Team REMS

RECOURCEFUL ENGINEERS MANAGING SOLUTIONS




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1 Problem Formulation

1.1 Introduction

In this section, Team REMS introduces the background, objective statement, and black box model to solve the social distancing problem that the indoor science labs have at Six Rivers Charter School.

1.2 Background

Team REMS includes Kevin Stofer, Amber Elving, Molly Milford and Javier Ramos-Cool, students in Engineering 215 at Humboldt State University in the Fall of 2020. COVID-19 created a need for students and teachers to safely interact while still maintaining a standard of education. Six Rivers Charter School in Arcata, California is hoping to open their doors to students again in the Spring of 2021 and their small population of students allows them to test out social distancing practices without risking the safety of staff and students. Bethany Schmidt is a science teacher at Six Rivers Charter School who has requested designs from the Engineering 215 class. Science labs are highly interactive and require a lot of hands-on learning, so special accommodations are necessary to allow the students to have the best possible learning experiences under the circumstances of COVID-19. Team REMS seeks to ease the transition between online learning and in-person classes by creating a design that would mitigate exposure to COVID-19.

1.3 Objective Statement

The objective of Team REMS is to design and build a cost-effective indoor lab station that is replicable and easy to maintain. While abiding by the rules and regulations of the Centers for Disease Control and Prevention (CDC), local school board and Humboldt county, Team REMS is creating an effective product that will both foster education and mitigate exposure to COVID-19. Figure 1.1 is the black box model and is created to show the design process with the black box representing the solution. The input on the left of the box represents the problem Six Rivers Charter School faces and the output on the right is the effect of the solution that sends the students back to school safely.

Figure 1.1 Black Box Model
This black box model represents the problem students face at Six Rivers Charter School and the solution to the problem.

2 Problem Analysis and Literature Review

2.1 Problem Analysis

The problem analysis section identifies the criteria and constraints of Team REMS' and the client's idea. Problem analysis goes over the specifications, considerations, criteria, usage and production volume of the indoor lab product.

2.1.1 Specifications

This design needs to be able to attach to the laboratory tables while not causing any permanent damage to the tables in the lab. This design will need to be able to stop particles from flowing through it while also being transparent. Having circulation of fresh air is important. The barrier needs to be big enough to trap one's breath particles from going over to the next student's area. The surface will need to be easily disinfected.

2.1.2 Considerations

One thing to take into consideration is that the school might not be using this design long term. An assumption that the school will want to use this design long term is made. Team REMS needs to consider how high schoolers interact with the indoor lab product.

2.1.3 Criteria

Criteria	**Constraints**
Cost	The cost must be kept as low as possible without compromising safety, durability, and overall quality of the product.
Student-Instructor interaction	The product will need to aid in student-instructor interaction.
Maneuverability	Must be moveable and removeable
Interaction with heat	Must be able to withstand heat from Bunsen burners and other heat producing materials
Interaction with chemicals	Material of product must not decay, melt, or have any other harmful reactions in the presence of chemicals found in the lab.
Covid-19 safety	Must protect students from interactions with the virus when social distancing is not possible at their desks.
Aesthetics	Product must be visually appealing and multifunctional so that it can be used after covid-19 restrictions are lifted.
Collaboration with other students	Must allow students to interact safely.

Table 2.1 Criteria and Constraints

2.1.4 Usage

The product will be used by high school students participating in indoor Chemistry and Biology labs at Six Rivers Charter School. There will be multiple lab sessions per week in which product will be used. Each lab session will be comprised of approximately 14 students.

2.1.5 Production Volume

Team REMS will need to produce at least one product to serve as a sample for the classroom. From the design specifications it will be possible for the instructor or students to build more to supply the entire classroom.

2.2 Literature Review

2.2.1 Introduction

The purpose of the Literature Review is to gather background information about Six Rivers Charter School; how many students they have in their lab classroom at a time, what kind of classes they have in their lab, the materials they use and their usual safety measures they use in the lab. This literature review will also go over the most recent COVID-19 guidelines that the CDC and Six Rivers Charter School have put in place. Covid-19 Guidelines and Safety Measures

2.2.1.1 Masks

Using a mask that covers the nose and mouth of the wearer is effective in blocking airborne particles caused by breathing, coughing, and sneezing (CDC 2020).

2.2.1.2 Social Distancing

Social distancing, or physical distancing, is a precaution that is recommended by the CDC to decrease the spread of COVID-19. It entails staying at least 6 feet apart from people whenever possible (CDC 2020). Social distancing guidelines may be insufficient as one article concludes that large particles ejected from the mouth or nose while sneezing can travel more than 6 meters from the origin (Xie et al. 2007).

2.2.1.3 Hand Sanitation

The CDC recommends that everybody wash their hands regularly with soap and water especially after encountering other people or commonly used items such as door handles or shopping carts. When soap and water is not available, alcohol-based hand sanitizers with an alcohol content of 60%-95% is generally sufficient in removing harmful microbes (CDC 2020c, d). However, soap and water, when used correctly, can be more effective than hand sanitizer in cleansing hands of harmful pathogens and microbes when the hands of the user are visibly dirty and soiled (Ewen et al. 2010).

2.2.1.4 Surface Sanitation

The Centers for Disease Control recommends the following procedures to clean and disinfect surfaces of germs and COVID-19. First use soap and water to wash the surface clean of any dirt or other surface contaminants. Then use a qualified and regulated disinfectant that is listed on the CDC's "List N". If the disinfectant is on list "List N" then it is effective in killing COVID-19 (CDC 2020f).

2.2.1.5 Humboldt County Office of Education COVID-19 Guidelines

Humboldt County school districts will be able to decide how to reopen their schools based on state and local guidelines (HCOE 2020). The CDC has released information regarding what options there are for reopening schools and what risk level each option is. In simple and succinct terms, the more student-to-student and student-to-teacher contact there is, the higher the risk of infection of COVID-19 (CDC 2020b).

2.2.1.6 Humboldt County COVID-19 Information

As of October 1, 2020, Humboldt County has had 515 confirmed cases of COVID-19. This means that the emergency level in Humboldt County is 2 (yellow) which means that the risk of infection is moderate (News Flash 2020).

2.2.2 Barriers in Preventing the Spread of COVID-19

COVID-19 has caused a worldwide shortage in personal protective equipment (PPE) such as masks, gowns, and goggles which has prompted the World Health Organization to release interim guidance on the rational use of this protective gear. To minimize the need for PPE, the WHO recommended using physical barriers made of materials such as glass and plastic to reduce exposure to the COVID-19 virus (WHO 2020). To summarize, these dividers serve three main purposes:

1. Blocking respiratory droplets that could spread the COVID-19 virus,
2. Reinforcing social distancing boundaries, even when someone forgets, and
3. Reducing the need for other PPE such as masks and gloves.

2.2.2.1 Materials

Some commonly used materials in protective barriers include glass, acrylic (Plexiglass) and polycarbonate plastic. Plexiglass and plastic are highly recommended for the use in barriers because they are lightweight, easily shaped, and more affordable than glass dividers (Eykelbosh 2020). They are also able to resist more impact than glass which makes them durable and safe to use in classrooms with children.

2.2.2.2 Effectiveness

In a study conducted by Chih-Han Lin, MD et al. (2020), researchers tested the effectiveness of barriers in preventing the passage of respiratory particles from one side of the barrier to the other. A sprayer filled with a fluorescent agent was used to mimic how respiratory droplets would spread from a real person. According to the report, they first conducted a test without the barrier and had the test subject wear all WHO recommended PPE – mask (face-shield), gown, gloves, goggles, and hair cap - and found that the fluorescent agent still passed through the protective face shield and onto the person's skin. When they tested this process using the protective barrier, no particles passed through the barrier and reached the test subject.

