industries

In an effort not to reinvent the wheel, the retail and service industries, in particular the food service industry, were looked to for examples of barriers and crowd control methods.

2.3.8.1 Retail

The most prevalent method that the retail industry has instituted in the fight against the virus is that of see-through barriers in front of every register and other similar areas where customers need to interact with retail personnel. This is somewhat effective, as it stops particles from customers from hitting the retail personnel from the front. The biggest issue with this method of barrier is, however, that customers often reach around, move around, or ignore the barriers, as these barriers are only on one side of the register.

2.3.8.2 Food Service

The food service industry, in terms of preventing the spread of pathogens, is perhaps the most prepared. Plastic barriers, “sneeze guards,” have been in use far before COVID-19 came upon the world. Frequent hand washing is also a part of standard health and safety guidelines in the food industry.

2.3.9 CDC Guidelines

In order to best create a design that complies with all health and safety guidelines set forth by the government, CDC Guidelines will be followed in this design.

2.3.9.1 Guidelines for Schools and Student Families

CDC is the Centers for Disease Control and Prevention. According to the CDC the virus spreads through respiratory droplets produced when the infected person coughs or squeezes. The droplets can land in the mouth or nose of people that are within a 6 feet radius. Clean and disinfect frequently touched surfaces, so the desks in the classroom should be cleaned between student use, as well as the doorknobs. Have every student monitor their health daily and watch out for any symbols of the following: fever, cough, and shortness of breath.

These are the CDC school requirements for COVID-19: Avoid touching your eyes, nose, and mouth with unwashed hands when in class; implement multiple SARS-CoV-2 mitigation strategies (e.g., social distancing, masks, and hand hygiene); communicate, educate, and reinforce appropriate hygiene and social distancing practices in ways that are developmentally appropriate for students, teachers, and staff; maintain healthy environments; educate parents and caregivers on the importance of monitoring for and responding to the symptoms of COVID-19 at home; planning and preparing for when someone gets sick; and communicating appropriately to families about home-based symptom screening. These are all methods that will be practiced when reopening the schools.

2.3.9.2 Advantages of CDC Guidelines

The advantages of having the CDC requirements are that one can read the research to have an idea of how to set up the classrooms. The CDC shows how people get affected in different settings. The CDC also has a list of critical roles that need to be practiced by the schools and administrators. These critical roles are to be communicated to the parents as well so that if a student has any symptoms, they know what to do.

2.3.9.3 Schoolboard Recommendations

As public schools navigate the demands of reopening safely, they will bear the burden of added costs for personal protective equipment, increased cleanings and more. The COVID-19 pandemic has caused the widespread shutdown of the economy. Due to this extraordinary crisis, school districts across the country are facing operational and fiscal challenges. The Humboldt County Office of Education (HCOE) has made various different guides available to the schools to aid in their return to in-person learning. The guides contain descriptions of social distancing policies, cleaning procedures and schedules, and plans on what to do in the occurrence of a student, staff, or teacher's exposure to an individual with a positive test. These guidelines by the HCOE follow state and federal guidelines that are in accordance with suggestions and studies from the CDC.

2.3.10 Particulate Matter from Orators

In order to best create an effective barrier, the mode of transportation of the particles that the barriers must shield from must be known.

2.3.10.1 Traveling Tendencies of Particulate Matter

Respiratory droplets produced when an infected person coughs, sneezes, or talks These droplets can land in the mouths or noses of people who are nearby or possibly be inhaled into the lungs. Spread is more likely when people are in close contact with one another. After cleaning and disinfection, the following recommendations may help reduce the risk to workers and other individuals when vacuuming. Use a vacuum equipped with a high-efficiency particulate air (HEPA) filter, if available.

2.3.11 Air Filters

In order to best create an effective barrier, the mode of transportation of the particles that the barriers must shield from must be known.

2.3.11.1 Filter Material for Non-Positive Pressure Situation

When used in a barrier a filter is not exposed to much positive or negative pressure, meaning air is not being forced through the filter and will likely not travel through it given it is more restrictive than the surrounding air. The static pressure situations caused by no air flow allows a filter to be more effective and replaced less often. There are many different types of filter ratings that have different functions. According to the CDC MERV-13 is what is recommended to filter COVID-19 (David). It must be considered that this recommendation is based on a positive pressure situation, if the filter is used in a barrier there would be no positive or negative pressure. In a barrier likely any filter material that restricts airflow would stop COVID-19. If available MERV-13 or better is what should be used in any virus filtering situation.

3 Search for Alternative Solutions

3.1 Introduction

During these brainstorming sessions alternative solutions designs were developed. Each of the team's designs satisfy the objective statement and the criteria, offering an achievable option for the students to be able to remake. A total of six alternative solution designs were developed during two brainstorming sessions.

3.2 Brainstorming

The brainstorming CMF Design did was focused around fulfilling the design criteria while considering limitations, these were in the problem analysis portion of section 2. The team had three brainstorming sessions, all of which were conducted over zoom during the week of 10/12/2020. During the sessions all group members expressed their ideas without the limitations considered, based on these ideas, the team came up with more realistic ideas. During brainstorming CMF Design critiqued each other's ideas and used the critiques to modify and come up with better ones. Everyone's past experience of going to high school was also taken into consideration. The brainstorming sessions were all noted into a shared document on google drive, these notes are present in appendix A.

3.3 Alternative Solutions

The following is a comprehensive list of six alternative solutions that were developed during some delineated sketches done to give a virtual aid to the design. The sketches will be put next to each other and the team will choose the best one.

3.3.1 Queue Marks

The Queue marks on the floor to stay six feet apart consist of two separate choices. The Queue marks can be laminated paper with cute fun designs six feet apart from each other and from the teacher for safety. There can also be simply chalk markings on the floor to enforce the six feet apart rule.

Figure 3.1: Queue marks with colorful designs

3.3.2 Filter

In the team's interviews and observations, it was found that in retail and other public business locations where barriers are installed, customers often reach their heads around the barrier to hear better. CMF Design wanted to ensure that this would not happen for the SRCHS teachers, as this habit is not safe for the teachers or the students. To create a guided interaction with the barrier and discourage reaching around it, the team placed a filter in the center of the barrier. This would stop any particulate matter from traveling to the teacher and would also encourage students to speak into the filter rather than reaching around the barrier if there were sound/hearing issues.

