Maximizing education while minimizing COVID risk: priorities and pitfalls for reopening schools

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What do we already know?

In our July 13th Schools are not islands report, we found that with increasing transmission outside of schools, there is limited room to return students to in-person schooling. However, provided sufficient countermeasures are in place within schools and transmission outside of schools is declining, students may return in person without causing exponential epidemic growth. Since then, as parts of the country face rising cases, many school districts, including six of the seven largest in the nation, have announced plans to restart K-12 education fully remotely. These decisions will weigh most heavily on marginalized communities and those already at highest risk of COVID-19. This report explores the health risks associated with alternative reopening strategies.

What does this report add?

This analysis demonstrates that any return to in-person learning carries risk. An approach with only elementary schools returning to in-person on an A/B 2-day a week schedule[1], while other schools remain remote, would reduce the cumulative risk of COVID infection in students, staff and teachers in school to below 1.2 percent in the first three months of school, depending upon the community-wide COVID incidence rate in the two weeks prior to school reopening. These reopening strategies come at an educational cost, requiring students to spend up to 83 percent of school days at home, either through scheduled distance learning or due to infection-related quarantine.

What are the implications for public health practice?

Return to in-person learning will pose significant risks for students, staff and teachers. However, our results suggest that, depending on the incidence of COVID-19 in the community, a carefully organized incremental approach that returns the youngest students first with a reduced schedule would minimize the risk of infection within schools and provide important benefits to the neediest children. But the solution with the lowest health risk also has the highest educational cost, the majority of which lands on those communities and families already most under-resourced: those without access to technology and whose parents are essential workers. Decision makers must therefore balance the benefits of in-person education with the safety of teachers and staff, while continuing efforts to decrease the incidence of COVID-19 outside of schools. Regardless of the approach taken, it will be critical to monitor schools with symptomatic screening and react quickly to the emergence of cases in schools with testing and contact tracing.

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[1] A/B scheduling splits classrooms into group A students (who attend two days per week, e.g. Mon-Tue) and group B (who attend two different days per week, e.g. Thu-Fri).

Introduction

Public K-12 schools in Washington State closed due to COVID-19 transmission following an order issued by Governor Jay Inslee on March 12th, 2020. A recent study has estimated that school closures across the country were associated with a significant decline in both COVID-19 incidence and mortality [2]. Attention is now focused on the risks and benefits of reopening schools. The educational benefits of in-person learning are considerable, as described in a recent CDC report on the importance of reopening schools. Yet much remains uncertain about the role school-age students may play in COVID-19 transmission, and how effective school-based interventions may be in preventing transmission. Our previous modeling report revealed that schools are not islands: the precautions that people take to reduce transmission outside schools are as important to reducing the risks associated with a return to in-person instruction as the countermeasures taken within schools.

If schools resume in-person learning while the pandemic is still ongoing, classrooms will likely look quite different from previous school years. Our "Schools are not islands" report explored the potential impact of face masks, physical distancing, improved hygiene, classroom cohorting, symptomatic screening, and follow-up diagnostic testing and contact tracing in the context of various community-wide mobility scenarios. Results showed that schools could be reopened without triggering exponential growth, provided robust school-based interventions were implemented and community transmission was reduced by the start of the school year (Re < 1 and available hospital capacity remaining).

This report adds significantly to our prior analysis. Previously we modeled only students and teachers within schools, but here we have added in non-teaching staff to more accurately capture contact structures and disease transmission within schools. We are also more accurately capturing the scheduling dynamics of schools. Firstly, we are simulating a school week that is five days long and inactive on the weekends. We note that this assumes that students have no contact with their classmates on two out of every seven days and no associated increase in community-wide contacts in those two days. For strategies with hybrid or elementary-only scheduling, we are enabling students to be physically present in school on specific days and learning remotely on other days. While we acknowledged the uncertainty in transmissibility within schools and among students, we are now more rigorously testing the impact of these assumptions on our results.

