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The University of Texas at Austin

Mitigating COVID-19 in schools with face masks and proactive testing

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September 14, 2021

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COVID-19 Modeling Consortium

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Overview

Regions throughout the US are experiencing a COVID-19 wave, fueled by the Delta variant, that is straining healthcare systems and complicating the reopening of schools. To support city leadership, public health agencies, and school districts in mitigating risks for students and staff, we developed a granular model of COVID-19 transmission in schools. We use the model to estimate the impacts of two mitigation strategies—face masking and proactive testing of asymptomatic students—under three different scenarios for in-school transmission. We also consider a scenario in which students are separated into all-mask and no-mask classrooms, based on family preference.

The model incorporates epidemiological characteristics of SARS-CoV-2 transmission and contact patterns within and between classrooms, as well as school-wide contacts that occur in lunchrooms, at recess, on buses, etc. It also assumes that classes and households are quarantined for 10 days after a student tests positive. Full details of the model and scenarios can be found in the Methods section.

Assumptions and Scenarios

We consider the following scenarios, loosely modeling a small elementary school in the Austin Independent School District:

- 500 students total, divided into 20 classrooms of 25 students each
- 66 adult staff/faculty, with 70% vaccinated with a vaccine that reduces susceptibility by 66%
- community incidence of 150 new cases of COVID-19 per day per 100,000 people, as estimated for Austin on August 27, 2021 (corresponding to 5.9 introductions into the school per week)
- low, moderate, and high transmission scenarios corresponding basic reproduction numbers (R_0) of 1.0, 1.5 and 2.0, respectively, in the absence of face masks, testing, and

isolation/quarantine (transmission rates may depend on classroom ventilation, student density, hand hygiene, and eating protocols)

- students opting to wear face masks are either randomly distributed across classes or clustered into all-mask classrooms
- proactive testing entails periodically testing all students every 7, 14, or 28 days, in a staggered schedule, with a perfectly accurate rapid test
- following a positive test, the case is isolated for 10 days and their classroom and household are isolated for 10 days
- projections begin with an entirely susceptible population

Summary

We project the following for a ten-week period:

- Under the low, moderate and high transmission scenarios, we project that 11% (95% CI: 6%-17%) , 22% (95% CI: 13%-30%) and 33% (95% CI: 22%-44%) of students will become infected, respectively, in the absence of face masks and proactive testing. For adult staff/faculty, these values are 3.0% (95% CI:0%-9.1%)%, 3.9% (95% CI:0%-10.6%), and 5.1% (95% CI:0%-13.6%).
- Face masks and proactive testing—are projected to substantially mitigate spread. For example, consider the moderate transmission scenario.
    - If 50% or 100% of students opt to wear masks, then we would expect 34% or 60% fewer infections, respectively.
    - If students do not wear masks but are tested either once per week or once per month, then we would expect 78% or 46% fewer infections, respectively.
    - If 50% of students wear masks and all students are tested every week, then we would expect 84% fewer infections.
- Separating students into all-mask and no-mask classes is projected to lower infection risks for students who wear masks and increase risks for students who do not. However, separating classes is *not* projected to impact the *overall* infection rate in the school.

We are posting these results prior to peer review to provide intuition for policy makers, schools and the public regarding the risks of COVID-19 transmission within schools and effective strategies for preventing transmission.

Projected COVID-19 transmission in schools with face masks and proactive testing

During COVID-19 surges, schools will be at high risk for introductions that can disrupt education and threaten the health and safety of the community. At the start of the school year in 2021, state laws in Texas prevent public schools from requiring face masks. Some communities are starkly divided over the issue, with some families refusing masks and others strongly advocating for their use.

To address questions posed by policymakers in Austin, Texas, we modeled the transmission of COVID-19 in schools under scenarios in which we vary the following inputs:

Transmission rate: The basic reproduction number (R_0) describes the expected number of infections caused by a single infected student arriving at the school over the course of their infection, in the absence of mitigation (i.e., no face masks, testing, case isolation, or contact quarantine). This quantity indicates whether outbreaks will grow ($R_0>1$) or decline ($R_0<1$). We assume that transmission risks are either low ($R_0=1$), moderate ($R_0=1.5$), or high ($R_0=2$).