2.2.2.3 Installation and Dimensions

The barrier must allow enough space for the person to breathe while keeping their breath particles on their side of the barrier. This breathing zone is a circle with a minimum radius of 12 inches extending from the person's nose (Eykelbosh 2020). Thus, a barrier must be built to accommodate the tallest person the barrier would be used by. Protective barriers also typically have a slot or opening that allows people to pass through materials when interaction is necessary.

When installing a protective barrier there are three main techniques: free-standing, mounted to the desk or surface, and hanging from the ceiling (Eykelbosh 2020). With a free-standing model, side panels should be attached to create more stability otherwise the structure would easily fall over. The surface-mounted technique is the most stable but also makes moving the barrier more difficult. The hanging partition is both visually appealing and sturdy because it cannot easily be knocked over or tampered with. On the other hand this method leaves a gap between the surface and the barrier and since it is not stationary, this could cause air to be wafted from one side of the partition to the other, possibly allowing droplets to pass through.

2.2.2.4 Sanitization

Although the protective barriers prevent respiratory particles from passing to neighboring people, these droplets still adhere to the surface of the partition and the surrounding surfaces. Because of this, the entire area must be sanitized after each use by a new user and should be sanitized once a day if it was not used at all as a precaution. In countries where in-person school has resumed, the sanitization recommendations for workspaces and barriers include first cleaning the surface using a mild soap and water and then following that with a disinfectant such as chlorine dioxide (Melnick and Darling-Hammond 2020).

2.2.3 Laboratory Material

A classroom laboratory has materials used to protect the students and laboratory equipment from potential damage caused by experiments and normal wear and tear.

2.2.3.1 High Pressure Laminates

High pressured laminates are used in a laboratory setting on the desktops and counter space. The most commonly used laminate is sold by a company called Panolam. This company sells a product called ChemGuard and is found in high school laboratory settings. High pressure laminates are made of highly compressed panels of wood, pressurized at 1,200 psi and then heat treated at 340 degrees Fahrenheit. The high-pressured laminate surface is then cooled, and a melamine resin layer is added to the top (Hiziroglu 2012). This type of laminated surface is scratch and heat resistant.

2.2.3.2 Glassware

Glassware comes in seven forms in a laboratory and is required for different levels of temperature, the chemicals they may contain during an experiment and their interaction with the electromagnetic field. Below are the basics needed for a generic lab (CBSC add date of article here):

Actinic Glass

Borosilicate Glass

Fused Quartz

Heavy-walled glass

Fritted glass

Coated glassware

Silicone glassware

Glass items commonly found in a high school laboratory are:

Beaker (50, 250, 400, 1000 ml)

Erlenmeyer flask (100, 250, 500 ml)

Funnel

Graduated cylinder (10, 25, 100, 500 ml)

Petri dish

Stir bar

Test tube (16 100 mm and 24 150 mm)

Volumetric flask (100, 500, 1000 ml)

2.2.3.3 Other laboratory Items

There are many items found in laboratories that are not glass but are imperative to the experiments that are performed. These common items are normally shared items during an experiment (CBSC add date of article if you can):

Balances (digital and manual)

Bunsen burners

Filter paper

Support stand with rings

Test tube brush

Test tube clamp

Test tube rack

Thermometer (alcohol immersion capability)

Wash bottle

Wire gauze with ceramic center

2.2.4 Laboratory Safety Equipment

Laboratory safety equipment is standard across all of California's high schools. District, local and state requirements are considered when following safety guidelines at any school in California. Students at Six Rivers Charter School will need the following personal protection equipment in their lab.

2.2.4.1 Dress code

All students must wear appropriate clothing. Appropriate clothing is clothing that is not bulky, with no hanging jewelry, long hair pulled back and long sleeves will be rolled up. Shoes must be close-toed. (Breazeale, Waters 241). The COVID-19 dress code will include masks.

2.2.4.2 Goggles

Eye protection is an essential part of personal protective equipment in any laboratory. The National Science Teachers Association (2020) states that all protective eye wear worn in a laboratory should be ANSI approved Z87-1 chemical-splash goggles to ensure complete eye safety in the presence of harmful chemicals or materials. These goggles should always be worn in the laboratory, unless the instructor specifically states that goggles are not required for the activity. The following list includes scenarios when proper eye protection must be worn (NSTA 2020):

- In the presence of chemicals, dust, and fumes,
- When working with heat sources such as Bunsen burners or hot plates,
- When generating projectiles or working with materials under high pressure which could cause rupturing and flying particles,
- When working with biological specimens, and
- When using sharp materials or tools (NSTA).

These goggles should fit snugly to the person's skin around the eyes to prevent the passage of harmful materials. They should also be properly disinfected after each use.

2.2.4.3 Gloves

In the presence of harmful chemicals or biological elements such as blood, gloves must be worn to protect the student. Typical gloves used in a school laboratory include chemical resistant neoprene or latex gloves, and for those that have latex allergies, nitrile gloves can also be used. Occasionally in a lab, students also work closely with hot materials and instruments which can warrant the need for heat-resistant gloves if the items need to be handled directly rather than using a tool to hold the hot item.

2.2.5 Six Rivers Charter School Interviews

2.2.5.1 Don Perry, Principal of Six Rivers Charter School (Sep. 25, 2020)

In an interview with Don Perry, the Principal of Six Rivers Charter School, we discussed the question, "What would school life be like with kids back in school?" We concluded that the students would more than likely be required to wear masks. There would also likely be a system in place for how students enter and exit a building. We talked about budget for the engineering design project and ways that we can keep the price low. There is no set number value for what the project should cost, but we will do our best to keep costs low while not letting that affect our ability to create a good product.

2.2.5.2 Bethany Schmidt, Science instructor at Six Rivers Charter School (Oct. 3, 2020)

1) *What kind of labs are we needing to design for?*

There will be a Biology lab. There will also be Chemistry labs.

2) *How will each lab be facilitated?*

Here kids will need to work together but they do not need to share any of the tools they use in the lab. It is possible for them to all have their own tools. Because of the design of the room and the stationary desks they have, they will not be able to implement the idea that each student will have their own desk on wheels. Our design will have to be designed to be compatible with the lab desks they are using now.

3) *How many lab classrooms are there and how many students in each classroom?*

There is one classroom that will have two different classes, 9th and 10th grade, using it. This consists of about 28 students total using the classroom. Each class would use the lab at different times, so we are looking at 14 kids per use.

4) *Do you already have an idea of what you'd like the design to look like?*

Bethany was describing her ideas of what she imagines if students could go back to school before a vaccine is released. Her ideas consist of partitions that are transparent. Students will be sitting at desks with clear dividers dividing them. She will be able to walk up to students and see their work while being safe. Students will also be able to communicate through the shields and help each other. One of the learning objectives for Six Rivers Charter School is collaborative learning. Students need to be able to collaborate about labs to help them learn the skill. It would be nice to be able to reuse the material once COVID-19 is over. Partitions can be used later to help kids who have a hard time focusing, focus. It could also be used for testing. The classroom has only one vent to move noxious gases out of the room. Bethany mentioned an idea of having a better venting system at the school. Air would be pulled through a filter and pushed outside so that there was always fresh air circulating through the lab. The room has a very tall ceiling. The vent they have now would most likely not be effective in creating a good flow of air.

