Making sense of the research on COVID-19 and school reopenings

Benjamin W. Abbott[1], John M. Chaston[2], Jonas Bush[2], Chantel Sloan[3], Brian Poole[4], Mitchell Greenhalgh[1], S. Isaac St. Clair[5], Haley Moon[1], Jacob Gudmundsen[6], Sarah Gottfredson[2], Isabella M. Errigo[1], Skyler Lemmon[2]

1. Brigham Young University, Environmental Science; 2. Brigham Young University, Genetics, Genomics & Biotechnology; 3. Public Health, Brigham Young University, 4. Brigham Young University, Microbiology & Molecular biology, 5. Brigham Young University, Statistics; 6. Brigham Young University, Economics

The interpretation and content of this report are those of the authors.

Published on 11 August 2020, last updated on 21 August 2020.

Last month, we published a nontechnical review of the scientific evidence on masks and prevention of COVID-19[1]. We did not anticipate the intensity of public interest, but we were heartened by the sincere and widespread desire for reliable information on this crucial public health issue. The outpouring of questions, thanks, and criticisms made it clear that there is an unmet demand for independent and accessible research on COVID-19. Of all the feedback we received, one request was the most common by far: *can you do a follow-up report on the reopening of schools?* While much information is already available in nontechnical formats (for example, the CDC, KFF, and Utah Department of Health all have excellent summaries on this subject), we felt a duty to review the available recommendations and research for those in our community and state. Our 12-person team compiled and read more than 200 additional scientific studies pertinent to COVID-19 in school settings. While this "rapid review" approach is not perfect (see the "Deep dive" section), we have done our best to accurately reflect the evidence we found. Compared to our mask report, there were more "preprints" (papers still undergoing review) and overall knowledge gaps about COVID-19 and schools, reflecting the complexity and uncertainty of this topic. As for the mask report, we received no funding to do this work. There are four sections with increasing levels of detail: **1.** Executive summary, **2.** Common questions, **3.** Deep dive, **4.** FAQs. We hope this is useful as you decide what is best for your family and as our community faces this threat together.

***Note**: We use the terms "infant" (<1 year), "children" (1-10 years), "adolescents" (11-18 years), and "youth" (all these groups together). "Teacher" refers to all adult employees unless otherwise stated.*

Executive summary:

1. Children (0-10 years old) and adolescents (11-18) are not immune to COVID-19, though the disease is usually less severe and less easily transmitted by children[2–8]. Children may be one-third to one-half as susceptible to COVID-19 as middle-aged adults, though adolescents show intermediate to near-adult susceptibility and transmission[2,9,10]. Transmission by children appears to account for a small minority of overall community and household cases (likely no more than 5 to 10%)[3,11–13].
2. Evidence on teachers' risk of infection in school reopenings is limited. Risk of infection may vary based on the school type (lower in elementary, higher in junior high and high school), though this is not well established[14–17]. Adult to adult contacts within schools may be the greatest risk for teachers[18]. Protective measures are needed because 1 in 4 teachers is in a high-risk category for COVID-19[19].
3. Many countries have reopened primary and secondary schools with safe outcomes for students and teachers[14,18,20,21]. Some outbreaks have occurred, particularly associated with high schools[15–17]. Factors increasing likelihood of success seem to include: low community spread, preventive measures at school (social distancing, masking, handwashing), rapid testing, contact-tracing, and cohorting[22,23].
4. No countries have attempted to reopen schools with the level of community spread that the U.S. is currently experiencing. Daily cases in countries that have reopened successfully are typically below 20 per million people[20]. That number is currently 199 for the U.S. and 120 for Utah[24]. Early reports from U.S. districts that have reopened suggest frequent exposures, highlighting how reducing community spread should be paramount.

5. There are substantial risks and costs associated with not reopening schools, especially for primary and secondary school children, including decreased psychological wellbeing, social development, educational progress, nutrition, and safety[25–33]. While risks can be dependent on or mitigated by family circumstances for some, many children are highly vulnerable to harm from full school shutdowns[34,35].
6. Safe reopenings cannot be achieved by interventions at school alone. In-school protective measures must be implemented along with family actions and community support to lower student, teacher, and community infection rates[21–23,36–38].
7. Observational and modeling studies suggest that risk of outbreaks is very high in colleges and universities[39–42]. This is due to residential and nonresidential student interactions and high transmission among young adults. Widespread and rapid testing, a large quarantine capacity, and a sustained level of vigilance will be needed before campuses can be safely reopened for in-person instruction, even with mask-wearing and social distancing practices in place for classrooms.

Common Questions:

How dangerous is COVID-19 for youth? Though less is known about COVID-19 in youth than in adults, studies indicate lower risk of severe symptoms in youth[4,6,20,21,23,43,44]. For example, in the U.S., youth account for 7% of reported COVID-19 cases, but 1% or less of hospitalizations and deaths[20]. Roughly 90% of infected children have been either asymptomatic or had mild symptoms, though infants have shown a greater risk of developing severe or critical symptoms[4,45,46]. Together, these studies suggest that infants and children are likely one-third to one-half as vulnerable to COVID-19 infection as adults, but that this benefit decreases as adolescents reach adulthood[2,4,10,47]. These differences appear to be associated with their immune and circulatory systems[48–50]. However, youth who are hospitalized for COVID-19 have similar rates of serious complications as adults, with approximately one in three ending up in intensive care units[51]. Also, preexisting conditions can substantially increase the risk of severe symptoms in youth, as for adults [4,52].

How important are youth in COVID-19 transmission? Unlike influenza[53], where they are major vectors, children appear to be minor contributors to the spread of COVID-19[3,5,11,12]. However, adolescents (especially older teenagers) appear to transmit the disease as easily as adults[2,10,15,18]. Because there has been less COVID-19 testing in children than adults, these estimates remain uncertain, with specific estimates of child transmission ranging from ~20% to 85% the rate of adults[2,18]. A more common way to estimate the role of children in community spread is to determine how often a child was the first or "index" case in a home, school, or community. These studies consistently find that children are responsible for less than 10% of cases [2,8,11,54]. As described in more detail below, day cares and elementary schools are also usually associated with very few cases of child-to-child spread.

However, adolescents (especially older teenagers) appear to transmit the disease as easily as adults[10]. Observations of rapid spread in at least 3 junior high and high schools suggest that adolescents transmit the disease at near-adult levels[15,16]. The most definitive study on transmission across age groups found that 18% of household contacts of infected adolescents caught COVID-19—higher than any other age group tested (versus 5% of household contacts for children)[10]. We note that transmission outside of the home was much lower for youth and adults (~1% of non-household contacts), likely associated with stringent physical distancing and masking during the time period of the study [10].

The biological basis for these differences in youth is not clear, though the pattern of less severe disease in youth and less transmission in children appears consistent across all regions with relevant

data[4,6,7,10,44,50]. Possible explanations include differences between children and adults for height, social norms, immune activity, previous exposure to other diseases, and viral loads[2,5,10,55–58]. To the last point, reported viral loads in youth have been higher, the same, or lower than adults, depending on the study[5,57,58].

How effective were initial school closures at slowing COVID-19? Because children are known to be major vectors of spread for other respiratory diseases, it was initially believed that widespread school closures at all educational levels were needed to prevent the spread of COVID-19[60]. Retrospective analyses and modelling studies have mixed conclusions on the effectiveness of school closures in mitigating community spread of disease. Analyses based on data from China[61] and the U.S.[62] suggest that school closures were associated with slowing the initial wave of COVID-19 in those locations. Conversely, models based on spread in Canada[63], Brazil[64], the UK [65], and Japan[66] found that school closures were not major predictors of community transmission of COVID-19, suggesting the spread of disease cannot be mitigated by school closures alone. One of these studies estimated school closures would reduce deaths by 2-4%, a much smaller benefit than the effect of other interventions such as physical distancing, home isolation, household quarantine, and masking[65].

Box 1. Don't take our word for it

Given the high stakes and controversy surrounding this issue, many parents, teachers, and administrators don't know where to turn for reliable information about the risks and benefits of reopening schools. Our report draws on findings of many independent research groups who have considered this issue from diverse and sometimes opposing perspectives. Our report cannot (and does not seek to) replace the authoritative recommendations made by public health organizations. We urge all readers to dig deeper and evaluate the strength, findings, and implications of the available evidence (see Box 2). To facilitate this, we have compiled PDFs of references here.

