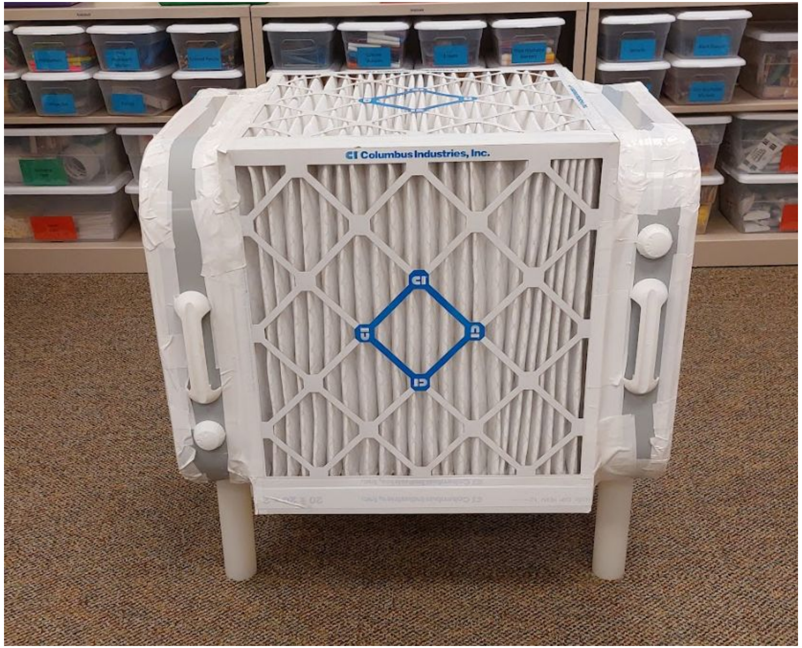
# Improving Indoor Air Quality

Dual-Fan Stilts (DFS) Box


Side view of the DFS Box (Above).




Front view of the DFS Box (Above).

# Introduction:

During the winter of 2022, our class studied plagues, pandemics, and viruses to learn about past methods of prevention for widespread illnesses. We hoped to use what we learned to apply some of those methods of prevention at our school, to reduce the amount of student and staff absences. Some of the methods of prevention that we researched included washing hands, quarantining when sick or exposed, social distancing, and wearing masks (Https://www.CDC.gov, 2022). Then, we came across a newer method of prevention, called a Corsi-Rosenthal (CR) Box. A CR box is "a DIY air filter using 4 merv 13 filters and a box fan". (Filmer, 2022) From there, we contacted Dr. Megan Jehn, a epidemiologist at Arizona State University (ASU), to learn more. She set up a Zoom meeting for us to speak with ASU engineers, scientists, lawyers, epidemiologists, and even one of the cocreators of the CR Box, Jim Rosenthal. From them, we learned how poor air quality contributes to the spread viruses through particulate matter (PM). PM can be collected and measured using a Quant AQ Modulair PM sensor (Andino, 2022). This device, measures PM in microns per square meter ($\mu g/m^3$). The Modular PM sensor can take readings of PM 1, PM 2.5, and PM 10, however, if we want to reduce the size of virus PM, we should focus on PM 2.5 because it's the average size of viruses (Jehn, 2022).

After our Zoom meeting with ASU and Jim Rosenthal, we wanted to build CR boxes on our campus to see if they could help us improve the indoor air quality and reduce the amount of absences on our campus. So, Dr. Jehn came to our campus and guided us in building our first CR boxes. She then let us borrow a Quant AQ Modulair-PM sensor to track the efficiency of the CR Box in our classroom.


Presentations on past viruses, pandemics, and methods of prevention (Left).

