Perspective: Thinking outside the classroom to minimize risk of SARS-CoV-2 transmission while enhancing the student experience during COVID-19*

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As public and private school districts and colleges and universities move toward their goal of a safe, healthy, and engaging semester for students, faculty, and staff, I am making publicly-available my perspective on the best practice to reduce the risk of SARS-CoV-2 transmission through airborne respiratory particles, which is thought to be a significant transmission route (*1-3*). Undoubtedly, most school districts are well-informed and have already been considering the most commonly-cited mitigation strategies such as masks, six-feet separation, enhanced ventilation, sanitization (of air and surfaces), time restrictions, and de-densification of indoor environments, among others. Indeed, many re-opening plans, whether for businesses or universities, are centered on these strategies. Here, I do not reiterate the merits of those strategies, which have already been widely discussed within the public media. Rather, I focus on the less-discussed practice that could minimize risk even more than other mitigation strategies (aside from complete isolation and remote learning). Specifically, I assert that if our goal is to minimize the risk of SARS-CoV-2 transmission *as much as possible* during on-site teaching and learning, we cannot do so by occupying the same spaces that we have become accustomed to. From both a mechanistic and epidemiological perspective, to minimize the risk of disease transmission, **it is unambiguous that we must step out of the indoor classroom and get outside** as much as possible, as illustrated in Figure 1.

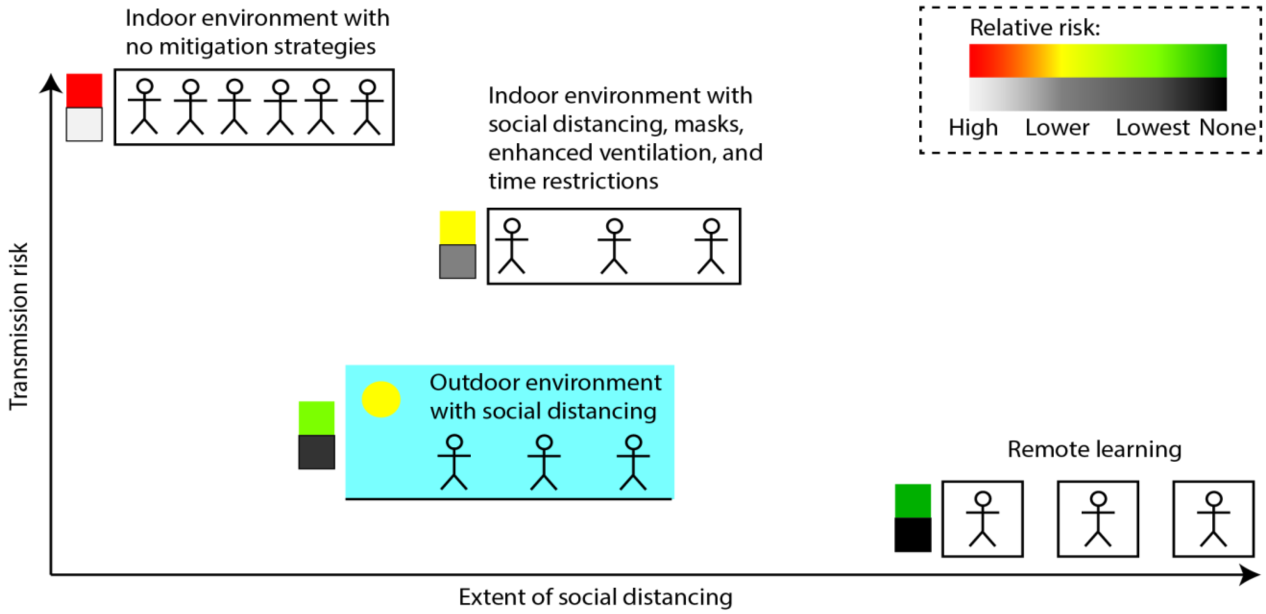

Figure 1. The relative risk of disease transmission indoors compared to outdoors. The risk is significantly lower outdoors than inside. Illustrative depiction only; that is, not constructed from specific quantitative data.