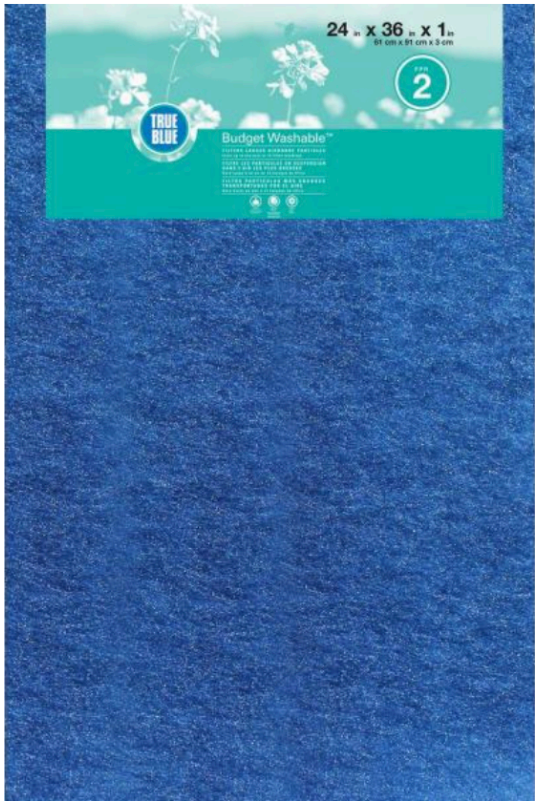

Figure 3.2: Filter that was used for prototyping

Figure 3.3: Prototype filter in the wooden frame barrier

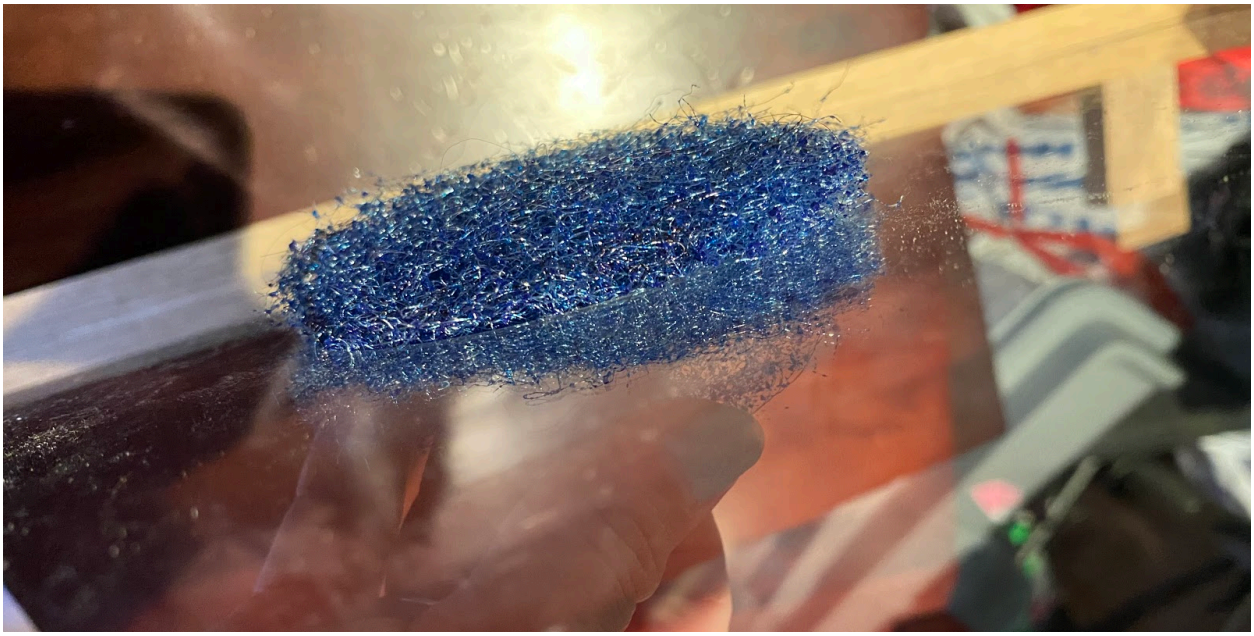

Figure 3.4: Another view of the prototype filter in place

3.3.3 Retractable soft barrier (large)

A retractable soft barrier would hang from the ceiling and would be easily movable away or into place. It would consist of three roll up mechanisms, attached to the ceiling, that would surround the desk, creating a confined space so that no particles could approach the teacher. The plastic sheets could be used together, as in all three at the same time if the teacher feels as though that is needed, or only one at a time.