Key inputs, assumptions, and limitations of our modeling approach

We used Covasim, an agent-based model of COVID-19 transmission and interventions developed by IDM, to estimate the impact of school reopening on disease transmission and the extent to which screening, testing, and tracing of students and teachers as well as alternative in-person and remote schedules could mitigate epidemic spread within and outside of schools. Covasim includes demographic information on age structure and population size; realistic transmission networks in different social layers, including households, schools, workplaces, long-term care facilities and communities; age-specific disease outcomes; and within- and between-host variations in infectivity to capture sub- and super-spreading and front-loaded infectivity. We modeled schools to match age mixing patterns between students within elementary schools, middle schools, and high schools [3] (see Appendix A for more details on the school network structure). Key inputs and assumptions of our modeling approach have been documented in our initial methods article [7], the updated methodology [8], and our previous schools report.

We anchored the analysis to directional trends of the COVID-19 epidemic in order to provide results that may be applicable to different settings. We simulated a test positivity rate of approximately 2-3%, but did not vary this as part of the analysis. We used the effective reproductive number in the absence of school reopening and the number of cases in the last two weeks of August as signals of both the direction of cases as well as the size of the epidemic (see Appendix B for details on calibration). The results we present below reflect the case where the epidemic is declining slowly when schools are fully closed (i.e., Re = 0.9). If the epidemic is increasing exponentially (Re = 1.1), restarting K-12 education in-person only further adds to the problem. Thus, in conjunction with the assumption that the epidemic is controlled with full school closures, we considered three scenarios for the size of the epidemic in the two weeks prior to school reopening: 20, 50, or 110 cases per 100,000 individuals.

While agent-based modeling is able to capture many details of populations and disease transmission, our work has important limitations and assumptions that could impact our findings. Specific uncertainties and assumptions include:

Disease dynamics: infectivity, susceptibility, symptomiticity

- There is still a high degree of uncertainty around the susceptibility, symptomiticity/severity, and infectivity of COVID-19 in children, particularly since schools in most locations shut down early in the epidemic. Our analysis is based on the most recent scientific literature for each of these parameters. We assumed individuals under 20 had a 45-50% reduced risk of developing symptoms [4] and 33-66% reduced risk of acquiring infection [1].
- We assume that an infectious individual is 5 times more likely per day to transmit to a household contact than a school contact, based on estimated numbers of hours spent in each setting per week. We varied this assumption to transmission per contact in schools equal to household transmission in sensitivity analysis.
- After being diagnosed, all individuals are assumed to reduce their daily infectivity by 70% for home contacts, 90% for community contacts, and 100% for school and work contacts. Additionally, the household contacts of these individuals may be traced, notified, and school contacts removed from school for a full 14-day quarantine period. While we anticipate that schools will be able to help identify contacts of diagnosed students or staff, the large number of contacts within schools may place additional burden on local or state contact tracing efforts and our analysis does not represent this.
- We assume that household transmission is not reduced while children are attending school in person, nor that it increases when students are learning remotely.

Structural assumptions

- We are not modeling increased transmission associated with parents/guardians returning to work following a return to in-person learning.

- We assume students who participate in remote learning are not in contact with anyone from school. On days that students are learning remotely, we do not account for any potential interaction students may have in a congregate care setting, such as an alternative after-school care program.
- We do not explicitly model the distribution of school sizes by school types, whereby high schools tend to have more students than both elementary and middle schools, due to data limitations at the time of model development.
- We have assumed that, if implemented, all elementary and middle schools will be able to enforce classroom cohorting, whereby students are grouped into a classroom and are only in contact with other students and teachers in that classroom. We note that cohorting may be difficult to implement given the complexity of class scheduling for student bodies with multiple academic tracks, elective classes, and degree requirements.
- We assumed that, if implemented, syndromic screening would occur daily in schools and students or teachers presenting with COVID-like symptoms would be sent home. Those who are symptomatic may be asked to take a diagnostic test, which we assumed returns a result within two days. Students who received a negative test result return to school the next day, and students who received a positive test result are isolated at home for 14 days. Our results do not depend on school staff administering the diagnostic tests.
- We do not account for school days lost due to non-COVID-related sickness, except for students with influenza-like illness symptoms who screen positive and are sent home.
- We only considered specific strategies for reopening of elementary, middle, and high schools in this analysis. We are not considering the impact of pre-school and universities.
- We are not explicitly modeling after-school care, which many working parents depend upon to cover the gap between school hours and working hours. Families who use these services may also be more likely to be essential workers. We also do not model transportation to and from school, which may be an important source of transmission and which also depends on school resources.