As you evaluate the evidence, **here are five reports on school reopening during COVID-19 that we found particularly useful**:

1. *What do we know about children and COVID-19* (KFF)
2. *School openings across the globe suggest ways to keep coronavirus at bay, despite outbreaks* (Science)
3. *The urgency and challenge of opening* (JAMA)
4. *COVID-19 in children in school settings* (ECDC)
5. *School closure and management practices* (Lancet)

For **best practices about COVID-19 in school settings**, here are five resources with different levels of detail:

1. *Schools and childcare programs* (CDC)
2. *Utah COVID-19 School Manual* (UDOH)
3. *COVID-19 Planning Considerations* (AAP)
4. *Evidence-base theory for reducing COVID-19 transmission in reopened schools* (Health & Place)
5. *Best Practices for Reopening WA Schools* (Kinetic West)

Finally, we found these resources to be particularly informative and empowering **for parents**:

1. *Coronavirus guide for parents* (UNICEF)
2. *Back to school planning and checklists* (CDC)
3. *What parents can learn from childcare centers* (NPR)
4. Resources for schools and families (Kaiser Permanente)

What can we learn from school reopenings in other places? Because of differences in academic calendars, many other countries already have experience with school during the COVID-19 pandemic[17,21,67]. The successes and failures of other countries can inform decisions in the U.S., though cultural differences make direct comparisons or predictions unreliable. The first reports of reopenings in other U.S. states are also now coming out[68–70], providing a more comparable, though also more anecdotal analogue.

Thankfully, most countries that have reopened primary and secondary schools have seen very low or no transmission at school, though there have been outbreaks ending in school reclosure in a few

countries[20,21]. We outline a few examples from successful and failed reopenings in the paragraphs below but see the "Deep dive" section for a detailed analysis of more than a dozen countries with available data.

Successes:

A comparative study of infection in students and teachers in Finland, which closed schools during the initial outbreak, and Sweden, which kept schools open, found similar rates, indicating that school interactions did not enhance spread[71]. Similarly, a contact-tracing study from Australia found that preventative measures similar to the CDC and UDOH guidelines[22,36] largely contained spread in primary and secondary schools when infected individuals attended[18]. Similarly nine of ten childcare facilities with infected individuals experienced no secondary spread, though the remaining childcare facility had a substantial outbreak[18]. Open primary schools in Denmark, Norway, Sweden, and Canada appear to have had little influence on COVID-19 spread[17]. Finally, a meta-analysis of various parts of the world showed that schools had been a relatively uncommon source of community spread[72].

Setbacks and failures

Several countries have experienced school-related outbreaks of COVID-19. The most serious case we are aware of occurred in Israel, where a middle school and a high school experienced major outbreaks within 10 days of reopening[16]. One hundred fifty-three students and 25 staff contracted COVID-19, representing 13% of the student body and 17% of staff. The researchers suggested that contributing factors could have been larger class sizes (35-38 students), classroom distancing of only 4 feet, a temporary mask exemption, and continuous air conditioning[16]. Canada and Chile have also experienced school-related outbreaks that have resulted in partial or complete reclosures, though not as serious as Israel's [20,21]. In Chile, the spread was more pronounced in primary schools than in high schools—primarily attributed to teacher-teacher or teacher-student transmission[73]. Finally, reopening high schools in Germany was associated with increased levels of student-to-student spread, and the same may have been true before a school was closed in France [15,17].

Together, these accounts support two general conclusions for areas experiencing limited community spread (Table 2). First, when preventative measures are taken, primary schools do not appear to be associated with increased spread of COVID-19 compared to other places and activities in the community[6,14,21,44]. Second, junior highs and high schools can also reopen safely, though enhanced vigilance is needed to prevent transmission[15–18].

How relevant are successes and failures in other countries to our situation in the U.S.? While the U.S. and Utah can learn from many of these international examples, direct comparisons are difficult because of large differences in local infection rates. Daily cases per million people in countries that have reopened successfully are typically below 20 (Table 1)[20,60]. That number is currently 199 for the U.S. and 120 for Utah [24]. Only 5 counties in Utah (Rich, Wayne, Morgan, Emery, and Uintah) have case rates below 20 per day per million people (based on 7-day averages)[74].

We found no reports of countries that have tried to universally reopen schools with the level of community spread that the U.S. and Utah are currently experiencing[17,20]. Consequently, it is not known how school reopenings in the U.S. will affect community spread or whether preventative measures that have proven effective at creating a safe school environment in areas of low spread will work in areas of high spread. Based on data from other countries, areas with greater background levels of disease are expected to have greater spread within schools, potentially feeding back to the community[17].

Most school districts in the U.S. have not yet opened, and only early news reports are available from the states that have reopened schools. We list a few accounts in this paragraph for context, though we

note that outbreaks are more likely to make headlines than smooth reopenings. Consequently, it will likely be several weeks before a quantitative comparison of successes and reclosures is available. Within the first week, one Georgia school district identified 11 COVID-19 cases. These individuals had contact with approximately 250 students and staff in a district of ~45,000, triggering quarantine due to possible exposure[70]. In a second Georgia school district, 260 faculty and staff of ~24,000 personnel were quarantined prior to the return of students due to infection or contact with individuals who tested positive[69]. In a third school distict in Georgia, a high school with 9 positive cases in the first week (3 adults, 6 students) temporarily shut down in-person instruction for 2 days to allow for school cleaning[75]. In the case of the high-school, physical distancing and masking did not appear to be enforced. While Georgia has a positivity rate similar to Utah (10.9% versus 10.5%), it has a much higher daily case load: 419 per million in Georgia versus 120 per million in Utah[24,76]. Similar reclosures are being reported from Tennessee[68]. Most of these cases are attributed to non-school community spread[69,77], highlighting the pressure that high community transmission puts on school protective measures[17].

	Date of reopening	Daily Cases	Daily Cases Per Million Population	Positivity Rate (%)
		(7-day averages)		
United States	—	**65,750.4**	**198.6**	**8.3**
Belgium	5/18/2020	291.3	25.1	2.1
Denmark	4/15/2020	205.7	35.5	6.2
France	5/11/2020	1,110.9	17.0	1.1
Germany	5/4/2020	1,140.3	13.6	2.4
Greece	6/1/2020	5.6	0.5	0.1
Israel	5/3/2020	126.7	14.6	1.4
Japan	4/24/2020	439	3.5	8.7
South Korea	6/8/2020	44.4	0.9	0.3
New Zealand	5/14/2020	1.1	0.2	0
Norway	4/20/2020	93.3	17.2	3.8
Switzerland	5/11/2020	57.1	6.6	1.3
Taiwan	2/25/2020	1.1	0.0	0.2
Vietnam	5/18/2020	4.6	0.0	0

Table 1. School Re-Openings: Country Comparisons on Key Metrics Compared to Current U.S. Data. Adapted from *What Do We Know About Children and Coronavirus Transmission* (KFF).
Notes on the analysis: U.S. estimates calculated based on August 2020. Data represent 7-day averages around the reopening date. SOURCES: COVID-19 data from: "Coronavirus Pandemic (COVID-19)". Published online at OurWorldInData.org. Retrieved on July 28, 2020. School reopening dates from: University of Washington, Summary of School Re-Opening Models and Implementation Approaches During the COVID 19 Pandemic, July 6, 2020

Is there a specific rate of positivity or number of cases that is safe or unsafe? Even though several criteria have been proposed as prerequisites for safe reopening, there is no scientific evidence of a specific threshold or value that distinguishes safe from unsafe conditions[22,25,67,69,78]. This is because the likelihood of a successful school reopening is the product of at least two factors: **1.** the effectiveness of in-school protective measures and **2.** the infection rate in the community where the school operates[41,79]. For example, the more cases of COVID-19 in a community, the more likely an outbreak occurs at school, all other factors equal. Likewise, the more vigilant and engaged efforts in the school environment, the less likely an outbreak occurs at school, at a given level of community spread. Because of this interaction, the

safe conditions for reopening are dependent on local conditions in the community and school settings[22,36].

The international comparisons above reinforce this context-specific view (Table 1). For example, Japan was able to successfully reopen schools with a positivity rate of 8.7% (higher than the current U.S. average), whereas Israel had a large outbreak at a positivity rate of 1.4%[15,17]. The best quantitative thresholds of which we are aware were reported by a modelling study on the UK: it predicted that to completely reopen UK schools without a second wave of infection, 75% of symptomatic individuals would need to be tested and quarantined, together with 68% of their contacts[80]. Conversely, if only 18% of symptomatic cases were tested and isolated (with the 68% of contacts), at least 2 waves of infection would result, each with more than double the cases from this past winter in the UK[80]. These numbers underscore the importance of community testing and tracing.

The question of what positivity rate or case count (either in-school or in-community) constitutes an acceptable risk remains a policy question that should ideally be considered openly with input from public health experts, parents, teachers, staff, administrators, and decision makers[22,25,38]. Though "bright lines" demarcating safe and unsafe conditions do not exist, setting practical thresholds can be a useful way of increasing likelihood of accountability if goals are not met and improving responsiveness when conditions change[79]. Whether these thresholds are quantitative (such as a specific positivity rate or case number) or qualitative (such as "a sustained decline" or "limited community spread"), they should be adequately defined so all interested parties can objectively assess whether they have been met[22,36,67,69].

How risky is reopening for teachers? For ethical and practical reasons, the recommendation to open schools should not be in conflict with the safety of teachers[13,25,80]. Unfortunately, we are not aware of any research that has exclusively studied the risk of infection to teachers relative to another fields of employment or relative to general community spread. However, studies on infection rates in schools nearly always include teachers and staff, providing some insight to infection risk[14–16,18]. Such studies and reports seem to indicate that teachers, staff, and administrators are not at heightened risk compared to other occupations and activities in the community[6,14,21,44]. However, it is also clear from these studies and first principles that there is risk of infection for teachers at schools, especially in areas with high levels of community spread and/or when best practices are not carefully implemented[15,17,20]. This highlights the need for precautions and special considerations for teachers with risk factors include age and underlying conditions[20]. These risk factors are usually not reported for teachers in the cited studies, meaning we cannot consider their possible roles in different outcomes for individuals and school systems.