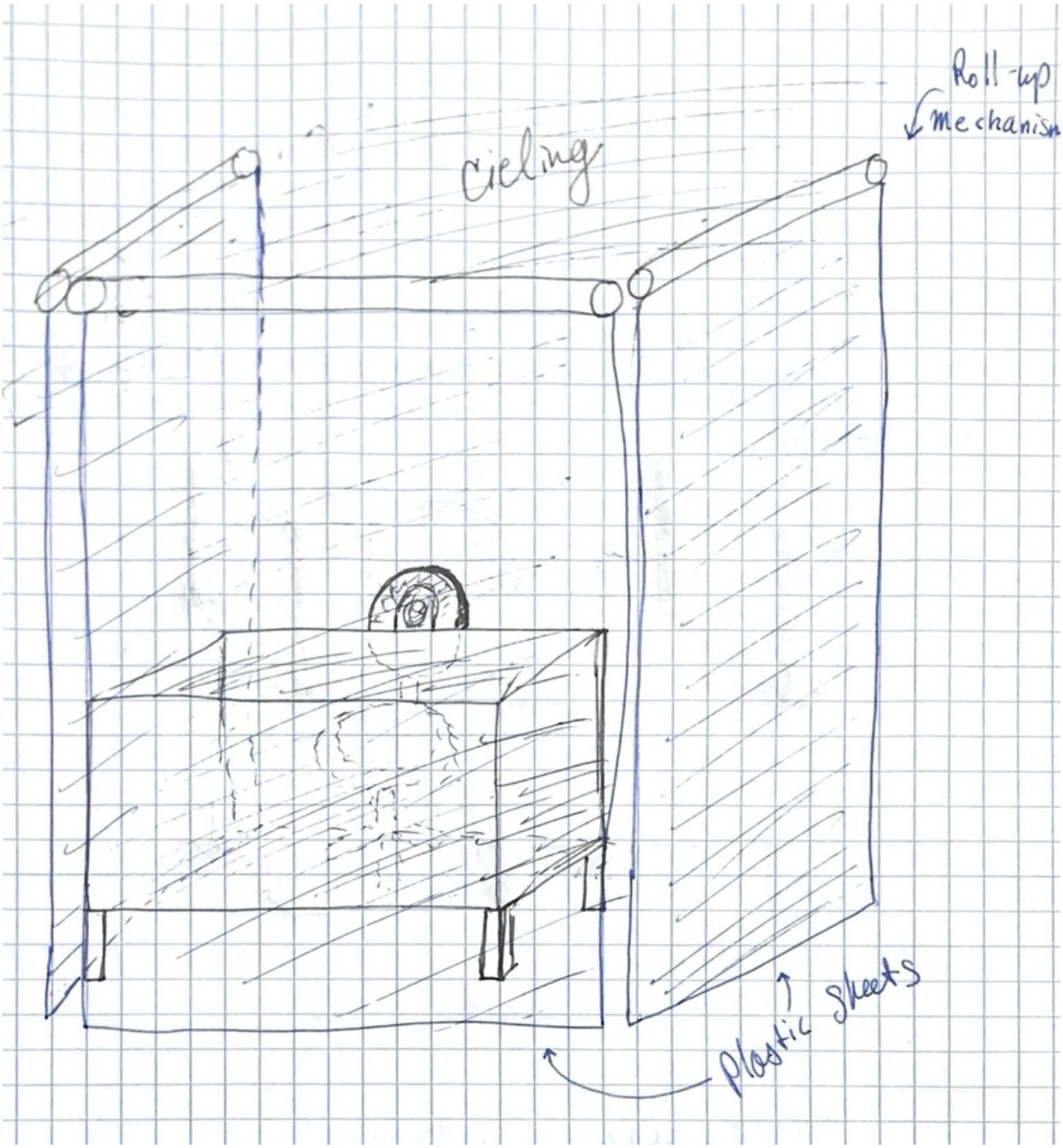

Figure 3.5: Large Retractable Soft Barrier

3.3.4 Retractable soft barrier (small)

This solution uses much the same idea as the large retractable soft barrier, however rather than being pulled down from the ceiling, it is pulled up from where it is fixed onto the desktop. Locking mechanisms affix the plastic sheets into place when the teacher wants them to be pulled up, and they can be used all at the same time or one at a time, however the teacher sees fit. They would be placed on three sides of the desk, with poles also attached to the desk to affix the plastic sheets to when deployed.

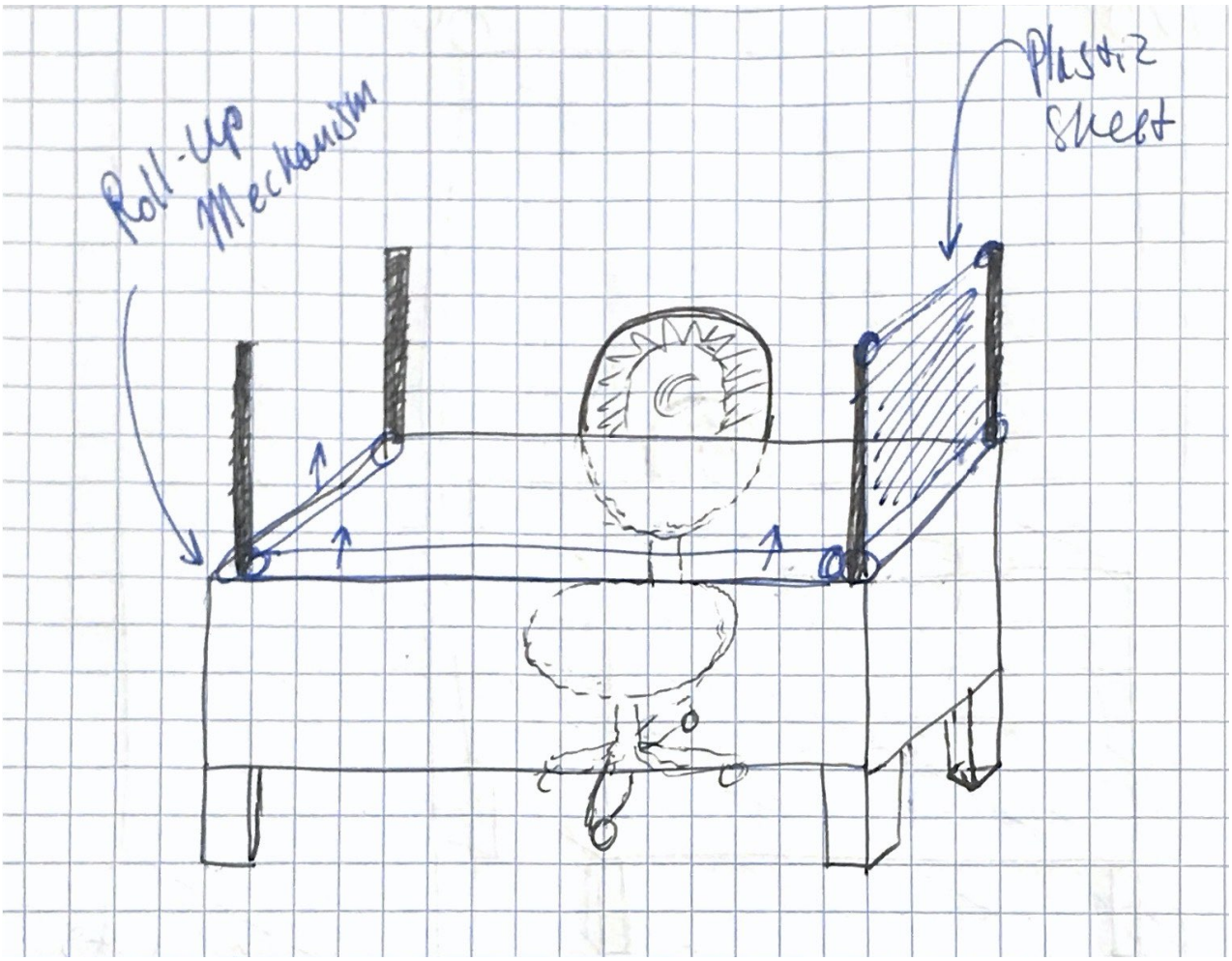

Figure 3.6: Small Retractable Soft Barrier

3.3.5 Retractable Solid Barrier

The retractable solid barrier method uses a sliding plexiglass sheet to enable a smooth and fast transmission from no barrier on a workstation to have a fully functioning barrier. The barrier is positioned between two sliders which are fastened to the teacher's workstation, when used the plexiglass sheet is pulled up and locked into place with a pin on one slider. The whole operation of raising or lowering the barrier would take under a minute and be very simple. Having no barrier would be useful when no students are nearby, and the teacher would like to address the whole class without any sort of sound or vision interference. When a student approaches, the barrier could be pulled into place and would protect the teacher from exposure to droplets being projected by the student.