School reopening scenarios

We identified and compared alternative school reopening strategies to the status quo of reopening schools with no interventions or countermeasures as well as not reopening school at all. These were:

1. All in person with no countermeasures
2. All in person with countermeasures
3. All in person with countermeasures and A/B scheduling
4. Elementary and middle in person with countermeasures, high school remote
5. Elementary in person with countermeasures, middle and high school remote
6. Elementary in person with countermeasures and A/B scheduling, middle and high school remote
7. All remote

Countermeasures are non-pharmaceutical interventions (NPIs), which implicitly include face masks, six foot separation, and hand washing, which together are assumed to reduce transmission by 25%; class cohorting, in which students and teachers have no contact outside their own classroom; and symptomatic screening, with 50% follow-up diagnostic testing and 50% follow-up contact tracing. A/B scheduling splits classrooms into group A students (who attend two days per week, e.g. Mon-Tue) and group B (who attend two different days per week, e.g. Thu-Fri).

We applied our interventions to elementary, middle, and high schools and assumed that pre-schools and universities will remain closed. We assumed that high schools would not be able to implement classroom cohorting, as it would be too challenging to coordinate the highly variable schedules of students at this level. We simulated the first three months of the school term (Sept. 1st - Dec. 1st).

Results

In-person schooling, even with sufficient countermeasures and R_e of 0.9, poses significant risks to students, teachers, and staff. Even on the first day of school, we find that 5% - 42% of schools would have at least one person arrive at school with active COVID-19 (including all students, teachers, and staff), depending on the incidence of COVID in the community and the school type (Figure 1). These infections may show few symptoms and go undetected, especially if they are in younger children. Symptomatic individuals may stay home or be screened immediately upon arrival. Active COVID-19 infections also may not lead to onward transmission within schools, depending on per-contact infectivity. This highlights the importance of procedures within schools to minimize risk of transmission, detect and isolate cases, and contact and quarantine any known contacts.

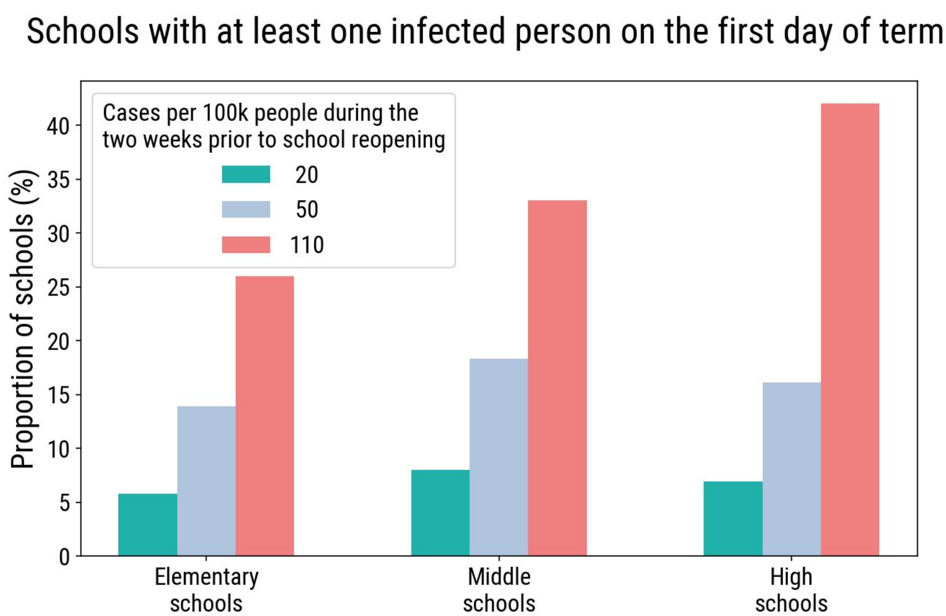

Figure 1*: Percent of schools with at least one infectious individual on the first day of school, averaged across the top 20 parameter sets. A limitation of this analysis is that we do not explicitly model the distribution of school sizes by school type, so may underestimate the risk in high schools, which tend to be larger in size than middle and elementary schools, relative to elementary and middle schools.*