2.2.6 Interviews: Informed Individuals Outside of Six Rivers Charter School

2.2.6.1 Sean Reynolds: Chemistry Instructor at Lake Tahoe Community College

Sean brought up reasons why in-person schooling can be very difficult when trying to follow the CDC guidelines. There are scenarios when students do need to use the same device or if the teacher is showing the class an example, he needs to be able to show them all at once. This would involve students getting close to each other. He comes up with an interesting topic about splitting the class in half; half of the students worked on problems while the other half worked on the lab. Less people in a classroom is always better. Sean Reynolds also points out air flow. In a science lab you do not want dirty air getting in. A lab needs to be clean and sterile. Having an air filtration system might be the best way an engineer could help. Air filtration in a lab provides help far beyond the COVID-19 situation.

2.2.6.2 HSU student

I talked with an HSU student that is taking in person labs this semester. While he is in lab, they have the fume vents open on one side of the room as well as the windows on the other side of the room. This creates a constant flow of fresh air in the lab room. Bethany talked about how having a fume hood in her lab at Six Rivers Charter School would be helpful in creating a draft as well as removing harmful gases from the room.

3 Alternative Solutions

3.1 Introduction

Alternative solutions to solve the problem were created during brainstorming Zoom meetings. While coming up with new designs the team considered the criteria and constraints of each design to come up with the most realistic prototype. The eight potential designs are presented in section 3.3.

3.2 Brainstorming

During two Zoom brainstorming meetings, Team REMS came up with eight designs to satisfy the requirements for this project. During each session, the team used pencil and paper to sketch possible solutions. Each member would create their own design or work and build off another member's design. The team utilized screen share and shared documents to come up with these ideas virtually.

3.3 Alternative Solutions

Listed below are eight solutions that Team REMS has decided as good possibilities for their final project. Many of the ideas are similar and will be used together to create the final project. Each solution will have a picture to better articulate the meaning and design of each individual solution the team generated.

3.3.1 The Portable Lab Tray

The Portable Lab Tray would be a lab tray a little smaller than an average classroom desk. It would be mobile so students could work and participate in labs from anywhere in the lab room as long as they have a flat surface on which to place the tray. The tray would have a ring stand, heat pad, and a test tube rack built in with sufficient space to work as well. The tray would be made of a type of wood or recycled plastic. Recycled plastic would be the best option since it is easy to clean and sanitize between lab sessions. Figure 3.1 shows a top view of the Portable Lab Tray in its simplest form. Figure 3.2 shows what the Portable Lab Tray could look like on a student's desk.

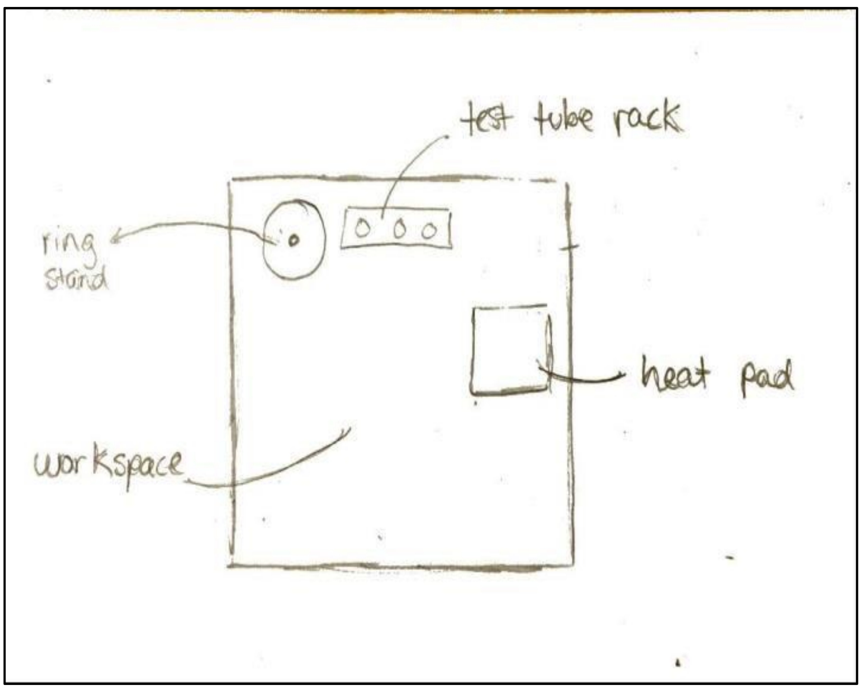

Figure 3.1 Top view of the Portable Lab Tray.
(Photo by Javier Ramos-Cool)

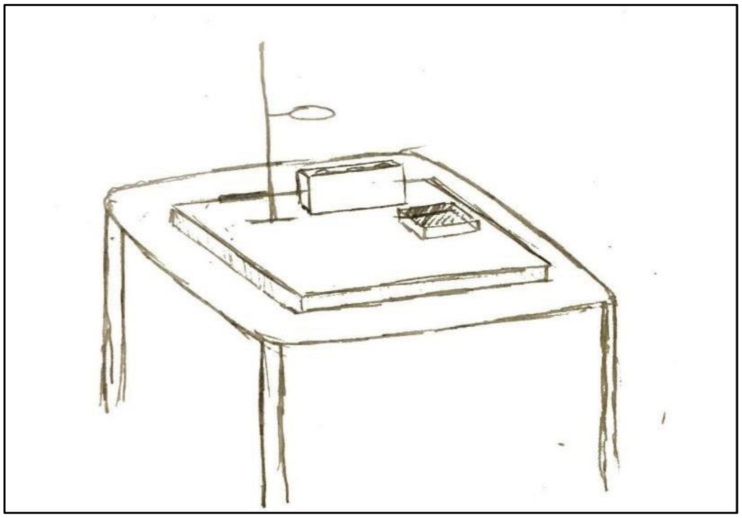

Figure 3.2 Orthographic view of the Portable Lab Tray on a student's desk.
(Photo by Javier Ramos-Cool)

3.3.2 The Mobile Lab Station

The Mobile Lab Station would be a two-person mobile lab station that could be moved anywhere in the lab room to abide by social distancing guidelines. There would be a shared plexiglass barrier as well as two plexiglass side panels to further protect students from salivary projectiles. Each of the two students would have their own lab bench where they could conduct experiments. Figure 3.3 shows a top view of the Mobile Lab Station and its different components. Included in the Mobile Lab Station would be a ring-stand, heat pad, waste receptacle, a test tube rack, and ample space to conduct experiments. In addition to blocking salivary projectiles from other students, the plexiglass barriers would act as "white boards" where students can write notes on the fly while conducting experiments using a dry erase pen. Figure 3.4 shows the orientation of the plexiglass barriers and the students' sitting position.