To be clear: what I am proposing here is different than students sitting on the lawn while faculty lecture on a portable chalkboard (although this *would* be beneficial still). I am proposing that one or more outdoor spaces be setup that are designed to teach in. This could be as simple as portable chairs and a whiteboard and/or projector under a shade tent. Even a small-scale effort, where a single outdoor classroom is available for faculty to schedule if they choose, would reduce the risk on campus overall, and dramatically reduce the risk for students and faculty that utilize the space (although the more outdoor classrooms being utilized, the greater the benefit). While there are some hurdles and scheduling issues that must be considered to make outdoor classrooms a reality, I argue that the outdoor environment should not be an overlooked aspect of our campus life moving forward; there is simply no better way (aside from remote learning) to minimize the risk of COVID-19.

*Note: This was originally written May 2020 – Since then, the evidence for airborne transmission has only gotten stronger, thus strengthening the need for outdoor spaces, and a model by Prof. Jose Jimenez has been developed (based on the work of many researchers) that clearly demonstrates the assertion of reduced outdoor risk. Originally written specifically for Trinity University, I have since modified for relevance to pre-K–12 and other universities. I am not an expert on infectious disease transmission, but an expert in aerosol physics/chemistry, and thus well-qualified to interpret and compile relevant information on airborne transmission, and present it in a (hopefully) useful form for school officials.

The benefits of outdoor learning could include:

- ***Minimized risk of disease transmission from students to faculty/staff (and vice versa), and student to student during time spent in class.*** This assertion is based on mechanistic evidence as well as epidemiological observations (*4*). This will demonstrate to students (and their parents), faculty, and staff that schools are using evidence-based decisions to keep them safe. Further, faculty who prefer to minimize their own risk, or who have students in high-risk populations, would have that option.
- ***The outdoor classroom is an appealing aspect of life to many students.*** No university brochure is complete without a picture of class being held among the backdrop of outdoor campus areas. The outdoor classroom may present students with an opportunity to feel as if their campus experience has been enhanced, rather than damaged, by the COVID-19 changes to campus. For K-12 students, the outdoors is simply a place of happiness (in my experience).
- ***Outdoor interactions can be longer and more meaningful while still minimizing risk.*** Student-student and student-faculty interactions can last for longer periods in an outdoor environment while still minimizing the risk of disease transmission.
- ***The strategy would be low-risk.*** Utilizing existing outdoor spaces is low-risk in terms of cost, and in the face of inclement weather or extreme heat, indoor spaces would still be available. Many of the supplies necessary to construct an outdoor classroom are likely already available through facilities; a shade tent, folding chairs, and whiteboards.
- ***Lowering the risk of transmission during classroom time will also lower the risk of transmission through the dorms and lab-based courses.*** Lowering the risk at any point in time will lower the risk overall; that is, if a student is less likely to be infected during their time in class, they are less likely to spread the virus upon return to their dorms or within laboratory-based courses that can only be delivered inside. (Note: other risk mitigation in dorms is still advised.)
- ***Outdoor classrooms can minimize airborne transmission as well as surface-contact transmission.*** With no door to open, there is a lower risk of contact transfer.