Proactive testing frequency: SARS-CoV-2 is known to spread silently from individuals who are pre-symptomatic or asymptomatic. Since children are more likely than adults to be asymptomatic, periodic asymptomatic testing is an effective strategy for detecting cases before they have an opportunity to infect others. We model *proactive testing* in which all students are tested either weekly, every two weeks, or monthly, on a staggered schedule[1]. After testing positive, cases immediately enter a 10-day isolation period, and their classmates, teacher, and household simultaneously begin a 10-day quarantine.

Face mask usage: We assume that face masks reduce susceptibility to infection by 26% and infectiousness to others by 26%, and compare scenarios where 0%, 50%, or 100% of students are wearing face coverings.

Separation of classes: We assume either that students opting to wear face masks are randomly distributed across all classes or that students are separated into all-mask and no-mask classes.

Our projections suggest that face mask usage can substantially reduce the expected proportion of students that will be infected in the ten-week period, across all combinations of transmission rates and testing frequency (Figure 1 and Table 1). Proactive testing would also be expected to avert a large fraction of infections, even if administered only once per month (Figure 1 and Table 1).

[1] We also assume that 90% of *symptomatic* cases test following the onset of symptoms. They enter a 10-day isolation period an average of 6.3 days after they were first infected. Their classmates and household simultaneously begin a 10-day quarantine.

We also project the average number of school days missed per student over the first 50 days of the school year (Figure 2). Consider the moderate transmission scenario with 50% of students wearing face masks. Without proactive testing (i.e., symptomatic testing only), we would expect students to miss an average of 5 days of school (10%) during the first ten weeks of the school year. Since proactive testing increases the detection of cases, it also increases absenteeism due to isolation and quarantine. For example, with proactive testing every other week, we would expect the average days missed to increase to 9 (18%).

Separating students into different classes based on face mask usage would not be expected to impact the overall infection rate (Figures 3 and 4). However, we project that the risks of infection would decrease for students in all-mask classes and increase for students in no-mask classes.

