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Implementing Covid-19 Routine Testing in K–12 Schools: Lessons and Recommendations from Pilot Sites

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Executive Summary

In the 2020–2021 school year, many schools and districts around the country implemented routine Covid-19 testing to proactively detect cases among teachers, students, and staff and stop the spread of the virus. Such testing made it possible for many communities to gain the needed support from teachers and parents to reopen schools and resume in-person learning, helping to guard against learning loss for an entire generation of students. Even as public attention has turned to vaccines, testing remains essential for making schools a safe and trusted environment because it offers an important layer of protection. This protection is especially critical as schools and communities contend with the emergence of new Covid-19 variants, delayed vaccine rollout for young children, and the relaxation of other key mitigation measures such as masking and distancing.

> **Routine testing can be highly effective at reducing within-school Covid-19 transmission, with some testing strategies completely eliminating transmission.**

Furthermore, new federal funding provides school districts with the resources necessary to implement and sustain routine testing programs through the coming school year, although many will require practical guidance and hands-on assistance to implement routine testing in school settings. As the learning partner for The Rockefeller Foundation's K–12 Testing Protocol Demonstration Project, Mathematica has found that routine testing can be highly effective at reducing within-school Covid-19 transmission, with some testing strategies completely eliminating transmission. But to sustain successful routine testing programs in the fall, schools will require the ongoing support of community leaders to retain trust in and enthusiasm for testing as well as coordinated guidance and resources from state and national education and public health authorities.

This demonstration project included six sites (states, cities, and school districts) partnering with Duke-Margolis Center for Health Policy and Johns Hopkins University to implement routine Covid-19 testing in 335 schools across the country between September 2020 and June 2021. These pilot sites administered nearly 200,000 Covid-19 tests, including many of the 140,000 BinaxNOW tests that the U.S. Department of Health and Human Services provided sites as well as other rapid antigen and polymerase chain reaction (PCR) tests procured by state officials or school districts themselves.

The following table describes key findings and considerations about the acceptability, feasibility, and effectiveness of routine testing in the 2021–2022 school year based on insights from pilot sites and the results of Mathematica's agent-based modeling, which was used to estimate the impact of routine testing.

Key findings and considerations for the 2021–2022 school year

Acceptability: Program planning and design
Participation in routine testing ranged widely in pilot sites from less than 1 percent to 68 percent of all students in the school district, and sites identified a few key factors that can encourage greater participation: • A simplified informed consent process (for example, using electronic consent forms or opt-out strategies when possible) • Making testing as accessible as possible (for example, by offering classroom-based testing) • Keeping testing programs consistent (that is, who is tested, how, and how often) • Relying on respected leaders to communicate the importance of ongoing testing

Feasibility: Mobilization and set-up
Most pilot schools found it challenging to implement routine testing, and most will require considerable support to continue testing in the fall, including: • Detailed operational guidance, practical assistance, and resources from federal and state public health and education authorities to navigate logistical, regulatory, and procurement needs • Creative approaches to reduce testing delays and logistical burdens on school staff, such as mobile testing
Effectiveness: Monitoring and evaluation
Modeling results showed that routine testing can greatly reduce or eliminate within-school Covid-19 transmission. The modeling results also showed that: • For higher-risk schools relying on testing to reduce within-school transmission, pooled PCR testing is generally the most effective strategy. Serial antigen testing is a close second. • The most effective strategies for decreasing transmission also increase the number of in-person school days lost. However, effective testing strategies also decrease the risk of a large outbreak that may force schools to close. Schools will need to weigh this tradeoff when making testing decisions.

The rest of this report provides cross-cutting findings, recommendations and key considerations related to the acceptability, feasibility and effectiveness of routine testing, as schools look ahead to the next school year and beyond. The report also includes site-specific profiles detailing each site's routine testing program, testing participation and Covid-19 case data, and lessons learned.

The six pilot sites represent a diverse group of states, cities, and school districts from across the U.S. The diversity of perspectives allowed Mathematica to identify common facilitators and challenges across a variety of contexts that may provide useful insights for other schools interested in implementing routine Covid-19 testing programs, summarized in this report. In addition, Mathematica developed a K–12 testing impact estimator, based on modeling results, that schools and districts can use with their public health partners to assess the potential impact of different testing strategies under various contexts.