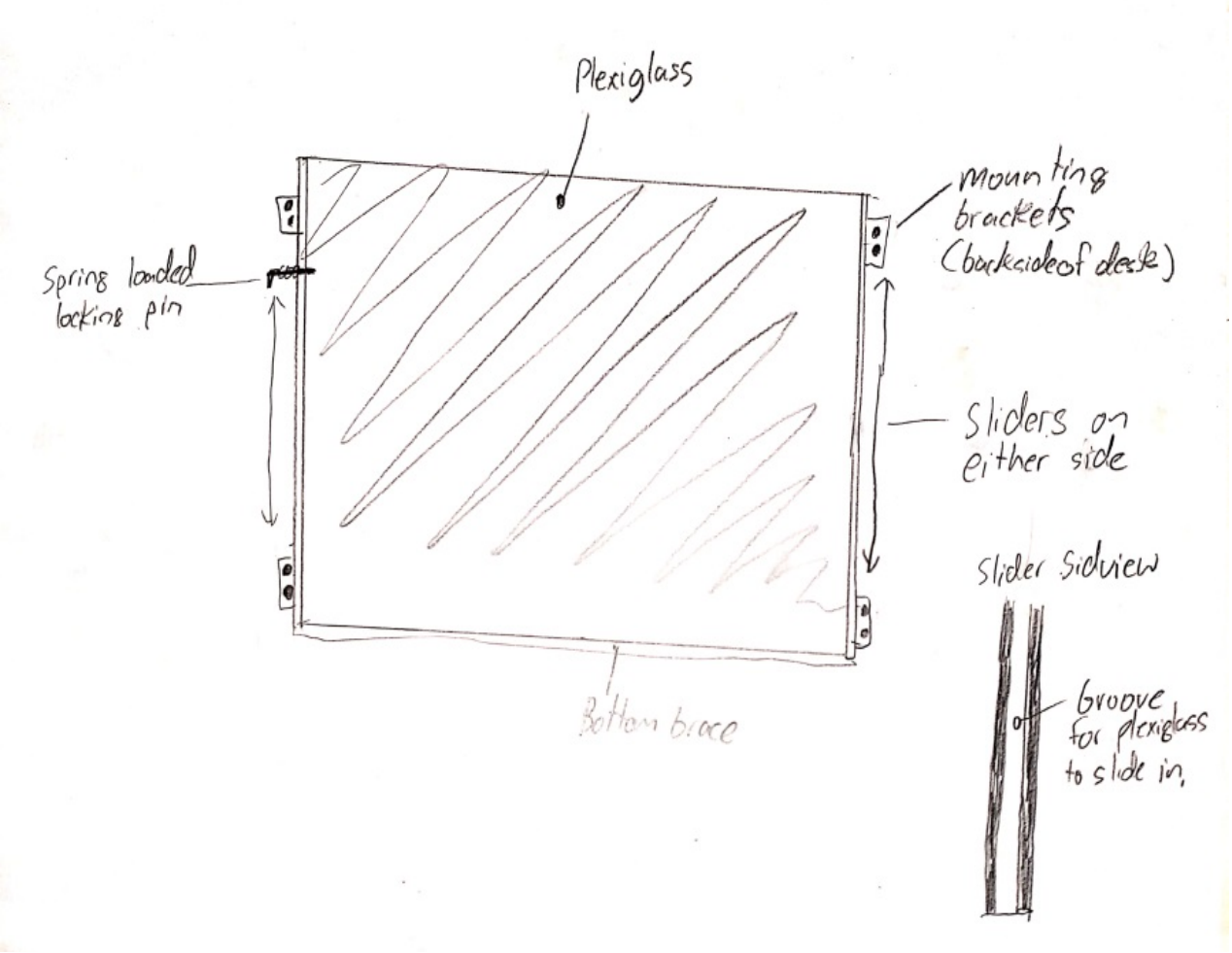

Figure 3.7: Retractable Solid Barrier

3.3.6 Rolling/Stationary solid barrier (Large)

The basis of this design is that it could be easily moveable by the students and teachers, and easily positioned wherever protection is desired and needed. A pipe frame would encase a plexi or plastic sheet, that would then stand vertically, separating people. This design has multiple variances. The barrier material could be either plexi glass or some similar solid material, or a soft, flexible clear plastic material. The panel could be either a single, stand-alone panel, or could be multiple panels attached to each other, creating a very flexible and unique barrier set up. Both of these variances could also be on wheels. These would be several feet tall in order to provide a barrier when people are moving around as well as when they are sitting.