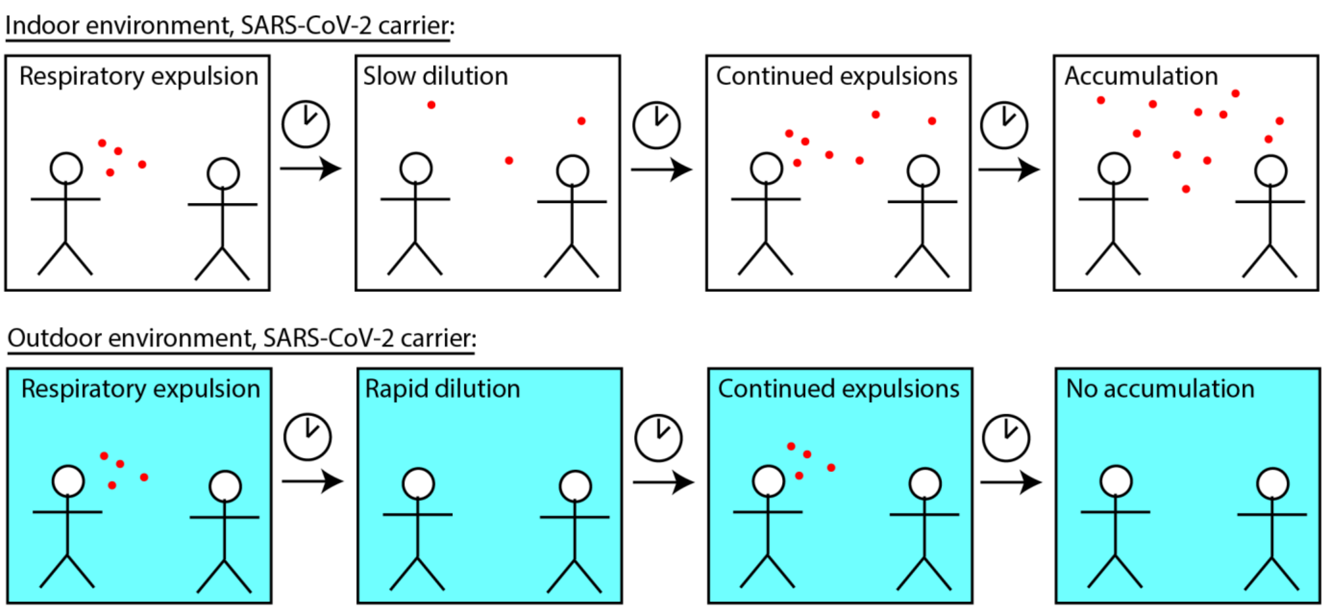

Figure 2. Illustrated representation of how airborne viruses (represented by the red dots) accumulate in indoor versus outdoor environments over time. Indoors, accumulation occurs. Outdoors, rapid dilution occurs via aerosol transport. Thus, exposure remains lower outdoors.

Why Getting Outside Minimizes Risk of Airborne Transmission: Potential Insight.

Imagine sitting outdoors around a campfire. Many have had this pleasure, and know it to be a rather pleasant experience. Outdoors, smoke does not accumulate enough to be overwhelming and acutely dangerous. Now imagine if a campfire were blazing in a typical school classroom. Even if all doors were open and the ventilation system was operating at full capacity, the smoke would rapidly accumulate and pose a significant health hazard to those present. Similarly, as illustrated in Figure 2, the risk of airborne SARS-CoV-2 transmission is much lower outdoors because infected respiratory particles cannot readily accumulate to unsafe levels, whereas accumulation can rapidly occur indoors.

There is strong evidence for low-risk of transmission outdoors from contact tracing as well as from a mechanistic understanding. For example, one early study found that only 2 of 1245 confirmed COVID-19 cases occurred outdoors (*4*). In part, the low incidence of outdoor transmission stems from the fact that we spend the majority of our time inside. However, this explanation is inadequate and cannot alone account for the extremely low rate of outdoor transmission. To understand why outdoor environments are safer, it is necessary to consider aerosol physics within indoor versus outdoor environments. Briefly, I address one potential factor below.

SARS-CoV-2 is known to be found in respiratory particles when a person coughs, sneezes, talks, and breathes (*1-3,5,6*). Sneezing and coughing create large particles that can rapidly fall and can contaminate surfaces or individuals, but also stay suspended for longer periods of time (seconds to minutes). These largest particles contain the highest viral concentration and pose an acute risk; masks and six-feet of separation are intended to mitigate the chances of the droplets contaminating a person or surface. Additionally, coughing, sneezing, talking, and breathing also create smaller particles that can also remain suspended in the air for longer periods (minutes to hours). As illustrated in Figure 2, these suspended particles can accumulate in an indoor environment. Thus, through prolonged exposure, they pose a significant risk (*1-3,5*). While inhaling a few of the particles would likely be insufficient to create an infection, it is possible to inhale thousands of viruses when an infected individual is enclosed in an indoor space and respiratory particles accumulate (*1*). With prolonged exposure, an infection becomes more likely for healthy individuals (*1*).

By contrast, in an outdoor environment, expulsion of respiratory particles does not result in accumulation. Rather, the particles are more likely to be rapidly diluted and carried away. In the outdoor environment, exposure remains continually low and does not increase as much over time. Thus, the chances of exposure overwhelming the immune response remains low, at least in principle, as illustrated in Figure 3. Although the chance of infection remains non-zero, the outdoor environment still represents the lowest risk, particularly when combined with social distancing and masks to further prevent large droplets from depositing directly onto individuals. Thus, despite the scheduling difficulties (which could be overcome through modified schedules and alternating indoor-outdoor schedules), **outdoor classrooms represent the safest opportunity to return to onsite learning**.