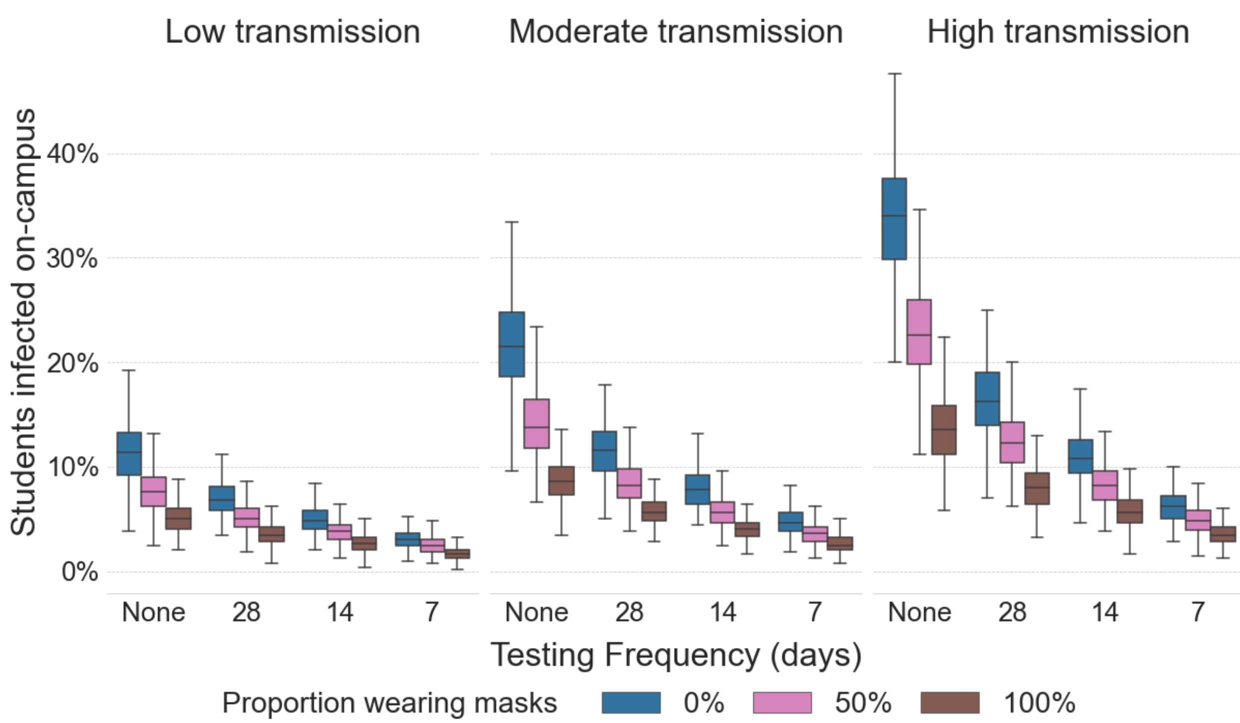

Figure 1. Projected impact of proactive testing and face mask use on the percent of students infected in a school with 500 students during the first 10 weeks of the school year. From left to right, the three panels correspond to a low, moderate, or high transmission rate within the school. Colors indicate the proportion of students wearing face masks, either no students wear masks (blue), half of students wear masks (pink), or all students wear masks (brown). The values along the x-axis indicate the frequency of proactive testing. For example, a frequency of 28 means that students are tested once every four weeks, on a staggered schedule. Each box plot indicates the distribution of projections across 300 simulations with the specified scenario (transmission rate, frequency of testing, and mask usage). The projections assume that there are 150 new daily infections per 100,000 individuals in the surrounding community. Upon a positive test result the entire classroom and household of the person testing positive are quarantined for 10 days.

Table 1. Projected percent of students infected in a school with 500 students during the first 10 weeks of the school year, with various combinations of proactive testing and face mask use.

		Cumulative incidence		
Testing frequency (days)	**Percent wearing masks**	**Low transmission**	**Moderate transmission**	**High transmission**
None	**0%**	11.5% (6.2-17.6)	21.6% (13.1-30.1)	33.7% (21.6-44.5)
	50%	7.7% (4-12.1)	14.3% (8.9-21.6)	22.9% (14.5-32)
	100%	5% (2.4-8)	8.7% (4.7-13.3)	13.7% (7.5-21.1)
28	**0%**	7% (4.2-10.8)	11.6% (7-17.1)	16.4% (10.2-23.4)
	50%	5.1% (2.8-8)	8.4% (4.6-12.6)	12.4% (7.4-18.3)
	100%	3.5% (1.5-5.8)	5.7% (3.2-8.4)	8% (4.1-12.2)
14	**0%**	4.9% (2.5-8.1)	7.9% (4.8-12.2)	11% (6-15.5)
	50%	3.8% (1.7-6.2)	5.7% (3.2-8.7)	8.2% (4.8-12.4)
	100%	2.6% (1.2-4.4)	4% (1.9-6.5)	5.7% (3.2-8.6)
7	**0%**	3% (1.4-5.2)	4.7% (2.6-7.6)	6.2% (3.4-9.5)
	50%	2.4% (1-4)	3.6% (1.6-6.5)	4.9% (2.6-8)
	100%	1.6% (0.5-3.2)	2.5% (1-4.5)	3.5% (1.6-5.6)