In our review, there were several common trends that may be indicative of risk levels (see Deep dive). For example, primary school should be equally careful around other teachers as students[20,73], consistent with the expectation that children may transmit the disease at lower rates than adults. Likewise, Jr. high and high schools are likely riskier than primary schools for teachers, all other factors held equal[15,17].

What are the risks of not reopening public schools? Educational and public health researchers and leaders have emphasized that keeping schools closed entails a suite of serious consequences for children, families, and the broader community[25,26,30,32,33]. These problems are not just hypothetical. Many studies have now documented substantial impacts from the school closures this spring[81–84].

Perhaps the most obvious consequence of closed schools is decreased learning. Across subjects and grades 3 through 8, student's academic progress is estimated to have decreased by 30% compared to past years due to early closures[85]. The long-term professional consequences of decreased academic achievement are currently unknown, but several studies estimate they could be substantial[86,87].

School closures also affected the nutritional wellbeing of school children in several ways. Loss of access to school food resources caused food insecurity for 17% of U.S. households with elementary age children by the end of April, 2020—up from 3% in the reference period in 2018[88]. The decrease in physical activity and balanced nutrition associated with school closures may also contribute to weight gain and obesity, which is one of the primary risk factors for severe COVID-19[32,89,90].

For many children, loss of school activities and support from teachers and staff can increase risk of abuse and mistreatment. For example, reports of child mistreatment in Florida decreased by 27% in March and April compared to previous years[26], though evidence from other studies suggests that actual mistreatment went up during the same period[91]. When scaled to the entire U.S., this suggest that over 200,000 reports of abuse, neglect, and abandonment went unreported in March and April alone[26]. More generally, changes to social and family relationships associated with COVID-19 mitigation measures can simultaneously increase risk of abuse and decrease support structures to deal with it[91].

Disruption to academic and social development at school also has serious psychological and mental health effects. Anxiety, depression, and a decrease in stress-management activities and capacity have been observed[60,82,84]. Increases in substance abuse and suicide have also been predicted[92].

Virtually all of these costs and risks are greater for children in underprivileged or minority groups[34,93,94], emphasizing the need for a coordinated response that considers all the threats to the wellbeing and health of youth, not only those posed directly by COVID-19[28,84]. For example, greater poverty is associated with lower compliance with shelter-in-place orders[95] and higher COVID-19 death rates[96]. This could be because a greater proportion of jobs that are classified as essential or that do not provide paid time off, emphasizing links between economic and public health priorities.

There are ways that families and communities can mitigate the side-effects and collateral damage of COVID-19 disruption[25,84]. For example, schools can prioritize in-person attendance for underprivileged students and children of essential workers, and provide as many services as possible remotely. Because the harm of educational disruption appears to be greater for elementary-school children—the group for whom reopenings is also less risky—the consideration of costs and benefits could lead to different conclusions for primary and secondary schools in the same community.

Together, these findings suggest that there will be tradeoffs between risk of COVID-19 exposure in school environments and risk of side-effects from school shutdowns. The only way to avoid this zero-sum situation is by aggressively controlling COVID-19 in the community. Bringing down community spread is a "win-win" that simultaneously increases school safety and decreases need for school disruptions.

What specific measures and general practices are most effective at limiting spread at school?

We urge all decision makers, administrators, teachers, and community members to carefully consult the state and federal recommendations for school reopenings, which have been developed by professional teams of public health and education experts. The materials provided by the CDC are the gold-standard of actions that are most likely to create a safe environment in our schools, families, and communities. We refer the reader there for more in-depth recommendations on interventions such as hand-hygiene, mask-wearing and social distancing. These recommendations comprehensively consider student and teacher wellbeing holistically, as well as integrating practical and interpersonal considerations. Though politicians have sometimes publicly sought to influence these recommendations [99], we found that they were impartial and evidence based.

In the handbooks, fact-sheets, and roadmaps we evaluated[21–23,36–38], most recommendations fell into one of three categories: **1.** School interventions (measures to be taken by staff, teachers, and students

while at school), 2. Family actions (activities that can educate and prepare students and members of the household to participate in school safely), and 3. Community support (policies and networks that ensure rapid communication and adaptive management). There was universal agreement that safe reopenings cannot be achieved by interventions at school alone. A full-court approach of reducing likelihood of transmission at school while working to drive down numbers in the community is needed. This is most likely to occur when parents and teachers, administrators, and staff have open communication and mutual trust[22,23,25,80].

Because operating schools during the pandemic is so new, most recommendations are based on general principles of public health combined with what is known about the specific pathology of COVID-19[21,22]. There are not quantitative estimates of the specific effectiveness of most measures, though the evidence from international comparisons, epidemiological simulations, and experience with past outbreaks suggests that many interventions can be highly effective at limiting spread when they are consistently implemented by students, staff, and parents[22,23].

We highlight one intervention that was singled out for its lack of effectiveness: universal symptom screening at school entrances[97]. Because of the pathology of COVID-19 in children and adolescents, these checks miss many infected individuals (false negatives) while catching many uninfected (false positives)[98]. Because of this and other disadvantages such as disruption to student routines, universal symptom screening at school entrances is not recommended[97].

In areas with high infection in the community, it should be assumed that infected students and adults will end up at school. Consequently, no single measure should be relied on as an absolute shield from disease spread. Instead, combinations of all the recommended measures methods are most likely to be effective[22,23,25]. Consistent implementation of these measures is most likely when teachers, parents, students, staff, and administrators understand the reason for the recommendation and then receive age-appropriate training on how to carry it out[22,38].

What are the risks and benefits for colleges and universities? There is less information about the dynamics of COVID-19 in higher education settings than there is for primary and secondary schools[40–42]. One of the most definitive simulations of COVID-19 spread in colleges and universities concludes that it is impossible to contain an outbreak without frequent universal testing[41]. The authors conclude, *"symptom-based screening alone was not sufficient to contain an outbreak, and the safe reopening of campuses in fall 2020 may require screening every 2 days, uncompromising vigilance, and continuous attention to good prevention practices."*

To our knowledge, that frequency and extent of testing far exceeds current plans of any university or college in Utah[100], suggesting that outbreaks may quickly get out of hand. There is conflicting evidence about the importance of test accuracy, with some simulations suggesting that inaccurate tests results in unmanageable quarantine sizes[39], while others find that testing frequency (even with imperfect tests) is paramount[41]. Studies agree, however, that interactions outside the classroom, especially in student housing and social events, can overwhelm measures focused only on limiting exposure in classroom settings[39–41,101].

In addition to extensive and rapid testing, campuses will need a large quarantine capacity and a high and sustained level of vigilance to safely reopen for in-person instruction. As for K-12 schools, developing a rapid and reliable network for disseminating infection information and policy adaptations is crucial. Additionally, given the issues with COVID-19 testing in Utah[102,103], it might be prudent for universities and colleges to develop in-house capacity for testing.

The cost-benefit analysis of remote learning in higher education is somewhat reversed, compared to primary schools. Remote learning is a viable, if imperfect option for educational progress with college students, and the risk of outbreaks appears to be very high. One approach would be to offer remote learning for most students, while welcoming at-risk students back to campus based on needs and specific situations. This would mitigate the worst tradeoffs associated with shutdowns and substantially reduce the risk of costly and deadly outbreaks.

Deep Dive:

Box 2. Understanding uncertainty

As for many questions about COVID-19, the effects of children and adolescents returning to school are not currently understood. In fact, they will not be fully known until after this crisis is long gone. As you read this report and other materials about COVID-19, we invite you to consider the following points about how considering uncertainty can improve decisionmaking.