Covid-19 presented all pilot sites, and many schools across the country, with their first opportunity to develop and deliver health services in a school-based setting. These findings and recommendations also have wider implications for developing and delivering public health services in a school-based setting—such as flu shots, Covid-19 vaccinations or boosters, or other routine immunizations. If successful, schools can capitalize on opportunities to apply the capacity, partnerships, and infrastructure they have developed through the pandemic to support and complement other important public health efforts.

Given the significant learning losses that the Covid-19 pandemic has already caused, the Centers for Disease Control and Prevention is urging schools across the country to fully reopen in the fall.[1] As more students, teachers, and staff gather in schools, and as other mitigation measures such as mask mandates are removed, public health experts have acknowledged that routine testing can offer a critical layer of protection[2] and allow schools to safely remain open in the coming year.

[1] https://www.nytimes.com/2021/07/09/health/cdc-schools-reopening-guidelines.html
[2] https://www.wsws.org/en/articles/2021/07/12/scho-j12.html

I. Introduction

The Covid-19 pandemic prevented 55 million students across the U.S. from attending school in person for much of the 2020–2021 school year (Kuhnfeld et al. 2020). Experts estimate the impact on students' learning to be significant, with long-term learning losses potentially shaping children's educations for years to come and disproportionately disadvantaging poor students and students of color (Dorn et al. 2020). A lack of in-person schooling also limits many students' access to critical resources such as food, health services, and opportunities for socialization, and puts severe strain on working parents (Hoffman and Miller 2020). Given the enormous and far-reaching implications of school closures and remote learning, schools across the U.S. have searched for opportunities to ways to provide high quality instruction while keeping students, teachers, and staff safe. Along with mitigation strategies such as grouping students into pods and requiring masks on school grounds, many schools and school districts around the country turned to routine Covid-19 testing.

Even as vaccines are rolled out and case rates fall, routine testing[3] will likely be needed in many schools across the country for the 2021-2022 school year. A growing body of evidence indicates that routine testing and early identification of asymptomatic individuals can be highly effective at preventing Covid-19 transmission within schools, especially while vaccines remain unavailable to young children (Moghadas et al. 2021). Testing can offer an important layer of protection as schools and communities contend with the emergence of new Covid-19 variants, delayed vaccine rollout for young children, and the relaxation of other key mitigation measures such as masking and distancing. Additionally, $10 billion in new federal funding[4] provides school districts with the resources and technical assistance needed to implement and sustain routine testing programs through the coming school year. Building on the early insights and recommendations from the K–12 Testing Protocol Demonstration Project's January 2021 report, this report offers schools and districts considerations and guidance as they prepare to offer routine testing in the fall. Drawing on the experiences of six pilot sites participating in the demonstration project, the report addresses the following key questions, with the goal of highlighting promising practices and action-oriented recommendations that can inform schools' implementation of routine testing:

1. **Acceptability: Program planning and design.** How do schools obtain buy-in from key stakeholders (such as school officials, parents, students, and teachers), and how can the testing program be designed to encourage appropriate participation from these stakeholders?
2. **Feasibility: Mobilization and set-up.** How feasible is it to mobilize the capacity and capabilities needed to implement a Covid-19 testing program in K–12 schools?
3. **Effectiveness: Evaluation.** What is the potential impact of implementing such programs on in-school infections and in-person learning days? How can schools assess the effectiveness of their testing programs?
4. **Sustainability: Looking ahead.** What key resources are needed for schools to sustain their testing programs? How might policymakers at all levels play a role in supporting schools to implement routine testing in the 2021–2022 school year?

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[3] Throughout this report, we use "routine testing" to refer to regular Covid-19 testing of all or some individuals in a school, regardless of their symptom or exposure status. This is in contrast to symptomatic diagnostic testing, which is used to diagnose Covid-19 in people who are showing symptoms.
[4] https://www.hhs.gov/about/news/2021/03/17/biden-administration-invest-more-than-12-billion-expand-covid-19-testing.html

The six pilot sites represent a diverse group of states, cities, and school districts from across the U.S. These pilot sites administered nearly 200,000 Covid-19 tests, including many of the 140,000 BinaxNOW tests that the U.S. Department of Health and Human Services provided sites as well as other rapid antigen and polymerase chain reaction (PCR) tests procured by state officials or school districts themselves. Testing was administered at 335 locations across the six pilot sites between October 2020 and June 2021. Participation rates in school-based testing programs across pilot sites ranged from less than 1 percent (in New Orleans) to about 68 percent (in Los Angeles) of all students in the district and 25 percent (in Tulsa) to 100 percent (in Los Angeles) of teachers and staff in participating schools.