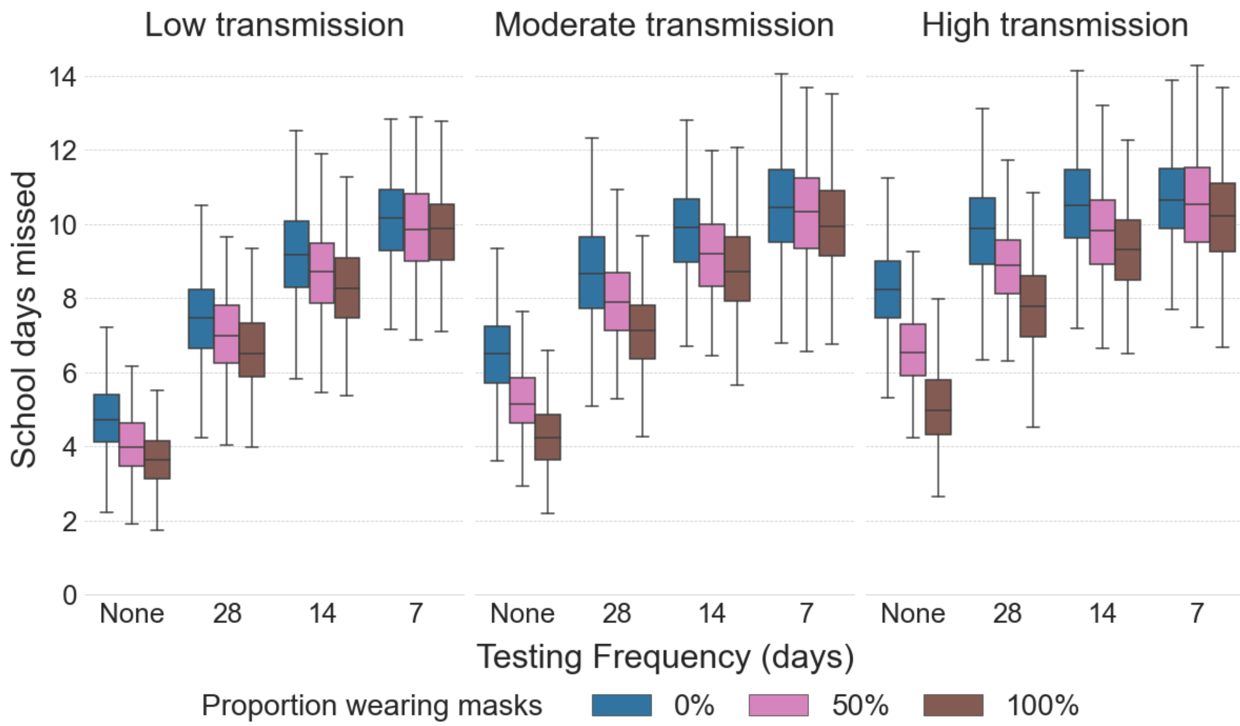

Figure 2. Projected average school days missed per student during the first 10 weeks of the school year (50 school days) due to isolation and quarantine following positive tests. From left to right, the three panels correspond to a low, moderate, or high transmission rate within the school. Colors indicate the proportion of students wearing face masks, either no students wear masks (blue), half of students wear masks (pink), or all students wear masks (brown). The values along the x-axis indicate the frequency of proactive testing. For example, a frequency of 28 means that students are tested once every four weeks, on a staggered schedule. Each box plot indicates the distribution of projections across 300 simulations with the specified scenario (transmission rate, frequency of testing, and mask usage). The projections assume that there are 150 new daily infections per 100,000 individuals in the surrounding community. Upon a positive test result the entire classroom and household of the person testing positive are quarantined for 10 days.