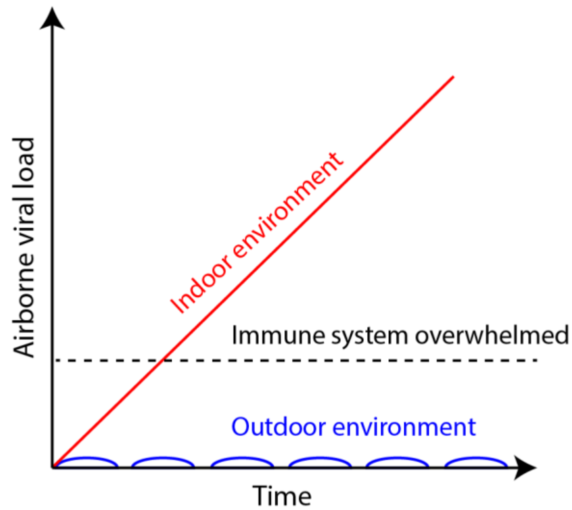

Figure 3. If an infected individual remains inside an enclosed room, accumulation of airborne viruses can occur and increase the exposure to non-infected individuals. Outdoors, accumulation does not occur because, after each respiratory expulsion, the particles are transported away and diluted. In principle, this can help keep the exposure low enough such that the immune system does not become overwhelmed. In practice, this is what has been observed (*4*). (Note: the above plot is an illustrated representation of a theoretical response, and does not contain actual data.)

This assertion is demonstrated clearly using the model (*7*) developed at CU-Boulder. In a space of 500 sq. ft., an infected instructor, and 60 susceptible students, an outdoor classroom would have an effective transmission rate of 0 new infections in 50 min (without masking) whereas in an indoor classroom, ~2 new infections are predicted, even with masking (50% assumed efficiency for the masks) due to airborne transmission. Outdoors is simply safer.

Even epidemiologists agree: outdoors is better, as explained in a recent NPR article (*8*):

"Here's [Dr. William Miller, an epidemiologist at Ohio State University]'s rule of thumb: The more *time* you spend and the closer in *space* you are to any infected people, the higher your risk. Interacting with more *people* raises your risk, and <u>indoor *places* are riskier than outdoors</u>.

Dr. Emily Landon, a hospital epidemiologist and infectious diseases specialist at University of Chicago Medicine, has her own shorthand: "Always choose outdoors over indoor, always choose masking over not masking and always choose more space for fewer people over a smaller space."”

Some other considerations:

- Indoor environments will always remain a necessity, thus ventilation improvements are still recommended.
- Summer heat will be uncomfortable in August. Cooling fans would help students and faculty be more comfortable while also enhancing the removal of airborne respiratory particles.
- While outdoor environments can mitigate the spread of disease through respiratory droplets and aerosols, surface contact remains a concern. For example, if an infected individual touches their eyes, nose, or mouth, and then proceeds to touch another surface, there is still the risk of transmission through surface contact. Sanitization is still recommended.

References

1. Morawaska et al. “Airborne transmission of SARS-CoV-2: the world should face the reality.” DOI: 10.1016/j.envint.2020.105730

2. Meselson. “Droplets and Aerosols in the Transmission of SARS-CoV-2”. DOI: 10.1056/NEJMc2009324.

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5. Anfinrud et al. “Could SARS-CoV-2 be transmitted via speech droplets?” DOI: 10.1101/2020.04.02.20051177.

6. Lewis, D. “Mounting evidence suggests coronavirus is airborne — but health advice has not caught up”. Nature, News Feature: https://www.nature.com/articles/d41586-020-02058-1. Accessed July 9, 2020.

7. Developed and curated by Prof. Jose Jimenez, CU-Boulder, based on work and input from Linsey Marr, Shelly Miller, Giorgio Buonnano, Lidia Morawska, Don Milton, Julian Tang, Jarek Kurnitski, Xavier Querol, Matthew McQueen, Joel Eaves, Alfred Trukenmueller, Ty Newell, Greg Blonder, Andrew Maynard, Nathan Skinner, Clark Vangilder, Roger Olsen, and others. Link: https://tinyurl.com/covid-estimator. Description: https://cires.colorado.edu/news/covid-19-airborne-transmission-tool-available.

8. https://www.npr.org/sections/health-shots/2020/05/23/861325631/from-camping-to-dining-out-heres-how-experts-rate-the-risks-of-14-summer-activit. Accessed May 24, 2020.

An (incomplete) list of leading experts on airborne transmission leading real-time discussion through social media:

Profs. Linsey Marr, Shelly Miller, Jose Jimenez, Richard Corsi, Kim Prather, self.