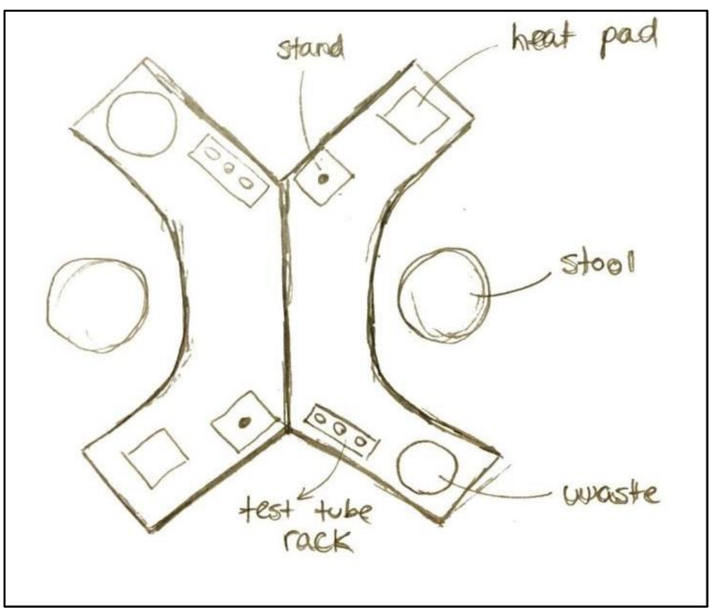

Figure 3.3   Top view of the Mobile Lab Station showing its components
(Photo by Javier Ramos-Cool).

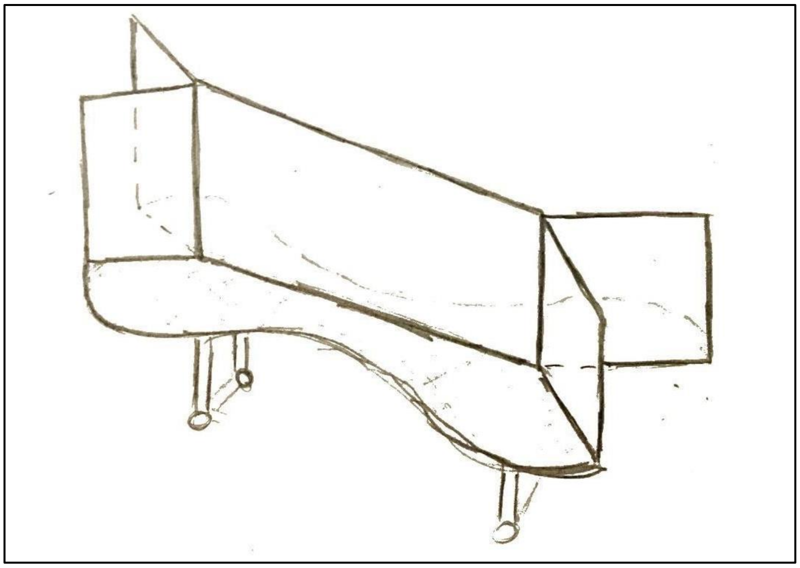

Figure 3.4 Orthographic view showing the orientation of the barriers
(Photo by Javier Ramos-Cool)

3.3.3 Barrier with Projector

The plexiglass barrier would be completed with three pieces of plexiglass mounted in a specific way around each student. The students will still need to practice social distancing. The projector would be a way for the teacher to still be able to communicate their ideas without the students leaving their barrier and looking at the white board or projected lesson plan at the front of the room. The projector would also give the student room, so they are not cluttered at their desk with lesson plans. Having the projector would also minimize contact between students and teachers through paper lesson plans. The teacher can control these projectors manually.

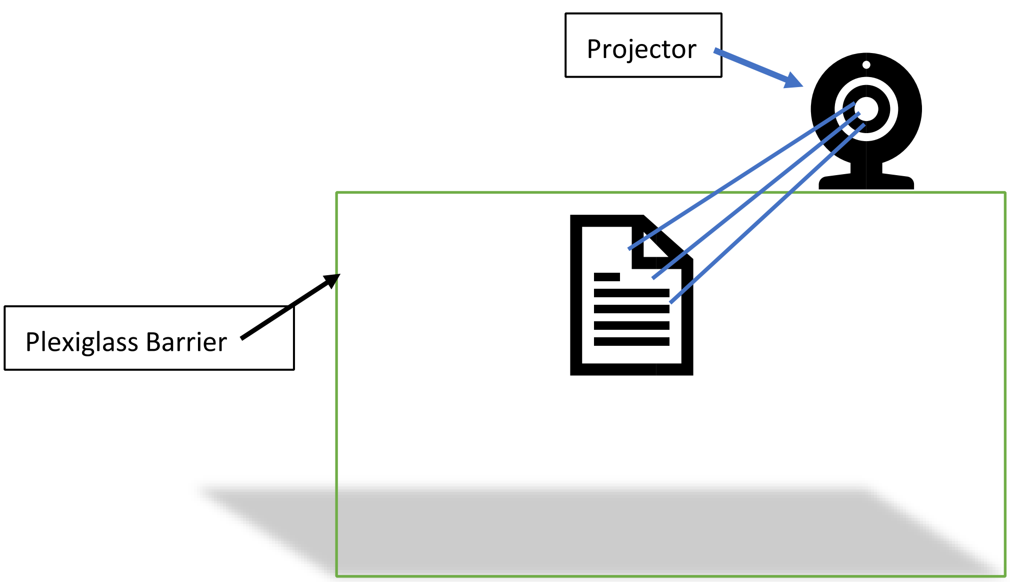

Figure 3.5 Front view of barrier with projector
(Photo by Amber Elving)

3.3.4 Barrier with Projector and Fan

The plexiglass barrier would be completed with three pieces of plexiglass mounted in a specific way around each student. The students will still need to practice social distancing. The projector would be a way for the teacher to still be able to communicate their ideas without the students leaving their barrier and looking at the white board or projected lesson plan at the front of the room. The projector would also give the student room, so they are not cluttered at their desk with lesson plans. Having the projector would also minimize contact between students and teachers through paper lesson plans. The teacher can control these projectors manually. In some experiments, students should not inhale the fumes from the chemicals they are working with. Another object that could be attached to the plexiglass barrier is a small fan. The fan would create air movement and would be attached to the top of the plexiglass barrier, pulling air out through the top. A real fume hood would also need to be implemented for labs to be conducted safely.

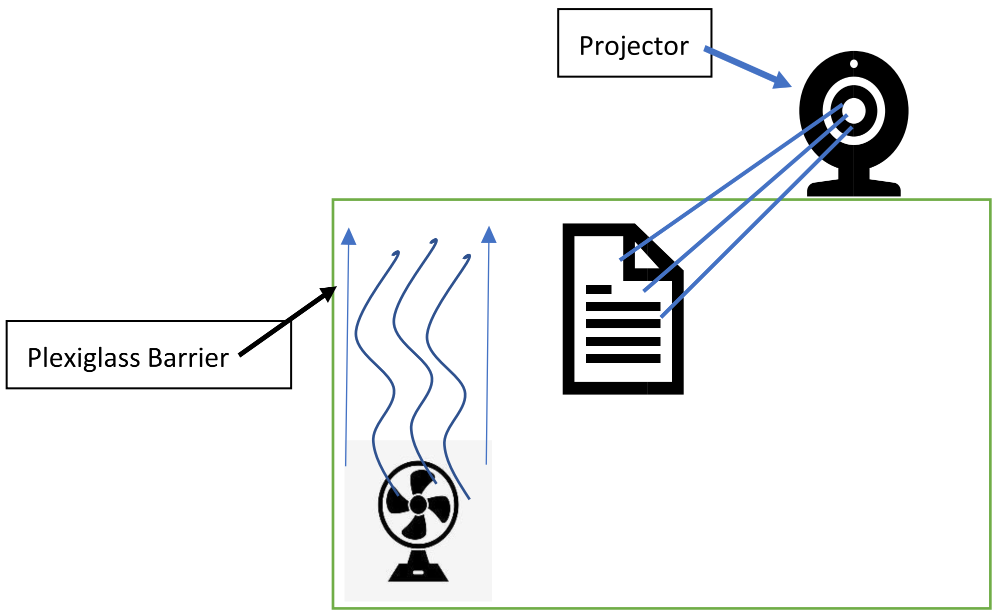

Figure 3.6 Front view of projector with barrier and fan
(Photo by Amber Elving)