The K–12 Testing Protocol Demonstration Project

In September 2020, six pilot sites (Rhode Island; Los Angeles, CA; Louisville, KY; New Orleans, LA; Tulsa, OK; Washington, DC) partnered with The Rockefeller Foundation to launch the Covid-19 Testing Protocol Demonstration Project. Pilot sites were also members of the Pandemic Solutions Group (PSG), a network of public officials spanning 52 U.S. cities, states, counties, and tribal nations that represent nearly 70 percent of the U.S. population. The PSG was designed to support rapidly scaling Covid-19 testing, tracing, and tracking in their communities. Importantly, pilot sites also participate in the Cross-City Learning Group (CCLG), a community of practice that meets regularly for in-depth discussion and knowledge sharing around school-based testing. The CCLG has met 24 times between September 2020 and June 2021.

In October, HHS made 20,000 Abbott BinaxNOW rapid antigen tests available for K–12 schools in each participating pilot site. The schools used these tests to launch or augment their school-based Covid-19 testing programs aligned with the *Risk Assessment and Testing Protocols for Reducing SARS-CoV-2 Transmission in selected K–12 Schools* (Rivers et al. 2020). These testing protocols provide guidance on how to assess the level of risk of Covid-19 transmission in schools and how to develop a program to routinely test students, teachers, and staff tailored to the site's risk level and context.

Each of these sites implemented a variety of approaches to school testing as shown below. Mathematica, as the learning partner for the demonstration project, leveraged the variation across sites to better understand and generate evidence about the acceptability, feasibility, and effectiveness of adding a testing program to schools' existing Covid-19 related plans.

	Testing overview	Testing site(s)	Testing strategy	Percent or number opted-In	Tests administered	Status of schools
Rhode Island	• Extensive off-site testing program for K–12 students and families. • Pilot of BinaxNOW on-site testing in a high-needs population (Central Falls), which informed expansion of school-based testing across the state.	• 109 • Location: schools	• Screening	• Students: 55% (72,000/130,000) • Staff: 50% (25,000/50,000)	• about 147,000 since testing began in December	• Elementary and middle schools: in person and hybrid since September • High schools: hybrid since September
Los Angeles, California	• Community-based testing protocol for schools developed by Office of the Mayor, County Health Department, and University of Southern California. • Pilot of BinaxNOW in schools and in-person and remote learning programs. • Focus groups with key stakeholders and a validation study on the effectiveness of BinaxNOW tests in detecting infection in children.	• 65 • Location: ALCs and public schools	• Screening • Diagnostic	• Student athletes: 100% (506/506) • Students at ALCs: 48% (396/818) • Coaching staff: 100% (50/50) • ALC staff: 100% (188/188)	• 10,076 (as of 6/4/21)	• All schools: allowed to be in person • ALCs: Off-site options to facilitate remote learning

	Testing overview	Testing site(s)	Testing strategy	Percent or number opted-In	Tests administered	Status of schools
Louisville, Kentucky	• Testing program across select learning hubs launched by Jefferson County Public Schools and community-based organizations that facilitate distance learning for families that cannot stay home with their students. • Pilot of BinaxNOW as an asymptomatic antigen testing program in learning hubs, which has since scaled up to include regional testing sites at various schools.	• 30 • Locations: regional testing sites in schools, learning hubs, Central Office Nutritional Center	• Screening • Surveillance	• Students: 264 (total population not provided) • Staff: 251 (total population not provided)	• 20,000 BinaxNOW tests distributed to local sites for use	• All schools: in person/hybrid since March
New Orleans, Louisiana	• School-based mobile testing program using PCR testing. • BinaxNOW administered by school nurses to symptomatic students and staff as needed for diagnostic purposes.	• 55 • Location: schools	• Diagnostic • Screening	• 265 (total population of students and staff attending in person varied significantly across the year)	• Total BinaxNOW: 40 (January–June) • Total PCR: 465 (January–May)	• Elementary schools: in person since late September • Middle and high schools: in person/hybrid since mid-October
Tulsa, Oklahoma	• Testing available for teachers and staff in November 2020. • With in-person learning starting February 2021, diagnostic and screening testing offered to students and staff, administered by school nurses. • In March 2021, vendor hired to assist with data management.	• 68 • Location: schools	• Diagnostic • Screening	• Students: 600+ • Staff: 25% (1,356/5,400)	• 625 students since student testing began in March • 1,356 staff since staff testing began in December 2020	• All schools: in person/hybrid since March
Washington, DC	• Piloted regular asymptomatic testing for all students in January 2021. • Regular testing to students every week and staff every other week using BinaxNOW and PCR tests.	• 8 • Location: Friendship schools	• Screening	• Students: 42% (291/686) • Staff: 94% (424/450)	• BinaxNOW: 6,267 • PCR: 2,665	• All pilot schools: in person since March