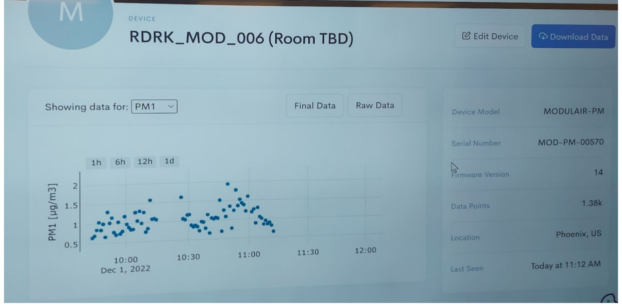
Zoom meeting with ASU and Jim Rosenthal to find out more about the Corsi-Rosenthal Box and indoor air quality (Left & Right).

Our very first box, built with help from Dr. Jehn, from ASU (Right).

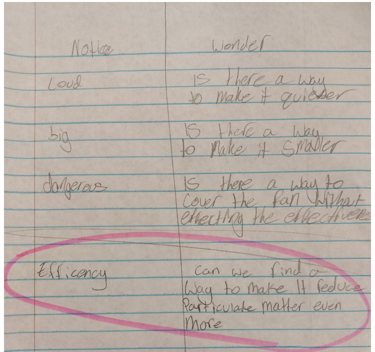
## Introduction Continued:

According to the data from the Quant AQ dashboard, the CR Box in our classroom was very effective at reducing PM 2.5. We watched the numbers go down in real time. Then, we teamed up with ASU in a data collection research study, where our school built CR boxes for each classroom on campus and ASU collected and analyzed data from our classrooms. From that study, ASU "Observed a measurable improvement in indoor air quality across the majority of the classrooms." (Jehn, 2023)

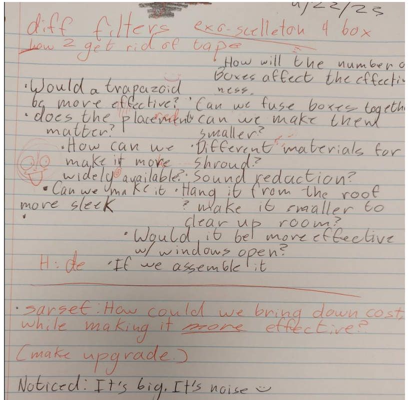
After seeing such improvements in our indoor air quality, and noticing less absences during the 2022-2023 school year, we wanted to see if we could improve the air quality even more this year, so we brainstormed ways to alter the design of the original CR box to make it even more efficient.

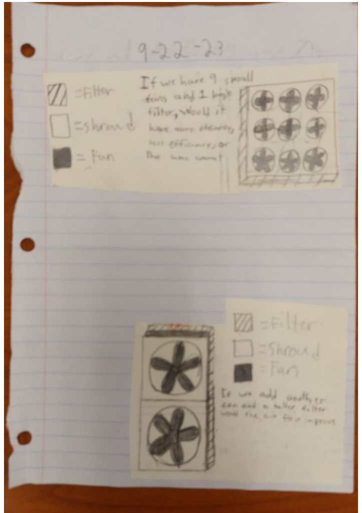


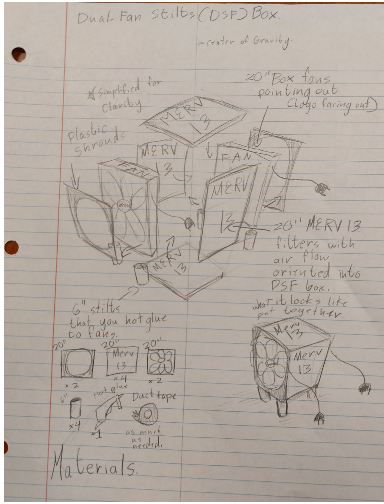

PM readings from the Quant AQ dashboard before and after we installed our first CR Box in our classroom (Above).




Our "Notice and Wonder" sheets as we reflected on our our Corsi-Rosenthal boxes from 2022-2023 (Left & Right).




Some of our designs that we thought could improve the air quality more than the original Corsi-Rosenthal Box (Above & Left).