Closely examining infections present in school, our model shows that either A/B school scheduling or an incremental approach that returns elementary schools in person and keeps all other students remote can mitigate the presence of COVID within (and outside of) schools. In the absence of any countermeasures in schools, we can expect between 9.5 and 24.6 percent of teaching and non-teaching staff and between 6.4 and 17.2 percent of students to be infected with COVID in the first three months of school, depending upon the incidence rate (Figure 2): when there is more COVID in the population, there will inevitably be more COVID in schools. At the lowest incidence rate, **schools can lower this risk to as low as 0.3 percent for staff and 0.2 percent for students by returning elementary schools either full-time or with a hybrid schedule while all other grades continue learning remotely**.

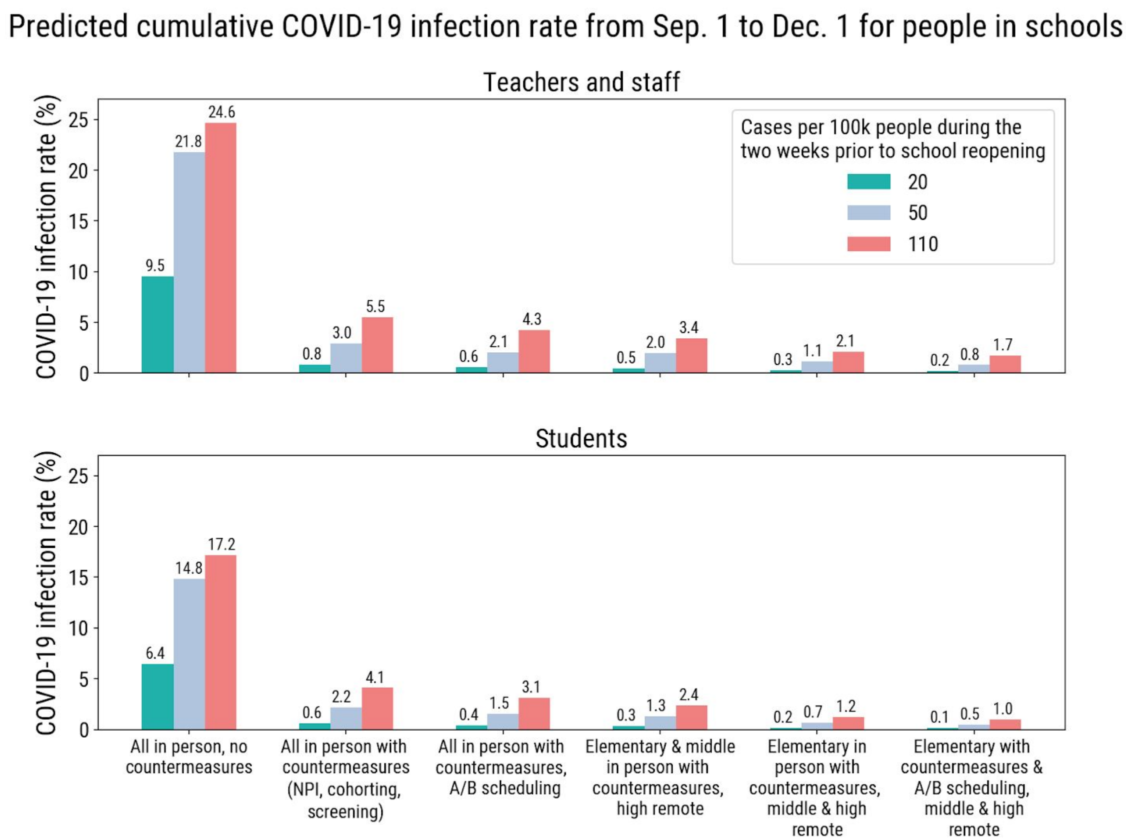

Figure 2*: Cumulative COVID-19 infection rate for students, teachers and staff physically present in schools during the period of school opening (September 1st to December 1st), averaged across the top 20 parameter sets.*

We find that an A/B scheduling approach, in which classrooms are split into two groups that attend school two days a week on different days, reduces COVID-19 transmission in schools nearly as much as an elementary only approach. The key difference between these approaches is that A/B scheduling gives all K-12 students some time for in-person learning, whereas the elementary-only approach restricts in-person learning to elementary school students, at least initially.