Note: Unless otherwise noted, tests administered or distributed refers to the BinaxNOW tests received from HHS for the pilot program. "Routine testing" refers to regular Covid-19 testing of all or some individuals in a school, regardless of their symptom or exposure status. This is in contrast to symptomatic diagnostic testing, which is used to diagnose Covid-19 in people who are showing symptoms.

ALC = alternative learning center; PCR = polymerase chain reaction.

Methods used in this report

This report provides learnings and insights collected from pilot sites implementing school-based routine testing programs between October 2020 and June 2021. Key data sources for this report include documentation, key informant interviews with testing leads at pilot sites, and summary testing and case data provided by pilot sites (Exhibit I.1).

Exhibit I.1. Data sources

Source	Description	Time frame
Documentation	Notes and supplemental documents from weekly and biweekly convenings hosted by The Rockefeller Foundation Biweekly updates summarizing sites' emerging wins and challenges, upcoming plans, and summary data on participation in testing programs	October 2020–June 2021 (notes); March 2021–June 2021 (biweekly updates)
Key informant interviews	17 semi-structured interviews with testing leads at 6 original pilot sites and 2 new sites that shared their experiences with testing (Details in Appendix Exhibit B.1.)	October 2020–June 2021
Site testing and case data	Longitudinal data on positive cases, close contacts and/or other important testing metrics that sites tracked on public dashboards or provided directly to Mathematica (Details in Appendix Exhibit B.2)	October 2020 (or later if data not available)–June 2021

Qualitative analysis. We abstracted information from site documentation and interview notes along the four key learning questions enumerated on page 7 and identified themes accordingly. Based on the analysis, we developed a detailed profile of each pilot site and identified common implementation themes across sites. We also describe pilot sites' current planning and considerations for designing and implementing a feasible, acceptable school-based testing program in the 2021–2022 school year.[5]

Quantitative analysis. We conducted descriptive analyses using data from pilot sites' biweekly updates (e.g., number of tests administered, student/staff opt-in rate) and public or internal dashboards (e.g., number of cases and close contacts). Because each pilot site collected data in different ways, we did not seek to combine data across sites, but instead conducted site-specific descriptive analyses. Detailed results can be found in individual site profiles in Appendix A.

[5] The pilot sites discussed in this report, and the key informants interviewed for this effort, are different from the schools and districts covered in another report also supported by The Rockefeller Foundation (Faherty et al. 2021).

Agent-based modeling. We used information provided by pilot sites to construct ABMs. We used these models to investigate differences in within-school Covid-19 transmission rates and in-person learning that might be expected across the universe of different testing scenarios that pilot sites could choose, and to compare these scenarios to a baseline scenario in which only symptomatic diagnostic testing is offered. Specifically, we examined different test types (pooled PCR testing, single-day antigen testing, or serial antigen testing on back-to-back days); different frequencies ranging from monthly to twice weekly; and different testing audiences (students, teachers/staff, or both). We used these models to create an impact estimator that describes the potential impact of testing programs on in-school infections and in-person learning, above and beyond the impact of other mitigation strategies a school might implement, such as masking and distancing.[6] Other schools, school districts, and their public health partners can use the impact estimator to assess the potential impact of different testing strategies in their schools in the coming school year. More details about the methods, assumptions, and inputs for the ABM can be found in Appendix C.

Agent-based modeling

How does ABM work? ABMs are computational models that imitate how interactions of individuals ("agents") contribute to community-level outcomes. ABMs use available data on infection spread; people's behaviors (such as physical distance, wearing masks, and testing); and people's characteristics to predict the likely spread of disease in a school.