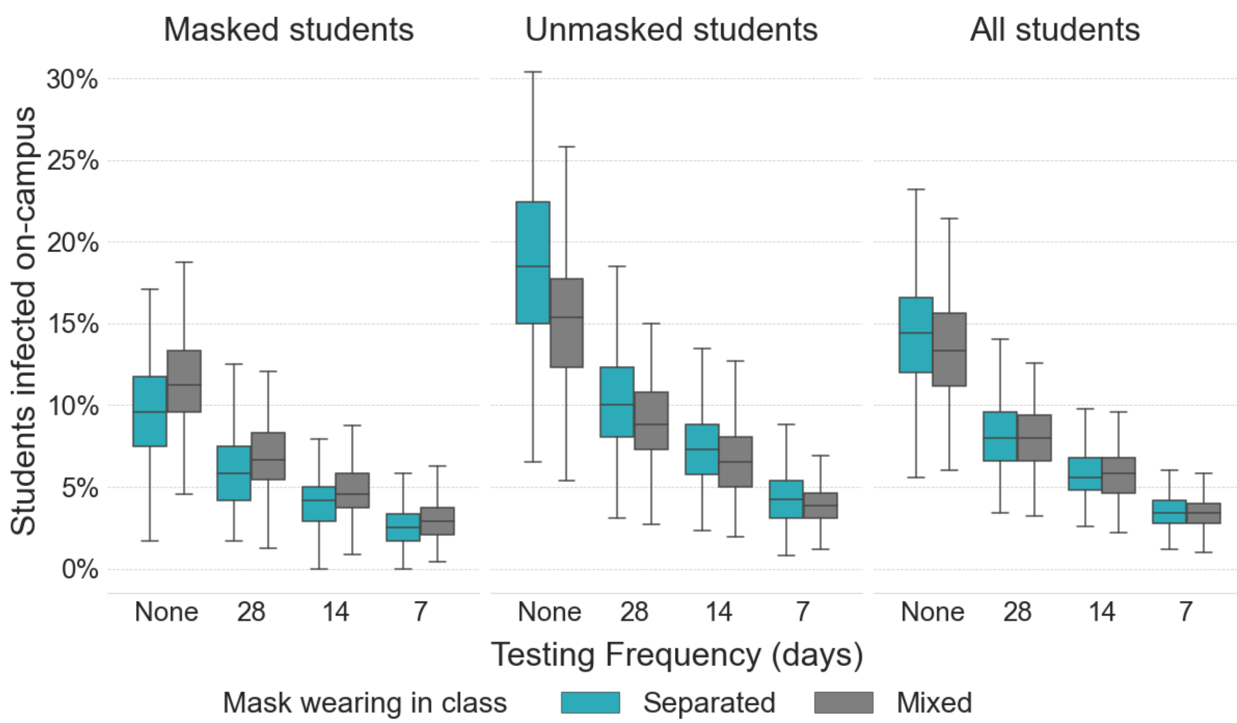

Figure 3. Projected impact of separating students into classrooms based on mask use, depending on the frequency of proactive testing. Projections are for a school with 500 students during the first 10 weeks of the school year, assuming a moderate transmission rate and that 50% of students opt to wear masks. From left to right, the panels represent students opting to wear face masks, students not wearing face masks, and all students combined. Colors indicate whether students wearing face masks are separated in all-mask classrooms (cyan), or not (grey). For example, a frequency of 28 means that students are tested once every four weeks, on a staggered schedule. Each box plot indicates the distribution of projections across 300 simulations with the specified scenario (frequency of testing and class separation). The projections assume that there are 150 new daily infections per 100,000 individuals in the surrounding community. Upon a positive test result, the entire classroom and household of the person testing positive are quarantined for 10 days.