Our results support the strategy of returning elementary school students to school either full-time or with an A/B schedule while keeping all other students remote for the first three months of school to best minimize the risk of COVID-19 infection in schools. **Returning elementary schools in-person first is both relatively lower-risk and higher-benefit**—elementary school aged children are less susceptible to infection [1] and potentially less likely to transmit infection [5]. Additionally, they benefit more from in-person learning and pose more of a burden on family members. These results can be supported by experience globally, where we have seen countries return elementary school aged students to school and returning older students at a later stage after observing an absence of significant school-based transmission [1,2]. However, these countries had a significantly lower COVID-19 incidence rate prior to reopening schools than many parts of the country, including Washington State, are experiencing today.

These strategies come at a significant educational cost, **requiring up to 83 percent of school days to be spent at home, due to either planned distance learning or related to detected COVID-19 infection** (Figure 3). We find that, provided sufficient countermeasures within schools, the COVID-19 infection rate in the population prior to school reopening has more influence on the COVID-19 infection rate within schools than the specific reopening strategy: **we expect an over seven times reduction in the infection rate for people in schools if schools are reopened when the incidence rate in the community is at 20 per 100,000 compared to 110 per 100,000**. At any given size of community transmission, additional countermeasures will have a much more marginal impact on the rate of infection within schools for a large cost of missed in-person school days. We note that days of distance learning are not experienced equally by students and the benefit gained varies considerably based on both age and other factors such as socioeconomic status.