What can ABMs tell us? For this project, an ABM can

- Provide insight into whether and how different testing strategies can reduce within-school transmission and loss of in-person school days
- Help decision makers decide what testing strategies will best serve their needs in the 2021–2022 school year

Roadmap for this report

The rest of this report will focus on cross-cutting findings and recommendations for schools and districts preparing for routine testing in the 2021–2022 school year, with an emphasis on new or updated findings since the January report related to the acceptability (Section II), feasibility (Section III), effectiveness (Section IV), and key considerations as schools look ahead to the next school year and beyond (Section V). Site-specific profiles are included in Appendix A detailing each site's routine testing program, testing participation and Covid-19 case data, and lessons learned. These insights could be useful for policymakers and school leaders at the district, state, and national levels as they identify opportunities to support schools during the transition back to in-person learning.

[6] We focus on these two primary outcomes in our report, but the impact estimator provides insights on three additional key outcomes: total number of infections detected in a school (regardless of their origin), proportion of all infections that are first detected via routine testing, and weekly number of tests needed.

II. Acceptability of school-based testing

Routine Covid-19 testing will continue to serve as a valuable tool to keep schools safe in the 2021–2022 school year. Therefore, schools will need to identify ways to keep the school community—including students, parents, teachers, and staff—engaged with routine testing programs in the fall, even as the broader public's attention shifts towards other priorities such as vaccination. Pilot sites identified some key strategies to keep stakeholders engaged and participating, including applying opt-out approaches (whereby students and staff are automatically involved in routine testing unless they specifically request not to be tested) when feasible and simplifying the informed consent process. In addition, avoiding unnecessary changes to the routine testing program and maintaining clear, effective, open lines of communication with key community stakeholders are important strategies for increasing the likelihood that school communities accept testing as a routine part of the school experience.

Insights about acceptability

1. When acceptable and feasible, using opt-out approaches removes barriers to participation in testing.
2. A clear and streamlined informed consent process helps parents better understand testing and makes it easier to opt in.
3. Offering in-classroom testing and promoting vaccination and testing simultaneously can help maintain enthusiasm for testing.
4. Keeping the testing program as stable as possible helps build stakeholders' trust in and comfort with testing as a routine part of the school experience.
5. Using respected leaders to communicate about the testing program continues to be an important way to combat misinformation and retain support for testing.

In this section, we discuss cross-cutting challenges that schools have faced regarding acceptability and uptake of ongoing testing in 2021, as well as promising solutions to overcoming these barriers in the next school year.

Promoting participation in school-based testing programs

Schools can encourage greater participation in routine testing by applying opt-out approaches wherever feasible, simplifying the informed consent process, and finding new ways to make testing easier and more accessible as vaccination rates increase.

Summary of findings. Early enthusiasm for school-based testing programs has not translated into high participation rates among students. Pilot sites reported that an opt-in approach to testing, combined with challenging or confusing consent processes, might have created barriers to participation in testing programs. Using opt-out strategies where feasible and making it easier for parents to provide consent could help boost participation rates. Participation could also have been affected by the timing of testing program rollout; many schools began implementing their testing

A digital approach to parental consent: insights from the field

To make it easier for students to opt into testing, the University of Illinois at Urbana-Champaign ShieldT3 Team is exploring the use of a digital consent form that could be accessed via student Chromebooks and digitally signed by parents to allow their children to participate in testing.

programs in early 2021, just as vaccines were becoming available and case rates were declining. In the context of ongoing vaccination in the next school year, pilot sites identified promising approaches for promoting participation in testing.

> **"I think we all underestimated the challenge of getting parents to agree with testing."**
> ***– Testing lead, Louisville***

When acceptable and feasible, using opt-out approaches removes barriers to participation in testing. In fall 2020, while pilot sites were still in the planning and early implementation stage of their testing programs, sites reported that school-based testing programs were well received in the abstract by the school community and other partners. As schools finalized the details of their testing approach and implemented testing in early 2021, all were hesitant to use an opt-out approach because of concerns about the legal ramifications of an opt-out program and instead relied on voluntary opt-in participation. These opt-in approaches require regular consent from staff and students (or their parents) to be tested. In Tulsa, for example, parents preferred the flexibility of the opt-in approach.

Some pilot sites were able to approximate an opt-out approach with some populations of students or staff, which helped them achieve high participation. For example, pilot schools in Los Angeles and Washington, DC, required testing for student athletes to compete and for teachers and staff to teach in person at alternative learning centers and learning hubs; this strategy resulted in near-universal participation in testing for these groups.