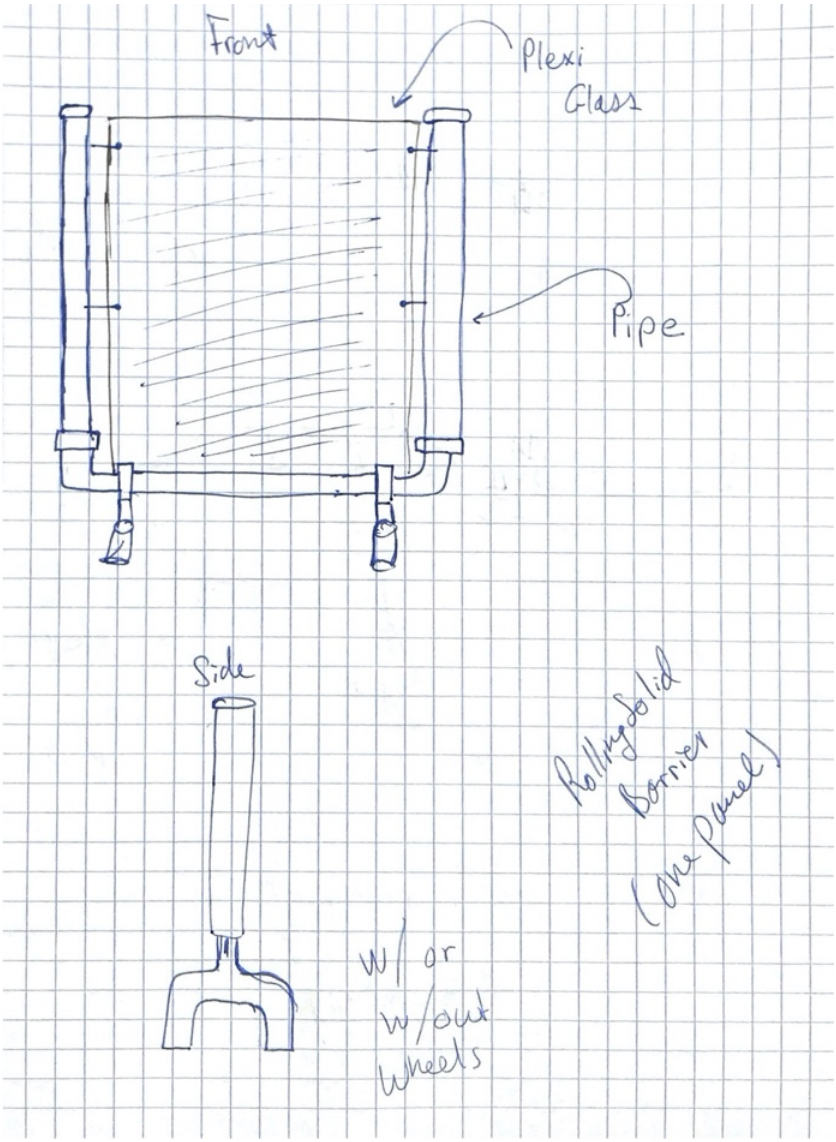

Figure 3.8: Large Stationary Solid Barrier

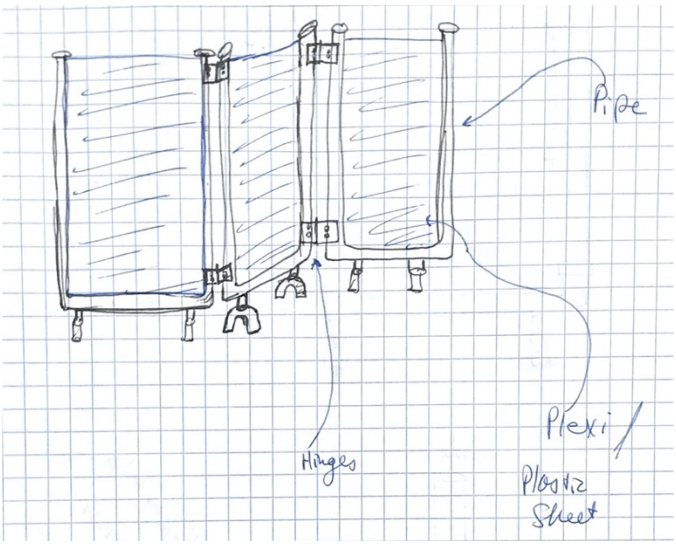

Figure 3.9: Large Multiple Panel Rolling/Stationary Solid Barrier

3.3.7 Stationary Solid Barrier (fixed/small) & (Desktop/mobile)

The stationary desktop barrier serves the same purpose as the retractable solid barrier; the only difference is the stationary barrier is in a fixed position on the workstation. Having the barrier fixed would remove the complication of having to lock the barrier in place and make it inherently more durable. The other benefit to the stationary barrier is it is much easier and less expensive to produce and install. The drawback to being fixed is it will always be in the way of sound and sight whether or not there is a student within six feet.

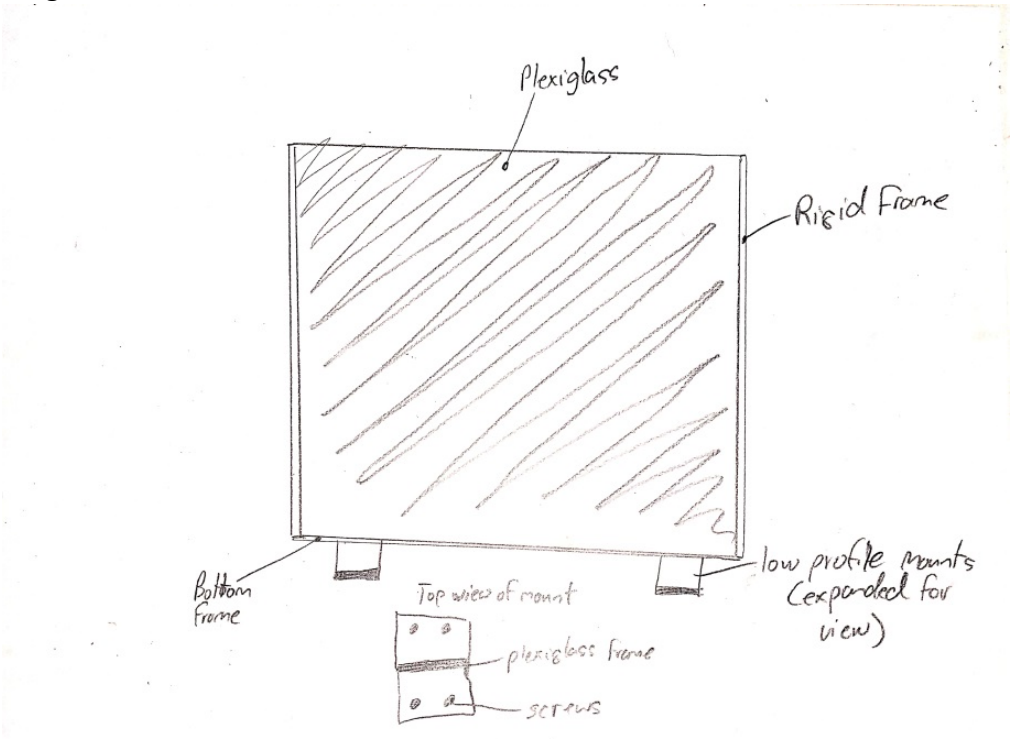

Figure 3.10: Small Stationary Solid Barrier

4 Decision Phase

4.1 Introduction

In this section, the decision of the final solution is made. Several criteria are considered, and the alternative solutions are rated based on the Delphi Method, which is comprised of the criteria that was created that included the needs of the client. The Delphi Method produced a solution that was based on the team's weighting of the criteria. Based on group discussion and the Delphi Method, a final decision is made in this section regarding which solution will be prototyped.

4.2 Criteria Definition

The criteria listed below give a summer of what the project needs to fulfill, therefore these criteria are used to make a decision on the final product.

1. Student Replicability: Must be replicable by students
2. Effectiveness: Must be able to protect teachers from COVID-19 transmission effectively in a variety of situations.
3. Cost: Must be within a reasonable price range of $150 per unit.
4. Unobstructive: Must not impair the learning environment

Table 1: Weighted Criteria

Criteria	
List	Weight
Student Replicability	10
Effectiveness	10
Cost	5
Unobstructive	8

4.3 Alternative Solutions

A variety of alternative solutions have been suggested and are being considered, below is a list of the alternative solutions in Section 3. Refer to Section 3 for more details.