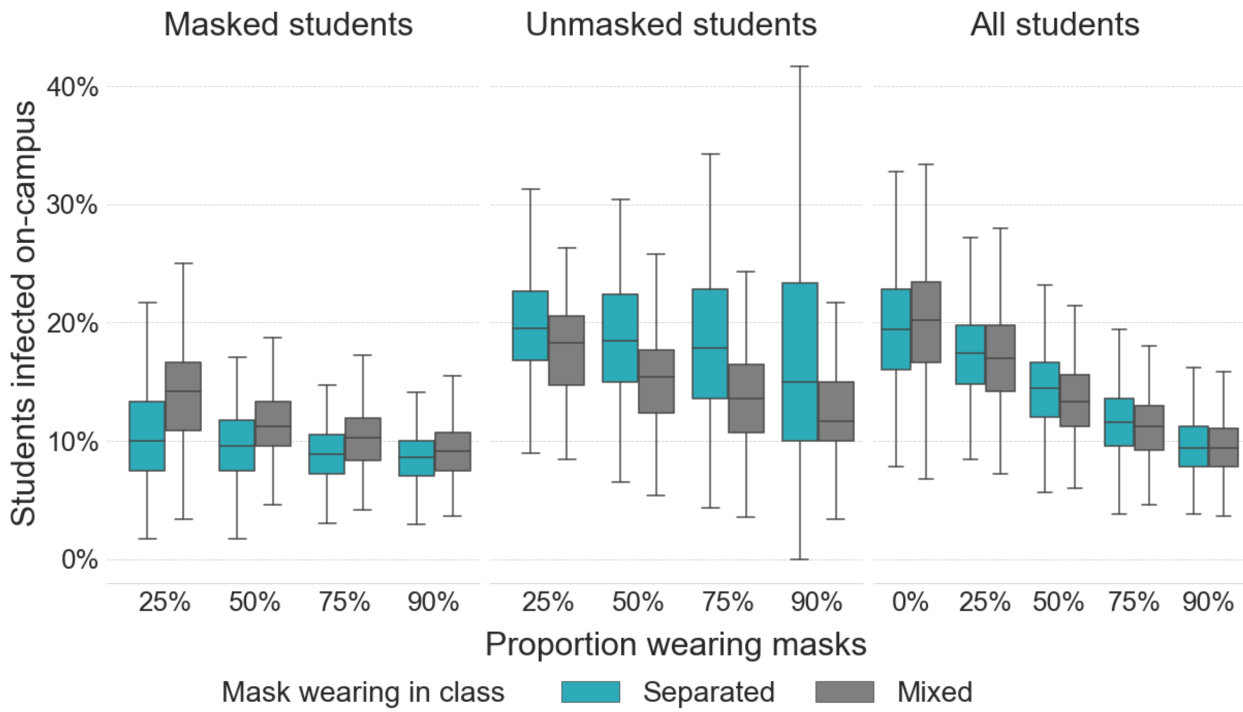

Figure 4. Projected impact of separating students into classrooms based on mask use, depending on the overall proportion of students opting to wear masks. Projections are for a school with 500 students during the first 10 weeks of the school year, assuming a moderate transmission rate and no proactive testing. From left to right, the panels represent students opting to wear face masks, students not wearing face masks, and all students combined. Colors indicate whether students wearing face masks are separated in all-mask classrooms (cyan), or not (grey). Each box plot indicates the distribution of projections across 300 simulations with the specified scenario (proportion wearing masks and class separation). The projections assume that there are 150 new daily infections per 100,000 individuals in the surrounding community. Upon a positive test result, the entire classroom and household of the person testing positive are quarantined for 10 days.

Appendix - Model Details

Our agent-based model of COVID-19 transmission in schools models interactions between students and adults in the school environment. It explicitly includes student households and indirectly considers community transmission through daily introductions of new cases.

Figure S1 depicts the structure of the COVID-19 transmission model. Infected individuals initially move to the exposed compartment (E) before first progressing to either a presymptomatic (P^Y) or pre-asymptomatic (P^A) compartment, then progressing to a symptomatic infectious (I^Y) or asymptomatic infectious (I^Y) compartment, respectively, and finally recovering (R) with immunity.

The average incubation, pre-symptomatic, and infectious periods, as well as infectiousness through time, are based on [1] (Table S1). We assume that asymptomatic cases are two-thirds as infectious as symptomatic cases [2], and that 57% of infected adults and 20% of infected children become symptomatic [3,4].

The model makes a number of assumptions about the contacts between agents (Table S1). Students are assumed to spend six hours per day in a single classroom (with the same students) and two hours per day in contact with students throughout the school. When we assume that students are segregated into all-mask and no-mask classrooms, students still spend 25% of their time mixing with students from other classes.

We assume that 90% of symptomatic individuals seek testing, regardless of the frequency of proactive testing. When an individual tests positive through symptomatic or proactive testing, they are isolated and their entire classroom and household are quarantined for 10 days.