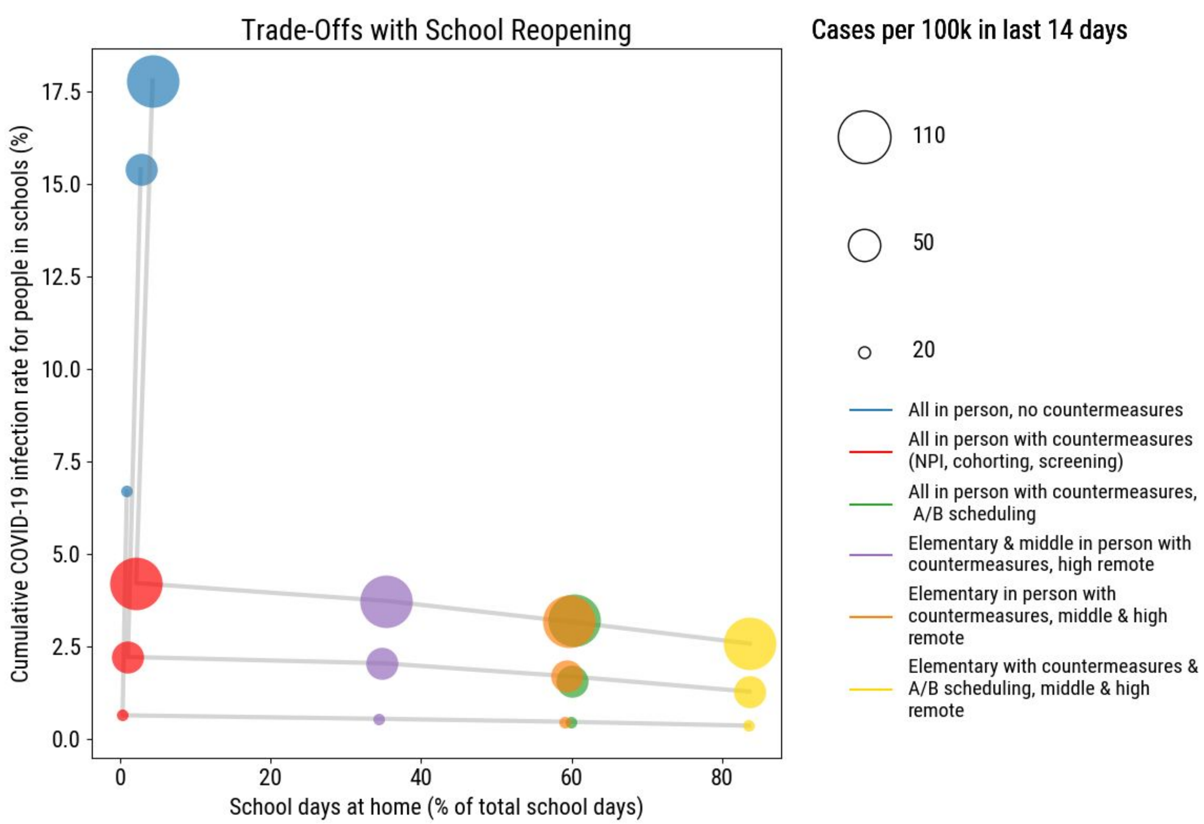

__Figure 3__: Tradeoffs between within-school infection rate and missed in-person school days (due to either scheduled distancing learning, quarantine, or infection).

Consistent with our first report, we find that **reopening schools will not significantly increase community-wide transmission, provided sufficient school-based interventions are implemented** (Figure 4). If community transmission is decreasing in the absence of in-person schooling, we can return to in-person learning with appropriate countermeasures without adding to community transmission. A limitation of our analysis is that we are not modeling an increase in transmission associated with parents and guardians returning to work following a return to in-person learning.