**Introduction Continued:**

Engineering Design Plan for the Original Corsi-Rosenthal Box:

Materials:

- Four 20” x 20” MERV 13 air filters.
- One roll of duct tape.
- One 20” box fan.
- One cardboard box (from the fan).
- One ruler
- One pair of scissors

Procedures:

1. Put the four filters into a square formation, with your air flow arrows pointing inside the cube.
2. Tape all the sides, at the seam.
3. Cut a 20” square, from the fan’s box, to use as a base, and tape it to the bottom of your cube.
4. Tape the fan to the other side of the cube, with the air flow pointing up and the cord hanging out.
5. Cut a 20” square with a 14” circle in the middle, from the other side of the fan’s box, to use as a shroud, and tape it on top of the fan.
6. Finally, check all of your tape to make sure there are not gaps and it’s sealed tightly.

Actual photo of a Corsi-Rosenthal Box that we built (Left).

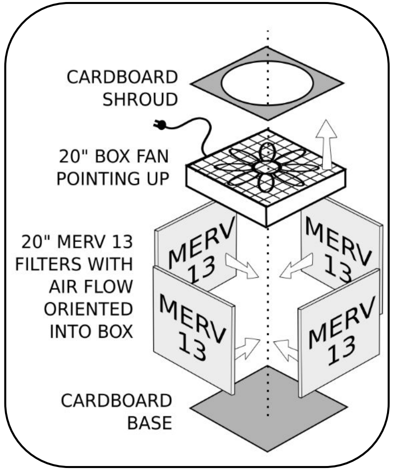



Illustration of a Corsi-Rosenthal Box assembly (Image by: Edge Collective) (Above).

## Question/Problem and Predictions:

Question:

How can we modify the design of the original CR Box to make it more efficient at reducing PM 2.5 in indoor spaces?

Hypothesis:

We hypothesized that we could make the CR Box more efficient by engineering a CR Box with two fans, instead of one, to increase the suction to reduce PM 2.5 faster than the original design.

## Engineering Component:

Our problem was that we needed to engineer a CR box with two fans, to increase the air suction, but we don't want to lose a filter that is needed to collect PM. Therefore, we altered the design of the original CR Box by adding two box fans to the right and left sides, instead of on top. Then, to ensure air flow through the bottom filter, we attached stilts to the bottom of the box and called it the Dual-Fan Stilts (DFS) Box.

Us building the box with two fans (Left).

Us adding stilts to the bottom of both of the fans (Left).

The completed DFS Box (Left).

## Engineering Component Continued:

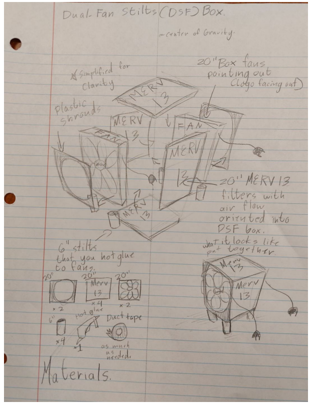
### Engineering Design Plan for Dual-Fan Stilts (DFS) Box:

**Materials:**

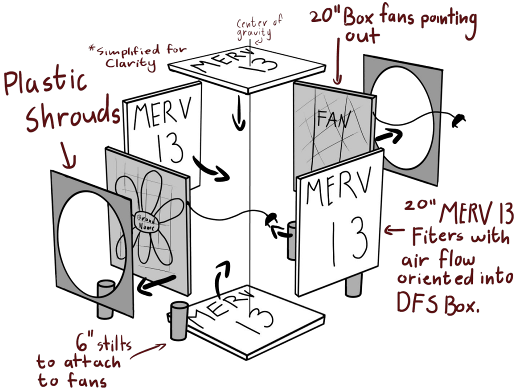
- Four 20” x 20” MERV 13 air filters
- One roll of duct tape
- Two 20” box fans
- Two 20” x 20” pieces of plexiglass
- One Ruler
- One pair of scissors
- One hot glue gun with multiple glue sticks
- Four plastic tubes, cut to 8”

**Procedures:**

1. Put the four filters into a square formation, with your air flow arrows pointing inside the cube.
2. Tape all the sides, at the seam.
3. Tape a fan to each side of the cube, with the air flow pointing out, to the right and left, and leave both cords out.
4. Cut a 14” circle in the middle of each piece of plexiglass and tape it to the top of each fan for the shrouds.
5. Finally, use hot glue to glue four plastic tubes onto the side of the fans, to act as stilts for the box to stand on.