A clear and streamlined informed consent process helps parents better understand testing and makes it easier to opt in. Pilot sites reported that obtaining signed consent forms, particularly from parents for students to be tested, was logistically difficult. For example, most sites required paper-based consent forms and had to figure out how to collect the signed forms in school drop-off lines because many schools limited parents and other visitors on campus. The language in testing consent forms was also a source of confusion in at least three pilot sites. In Los Angeles, some parents were confused about how testing specimens were handled, while in New Orleans and Rhode Island, some parents were confused by the need for multiple consent forms for various school-based activities. Clear language and simple protocols for collecting consent could make it easier for students and their parents to participate in testing. For example, New Orleans testing leads noted that having all consent forms together in an electronic format would make it much easier for parents to review and respond to all forms at once and for school administrators to track submission.

> **Variation in participation rates across schools**
>
> The rate of participation in school-based testing programs is one indicator of their acceptability. In pilot sites, participation rates in school-based testing programs ranged from less than 1 percent (in New Orleans) to about 68 percent (in Los Angeles) of all students in the district and 25 percent (in Tulsa) to 100 percent (in Los Angeles) of teachers and staff in participating schools.

Offering in-classroom testing and promoting vaccination and testing simultaneously can help maintain enthusiasm for testing. The timing of vaccine roll-out beginning in early 2021 coincided with most pilot sites reopening schools to in-person learning. According to some pilot sites, the availability of vaccines, particularly for teachers and

> **"The really low [test] positivity rates, combined with the vaccine rollout and states opening up impacts the urgency to test."**
> ***– Testing lead, Rhode Island***

staff, may have impacted students' and staff's appetite for ongoing routine testing and may have contributed to limited testing participation. In Rhode Island, for example, participation rates were higher among elementary students and lower among middle and high school students, presumably because of the availability of vaccines for older students. In Tulsa and New Orleans, enthusiasm for testing quickly subsided as vaccinations began to roll out.

As sites begin planning for their summer programs and next school year, they plan to try a number of approaches to encourage higher participation in testing. In New Orleans, for example, individual schools may try in-classroom testing during summer programs to test whether conducting testing in that setting encourages higher participation rates. New Orleans is offering and Los Angeles is considering offering Covid-19 vaccination at school testing sites. They believe that offering testing and vaccines in the same sites could both facilitate testing for unvaccinated individuals and encourage vaccine uptake. In New Orleans, early results from this approach suggest that vaccination rates are higher at schools that are requiring opt-out testing.

High participation makes testing useful: insights from the field

Los Angeles conducted focus groups with school stakeholders and found that parents thought school-based testing was particularly useful for younger children who do not have access to vaccines yet. In contrast, staff felt that testing could theoretically increase safety, but with such low participation rates, the administration of the testing program was instead viewed as a nuisance.

Communicating effectively with the school community

Schools can maintain community trust in, and support for, routine testing by keeping their programs consistent and working with trusted messengers to continue to communicate program details.

Summary of findings. Clear and frequent communication from trusted school leaders is needed to proactively maintain trust, combat misinformation, and maintain strong support for school-based testing. Pilot sites reported that despite limited participation in testing, they had strong support for their testing programs among parents, teachers, and other partners and that maintaining this support would be critical to testing programs' ongoing success in the next school year.

Keeping the testing program as stable as possible helps build stakeholders' trust in and comfort with testing as a routine part of the school experience. To maintain stakeholder trust in their testing programs, pilot sites have attempted to keep the testing approach as stable as possible over the course of the spring semester and aim to do the same when school resumes in the fall. In Washington, DC, representatives shared that keeping a consistent schedule and staff for testing helped to ease anxiety among individuals being tested. Other schools made some minor tweaks to their testing approach to increase access and availability of testing but kept other elements stable. For example, Rhode Island evolved its approach to offer confirmatory PCR testing if an individual tests positive using an antigen test by introducing mobile teams who can go to the location where the individual tested positive and collect a sample for PCR analysis on

> **"A lesson learned was how fragile and delicate the situation can be with the school district and local community as it relates to what school plans were. Changing plans eroded trust in the community."**
> ***– Testing lead, Los Angeles***

site. Otherwise, Rhode Island testing leads worked to keep key components of its testing program consistent.