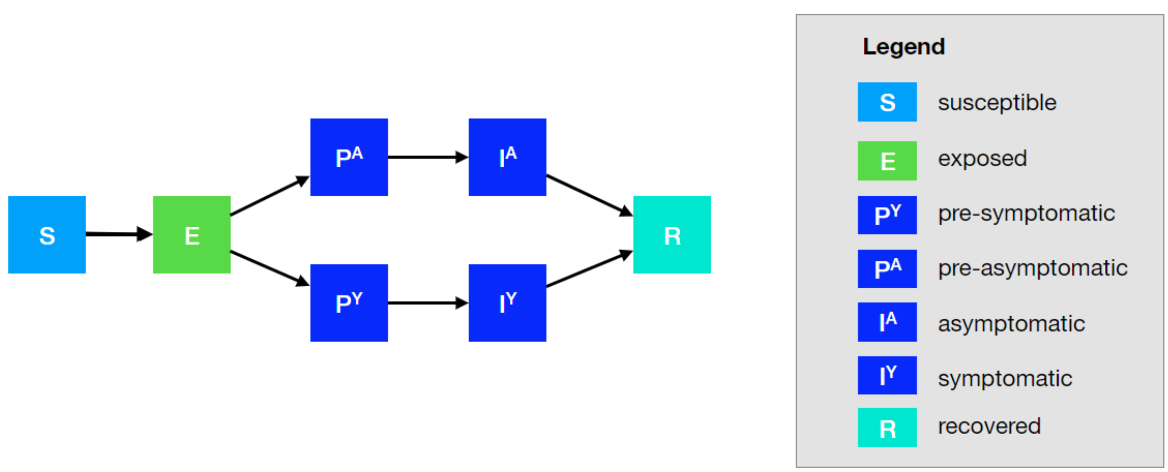

Figure S1. Schematic of the agent-based SEPIR model. Upon infection, susceptible individuals (S) progress to exposed (E) and then to either pre-symptomatic infectious (P^Y) or pre-asymptomatic infectious (P^A) from which they move to symptomatic infectious (I^Y) and asymptomatic infectious (I^A) respectively. All cases eventually progress to a recovered class where they remain protected from future infection (R). The proportion of individuals who become asymptomatic rather than symptomatic varies between children and adults.

Table S1. Model parameters.

Parameter	Value	Source
Simulation duration	10 weeks	
Number of students	500 (25 classrooms of 20)	
Number of adults in school	25 teachers, 25 bus drivers, 16 staff	
R_0: unmitigated basic reproduction number of children	3 scenarios: 1.0, 1.5, 2.0	
Community incidence	150 new cases per 100,000 per day	UT COVID-19 Modeling Consortium [5]
Masked students	3 scenarios: 0%, 50%, 100%	
Mask effectiveness	26% reduction in infectiousness 26% reduction in susceptibility	Mitze et al. [6]
Vaccination rate	70% of adults; 0% of students	
Vaccine impact	66% reduction in susceptibility	Fowlkes et al. [7]
Surveillance testing frequency*	4 scenarios (students only): None, monthly, every two weeks, weekly	
Isolation	10-day isolation after positive test (symptomatic and asymptomatic cases)	
Quarantine	10-days for classroom and household after positive test	AISD [8]
Proportion symptomatic	20% of children; 57% of adults	Davies et al., Gudbjartsson et al. [3,4]
Relative infectiousness of asymptomatic individuals	⅔	He et al. [2]
d_{inc}: duration of incubation period	d_{inc} ~ Triangular (3.2, 5.2, 7.2) days	Zhang et al. [9]
d_{pre}: duration of pre-(a)symptomatic period	$d_{pre} \sim d_{inc} \times$ Triangular(0.458, 0.558, 0.658) days (average 2.9 days)	He et al. [1]
d_S: duration of (a)symptomatic period	$d_S \sim$ Triangular(4,8,12) days	He et al. [1]

* The projections assume a perfectly accurate rapid test.

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