Hand drawn illustration of DFS box assembly (Above).



Computerized illustration of DFS box assembly (Above).

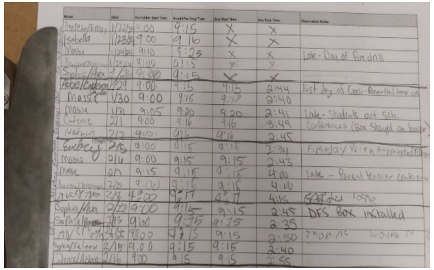
Actual photograph of a completed DFS box (Right).

# Investigative Methods and Procedures:

## Materials Needed for Study:

- Empty classroom (Study room)
- Cool mist humidifier
- Saline Solution
- QuantAQ Modulair PM
- CR Box
- DFS Box
- 15 Minute timer
- Sign-in sheet
- Graph paper
- Highlighters

The sign-in sheet to monitor who went into the study room and what times they did the study (Below).



## Study Timeline:

Week 1:Conduct the study with no CR box in the study room (No intervention) to collect baseline data.

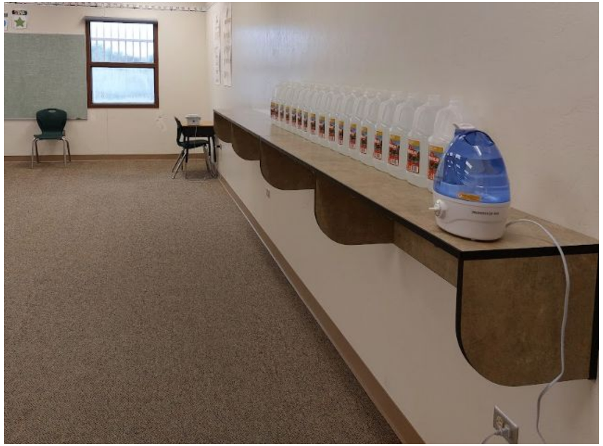
Week 2:Conduct study with the original CR box design in the study room.

Week 3:Conduct study with the DFS box design in the study room.

The humidifier used in our study, with a green dot to mark where to set the dial each time (Left).


The Modulair PM sensor that collects and measures PM in our study room (Left).

A photo of our study room set up with the humidifier and Modulair PM (Below).



**Investigative Methods and Procedures Continued:**

Study Procedures:

1. Set up the study room, with the humidifier, Modulair Pm sensor and box of the week (Only in Week 2 & Week 3) in a triangular configuration, far away from each other.
2. Plug in the Modulair PM sensor and leave it running throughout the entire study. Never unplug it!
3. Each day, enter the study room, at 9:00 am, shut the door, and sign in, with your name, date, and time.
4. Fill the humidifier to the top, using a saline solution and turn it on to a low setting, where the green dot is, and let it run for 15 minutes, while you wait outside the study room. This will pump PM into the air.
5. After 15 minutes, at 9:15 am, reenter the study room, turn off the humidifier, turn on the box of the week, to the lowest setting, and write the time on the sign in sheet.
6. Exit the study room and close the door behind you.
7. Do steps 3 through 6 every day and let the Modulair PM sensor continuously collect data.
8. Each day, after school, the teacher will unplug the box (Only in Week 2 & Week 3) to reset the experiment for the next day.
9. After one week of data collection, the teacher will print the raw data from the Quant AQ dashboard, and we will highlight the hours between 8:00 am to 2:30 pm.
10. After we highlight the raw data, we will create graphs so that we can see how long it took to get PM 2.5 back down to to it's starting baseline after we pumped PM into the room.
11. Finally, we will compare our graphs from each week to see which box was able to reduce the PM the fastest to determine which box is the most efficient.