3.3.5 Sliding Barrier

This design involves the use of a three-sided barrier (either plexiglass or transparent, rigid plastic). This design allows the teacher and student to see through the design while preventing respiratory particles from spreading throughout the classroom and protecting the student from neighboring classmates. The side panels will be mounted to the table using desk edge clamp mounts which are fastened to the desk by hand tightening without using screws to prevent damage to the table and for easy removal/ installation. The side panels will extend out from the desks edge to separate a student from their desk mate and deter students from interacting with classmates around the barrier. The front panel will be able to slide forward and backward to allow the student to bring the piece forward so they can use it as a writing board which can be easily erased. This method will help students solve problems and write notes so that the board is more appealing to them and not just an obnoxious wall around them. The main barrier wall is connected to the side panels on the top by a bracket attached to a wheel on each side which allows the panel to move forward and backward. There will be breaks on the wheels so that the board will stay in place wherever the student prefers it to be placed. On the bottom and two sides of the sliding panel there will be foam insulation tape, like the strips on the bottom of a door which prevent drafts. This tape has low friction so that the panel can still easily move but will keep the edges sealed so that the barrier still serves its purpose of protection regardless of the panel's placement.

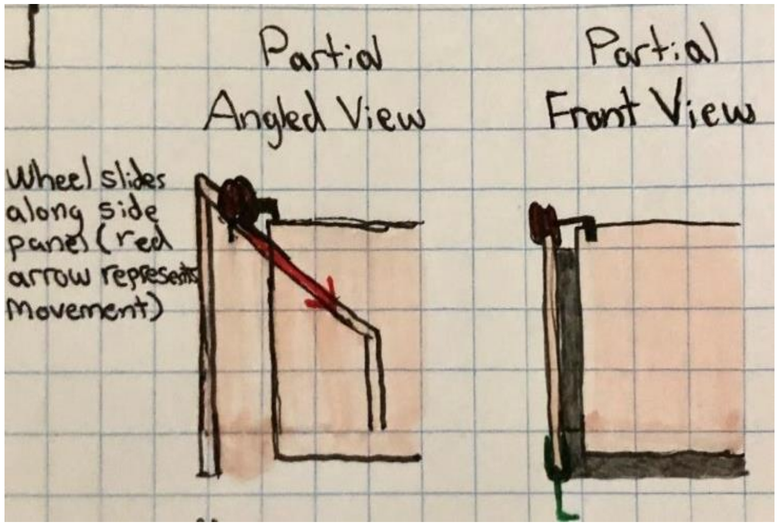

Figure 3.7 Partial views of sliding barrier (Photo by Molly Milford)

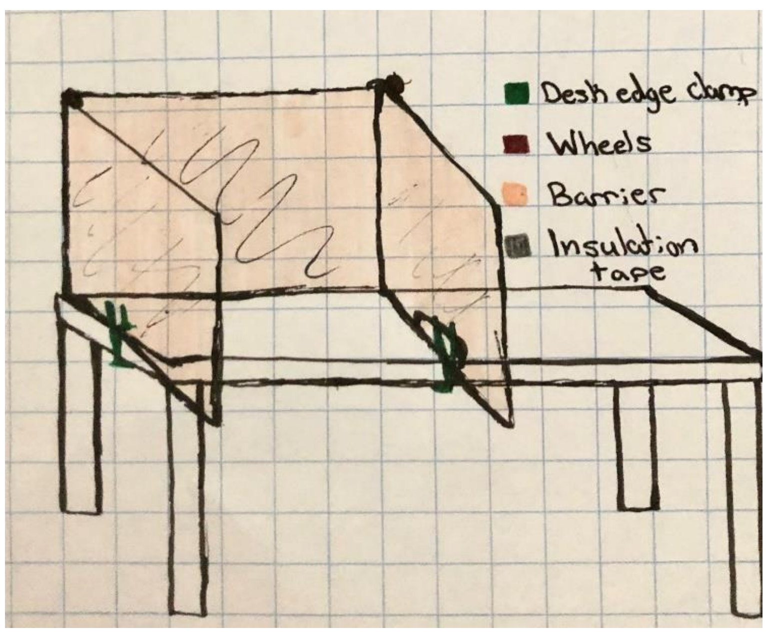

Figure 3.8 Complete view of sliding barrier (photo by Molly Milford).

3.3.6 The Fishbowl

The fishbowl method represents a design that each individual student would use. This would be a 1 size fits all "fishbowl". Each "fishbowl" would go over a student's head. There would be shoulder cushions so that the students head would be in the center of the bowl. The shoulder cushions would consist of "U" shaped pieces of plastic with a strip of one-sided stick cushion material that would be connected to the "U" shaped plastic. At the bottom of the bowl would be a cloth sleeve around the bowl that could scrunch around the students' neck. This will keep respiratory particles from floating under the bowl. Above each person's head, there would be a 3-layer system to keep the air inside the bowl fresh. The first layer would be a thin cloth material, the second method of filtration would be a fan, and finally a COVID-19 safe filter. The fan will be blowing in the vertical direction. The first cloth is to protect students' hair which should be used with a hair net for double protection to prevent hair from getting caught in the fan.

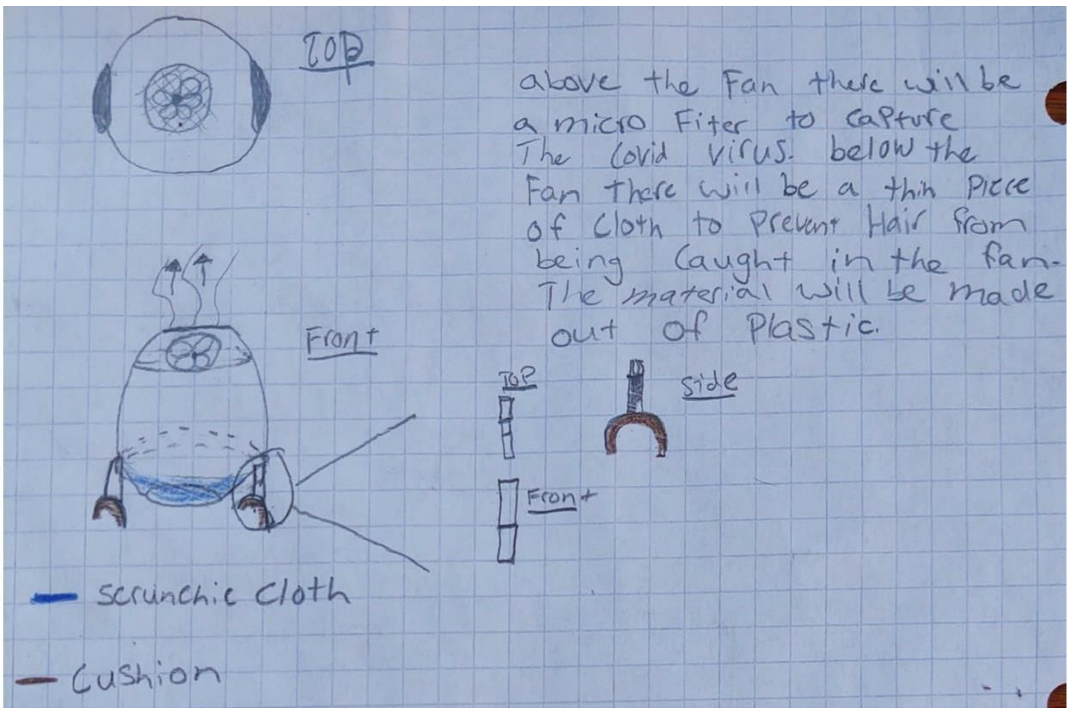

Figure 3.9 Front and top view of The Fishbowl
(Photo by Kevin Stofer)