- Queue Marks
- Retractable soft barrier
- Retractable soft barrier
- Retractable Solid Barrier
- Rolling solid barrier
- Stationary Solid Barrier

4.4 Decision Process

In order to derive a final decision much discussion amongst the group occurred. The decision process was aided through the use of a matrix decision technique named the Delphi method. This was done by weighting each criterion with an importance rating between 1 and 10; followed by also assigning each solution an effectiveness rating in each criteria category of 0 to 50. After the ratings were given, the criterion and solutions were oriented in an excel sheet which multiplied each solution effectiveness rating by the corresponding criteria weight value. The multiplied values of each solution were added into a final score. Once every solution was scored, they were compared, and the final score was the final design decision for which a prototype will be created. The ratings for each criterion were assigned based on the clients' needs and the importance of each category.

Table 2: Delphi Method Chart

Criteria		**Solutions**									
List	Weight	Large Retractable Soft Barrier		Small Retractable Soft Barrier		Retractable Solid Barrier		Large Rolling/Stationary Solid Barrier		Small Stationary Solid Barrier	
Student Replicability	10	10	100	15	150	35	350	45	450	45	450
Effectiveness	10	45	450	30	300	30	300	45	450	35	350
Cost	5	20	100	30	150	35	175	30	150	45	225
Unobstructive	8	20	160	30	240	30	240	40	320	45	360
Total		810		840		1065		1370		1385	

4.5 Final Decision Justification

As a team a conclusion was reached to design the final prototype based on the small stationary solid barrier alongside the que marks and a hand sanitizer dispensing add on. The latter two parts of the prototype were not dependent on which barrier type was chosen and would have applied to any prototype. In order to reach the conclusion of barrier type the team relied on the Delphi method to equally weight each team members' opinion and pair that with the relative criterion importance of the client. The small stationary barrier best fit the criteria, especially in the categories of cost and student replicability; it also satisfied the effectiveness criterion.

5 Specification of Solution

5.1 Introduction

In choosing the final design for the Desktop Pirate Protector, there were many specifics that that the team discussed and implanted.

5.2 Solution Description

The final product consists of three parts that work together to prevent the spread of COVID-19 and other diseases. All parts of the product build upon the fundamentals of social distancing and do not substitute for masks or six feet between individuals.

The main part of the design is a rigid acrylic barrier that uses a stand to sit on the instructor's desk to provide protection from airborne droplets. A guided interaction method is employed to promote interaction through the center of the barrier, this comes in the form of a reusable filter is installed in the middle of the acrylic sheet. This filter enables sound to go through the barrier but not viruses or other particulate. The tactic of the air filter in the main barrier should greatly increase the effectiveness of the barrier.

The desktop barrier has two variations, one of which has a wood frame and the other employs ABS and/or PVC pipe to serve as the frame. The reason for two different materials is ease of access to the different materials, also if the equipment to cut wood is unavailable the ABS is extremely easy to work with and can be put together with purchased fittings.

The second part of the design that ensures the effectiveness of the barrier is queue marks that go on the floor six feet from the teacher. The queue marks have been designed and are ready to print at whatever quantity is desired.

The final part of the design is a wall mount for a hand sanitizer dispenser (*Figure 5.2.3)*, it is recommended that all students and teachers use this upon entry and exit to the classroom. Given most hand sanitizer dispensers are manual, it is recommended to have one designated individual, likely the teacher, who pumps the dispenser for everyone else.

The three-part design will help create a safe space for students and teachers to return to in person learning.

Figure 5.1: Completed Pipe Barrier

Figure 5.2: Completed Wood Barrier (with filter)

Figure 5.2.2:

Figure 5.3: Hand Sanitizer Holder

5.3 Cost Analysis

Here the team analyzes the cost of building one wood barrier and one pipe barrier.

5.3.1 Material Costs

It was very important to CMF Design that the materials were cheap and easy to find in any hardware store. These goals were accomplished, and the cost for each barrier (wood and pipe) actually ended up being the same.

Quantity	Material	Source	Cost ($)	Total ($)
1	Wood (2”x2.5”x8’)	Hardware Store	$20	$20
40	Staples	Hardware Store	$3	$3
1	Acrylic Sheet	Hardware Store	$13	$13
1	Filter	Hardware Store	$4	$4
			Total	**$40**

Table 3: Wooden Barrier Cost analysis

Quantity	Material	Source	Cost ($)	Total ($)
1	ABS Pipe (8', 2" diameter)	Hardware Store	$7	$7
2	ABS T	Hardware Store	$2.50	$5
8	Zip ties	Hardware Store	$5	$5
2	ABS Elbow	Hardware Store	$5	$10
1	Acrylic Sheet	Hardware Store	$13	$13
			Total	**$40**