Dr. Jehn said, "It doesn't really matter how high the PM gets over a short period of time, but rather how long someone is in an area with high PM that can lead to health problems (Jehn, 2024).

# Investigative Methods and Procedures Continued:

## Study Variables:

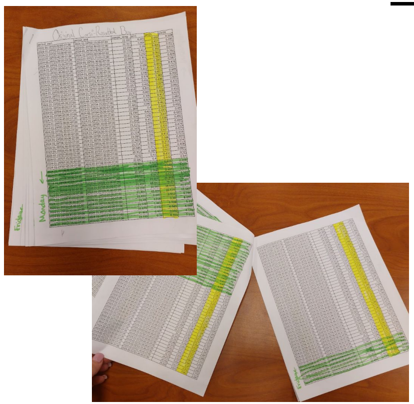
### Independent Variables:

- Types of boxes used in our research room
    - No intervention used
    - Original Corsi-Rosenthal box
    - Duel-fan stilts box

### Dependent Variable:

- The amount of PM 2.5 that is collected and measured.

Highlighting raw data from the Quant AQ Dashboard, from 8:00 am to 2:30 pm (Left & Right).



### Controlled Variables:

- The times that the experiment runs.
- The placement of the boxes, the Modulair PM sensor and the humidifier.
- The amount of humidity the humidifier produced.
- The same devices used each week (Quant AQ Modulair PM sensor and cool mist humidifier)

### Variables outside of our control:

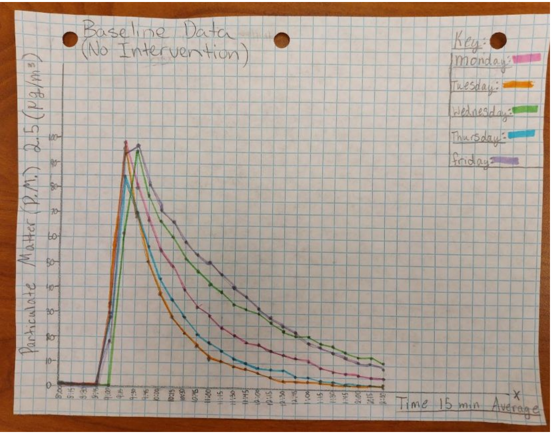
- The amount of PM that comes in from outside, when we opened the study room door.
- People entering the study room without permission.
- If someone starts the study late because their teacher won’t let them come to the study room on time.

## **Results and Data Visualization:**

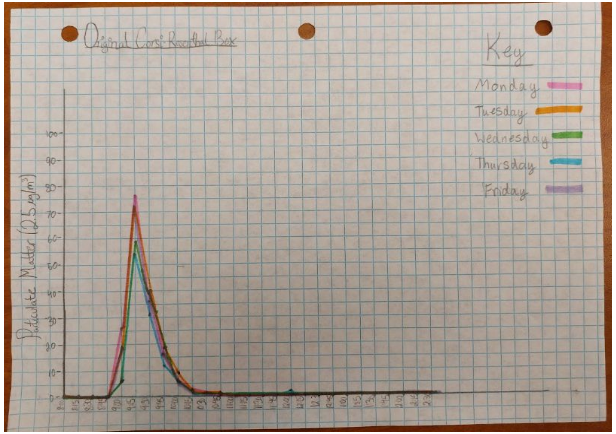
After we converted the raw data into line graphs, we noticed that Week 1's data, wasn't very consistent. Each day had different amounts of time that it took for the PM 2.5 to come back down, and it never fully reached it's starting baseline during our study times. Since this data was so inconsistent, we decided not to use that week's data.

However, when we looked at the graphs from Week 2 and Week 3, we noticed that they were very consistent. They both had spikes around 9:15 am ,each day, and then they came back down at similar rates.