3.3.7 Mounted Barrier

The mounted clear material will be mounted with "T" brackets and "L" brackets. We needed a way to mount something to the lab tables without doing any permanent changes to the tables. On the inside of all the brackets will be rubber for extra friction of holding the clear material in place. The "L" bracket will have a hand tightened screw so that it can be tightened to the lip on the back side of the table. There will be 4 "L" brackets place along the back side of the table, this will hold in the back panel. The divider panels will have 2 hooks cut out at the end. These hooks will slide through rectangular cutouts that will be cut out of the back panel. This will lock in the divider panels. For extra support there will be a" T" bracket. It will have adhesive so that it can stick to the table for support. The panels will slide into the slot on the "T" bracket.

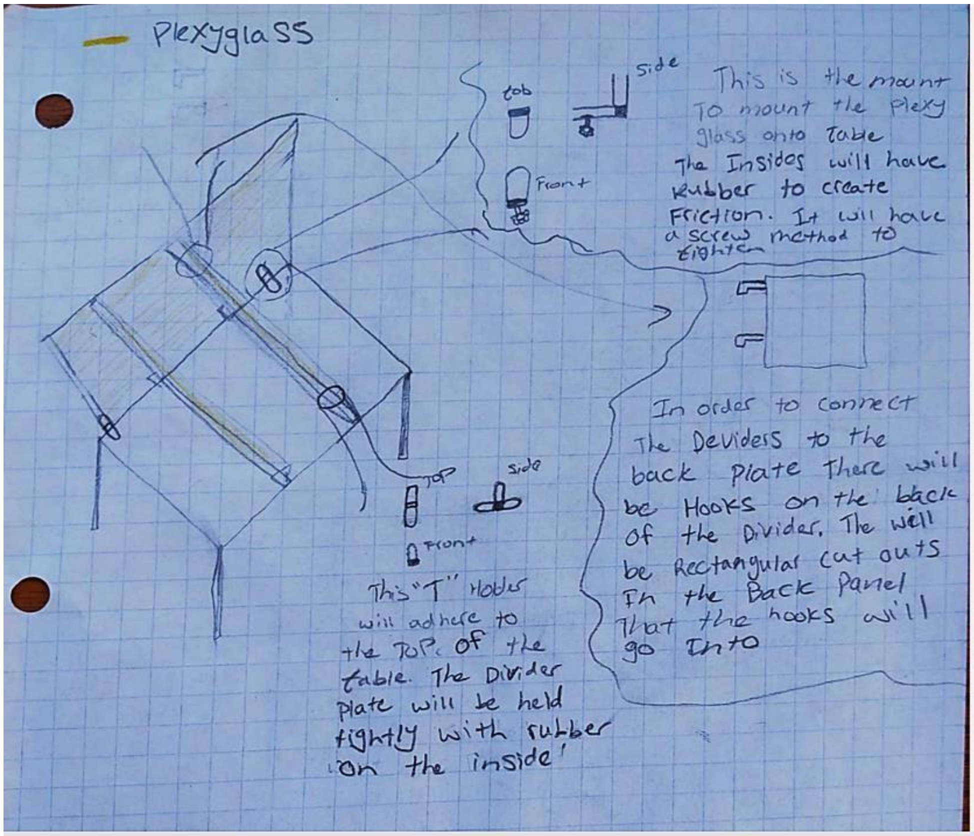

Figure 3.10 Diagram of mounted barrier with comments
(Photo by Kevin Stofer)

4 Decision Process

4.1 Introduction

Section 4 explains the different alternative designs for barriers and will use a process to choose the one that will fit the client's needs best. A meeting was held with the client to go over the alternative designs. We talked about each design and how it can be implemented in a classroom. There were some issues with air flow in the lab room that could cause complications with the final design but overall, the final design will be selected using a numerical scale called the Delphi matrix.

4.2 Criteria

The criteria are based off the specific needs of the client, and the CDC COVID-19 recommendations. The definitions of the criteria are listed below.

- **Cost**: The school plans on supplying $100. An additional $75 can be contributed by each team member. There are 4 team members. With these funds we need to build at least one working design for the classroom.
- **COVID-19 Safety**: The product needs to abide by COVID-19 safety regulations and minimize excessive exposure of students and teachers to COVID-19.
- **Aesthetics**: The product should look simple and elegant. It should not distract students from in-class work.

- **Student Collaboration**: The product should aid in student collaboration within the classroom setting.
- **Interaction with teacher**: The product should allow for the teacher to come within six feet of the student while still being protected.
- **Replicable**: The product needs to be able to be replicated many times.

4.2 Solutions

The alternative solutions from section 3 are displayed in the list below. They were created by the team and some of the designs were presented to the client to help finalize the decision.

- Portable Lab Tray
- The Mobile Lab Station
- Barrier with Projector
- Barrier with Projector and Fan
- Sliding Barrier
- Fishbowl
- Mounted Barrier
- Hanging Barrier

4.3 Decision Process

The Delphi method was used to decide the final solution for Six Rivers Charter school. Each part of the criteria was given a specific weight that best described the amount of need each criterion had to meet. The scale used was 1-10, with 10 being the highest importance and 1 being the lowest importance. After an interview with the client, the group came to a decision about the weights of each of the criteria. Then each solution was rated on a scale of 1-50 for how well the design met the specified criteria. This scale is represented as 50 being a criterion that best fits the solution and zero represents it not meeting the criteria at all. The team decided again on scores for each solution. The two numbers were multiplied and then added to create the final score for each solution. The solution with the highest final score was determined to be the best solution for the final design.

Table 4.1 The Delphi Model

Criteria (0-10 high)		**Alternative Solutions** (0-50 high)							
List	**Weight**	Portable Lab Tray	Mobile Lab Station	Barrier & Projector	Barrier with Fan & Projector	Sliding Barrier	Fish Bowl	Mounted Barrier	Hanging Barrier
Cost	8	45 / **360**	20 / **160**	20 / **160**	20 / **160**	20 / **160**	25 / **200**	40 / **320**	25 / **200**
Maeuverability	8	50 / **400**	45 / **360**	40 / **320**	35 / **280**	35 / **280**	50 / **400**	45 / **360**	10 / **80**
Covid-19 Safety	10	40 / **400**	50 / **500**	50 / **500**	50 / **500**	50 / **500**	45 / **450**	50 / **500**	40 / **400**
Aesthetics	7	45 / **315**	45 / **315**	40 / **280**	40 / **280**	50 / **350**	20 / **140**	45 / **315**	20 / **140**
Student Collaboration	6	25 / **150**	45 / **270**	30 / **180**	30 / **180**	30 / **180**	25 / **150**	35 / **210**	35 / **210**
Interaction with teacher	9	35 / **315**	30 / **270**	45 / **405**	45 / **405**	40 / **360**	35 / **315**	40 / **360**	40 / **360**
Replicable	9	50 / **450**	25 / **225**	35 / **315**	35 / **315**	25 / **225**	30 / **270**	45 / **405**	30 / **270**
Total		**2390**	**2100**	**2160**	**2120**	**2055**	**1925**	**2470**	**1660**

4.4 Final Decision

Table 4-1 shows that the mounted barrier solution is the solution that meets all the criteria that the team came up with. This decision also the design is moveable and replicable with the safety from COVID-19 at a 50. With the safety being the most important aspect of the project, the team decided to go with a mounted barrier option. This will be the best option in terms of price, maneuverability, safety, aesthetics, student collaboration, interaction with teachers and can be replicated.