Table 4: Pipe Barrier Cost analysis

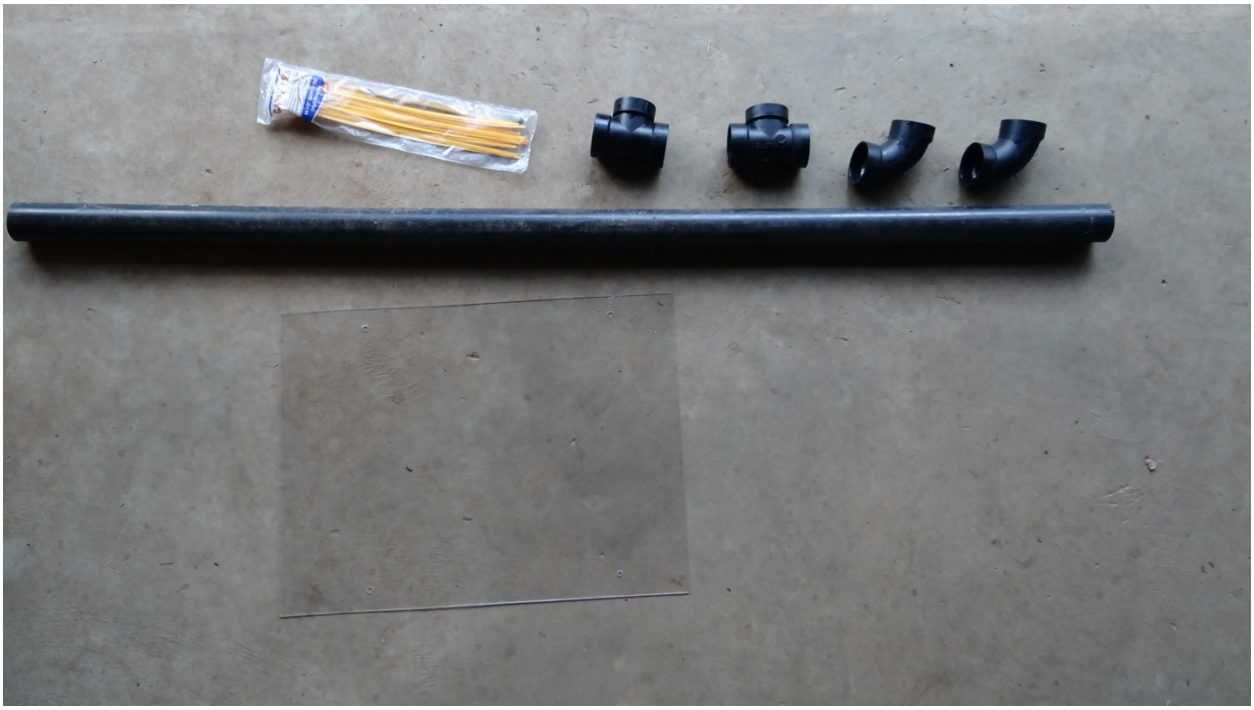

Figure 5.4: Materials needed for pipe barrier

5.3.2 Maintenance Costs

The filter is the only part of this design that has any maintenance costs associated with it, as the filter will need to be changed periodically.

5.4 Construction

Because the main criteria of the team was to make each as easily replicable as possible, which included the sub criteria of each unit being resizable, there are no fixed dimensions for either the pipe or wooden barriers. This was done on purpose in order to make sure that each barrier would be able to fit each teacher's desk. That being said, a video has been made by the team to show an example of how to construct the pipe barrier. The wooden barrier uses solely a saw and a staple gun and is made to fit the chosen acrylic sheet. Slats are sawed into the wooden frame pieces and then the acrylic sheet is slid into the slats, and a staple gun is used to fix all the pieces together.

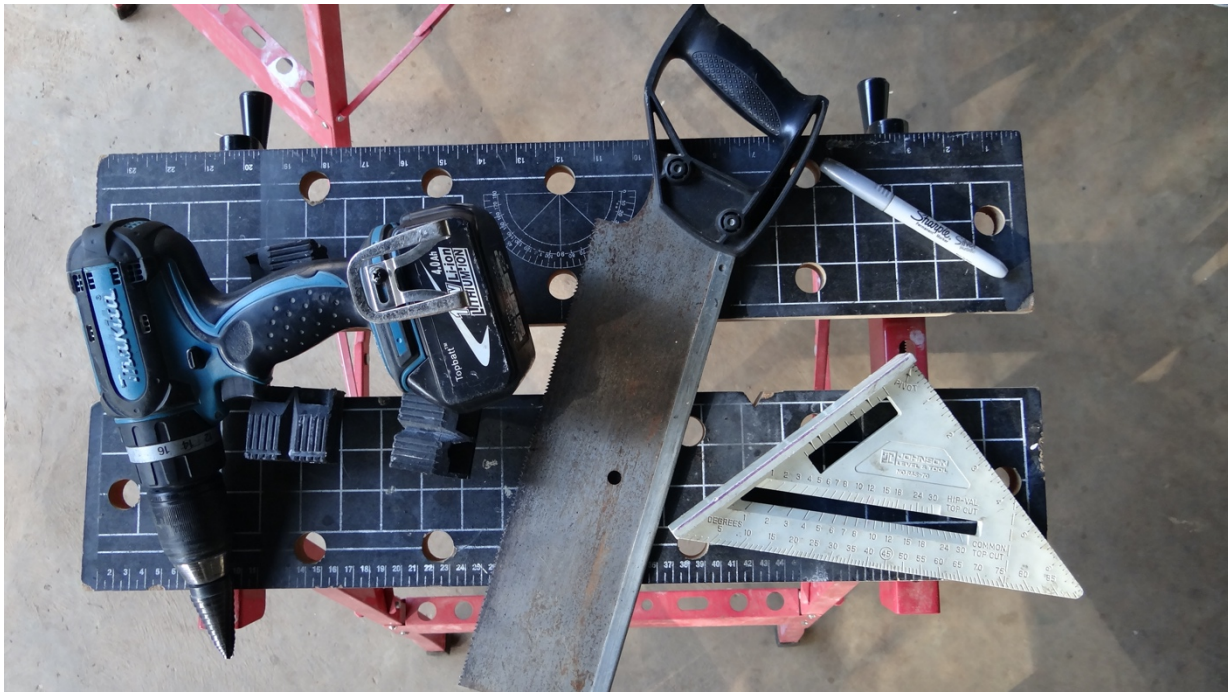

Figure 5.5: Tools required for construction of pipe barrier

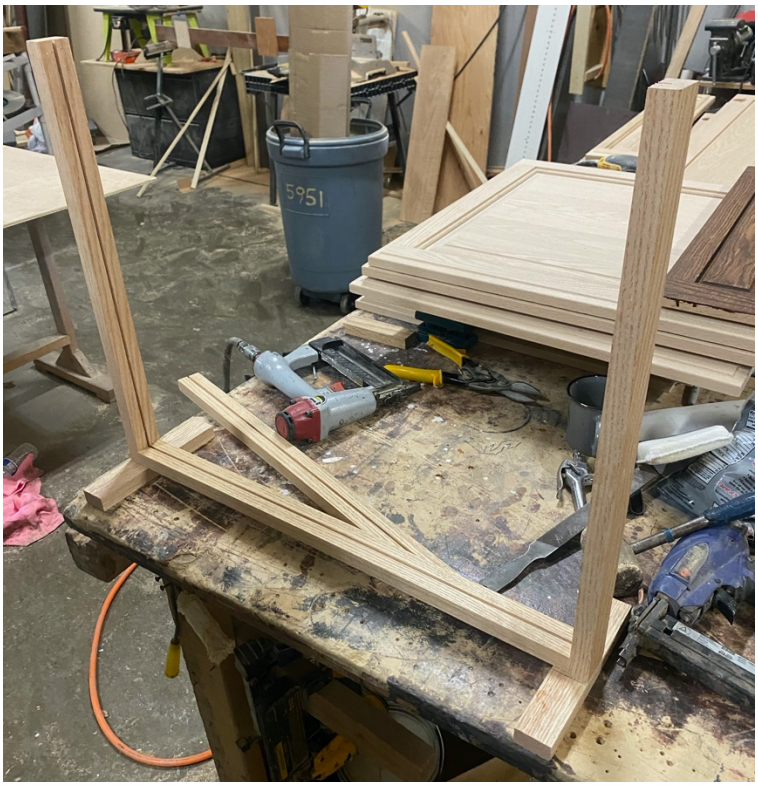

Figure 5.6: Construction of wooden barrier

5.5 Maintenance

Because students and teachers will be around the Desktop Pirate Protector almost daily, and because it is in place to essentially "catch" any bacteria that is directed towards the teacher sitting behind it, the Desktop Pirate Protector has the potential to become a trap for bacteria. However, seeing as it is not something that should be touched often, the cleaning of the barrier can be left to the user's discretion. Acknowledging this, CMF Design still recommends that the barrier be cleaned periodically. This can simply be done with any kind of sanitizer.