1. **Uncertainty is the norm.** In public health, like most applied research fields, it is rare to have definitive evidence before major decisions need to be made. Even with known diseases, outbreaks are difficult to measure and harder to predict. Though uncertainty can't be eliminated, it needs to be measured and mitigated, otherwise bad outcomes are more likely. Common approaches to improve decision making in the face of uncertainty include: incorporating the best available evidence, discussing unknowns, and carefully considering the risk of error (how serious would a false positive or false negative be in this case?). Repeatedly asking *"What if we are wrong,"*and then adapting how much evidence we require before moving forward is one application of the precautionary principle. This was straightforward on the question of masks and COVID-19, because the negative sideffects of masks were known to be very minor and multiple lines of evidence suggested substantial benefit. Applying the precautionary principle is murkier on the subject of school reopenings because there is substantial plausible harm associated with either choice.
2. **Not all studies are created equal.** Many public debates about policy-relevant science suffer from *"one-study syndrome"* where findings are cherry picked and then extrapolated to the whole issue. That is a recipe for bad policy. When considering whether the findings of a study are applicable to the question at hand, consider: 1. What is the strength of the evidence (often related to the sample size of the study), 2. Was the study designed to answer the question at hand, 3. Are there factors that could complicated interpretation of results, and 4. What are other studies on this subject finding? For example, many of the studies we have reviewed draw on a small number of observations. Likewise, some studies find the least severe disease incidence in children in areas where children were tested far less than adults. These studies may still be valid, but findings based on 1 or a few individuals or flawed experimental designs do not provide the same insight and confidence as studies that contain tens of thousands of individuals and a rigorous design.
3. **Correlation or causation?** The closing or opening of schools during COVID-19 often coincides with other important events such as community shutdowns, masking, physical distancing, or re-opening of businesses and community services. Longitudinal studies do provide useful evidence and field demonstrations of effectiveness, but any changes associated with various school policies or behaviors should not be unambiguously interpreted as resulting from the policy change. Likewise, underlying relationships between groups and health outcomes limits measurement of the important socienomic and racial disparites that are sometimes present.
4. **The value of peer review**. Before a scientific paper is published by a scholarly journal, it must be evaluated by two or more researchers in the field. This peer review is not infallible, but it provides a crucial quality control and reality check. Because COVID-19 is evolving so rapidly, much of the available information has not been fully peer-reviewed—it appears in preprints or general reports. Most of these studies are likely valid, and we have done our best to carefully review the methods and interpretations from the preprints we cite. However, we are certain there are details we have overlooked either from lack of expertise or time. Feel free to point out any such errors, and we will do our best to correct them rapidly.
5. **Crucial management decisions must be made in light of all the available evidence and uncertainty, not based on a single study or (even worse) a single statement or finding.** For a more detailed discussion of different types of scientific evidence and uncertainty, please consult the FAQs from our mask report.

Details on spread of COVID-19 by youth

Efforts to calculate transmission rates are challenging and vary with many factors, such as background rate of spread in an area, number of contacts, and viral load of the individual. For example, two studies estimated that children transmit at either ~20% or 85% the rates of adults[2,18]. A more common way to estimate the role of children in community spread is to determine when children were

the first case in a home, school, or community. For example studies in Asia (children were responsible for 3/31 traced cases)[8], Switzerland (3/39 traced cases)[11], and Israel (no more than 10% of 637 cases were likely caused by children)[2] routinely show that children are responsible for less than 10% of traced cases[54]. Estimates of transmission by children and adolescents are uncertain and based on small sample sizes (see above where the number of child-caused cases in a study is usually < 5). Thus, these values are likely to change, perhaps substantially, as more data become available[2,10]. However, it is unlikely that the overall trend of children being less susceptible to COVID-19 changes as data becomes available. For example, infants and children were only 1% of 72,314 cases tracked by the Chinese Center for Disease Control[7,105].

International case studies of COVID-19 in schools

The following reports summarize much of the same information covered here plus additional cases:

1. Department of Global Health at Washington University [67]
2. The KFF[20]
3. The CDC[22].

One of the best ways to learn about the effect of school settings on the community spread of COVID-19 is to examine spread in school settings this past winter and spring—a period when infected individuals attended schools but distancing measures were often not yet put in place.

In a high school in Northern France, COVID-19 appears to have been present for ~3 weeks before schools closed for holiday, after which additional distancing restrictions were implemented 2 weeks later to limit community spread[15]. Approximately 4 weeks later, 38%, 43%, or 60% of tested students, teachers or non-teaching staff had anti-SARS-CoV-2 antibodies, suggesting a high transmission rate at the school. These results were for 326 of 1262 school community members[15]. The frequency of antibody-positive results was likely influenced by participant recruitment (all participants were volunteers who responded to an e-mail), and the 6 week delay between school closure and testing (infections could have arisen from non-school sources). However, the results provide evidence that in areas where precautions are not in place to reduce school and community spread, there can be substantial transmission of COVID-19.

A second case study from the same city and time period (before restrictions were in place to limit community spread of COVID-19) reported the result of COVID-19 in six primary schools (510 students ages 6-11, 70 teachers or staff, and 760 family members)[14]. As was the case for the high school, three cases were designated as being present in the school before the holiday closure (although the primary school cases occured only 1-2, not 2-3 weeks before the holiday closure). Unlike the high school, the antibody-positivity rate of study participants was much lower (approximately 10.5% for all participants, with no difference based on ages). There was also no traceable secondary spread. Together, these studies indicate major differences between the potential spread of COVID-19 in primary and high schools before measures to restrict spread of COVID-19 were in place. Information on socio-economic, racial, and other demographics of the participants was not provided, but the city's demographics are >90% non-immigrant French nationals and ~20% age 65+. Following lockdown orders, a study of individuals in Paris, France showed infection rates among children were very low, suggesting that most spread to children was likely from adults[106].

In Australia, most schools stayed open during the "first wave" of COVID-19 from January to April of 2020. A contact-tracing study from the state of New South Wales (child population of 1.8 million) identified 15 schools and 10 childcare facilities where infected individuals attended while infectious [18].

Preventative measures were in place, similar to the CDC and UDOH guidelines[22,36]. Twelve of the 15 schools and 9 of the 10 the childcare facilities experienced no secondary spread. The remaining three schools experienced five secondary cases (out of 914 contacts), representing very low transmission. However, the remaining childcare facility experienced 13 cases of spread (out of 37 contacts), representing a substantial transmission event [18].

In other areas of the world, similar results have been observed. Tracing 3 pediatric cases of COVID-19 in schools in Ireland (ages 10-15; 1 in primary school, 2 in secondary school) before closures occured identified no secondary cases[107]. In Stockholm, Sweden where 514,000 children live and where daycares and primary schools were kept open, 63 children tested positive for COVID-19 over a 2-month period, and 1 child died: an infant where COVID-19 was attributed as a secondary cause of death[108].

However, in areas where community spread was higher, closing schools does appear to have lowered spread of the disease. For example, Denmark, Norway, and Germany closed schools as part of the effort to effectively reduce community transmission of disease [17]. Likewise, analyses based on data from China[61] and the U.S.[62] found significant benefits from closures during periods of community spread.

Risks to teachers

Below we summarize the best insights we could glean about how COVID-19 spread may affect teachers (referring to all adult school employees). One study that advocates for how teacher safety should not be in conflict with school reopenings may be useful for our readers[13].

Of 18 COVID-19 cases that arose in (were likely transmitted within) Australia elementary and preschools, 8 were cases of adults: 7 were transmitted by an adult and 1 by a child[18].

In A city near Paris, France tested for the presence of antibodies in high school and primary school members: students, teachers, staff. Note no contact tracing was performed, so the causes, whether in or out of school were not known. In the primary schools, of 510, 42, 28, and 641 students, teachers, staff, and parents, 8.8%, 7.1%, 3.6%, and 11.9% of tested individuals tested positive for anti-COVID-19 antibodies[14]. In the high school, of 240, 53, 27, and 211 individuals from the same groups, 36.3%, 8.0%, 4.1%, and 31.9% of individuals tested were positive for anti-COVID-19 antibodies[15]. Thus, regardless of the school, teachers and staff always had lower frequencies of infection than pupils and their parents. The results are consistent with the idea that student to teacher transmission is lower than student to student and student to family transmission, but the differences in infection rates could be due to non-school (community) spread or other factors

Additional school outbreaks that did not trace contacts identified greater infection rates among adults than pupils. A school-based outbreak of COVID-19 in Chile adults led to the highest infection rates among adults, attributed primarily to contact between adults, not child-to-adult interactions[73]. In Israel, 13 and 17% of tested students and teachers were positive for COVID-19[16].

A study that reviewed how school closures and reopenings were related to COVID-19 spread in several European countries identified that the proportion of adults testing positive was higher if they worked with children over 16 versus younger than 16 (Denmark) and concluded that student-to-student spread, but not student-to-teacher spread, increased upon high school reopening (Germany)[17]. The authors were very careful to warn against small sample sizes and very low transmission rates in most of the countries in their study, and that factors such as small classroom sizes among young but not older children could have contributed to the observed effects.

Taken together, the data on safety for teachers are sparse. One interpretation is that teachers should be most careful around other teachers, consistent with the expectation that children may transmit the disease at lower rates than adults (but one of the most definitive studies on the subject found adolescents transmit at the highest rates of any age group in the study[10]). The idea that an increased number of student contacts may offset students' reduced transmission rates is not consistent with the trend that, among traced contacts, teachers were more at risk of infection from other adults.

Detailed analysis of best practices

As we stated above, the best source for detailed **state and federal recommendations for school reopenings, which have been developed by professional teams of public health and education experts, are the materials provided by the CDC. These recommendations are the gold-standard of actions that are most likely to create a safe environment in our schools, families, and communities** and we recommend that all community members are intimately familiar with and follow them as fully as possible

Globally, most reopened schools have adopted distancing measures that are consistent with the CDC guidelines[22]: distancing, masking, hand hygiene, home symptom checks, disease testing, contact tracing, cohorting, and community involvement. There is a general pattern of heightened vigilance during initial reopenings, and then adaptive relaxation of measures if there are not outbreaks, or implementation of stricter measures if there are[22,23]. Successful reopening and then relaxation has often occurred in lower grades, where transmission appears to be lower and children may have fewer contacts out of school[21].