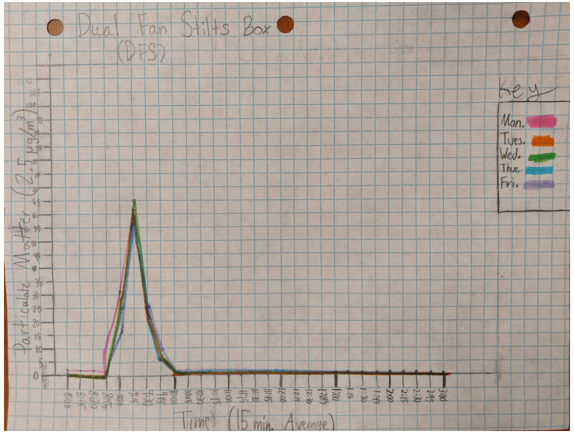
Making a line graph from the raw data (Above).




A hand drawn line graph of data collected on Week 1: No intervention (Above).



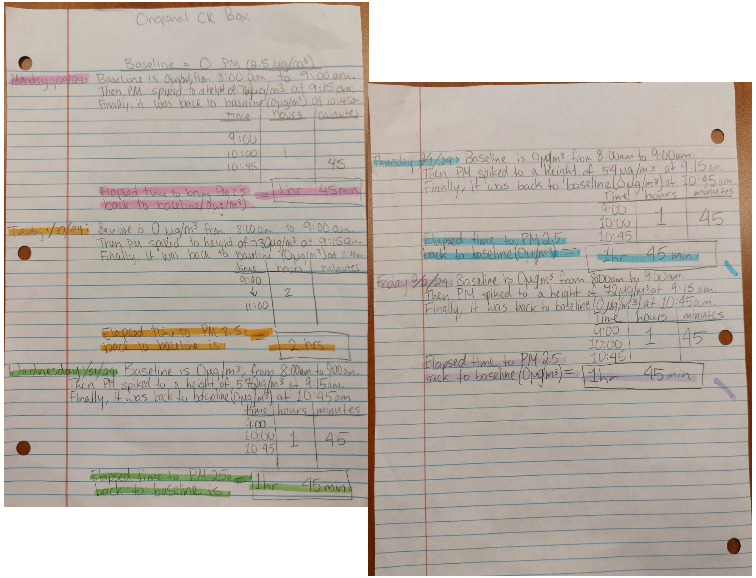

A hand drawn line graph of data collected on Week 2: The Original CR Box (Above).



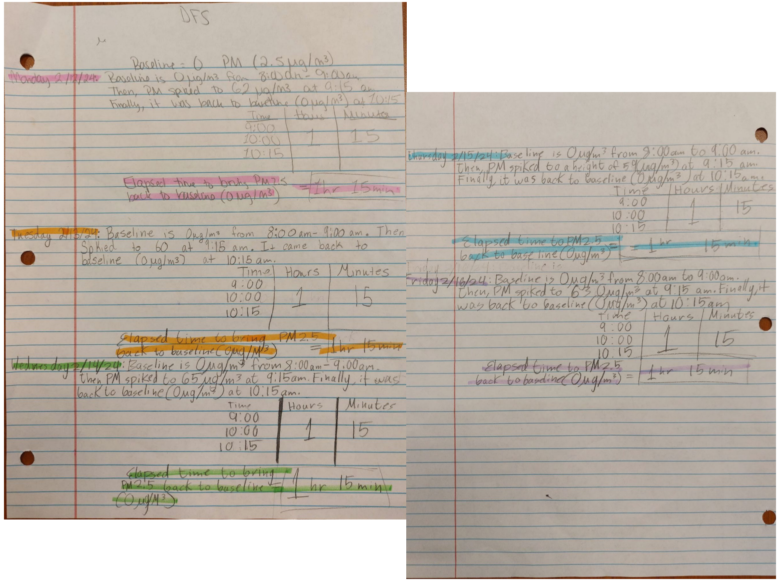

A hand drawn line graph of data collected on Week 3: The DFS Box (Above).