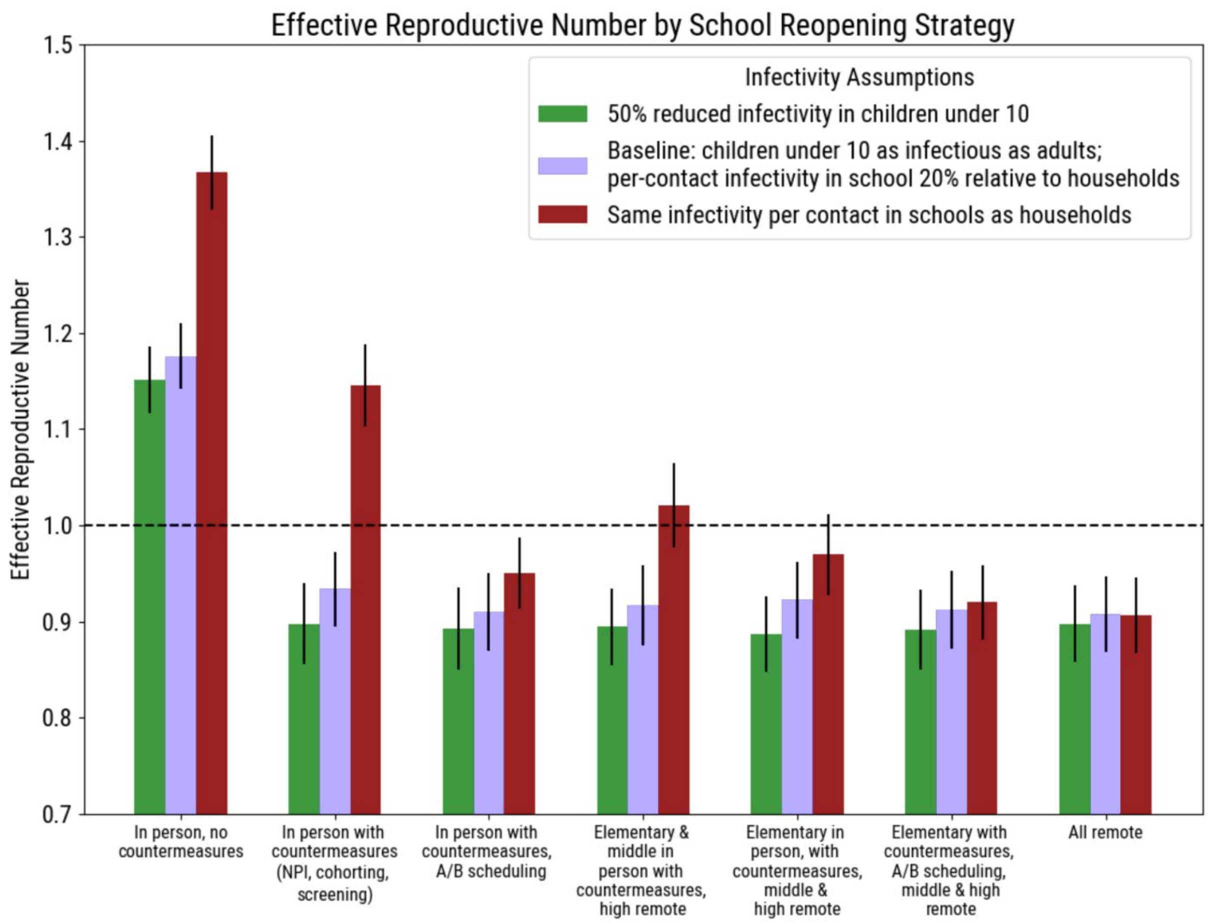

***Figure 4**: Effective reproductive number over the simulated period of school reopening (September 1st to December 1st), averaged across the top 20 parameter sets, assuming a COVID-19 incidence rate of 50 cases per 100,000 in the 14 days prior to school reopening. Error bars represent the standard deviation of the top 20 parameter sets. Regardless of infectivity, in all cases, young children are three times less susceptible to infection than adults. We are also not modeling an increase in transmission associated with parents/guardians returning to work when in-person learning resumes.*

Due to considerable uncertainty in the roles K-12 students, teachers, and staff play in COVID-19 transmission, we performed several sensitivity analyses to see if results were robust to a range of reasonable assumptions. A recent study using data from South Korea suggests that students under the age of 10 might be half as infectious as older students and adults [5]. Implementing this variation in the model only further supports the elementary-only approach. Our results are consistent even when we consider a 50 percent reduction in the infectivity of children under 10 years old**.**

A second sensitivity analysis addresses a key uncertainty in schools modeling: how much transmission actually happens in schools? Our baseline assumption is that an infectious individual is five times more likely per day to transmit to a household contact than a school contact, based on estimated numbers of hours spent in each setting per week as well as countermeasures that may be used in schools but not at home. We varied this assumption, allowing transmission per contact in schools to equal that of household transmission, which may be attributable to poor ventilation and overcrowding in schools. We found that results are sensitive to the relative infectivity within schools: if school-based contacts transmit as readily as household contacts, then schools would account for a much larger proportion of overall transmission and strategies with more in-person school days would increase within-school and community-based transmission. **In the face of increased transmissibility within schools, an A/B scheduling approach for either all students or just elementary school students (with the remaining students learning remotely) is preferred**.

Conclusions

Schools around the world are grappling with the challenge of returning to in-person learning in the COVID era. Much remains unknown about the role children play in COVID-19 transmission within schools and in the broader community, but the latest science suggests that younger children are less susceptible and show fewer symptoms if infected. From schools that never closed in Sweden to reopening examples in Europe and Asia, lessons on how the US might resume in-person learning are abundant and diverse. Our computational modeling synthesizes this evidence, and the latest results give reason for optimism.

Yet reopening schools is not a zero-risk activity. Symptom screening is imperfect, and COVID-19 will be present in the respiratory system of students, teachers, and staff on day one. Additionally, a return to in-person learning would allow parents and guardians return to work, which could be accompanied by an associated increase in transmission outside schools. But the solution with the lowest health risk has the highest educational cost, the majority of which lands on those families most marginalized and under-resourced: those without access to technology and private tutors, and whose parents or guardians work in the essential economy. Schools must open; the question is when and how, so as to balance the benefits of in-person education with the safety of teachers and staff, all while realizing that COVID is not just a school problem.