Recommended safety measures fell into three general categories: 1. Things to be done at school, 2. Things to be done at home, and 3. Support from and communication with the broader community. The reports universally pointed out that school reopening cannot safely and successfully occur by relying on in-school measures only. Support and education for parents and communication with all community members may be as or more important than measures taken within the school setting. Some common school, home, and community recommendations included:

In-school actions:

1. Protective measures (e.g. distancing, masking, hand hygiene, surface disinfection)
2. Testing and contact tracing
3. Communication mechanisms (e.g. alerts, comment and feedback networks, designated contacts)
4. Transparent and adaptive policies (e.g. transparent criteria for different actions, frequent public updates)

Home support:

1. Carefully read and understand educational materials and recommendations
2. Daily monitoring of children and family members for symptoms
3. Compliance with home quarantine when a child or family member is sick or has had direct contact with a sick individual. Direct contact usually means 10-15 minutes of contact with less than 6 feet of distancing and no mask, but these guidelines may move according to local, state, federal, or other policies as more information is gathered.
4. Teaching children how to properly distance, use masks, and wash hands

Community support:

1. Educate and encourage all individuals to practice protective measures (physical distancing, masking, limiting risky activities, hand washing)
2. Reduce the infection rate in the community through context-specific actions

3. Consider interventions that may reduce barriers to keeping sick students out of schools, such as finding ways to provide paid sick leave for parents and caregivers
4. Assuring community testing is accessible, rapid, accurate, and affordable

Illustrative examples from other regions

The Netherlands cut class sizes to 15 students, but did not enforce distancing among children under 12. Finland didn't change class sizes but kept the classes isolated from each other. Denmark held recesses, but enforced 'pods' among children[21]. Some schools that initially adopted transmission-reducing measures have or will pulled back on these: Quebec schools will remove distancing for pods of 6 children (distance maintained between pods); French preschools (children 5 and under) and the Netherlands (anyone under 17) have eliminated distancing altogether[21]. Mask wearing also varied: mandatory in China, mandatory for certain ages in Israel, mandatory under certain conditions in Germany, and not mandatory in Austria, Canada, Denmark, Norway, the UK, and Sweden[21]. As summarized above, lifting these measures prematurely or in the wrong setting (presumably when disease incidences are high) can lead to outbreaks, as in an Israeli high school where, along with other factors, students did not wear masks and could not distance more than 3.5-4 feet[16]. In short, a survey of 15 school reopenings showed that of many possible factors (partial reopening based on age, class sizes, shift attendance, facemasks, distancing, and temperature checks, and handwashing), only increased handwashing was universally adopted, and factor adoption (or not) was not associated with increased disease transmission in any case; note substantial disease transmission did happen in some instances[67].

Taken together, these findings emphasize the context-dependent nature of reopening schools, especialy with student age. Because positive tests and some transmission at schools are to be expected, virtually every recommendation and conclusion that we read emphasized the need for proactive planning and adaptive management[22,36]. Ensuring accurate data collection is communicated rapidly and that policies are adapted as necessary is perhaps the greatest single step we can take to avoid the worst outcomes. There is no single silver bullet that, included or excluded, is likely to lead to success or failure. Instead, a suite of careful responses that are most likely to be realistically implemented in a given area are the most likely path to a safe, robust return to schools[79]. The most commonly-adopted in-school precautions include avoiding the "three Cs": closed spaces with poor ventilation, crowded places, and close-contact settings, often by any of the following[16,109].

Because of the prevalence of within-household transmission and community spread generally, safety at school largely depends on actions of families and community members. It will require proactive participation of parents and other community members, including employers[110]. Efforts to educate and involve community member, and track and reduce disease transmission are key. Household efforts are also essential since transmission among members of a household is much more likely than transmission among non-household exposures [10,59,111].

Preventative support to ensure that parents, staff, and faculty have the resources they need to follow the protective measures will likely both reduce the risk of COVID-19 spread and provide substantial cost savings for districts by avoiding or reducing the number of individuals in quarantine and potential shutdowns[112]. For example, paid leave for all school employees when sick or quarantined, plus for caregivers of sick or quarantined employees, especially for individuals from low-income or minority backgrounds increases compliance with recommendations[110].

Consequences of school closures for children and families

The American Academy of Pediatrics (AAP) outlines the costs of sustained school closures succinctly and clearly[25]:

> *Schools are fundamental to child and adolescent development and well-being and provide our children and adolescents with academic instruction, social and emotional skills, safety, reliable nutrition, physical/speech and mental health therapy, and opportunities for physical activity, among other benefits. Beyond supporting the educational development of children and adolescents, schools play a critical role in addressing racial and social inequity. As such, it is critical to reflect on the differential impact SARS-CoV-2 and the associated school closures have had on different races, ethnic and vulnerable populations.*

Schools provide many children with nutrition, safety, and learning. By the end of April 1 in 5 households with elementary age children were experiencing food insecurity[88]. School teachers and staff are often formal and informal caregivers for students, ensuring that students are getting the correct treatment at home, as well as at school. It is estimated that 212,500 child maltreatment allegations went unreported in the United States, in March and April 2020, when schools moved to online instruction[26]. Students are also likely to not have grown as much academically during the 2019-2020 school year as previous years[85]. Alongside academic and physical care, school programs provide crucial opportunities for social interaction and growth for children. Social interaction within school programs is especially important for childhood development of skills such as language, communication, emotional, and interpersonal skills[113].

Socioeconomic inequalities exacerbate COVID-19 spread and consequences

One major concern in controlling the spread of the virus has been the disproportionate effects suffered by communities with higher poverty levels. This interacts with the question of school reopenings, because the individuals who most need support from school are also often the most affected by COVID-19 infection and serious side-effects. On the need side, parents with fewer financial means may not be available to fill in educational gaps for their children, whether from lack of technology or constraining work schedules[22,114]. As such, these children may not be able to participate in at-home learning to the same extent of peers in more affluent environments, potentially widening already existing achievement gaps[85,114]. For these families, in-person school is an important service, but safety measures are even more important for these households, who have diminished medical and financial resources.

On the COVID-19 consequences side, poverty level or minority status are strongly associated with worse outcomes from COVID-19, including death rates[94,96,115]. These groups have a higher proportion of the population with a pre-disposing underlying condition among communities in poverty, including hypertension and diabetes[116]. Additionally, some racial and ethnic groups appear to be more susceptible to COVID-19 for physiological reasons, potentially vitamin-D status [117]. In addition to these medical differences, low-wage and minority workers are also more likely to have “essential jobs”, have less healthcare coverage, and have difficulty taking time off from work without facing financial issues[118]. Racial and ethnic minorities are disproportionately represented in the industries considered essential or frontline workers, and many of them have reported living with someone considered “at-risk” due to age or pre-existing medical conditions[93,119]. Finally, racial and ethnic minorities are also more likely to live in

close quarters with immediate and extended family members, making it difficult to protect those high-risk individuals[94,116,117].

These demographic differences directly influence effectiveness of measures to contain COVID-19. For example, levels of compliance for shelter-in-place orders were much lower in impoverished communities when compared to more affluent counties, suggesting that many families may not be able to afford to socially distance[95]. Data from the Bureau of Labor Statistics also reports that only 9.2% of workers with earnings in the bottom 25% of the population can afford to work from home, as opposed to 61.5% of workers in the top 25%. Overall, they reported that those in the bottom 50% were 3 to 6-times more likely to be unable to afford to work from home when compared with the top 25%[118]. This problem has been exacerbated by the current economic situation, with approximately 16 million Americans facing unemployment in July of 2020[120].

The confluence of racial inequality and COVID-19 outcomes is particularly evident in our region on the Navajo Nation. Native American populations in Utah and surrounding states have some of the highest COVID-19 rates in the country[121,122]. Likewise, Black Americans have been disproportionately affected by the health, educational, and economic consequences of COVID-19 [94]. Because of past and current inequalities (e.g. higher rates of being victims of medical mistreatment), Black Americans have greater medical mistrust than the general population, contributing to being less likely to seek medical treatment or get tested for COVID-19 [94]. This highlights how building trust and solidarity among community members, institutions, and individuals is crucial to controlling the pandemic and safely reopening schools[94,112].

Together, these socioeconomic inequalities need to be considered and planned for as schools, parents, and our community decide how to move forward.