## Results and Data Visualization Continued:

Since the line graphs from Week 2 and Week 3 were so similar and it was hard to see which box was more efficient at reducing PM 2.5, we calculated the elapsed time that it took for each box to return to it's starting baseline number, each day. After we did this, it was easier to see that the average time it takes the Original CR Box to return to it's staring baseline is 1 hour and 45 minutes and the average time it takes the DFS Box to return to it's staring baseline is 1 hour and 15 minutes.



Hand written calculations of the elapsed time it took for the PM to get back down to its starting baseline from Week 2: The Original CR Box (Above).



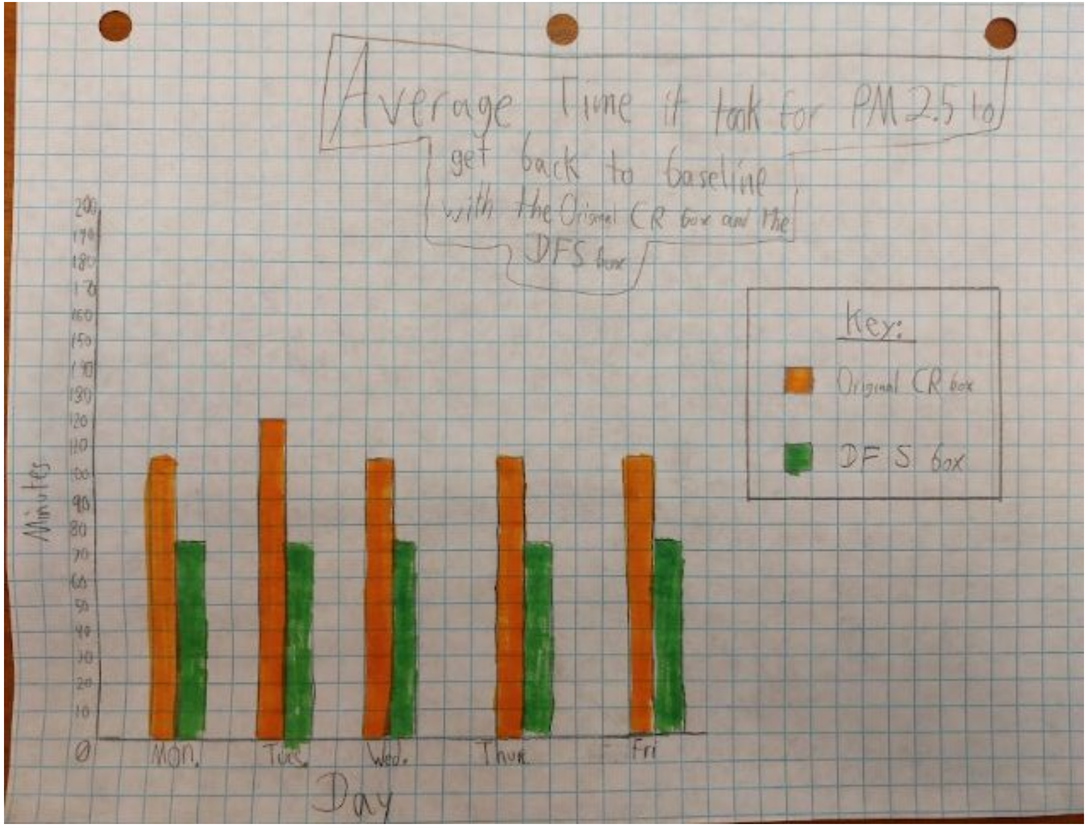
Hand written calculations of the elapsed time it took for the PM to get back down to its starting baseline from Week 3: The DFS Box (Above).

## Results and Data Visualization Continued:

After we calculated the average elapsed time that it took for both the Original CR Box and the DFS Box to get back to its baseline, we converted it into minutes only to show our data on a double bar graph.

The average elapsed time that it took for the Original CR Box to get back to its starting baseline was 105 minutes, while the DFS Box's average elapsed time to get back to its starting baseline was only 75 minutes.