5 Specification

5.1 Introduction

Section 5 will further describe the final solution chosen in the previous section in detail. Diagrams along with descriptions of the design are provided to show dimensions, materials used, and different perspectives to help visualize the mounted barrier. Charts are provided to examine the cost of hours dedicated to the project by the team, cost of materials, and cost of maintenance. Instructions for constructing and using the design are also provided.

5.2 Prototyping

5.3 Description of Solution

This barrier was created by Team REMS to protect Six Rivers Charter School students from excessive exposure to COVID-19 so they can safely return to in-person education in the science laboratory. The barrier features 3 sides of 2mm thick transparent vinyl which prevent respiratoy particles of neighboring students or teachers from coming in contact with the student behind the vinyl barrier. The transparent vinyl was chosen for the barrier material because it is less expensive than rigid plexiglass and easier to work with. The frame is made of 1.5”x1.5” Aluminum Angle and 0.75”x0.75” Aluminum Angle secured using nuts, bolts and washers. The vinyl is secured to the frame using multiple small strips of Gorilla Mounting Tape. Figure 5.1 below shows the final design and points out a few key elements of the barrier, including the detachable whiteboard that is clipped to the structure so students can easily remove it and use it for class activities.

Figure 5.1 Completed Barrier (photo by Javier Ramos-Cool)

5.3.1 Barrier Dimensions and Structure

The barrier was designed to fit the school laboratory's desks based off the measurements taken at the school. The width of the barrier is 36 inches to provide ample desk space for the students to work, while the 36-inch side panels extend from the back of the desk to 8 inches past the front desk edge. Aluminum angle bars were used to build the structure of the barrier because they are lightweight, strong, and easy to clean between uses of the barrier. Figure 5.2 displays all dimensions of the barrier to scale in inches, including the size of the aluminum bars.

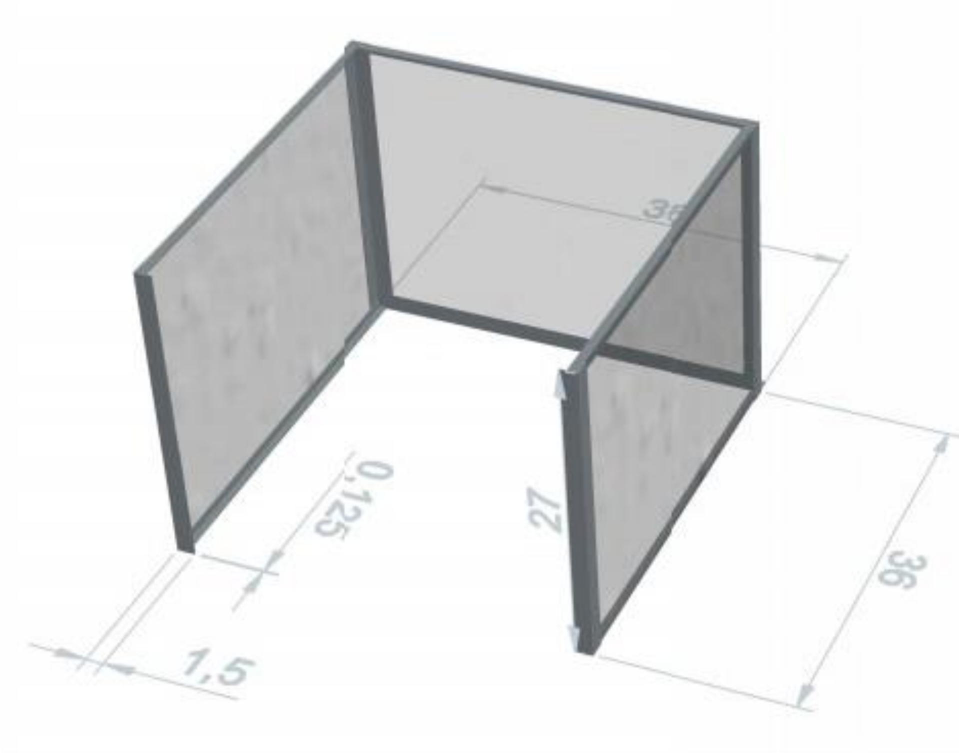

Figure 5.2 AutoCAD model displaying dimensions of barrier and aluminum angle bars (Created by Molly Milford)

5.3.2 Extended Side Panels

The two 36-inch side panels extend past the desk to allow the students to interact with their neighbor while remaining behind the barrier and staying protected from possible contact with COVID-19. Figure 5.3 below on the left is a scaled model showing what the barrier and side panels will look like on the classroom desks. Figure 5.4 shows what the barrier looks like from the side to demonstrate how far the side panels will extend past the desk edge.

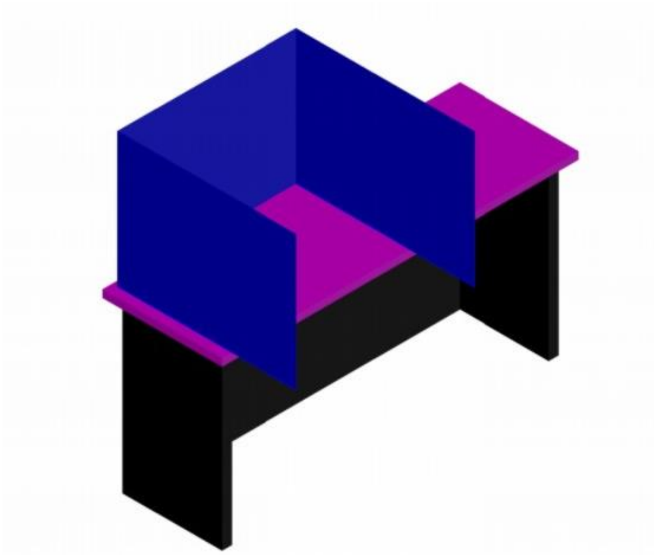

Figure 5.4 Scaled AutoCAD model of barrier on desk displaying extended sides. (Created by Kevin Stofer)

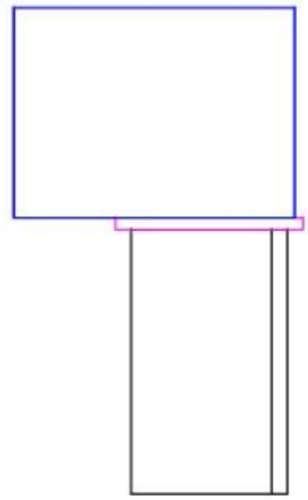

Figure 5.3 Side view of the barrier's side panels extending past desk edge. (Created by Kevin Stofer)

5.4 Cost

5.4.1 Design Cost

The design costs refer to the number of hours spent on the project as a team. Figure 5.5 displays a pie chart that shows percentages of how the total project time of 135 hours was split between each phase of the design process. Most of the time (51%) was spent on choosing and finalizing the design which includes prototyping, researching and purchasing materials, and analysis to choose the best design. Other categories include problem formulation, design brainstorming, design alternatives, and build time.