Glossary of common COVID-19 terms

- **Asymptomatic:** infected people who do not have symptoms
- **Pre-symptomatic:** infected people who will show symptoms but have not yet
- **Cases:** Infected people; in this report measured in new cases per million people per day
- **Cohorting:** Keeping people together in groups to limit the spread of the virus between groups.
- **Community Spread:** The virus passing from person to person inside a community, as opposed to only being brought in from outside
- **Contact-Tracing:** Identifying infected people and tracking down both where they caught the virus and contacts who may have been infected by them
- **Coronavirus, SARS-CoV-2, COVID-19:** Coronaviruses are a family of viruses. Several members of this family cause disease in humans or animals. SARS-CoV-2 is the novel coronavirus that causes the disease COVID-19.
- **Index case**: the first-occurring case in a group of people, such as a family, school, or classroom.
- **Primary spread:** Passing of the virus from one person to another
- **Secondary spread:** Passing the virus across two degrees of separation (person A to person B, then person B to person C)
- **Susceptibility:** Ability to catch the virus, or become sick when infected

- **Test positivity rate:** The number of tests that show infection compared to the total tests. Note that this is only looking at a proportion of tests, while the cases per million is a measure of all cases in the population.
- **Transmission:** Passing the virus to another person
- **Viral load:** The number of viral particles present in an infected person

Frequently Asked Questions (FAQs):

1. **How did you select the papers you included?** We generated an initial list of studies using Google Scholar and Web of Science. We focused this initial search on studies specifically dealing with COVID-19 and schools. As we read those papers, we added pertinent studies cited in that work to our list. Additionally, we considered all peer-reviewed studies that concerned individuals sent us. Our goal was to provide a non-technical summary for those interested in this topic. Because the medical literature on COVID-19 is so large, we cite many studies that are reviews, summaries, and commentaries on the state of the literature. While we also read many specific primary research articles, we favored citations of reviews and summaries to encourage readers to interact with the peer-reviewed holistic assessment of the state of scientific understanding. These synthesis papers are often more reliable and robust than any individual study upon which they draw [123]. They also avoid the "single-study syndrome," where one study is given undue weight without context from other work. Science is a joint venture and only reliable when the result is repeatable and falsifiable.
2. **How did you ensure you weren't getting a biased sample of studies?** We considered all the scientific studies and reports on COVID-19 and schools that we could find. We continue to consider all studies that are sent, so if we missed a particularly pertinent piece on COVID-19, children, and school contexts, please send it along. Likewise, if you see an error or point of confusion in the report, please let us know and we will investigate and update where justified. At the top of the report, we mention the "last updated on" date, so you can know when the last change was made.
3. **Why do you cite some non-scientific sources such as news articles and government reports?** As the COVID-19 situation is evolving so rapidly, it would be unethical to not consider breaking reports and findings, including responsibly reported news articles. While the findings from these sources do not carry the same weight as the peer-reviewed studies that often follow, we cite some of these news reports as they pertain to outcomes of school reopening. This information is directly applicable to the situation in Utah.
4. **Were you trying to prove something with this study?** Our only purpose in performing this research was to make more of the science available to the public. We take scientific integrity extremely seriously, and we have children, parents, and other family members trying to make sense of the research, just like you. There are not definitive answers to all of the "crucial questions" in the report, but we do our best to accurately represent the scientific literature, including pointing out where there are gaps in knowledge or large uncertainties.
5. **What can we do to contribute to better decisions surrounding COVID-19?** Especially during these politically charged times, all of us need to be extra vigilant and responsible about what we share and say. Whether it is this report or anything else, please read the article before reposting and interpreting it on social media. It's a matter of basic honesty and integrity, plus, the things we say and post have serious consequences in the real world. This is not just a question of academic debate, our lives,

livelihoods, and families are at stake. In this context, we don't have time for personal attacks and misinformation. Please help us elevate the debate so we can address the difficult decisions we all need to make.

REFERENCES

1. Abbott, B. W., Greenhalgh, M., Clair, S. I. S. & Bush, J. *Making sense of the research on COVID-19 and masks*. 11 https://pws.byu.edu/covid-19-and-masks (2020).
2. Dattner, I. *et al.* The role of children in the spread of COVID-19: Using household data from Bnei Brak, Israel, to estimate the relative susceptibility and infectivity of children. *medRxiv* 2020.06.03.20121145 (2020) doi:10.1101/2020.06.03.20121145.
3. Lee, B. & Raszka, W. V. COVID-19 Transmission and Children: The Child Is Not to Blame. *Pediatrics* **146**, (2020).
4. Ludvigsson, J. F. Systematic review of COVID-19 in children shows milder cases and a better prognosis than adults. *Acta Paediatrica* **109**, 1088–1095 (2020).
5. Ludvigsson, J. F. Children are unlikely to be the main drivers of the COVID-19 pandemic - A systematic review. *Acta Paediatr.* **109**, 1525–1530 (2020).
6. Munro, A. P. S. & Faust, S. N. Children are not COVID-19 super spreaders: time to go back to school. *Archives of Disease in Childhood* **105**, 618–619 (2020).
7. Zhen-Dong, Y. *et al.* Clinical and transmission dynamics characteristics of 406 children with coronavirus disease 2019 in China: A review. *Journal of Infection* **81**, e11–e15 (2020).
8. Zhu, Y. *et al.* Children are unlikely to have been the primary source of household SARS-CoV-2 infections. *medRxiv* 2020.03.26.20044826 (2020) doi:10.1101/2020.03.26.20044826.
9. Davies, N. G. *et al.* Age-dependent effects in the transmission and control of COVID-19 epidemics. *Nature Medicine* 1–7 (2020) doi:10.1038/s41591-020-0962-9.
10. Park, Y. J. *et al.* Early Release - Contact Tracing during Coronavirus Disease Outbreak, South Korea, 2020. *Emerging Infectious Diseases* **Volume 26**, (2020).
11. Posfay-Barbe, K. M. *et al.* COVID-19 in Children and the Dynamics of Infection in Families. *Pediatrics* **146**, (2020).
12. Li, X. *et al.* The role of children in transmission of SARS-CoV-2: A rapid review. *Journal of Global Health* **10**, 011101 (2020).
13. Walger, P. *et al.* Children and adolescents in the CoVid-19 pandemic: Schools and daycare centers are to be opened again without restrictions. The protection of teachers, educators, carers and parents and the general hygiene rules do not conflict with this. *GMS Hyg Infect Control* **15**, Doc11 (2020).
14. Fontanet, A. *et al.* SARS-CoV-2 infection in primary schools in northern France: A retrospective cohort study in an area of high transmission. *medRxiv* 2020.06.25.20140178 (2020) doi:10.1101/2020.06.25.20140178.
15. Fontanet, A. *et al.* Cluster of COVID-19 in northern France: A retrospective closed cohort study. *medRxiv* 2020.04.18.20071134 (2020) doi:10.1101/2020.04.18.20071134.
16. Stein-Zamir, C. *et al.* A large COVID-19 outbreak in a high school 10 days after schools' reopening, Israel, May 2020. *Eurosurveillance* **25**, 2001352 (2020).
17. Stage, H. B. *et al.* Shut and re-open: the role of schools in the spread of COVID-19 in Europe. *medRxiv* 2020.06.24.20139634 (2020) doi:10.1101/2020.06.24.20139634.
18. Macartney, K. *et al.* Transmission of SARS-CoV-2 in Australian educational settings: a prospective cohort study. *The Lancet Child & Adolescent Health* **0**, (2020).
19. Claxton, G., Kamal, R. & 2020. How Many Teachers Are at Risk of Serious Illness If Infected with Coronavirus? *KFF* https://www.kff.org/coronavirus-covid-19/issue-brief/how-many-teachers-are-at-risk-of-serious-illness-if-infected-with-coronavirus/ (2020).