This graph clearly shows that the DFS Box is more efficient at reducing PM 2.5.




Hand drawn double bar graph showing the average time, in minutes, that it takes for the Original CR Box and the DFS Box to get back to its starting baseline number (Above).

## Discussion and Interpretation:

It is our conclusion that the DSF Box is more efficient at reducing PM 2.5 than the Original CR Box. We have made this conclusion based on the average elapsed time that it took each box to return to its starting baseline number after we spike the PM in our study room, using a humidifier and a saline solution. After calculating the average elapsed time, we found out that it took the Original CR Box an average of 105 minutes to return to its baseline, while it only took the DFS Box 75 minutes to return to its baseline. That is a difference of 30 minutes, so the DFS Box is proving to be the more efficient box, when it comes to reducing PM 2.5 quicker.

Although we are proud to see our DFS Box come out on top, we did have some uncontrolled variables occur in our study that are perplexing. During Week 1 of the study, we had very inconsistent fall rates in the study room, when there was no intervention used.  Since this data is unexplained and we don't know why it happened, we decided not to use it when determining what box was more efficient. Instead, we noticed that  the Week 2 and Week 3 data looked very similar, so we decided to represent that in different ways to show that the DFS Box is more efficient box at reducing PM 2.5 due to the time it took to get back to it's stating baseline.


A photo of the more efficient box (Right).

## Implications and Ideas for Future Research:

According to our interview with Jim Rosenthal "People all over the world are creating their own designs to try to improve indoor air quality and as long as we are testing our ideas and share our discoveries, we will continue to improve our indoor air quality." (Rosenthal, 2022). These words have inspired us to do the same. We now have another Zoom meeting scheduled with Jim Rosenthal and the ASU Clean Air Initiative Group to share our study and hopefully inspire others. We will also be meeting with our school officials to discuss changing the design of the boxes that we have on campus from Original CR Boxes to DFS Boxes.

After our study, when we reached out to ASU and Jim Rosenthal to set up our Zoom meeting, we came across a recent article that he wrote titled, "Comparing the Performance of Corsi-Rosenthal Boxes Made with Box Fans and PC Fans." In this study, he tested multiple designs against each other and concluded that using multiple (6) PC fans with 4 MERV 13 filters was a more effective design than his Original CR Box design. (Rosenthal, 2023)

Now, to further our study, we would like to merge that design with our DFS Box design to see if we could further increase the efficiency of the DFS Box.

Corsi-Rosenthal Box with 6 PC Fans and 4 – MERV 13 Filters. (Photo taken from Rosenthal, 2023) (Right).

**References:**


1. "How to Protect Yourself and Others." Center for Disease Control and Prevention. Https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/prevention.html. 14 October 2024.
2. Filmer, Steve "ASU Volunteers Build DIY Air Filters to Help Valley Schools Fight COVID-19." ASU News. 26 January 2022. Https://news.asu.edu/20220126-arizona-impact-asu-students-faculty-build-filter-boxes-schools-fight-covid-19 accessed. 10 October 2022.
3. Jehn, Megan. Andino, Jean. Wani, Jessica. Olivas, Graciela. Fingesi, Tina. Rosenthal, Jim. "Women in STEM Zoom Interview." Conducted by students. 1 December 2022.
4. "DIY Air Purification Designs." Edge Collective. Https://edgecollective.io/airbox/. 12 January 2024.
5. Jehn, Megan. Andino, Jean. Palit, Tanya. Wani, Jessica. "Clean Indoor Air Research Study: Report 1." ASU Epidemiology. 28 April 2023.
6. Jehn, Megan. Andino, Jean. "Our Study Live Zoom Interview." Conducted by students. 19 January 2024.
7. Rosenthal, Jim. "Comparing the Performance of Corsi-Rosenthal Boxes Made with Box Fans and PC Fans." Tex-Air Filters. 5 June 2023. https://www.texairfilters.com/comparing-the-performance-of-corsi-rosenthal-boxes-made-with-box-fans-and-pc-fans/. 19 January 2024.