References

1. Zhang, J. et al. Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. Science 368, 1481–1486 (2020).
2. Auger, K. A. et al. Association Between Statewide School Closure and COVID-19 Incidence and Mortality in the US. JAMA (2020) doi:10.1001/jama.2020.14348.
3. Guclu, H. et al. Social Contact Networks and Mixing among Students in K-12 Schools in Pittsburgh, PA. PLOS ONE 11, e0151139 (2016).
4. Davies, N. G., Klepac, P., Liu, Y., Prem, K. & Jit, M. Age-dependent effects in the transmission and control of COVID-19 epidemics. 31.
5. Park, Y. J. et al. Early Release - Contact Tracing during Coronavirus Disease Outbreak, South Korea, 2020 - Volume 26, Number 10—October 2020 - Emerging Infectious Diseases journal - CDC. doi:10.3201/eid2610.201315.
6. Census profile: Seattle-Tacoma-Bellevue, WA Metro Area. Census Reporter http://censusreporter.org/profiles/31000US42660-seattle-tacoma-bellevue-wa-metro-area/.
7. Washington Office of Superintendent of Public Instruction, https://k12.wa.us/data-reporting/data-portal
8. Kerr, C. C. *et al.* Controlling COVID-19 via test-trace-quarantine. *medRxiv* 2020.07.15.20154765 (2020).
9. Kerr, C. C. *et al.* Covasim: an agent-based model of COVID-19 dynamics and interventions. *medRxiv* 2020.05.10.20097469 (2020).

Appendix A: Schools network structure

We simulated a representative sample of the 2.25 million King County, Washington residents in Covasim. We use student enrollment data for King County available from the 2018 American Community Survey [6]. This data gives an estimate of the enrollment rates by age for students attending any educational institution at the county level. Enrollment rates are given by age groups: 3-4 years old, 5-9 years old, 10-14 years old, 15-17 years old, 18-19 years old, 20-24 years old, 25-34 years old, 35 year old and over. The enrollment rate for the last group is estimated to be 2.7% and this rate is applied to ages 35 to 50 years old. School sizes are drawn from a distribution based on the enrollment numbers for Seattle area schools available for the year 2017 [7].

In order to model realistic school reopening scenarios, we equipped the model to generate networks within schools that reflect proposed cohorting by age and grade. We modeled schools to match age mixing patterns [3] between students within preschool, elementary schools, middle schools, high schools, and universities. Using the county-level school enrollment data [6], we simulate contacts within schools, mixing between students and teachers, and clustering of students into cohorts. Mixing of students and teachers can be thought of as following three main patterns: (1) students sorted in classroom cohorts of the same grade with one or two teachers, (2) students mixing with random contacts mostly within the same grade and at least one teacher, and (3) students mixing with random contacts across the entire school and at least one teacher. The first mixing pattern resembles the contact structures commonly found in pre-school and elementary schools, where students are generally taught by one teacher and stay with the same classroom of contacts throughout the day. The second pattern reflects mixing patterns often found in middle schools and high schools where students have individualized schedules and mostly interact with other students in the same grade. The third mixing pattern reflects university settings where student interaction occurs in classes, dorms, and in other spaces on campus. Student mixing in these institutions display less age assortativity because of the high variability of age when students enroll, use of common spaces such as libraries and dining halls, and other aspects of on-campus life.

In addition to students and teachers, schools also include additional staff members such as principals, counselors, nurses, maintenance, and cleaning staff. Using information on the estimated ratio of students to all staff members, we model the number of additional non teaching staff expected for each school and the contacts for them as random contacts across the entire school. This reflects the overall more varied contact patterns of non-teaching staff with students, teachers, and other staff members.

Appendix B: Calibration

We used an optimization procedure to find a set of parameters (varying the number of seeded infections at the start of the simulation and the reduction of workplace and community contacts) that resulted in our desired combinations of effective reproductive number in the absence of schools and cumulative incidence in the two weeks prior to the school year. We ran our analysis with the top 20 best fitting parameter sets.

We calibrated these model parameters using the Tree-structured Parzen Estimator sampler in Optuna, an optimization software. The sampler trains models of $p(\theta|y)$ and $p(y)$, where θ is a set of parameters and y is a (scalar) output of an objective function, to find the region of the parameter space that minimizes y. We defined the objective function to be the sum of squared differences between observed data (i.e., average effective reproductive number from September 1st to December 1st; cumulative COVID-19 cases in the two weeks prior to September 1st) and the corresponding model predictions.