20. Michaud, J. & Kates, J. What Do We Know About Children and Coronavirus Transmission? *KFF* https://www.kff.org/coronavirus-covid-19/issue-brief/what-do-we-know-about-children-and-coronavirus-transmission/ (2020).
21. Couzin-Frankel, J., Vogel, G. & Weil, M. School openings across globe suggest ways to keep coronavirus at bay, despite outbreaks. *Science* (2020).
22. CDC. *Preparing K-12 School Administrators for a Safe Return to School in Fall 2020*. https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/prepare-safe-return.html (2020).
23. ECDC. *COVID-19 in children and the role of school settings in COVID-19 transmission*. https://www.ecdc.europa.eu/en/publications-data/children-and-school-settings-covid-19-transmission (2020).
24. Utah Department of Health. Utah Case Counts | coronavirus. https://coronavirus.utah.gov/case-counts/ (2020).
25. American Academy of Pediatrics (AAP). COVID-19 Planning Considerations: Guidance for School Re-entry. http://services.aap.org/en/pages/2019-novel-coronavirus-covid-19-infections/clinical-guidance/covid-19-planning-considerations-return-to-in-person-education-in-schools/ (2020).
26. Baron, E. J., Goldstein, E. G. & Wallace, C. T. Suffering in Silence: How COVID-19 School Closures Inhibit the Reporting of Child Maltreatment. *Journal of Public Economics* (2020) doi:10.2139/ssrn.3601399.
27. Christakis, D. A. School Reopening—The Pandemic Issue That Is Not Getting Its Due. *JAMA Pediatr* (2020) doi:10.1001/jamapediatrics.2020.2068.
28. Crawley, E. *et al.* Wider collateral damage to children in the UK because of the social distancing measures designed to reduce the impact of COVID-19 in adults. *BMJ Paediatrics Open* **4**, e000701 (2020).
29. Dibner, K. A., Schweingruber, H. A. & Christakis, D. A. Reopening K-12 Schools During the COVID-19 Pandemic: A Report From the National Academies of Sciences, Engineering, and Medicine. *JAMA* (2020) doi:10.1001/jama.2020.14745.
30. Lancker, W. V. & Parolin, Z. COVID-19, school closures, and child poverty: a social crisis in the making. *The Lancet Public Health* **5**, e243–e244 (2020).
31. Marchetti, F. & Tamburlini, G. Time to go back to school: several good reasons beyond low infection risk. *BMJ* **370**, (2020).
32. Rundle, A. G., Park, Y., Herbstman, J. B., Kinsey, E. W. & Wang, Y. C. COVID-19–Related School Closings and Risk of Weight Gain Among Children. *Obesity* **28**, 1008–1009 (2020).
33. Sharfstein, J. M. & Morphew, C. C. The Urgency and Challenge of Opening K-12 Schools in the Fall of 2020. *JAMA* **324**, 133–134 (2020).
34. Armitage, R. & Nellums, L. B. Considering inequalities in the school closure response to COVID-19. *The Lancet Global Health* **8**, e644 (2020).
35. Masonbrink, A. R. & Hurley, E. Advocating for Children During the COVID-19 School Closures. *Pediatrics* (2020) doi:10.1542/peds.2020-1440.
36. Utah Department of Health (UDOH). *COVID-19 School Manual*. https://coronavirus-download.utah.gov/School/COVID-19_School_Manual_FINAL.pdf (2020).
37. Kinetic West. Best Practices for Reopening WA Schools. https://www.k12.wa.us/sites/default/files/public/workgroups/Kinetic-West-PPT-June-2-2020-Best-Practices-for-Reopening-WA-Schools.pdf (2020).
38. UNICEF. *Framework for reopening schools*. https://www.unicef.org/media/68366/file/Framework-for-reopening-schools-2020.pdf (2020).
39. Gressman, P. T. & Peck, J. R. Simulating COVID-19 in a University Environment. *arXiv:2006.03175 [physics, q-bio]* (2020).

40. Mossa-Basha, M. *et al.* Policies and Guidelines for COVID-19 Preparedness: Experiences from the University of Washington. *Radiology* 201326 (2020) doi:10.1148/radiol.2020201326.
41. Paltiel, A. D., Zheng, A. & Walensky, R. P. Assessment of SARS-CoV-2 Screening Strategies to Permit the Safe Reopening of College Campuses in the United States. *JAMA Netw Open* **3**, e2016818–e2016818 (2020).
42. Wang, C., Cheng, Z., Yue, X.-G. & McAleer, M. Risk Management of COVID-19 by Universities in China. *Journal of Risk and Financial Management* **13**, 36 (2020).
43. Mizumoto, K., Omori, R. & Nishiura, H. Age specificity of cases and attack rate of novel coronavirus disease (COVID-19). *medRxiv* 2020.03.09.20033142 (2020) doi:10.1101/2020.03.09.20033142.
44. Munro, A. P. S. & Faust, S. N. Addendum to: Children are not COVID-19 super spreaders: time to go back to school. *Archives of Disease in Childhood* (2020) doi:10.1136/archdischild-2020-319908.
45. Dong, Y. *et al.* Epidemiological Characteristics of 2143 Pediatric Patients With 2019 Coronavirus Disease in China. *Pediatrics* (2020) doi:10.1542/peds.2020-0702.
46. Lee, P.-I., Hu, Y.-L., Chen, P.-Y., Huang, Y.-C. & Hsueh, P.-R. Are children less susceptible to COVID-19? *J Microbiol Immunol Infect* **53**, 371–372 (2020).
47. Goldstein, E., Lipsitch, M. & Cevik, M. On the effect of age on the transmission of SARS-CoV-2 in households, schools and the community. *medRxiv* (2020) doi:10.1101/2020.07.19.20157362.
48. Brodin, P. Why is COVID-19 so mild in children? *Acta Paediatr.* **109**, 1082–1083 (2020).
49. Cyranoski, D. Why children avoid the worst coronavirus complications might lie in their arteries. *Nature* **582**, 324–325 (2020).
50. Varga, Z. *et al.* Endothelial cell infection and endotheliitis in COVID-19. *Lancet* **395**, 1417–1418 (2020).
51. Kim, L. Hospitalization Rates and Characteristics of Children Aged 18 Years Hospitalized with Laboratory-Confirmed COVID-19 — COVID-NET, 14 States, March 1–July 25, 2020. *MMWR Morb Mortal Wkly Rep* **69**, (2020).
52. Götzinger, F. *et al.* COVID-19 in children and adolescents in Europe: a multinational, multicentre cohort study. *The Lancet Child & Adolescent Health* (2020) doi:10.1016/S2352-4642(20)30177-2.
53. Reimer, A. & Toremalm, N. G. The mucociliary activity of the upper respiratory tract. II. A method for in vivo studies on maxillary sinus mucosa of animals and human beings. *Acta Otolaryngol.* **86**, 283–288 (1978).
54. Merckx, J., Labrecque, J. A. & Kaufman, J. S. Transmission of SARS-CoV-2 by Children. *Dtsch Arztebl Int* **117**, 553–560 (2020).
55. Cristiani, L. *et al.* Will children reveal their secret? The coronavirus dilemma. *European Respiratory Journal* **55**, (2020).
56. Midulla, F., Cristiani, L. & Mancino, E. What do differences in case fatality ratios between children and adults tell us about COVID-19? *European Respiratory Journal* **56**, (2020).
57. Heald-Sargent, T. *et al.* Age-Related Differences in Nasopharyngeal Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) Levels in Patients With Mild to Moderate Coronavirus Disease 2019 (COVID-19). *JAMA Pediatr* (2020) doi:10.1001/jamapediatrics.2020.3651.
58. Jones, T. C. *et al. An analysis of SARS-CoV-2 viral load by patient age*. http://medrxiv.org/lookup/doi/10.1101/2020.06.08.20125484 (2020) doi:10.1101/2020.06.08.20125484.
59. Li, W. *et al.* Characteristics of Household Transmission of COVID-19. *Clin Infect Dis* (2020) doi:10.1093/cid/ciaa450.
60. Viner, R. M. *et al.* School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review. *The Lancet Child & Adolescent Health* **4**, 397–404 (2020).
61. Zhang, J. *et al.* Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. *Science* **368**, 1481–1486 (2020).

62. 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.
63. Abdollahi, E., Haworth-Brockman, M., Keynan, Y., Langley, J. M. & Moghadas, S. M. Simulating the effect of school closure during COVID-19 outbreaks in Ontario, Canada. *BMC Medicine* **18**, 230 (2020).
64. Canabarro, A. *et al.* Data-driven study of the COVID-19 pandemic via age-structured modelling and prediction of the health system failure in Brazil amid diverse intervention strategies. *PLOS ONE* **15**, e0236310 (2020).
65. Ferguson, N. *et al. Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID19 mortality and healthcare demand*. http://spiral.imperial.ac.uk/handle/10044/1/77482 (2020) doi:10.25561/77482.
66. Iwata, K., Doi, A. & Miyakoshi, C. Was school closure effective in mitigating coronavirus disease 2019 (COVID-19)? Time series analysis using Bayesian inference. *Int. J. Infect. Dis.* (2020) doi:10.1016/j.ijid.2020.07.052.
67. Guthrie, B. L. *et al. Summary of School Re-Opening Models and Implementation Approaches During the COVID 19 Pandemic*. 18 https://globalhealth.washington.edu/sites/default/files/COVID-19%20Schools%20Summary%20%28updated%29.pdf (2020).
68. Mangrum, M. These Tennessee school districts are already reporting COVID-19 cases after reopening. *The Tennessean* (2020).
69. Shepherd, K. Teachers returned to a Georgia school district last week. 260 employees have already gone home to quarantine. *Washington Post* (2020).
70. Stanglin, D. & Shannon, J. 250 students and staff asked to quarantine in Georgia district after one week of school. *USA TODAY* (2020).
71. Public Health Agency of Sweden. Covid-19 in schoolchildren. 15 (2020).
72. Leclerc, Q. J. *et al.* What settings have been linked to SARS-CoV-2 transmission clusters? *Wellcome Open Res* **5**, 83 (2020).
73. Torres, J. P. *et al.* SARS-CoV-2 antibody prevalence in blood in a large school community subject to a Covid-19 outbreak: a cross-sectional study. *Clin Infect Dis* (2020) doi:10.1093/cid/ciaa955.
74. The New York Times. Utah Coronavirus Map and Case Count. *The New York Times* (2020).
75. AP News. The Latest: School from crowd photo shifts to online classes. *AP NEWS* (2020).
76. Georgia Department of Public Health. COVID-19 Status Report. *Georgia Department of Public Health* https://dph.georgia.gov/covid-19-daily-status-report (2020).
77. Miller, A. Georgia reaches 200,000 COVID-19 case mark; county hot spots remain. *Gwinnett Daily Post* (2020).
78. WHO. Q&A: Schools and COVID-19. https://www.who.int/news-room/q-a-detail/q-a-schools-and-covid-19 (2020).
79. Bonell, C. *et al.* An evidence-based theory of change for reducing SARS-CoV-2 transmission in reopened schools. *Health & Place* **64**, 102398 (2020).
80. Panovska-Griffiths, J. *et al.* Determining the optimal strategy for reopening schools, the impact of test and trace interventions, and the risk of occurrence of a second COVID-19 epidemic wave in the UK: a modelling study. *Lancet Child Adolesc Health* (2020) doi:10.1016/S2352-4642(20)30250-9.
81. Campbell, A. M. An increasing risk of family violence during the Covid-19 pandemic: Strengthening community collaborations to save lives. *Forensic Science International: Reports* **2**, 100089 (2020).
82. Galea, S., Merchant, R. M. & Lurie, N. The Mental Health Consequences of COVID-19 and Physical Distancing: The Need for Prevention and Early Intervention. *JAMA Intern Med* **180**, 817–818 (2020).
83. Bradbury-Jones, C. & Isham, L. The pandemic paradox: The consequences of COVID-19 on domestic violence. *Journal of Clinical Nursing* **29**, 2047–2049 (2020).
84. Douglas, M., Katikireddi, S. V., Taulbut, M., McKee, M. & McCartney, G. Mitigating the wider health effects of covid-19 pandemic response. *BMJ* **369**, (2020).