Figure 5.7: Franziska cleaning the pipe barrier

5.6 Prototype Performance

Various prototype barriers were created and tested throughout the design process. Two scale models were created to test for appeal, when presented to test subjects they were received very well so a full-size model prototype was created. The purpose of the full-size prototype was to test function, it was made with a large wood frame and cardboard barrier material. After testing the function of the barrier using a spray bottle and measurements of indirect airflow it was determined that the barrier did not need to be so large.

Figure 5.8: Scale model of pipe barrier

Another prototype was a piece of cardboard with a hole in the middle being compared to one without a hole. When a discussion through the pieces was attempted, it was found the one with the hole made it much easier to communicate; this led to the use of a hole and filter in the final product design.

Figure 5.9: Wooden barrier prototype

For the queue marks the visual appeal of several different designs were tested before determining the final print layout.

CMF Design employed various tactics in testing the final product.

Family members of the teammates were recruited to sit behind the barriers, and the effectiveness of both the barrier and the filter for guided interaction were tested by simply conversing with family members. Their behaviors were observed and documented. The family members were observed to lean into the filter rather than leaning around the barrier if the volume of one participant's voice was lowered.

The team's family members were again recruited in testing the effectiveness of the barrier against particulate matter. Water was sprayed at the barrier, and the amount of water that got on the family members was observed and documented. Baking flour was also thrown at the barrier with a family member behind it, and the amount of flour that stuck to the family member was observed on documented. In both cases, the direct effects of the matter thrown at the family member were lessened by the presence of the barrier.

Figure 5.10: Pipe barrier prototype testing

5.7 Implementation Instructions

After the barriers are built to fit the teacher's desk, they can simply be placed upon the teacher's desk in any orientation that protects the teachers from particulate matter that might be sent in their direction. There is no need to affix the barriers to the desk.

5.8 Results

After defining the problem, establishing criteria, creating alternative solutions, making a decision, and designing a solution, the Desktop Pirate Protector was created. This is a barrier that will allow for the safe return of teachers to schools. Proper use of the barrier will result in droplets from students being blocked before they can contaminate the teacher.

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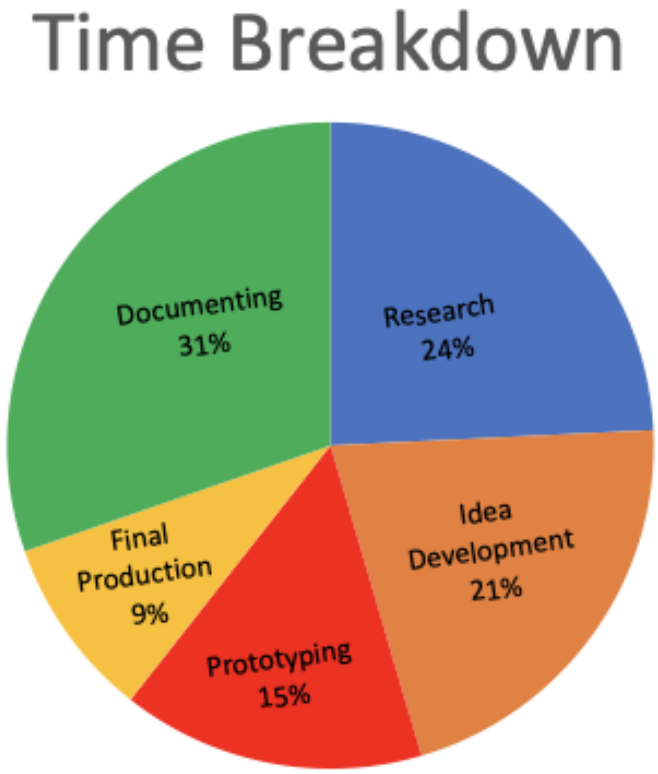
6 Appendices

6.1 Group Member Project Hours

The team completed a total of 105 hours together. CMF Design focused on the documentation and research steps, so that each subsequent part of the design process (Idea development, prototyping, and final production) could be as efficient as possible.



6.2 Appendix A

(copied and pasted from shared google document during a brainstorming session)
Criteria:
1. Must be replicable by students.
2. Must be able to protect teachers from COVID-19 transmission effectively in a variety of situations.
3. Must be within a reasonable price range.
4. Must not impair the learning environment.
Constraints:
1. Any individual solid barriers must be equal to or smaller than 32x20inches.
2. Needs to effectively block particulate from having a direct path between individuals.
3. Needs to be under $150 per unit.
4. Cannot block sound or vision to an impractical amount

Que marks on the floor to stay 6 feet away

Create a set of guidelines for the markings & where they should be
Chalk (or some other way of writing that could be erased)

Barriers

Retractable soft barrier (huge)
Three projector type rolls with soft plastic curtains that come out
Would be hard to clean possibly wouldn't block all air
3D locks/pin mechanisms

Retractable Soft Barrier (desk/small)
Shower curtain stuff in projector rolls attached to desk
Lock into place when teacher wanted to pull them up

Rolling soft barrier
Shower curtain type thing on wheels
PVC pipe/pipe frame

Rolling solid barrier (one panel)
Sheet of plexi glass on wheels
PVC pipe/ ABS pipe frame with plexi inside it
One with top pipe frame
One without top pipe frame
Holes in pipe/plexi glass
Castors (expensive)

Stationary solid barrier (Desktop) (mobile)
Small enough to fit on top of desk
stationary solid barrier (fixed)
Attached to desk
Adding a place for hand sanitizer dispensers

Stationary solid barrier (large)
Can be moved
Not rolling
Placed on classroom floor

Rolling Solid Barrier (multiple Panels)
With handles for ease of use/mobility
Could have school slogans on top of barriers
Easy to encapsulate something/group of people/someone
Light, easy to move away from/to an area
Easy to clean
Customizable to each classroom/workspace

Retractable solid barrier
Plexi glass
Slider attached to desk
Spring loaded or pins to hold in place
Sliders that would encapsulate desk
Sliding or locking mechanisms could be 3D printed
(is it even worth it to have retractable/movable barrier)
With holes that don't allow particles but allow sound

Shield that includes the board area

3D Printed Sliders

Extras:
Gap for sliding papers
Hole with no way for air to flow through but allows sound to go through

What are other schools doing
School demographics
Practices they're following