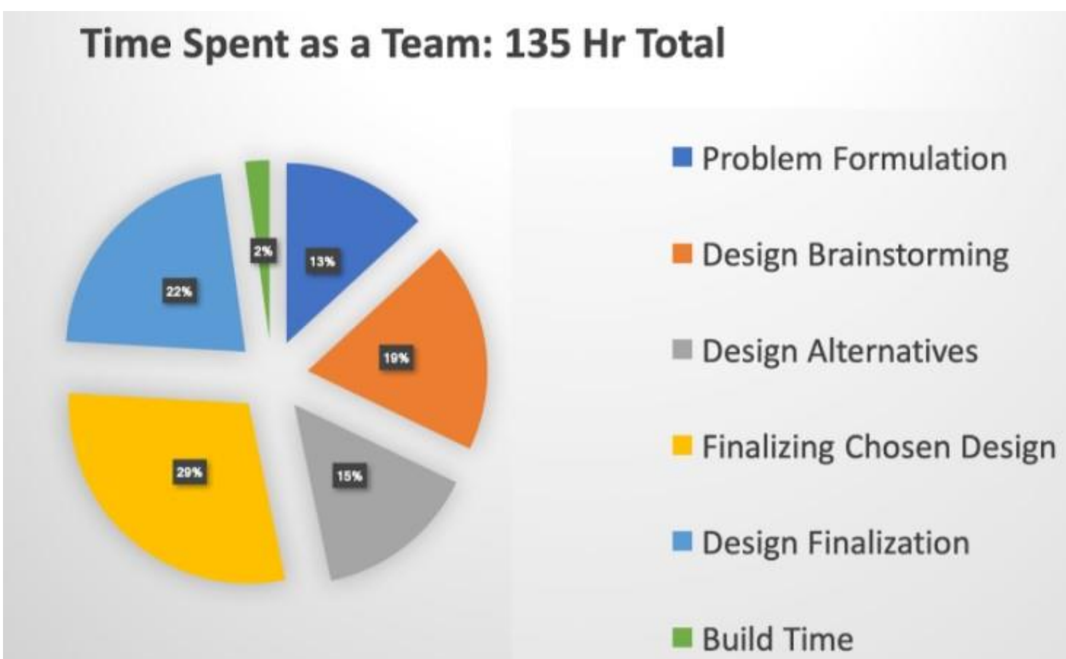

Figure 5.5 Total team design hours divided by project phases. (Created by Kevin Stofer)

5.4.2 Cost of Materials

Figure 5.6 below gives a pie chart to show how the total cost of materials was distributed between each item. The total cost of materials to build one barrier was $184, where 24% of this was the cost of the transparent vinyl, 64% for the L-bracket frame (aluminum angle bars), 5% for the double-sided tape, and 7% for the screws and nuts. The costliest item is the aluminum angle bars used to build the frame, since the design required a lot of this material which totaled to be six 36” pieces and four 27” pieces, which were cut to the proper sizes.

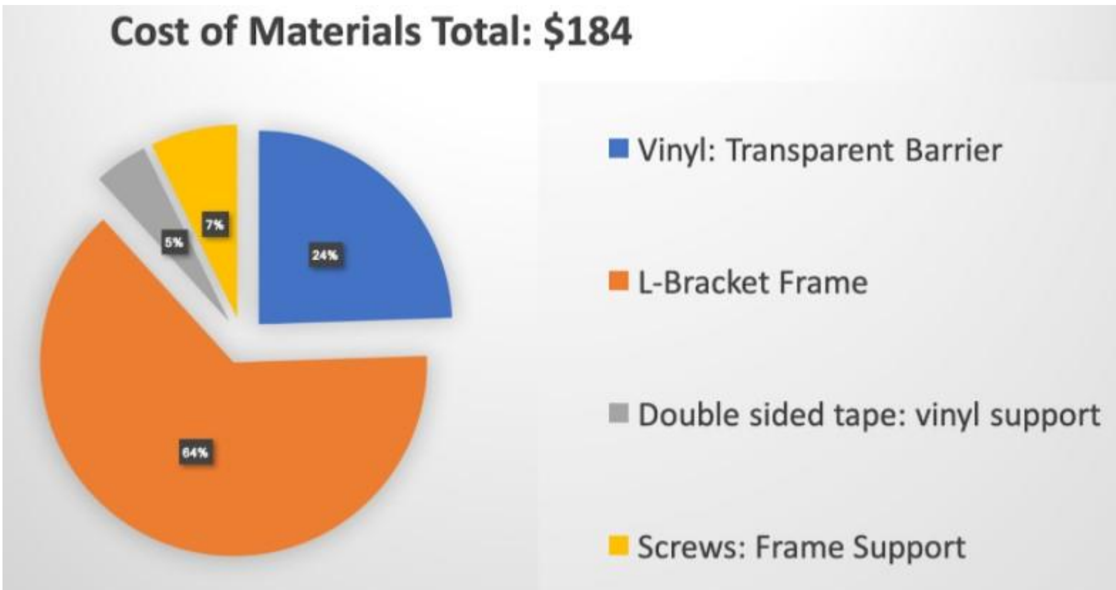

Figure 5.6 Cost of materials for the barrier
(Created by Kevin Stofer)

5.4.3 Cost of Maintenance

To keep the barrier safe and functional there are two maintenance tasks Team REMS found to be needed: cleaning the barrier and replacing the double-sided tape. The barrier must be cleaned after each use by a new student to keep the barrier clean of any possible contaminants that could be a health risk to the next person using the barrier. The barrier can be cleaned with any multi-surface or vinyl specific cleaner, which would cost around $10 on average for a 32 oz bottle and would last the entire year. Although it is not determined exactly how long until the double-sided tape will lose its effectiveness, Team REMS figured that it was possible for parts of the tape to peel back and require replacement after about a year. The maintenance cost per year, frequency, and amount of time needed to complete the maintenance task are all displayed in table 5.1 below.

Table 5.1 Cost of Barrier Maintenance

Maintenance Task	Frequency of Task	Time to Complete Task	Cost Per Year
Cleaning Barrier	After each use (~ 3x/day)	30 seconds / cleaning	~$10/ bottle of cleaner
Replace Tape	Once per year	20 minutes	$8.24 per roll of tape

5.5 Instructions for Barrier Use

The instructions to use the barrier are straightforward.

- Students must walk to their seat while maintaining six feet of separation
- Sit down behind the barrier
- Wash their hands with hand sanitizer
- Complete their in-class activities
- Sanitize the barrier with an approved cleaner and paper towels
- Walk out of the classroom while maintaining six feet of separation.

5.6 Results

The barrier Team REMS created was successful in many ways and met all the criteria to a certain extent. It protects the user from excessive exposure to COVID-19. It aids in student-teacher interaction by allowing the teacher to come within six feet while still maintaining an adequate level of protection. The cost to build the barrier was below the budget but we do believe that the cost could be lowered by purchasing materials in larger quantities if the need arises. The barrier is replicable but requires some practice to build it quickly. We have yet to see if it aids in student interaction as the barrier has not yet been implemented at Six Rivers Charter School. Feedback from Ron Perry, principal of Six Rivers Charter School, and Bethany Schmidt, science instructor at Six Rivers Charter School, has been very positive as of now December 11, 2020, but we expect more constructive feedback in the future when they are able to see the barrier in real life.

References

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