85. Kuhfeld, M. Projecting the potential impacts of COVID-19 school closures on academic achievement.
86. Dorn, E., Hancock, B., Sarakatsannis, J. & Viruleg, E. *COVID-19 and student learning in the United States: The hurt could last a lifetime*. 9 (2020).
87. Burgess, S. & Sievertsen, H. H. Schools, skills, and learning: The impact of COVID-19 on education. *VoxEU.org* https://voxeu.org/article/impact-covid-19-education (2020).
88. Bauer, L. The COVID-19 crisis has already left too many children hungry in America. *Brookings* https://www.brookings.edu/blog/up-front/2020/05/06/the-covid-19-crisis-has-already-left-too-many-children-hungry-in-america/ (2020).
89. An, R. Projecting the impact of the coronavirus disease-2019 pandemic on childhood obesity in the United States: A microsimulation model. *Journal of Sport and Health Science* **9**, 302–312 (2020).
90. Nogueira-de-Almeida, C. A. *et al.* COVID-19 and obesity in childhood and adolescence: A clinical review. *Jornal de Pediatria* (2020) doi:10.1016/j.jped.2020.07.001.
91. Usher, K., Bhullar, N., Durkin, J., Gyamfi, N. & Jackson, D. Family violence and COVID-19: Increased vulnerability and reduced options for support. *International Journal of Mental Health Nursing* **29**, 549–552 (2020).
92. Gunnell, D. *et al.* Suicide risk and prevention during the COVID-19 pandemic. *The Lancet Psychiatry* **7**, 468–471 (2020).
93. Dorn, A. van, Cooney, R. E. & Sabin, M. L. COVID-19 exacerbating inequalities in the US. *Lancet* **395**, 1243–1244 (2020).
94. Laurencin, C. T. & Walker, J. M. A Pandemic on a Pandemic: Racism and COVID-19 in Blacks. *cels* **11**, 9–10 (2020).
95. Wright, A. L., Sonin, K., Driscoll, J. & Wilson, J. *Poverty and Economic Dislocation Reduce Compliance with COVID-19 Shelter-in-Place Protocols*. https://papers.ssrn.com/abstract=3573637 (2020).
96. Finch, W. H. & Hernández Finch, M. E. Poverty and Covid-19: Rates of Incidence and Deaths in the United States During the First 10 Weeks of the Pandemic. *Front. Sociol.* **5**, (2020).
97. CDC. *Screening K-12 Students for Symptoms of COVID-19: Limitations and Considerations Screening Students for Symptoms*. https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/symptom-screening.html (2020).
98. Poline, J. *et al.* Systematic SARS-CoV-2 screening at hospital admission in children:a French prospective multicenter study. *Clin Infect Dis* (2020) doi:10.1093/cid/ciaa1044.
99. Soucheray, S. & 2020. CDC COVID-19 reopening guidelines shelved. *CIDRAP*.
100. USHE COVID-19. *Utah System of Higher Education* https://ushe.edu/ushe-covid-19/.
101. Lederman, D. Simulations of college classrooms in the fall don't bode well | Inside Higher Ed. *Inside Higher Ed* (2020).
102. Alberty, E. State extends TestUtah contract despite lab violations in federal audit. *The Salt Lake Tribune*.
103. Baird, R. How Utah's Tech Industry Tried to Disrupt Coronavirus Testing. *The New Yorker* (2020).
104. Lu, X. *et al.* SARS-CoV-2 Infection in Children. *N Engl J Med* (2020) doi:10.1056/NEJMc2005073.
105. Baud, D. *et al.* Real estimates of mortality following COVID-19 infection. *The Lancet Infectious Diseases* **20**, 773 (2020).
106. Cohen, R. *et al.* Assessment of spread of SARS-CoV-2 by RT-PCR and concomitant serology in children in a region heavily affected by COVID-19 pandemic. *medRxiv* 2020.06.12.20129221 (2020) doi:10.1101/2020.06.12.20129221.
107. Heavey, L., Casey, G., Kelly, C., Kelly, D. & McDarby, G. No evidence of secondary transmission of COVID-19 from children attending school in Ireland, 2020. *Eurosurveillance* **25**, 2000903 (2020).
108. Hildenwall, H. *et al.* Paediatric COVID-19 admissions in a region with open schools during the two first months of the pandemic. *Acta Paediatrica* **n/a**,.

109. Furuse, Y. *et al.* Early Release - Clusters of Coronavirus Disease in Communities, Japan, January–April 2020 - Volume 26, Number 9—September 2020 - Emerging Infectious Diseases journal - CDC. *Emerging Infectious Diseases* (2020) doi:10.3201/eid2609.202272.
110. Piper, K., Youk, A., Iii, A. E. J. & Kumar, S. Paid sick days and stay-at-home behavior for influenza. *PLOS ONE* **12**, e0170698 (2017).
111. Burke, R. M. Active Monitoring of Persons Exposed to Patients with Confirmed COVID-19 — United States, January–February 2020. *MMWR Morb Mortal Wkly Rep* **69**, (2020).
112. Killeen, G. F. & Kiware, S. S. Why lockdown? Why national unity? Why global solidarity? Simplified arithmetic tools for decision-makers, health professionals, journalists and the general public to explore containment options for the 2019 novel coronavirus. *Infectious Disease Modelling* **5**, 442–458 (2020).
113. Durlak, J. A., Weissberg, R. P. & Pachan, M. A meta-analysis of after-school programs that seek to promote personal and social skills in children and adolescents. *Am J Community Psychol* **45**, 294–309 (2010).
114. NCES. Student Access to Digital Learning Resources Outside of the Classroom. https://nces.ed.gov/pubs2017/2017098/index.asp (2020).
115. Tai, D. B. G., Shah, A., Doubeni, C. A., Sia, I. G. & Wieland, M. L. The Disproportionate Impact of COVID-19 on Racial and Ethnic Minorities in the United States. *Clin Infect Dis* doi:10.1093/cid/ciaa815.
116. Abuelgasim, E., Saw, L. J., Shirke, M., Zeinah, M. & Harky, A. COVID-19: Unique public health issues facing Black, Asian and minority ethnic communities. *Current Problems in Cardiology* **45**, 100621 (2020).
117. Raisi-Estabragh, Z. *et al.* Greater risk of severe COVID-19 in Black, Asian and Minority Ethnic populations is not explained by cardiometabolic, socioeconomic or behavioural factors, or by 25(OH)-vitamin D status: study of 1326 cases from the UK Biobank. *J Public Health (Oxf)* doi:10.1093/pubmed/fdaa095.
118. EPI. Not everybody can work from home: Black and Hispanic workers are much less likely to be able to telework. *Economic Policy Institute* https://www.epi.org/blog/black-and-hispanic-workers-are-much-less-likely-to-be-able-to-work-from-home/ (2020).
119. Rho, H. J., Brown, H. & Fremstad, S. A Basic Demographic Profile of Workers in Frontline Industries. *Center for Economic and Policy Research* https://cepr.net/a-basic-demographic-profile-of-workers-in-frontline-industries/ (2020).
120. Bureau of Labor Statistics (BLS). Employment Situation Summary. https://www.bls.gov/news.release/empsit.nr0.htm (2020).
121. Navajo Nation Sees High Rate Of COVID-19 And Contact Tracing Is A Challenge. *NPR.org* https://www.npr.org/2020/04/24/842945050/navajo-nation-sees-high-rate-of-covid-19-and-contact-tracing-is-a-challenge.
122. Kakol, M., Upson, D. & Sood, A. Susceptibility of Southwestern American Indian Tribes to Coronavirus Disease 2019 (COVID-19). *J Rural Health* (2020) doi:10.1111/jrh.12451.
123. Ioannidis, J. P. A. Why Most Published Research Findings Are False. *PLoS Med* **2**, e124 (2005).