Using respected leaders to communicate about the testing program continues to be an important way to combat misinformation and retain support for testing. In Louisville, school district officials partnered with the directors of learning hubs to communicate about the testing program with parents and students and to gather feedback from parents to improve the program. Washington, DC, pilot schools used experienced medical staff—some with pediatric experience and others who were well known in the community—to administer tests. These staff became a trusted source of information not only about testing, but also about general disease prevention and health promotion. The University of Illinois at Urbana-Champaign ShieldT3 Team also noted the importance of strong leadership buy-in; in one of its testing sites with a very supportive and communicative leader, participation rates among students are as high as 90 percent. Most sites noted that if key stakeholders understand and are comfortable with the details of their schools' routine testing program, they are more likely to support continued testing in the coming school year.

III. Feasibility of school-based testing

Prior to the Covid-19 pandemic, few schools had experience implementing large, complex public health interventions for their students and staff. Although many pilot schools have gained valuable experience and insights related to the feasibility of offering routine Covid-19 testing on site, implementing ongoing routine testing programs continues to be very challenging, and most schools will require considerable support to continue testing in the fall. Based on their recent experiences, pilot schools identified some key needs for making testing feasible in the 2021–2022 school year, including ongoing support and coordination from public health authorities to navigate ongoing logistical and regulatory requirements for testing implementation, as well as practical support for procuring the necessary testing-related supplies. Schools also found it helpful to work with external vendors to supplement internal capacity and support ongoing routine testing in the fall.

Insights about feasibility

1. Schools need ongoing support and coordination from public health and education authorities to navigate ongoing logistical and regulatory requirements for testing implementation.
2. A more coordinated response at both the federal and state levels is also needed to reduce duplicative efforts and implementation delays.
3. A mobile strategy is a feasible approach to offering timely and convenient access to testing.
4. External vendors can help increase staff capacity to sustain or expand testing operations.

In this chapter, we discuss the ongoing, cross-cutting barriers to feasibility that pilot sites have uncovered and sites' approaches for addressing these barriers in the next school year.

Implementing testing programs

> **Strong coordination and hands-on support from public health officials, schools, and school system leaders will be needed to help schools navigate legal, regulatory, and procurement issues and to minimize delays in implementing testing programs in the fall. Creative approaches such as mobile testing can also reduce testing delays.**

Summary of findings. All pilot sites reported continued challenges navigating legal, regulatory, and procurement issues, and the lack of coordinated response at the federal or state levels led to implementation delays and duplication of effort at some sites. Although sites had some access to guidance on key regulatory requirements such as how to obtain a Clinical Laboratory Improvement Amendment (CLIA) waiver, most still found it challenging to understand and comply with those requirements because none had previous experience obtaining a waiver and operating as a Health Insurance Portability and Accountability Act (HIPAA) compliant entity (which the CLIA waiver required). Some sites also found it difficult to procure testing-related supplies without help and advice from higher-level authorities like state health departments. Without this support, many sites had to delay implementation of their routine testing programs significantly in the 2020–2021 school year. Greater coordination, guidance, and hands-on assistance from public health and education authorities will be critical for schools to implement routine testing programs in a timely manner. Several pilot sites incorporated elements of mobile testing as a feasible way to offer routine testing to school communities and minimize delays in providing access to testing.

Schools need ongoing support and coordination from public health and education authorities to navigate ongoing logistical and regulatory requirements for testing implementation. To administer Covid-19 tests on site for screening and diagnosis, schools need a CLIA waiver. Los Angeles, which partnered with the University of Southern California (USC) to implement testing in city-operated learning hubs, also required Institutional Review Board approval to begin administering tests because of the research component of its program. Pilot sites also reported challenges with procuring sufficient personal protective equipment and hiring medical waste vendors or contracting with staffing agencies to implement their testing programs. In order to continue to implement routine testing in the fall, most sites believe that health and education authorities at all levels will need to provide more detailed and coordinated guidance on their legal and regulatory responsibilities, as well as practical, hands-on assistance in operationalizing this guidance and procuring the necessary supplies.

A more coordinated response at both the federal and state levels is also needed to reduce duplicative efforts and implementation delays. Although most pilot sites reported that their institutions tried to move as quickly as possible in 2020 and early 2021 to implement testing, in the absence of a coordinated federal or statewide response, many schools or districts found themselves duplicating effort and experienced delays. For example, the USC team, working with Los Angeles Office of the Mayor and county health department on testing in learning hubs, pursued its own CLIA waiver, but those efforts overlapped with California's statewide CLIA waiver which could have covered the testing efforts in Los Angeles. However, representatives from Los Angeles reported that had they waited for the state's CLIA waiver, testing would have been delayed by at least a month. Representatives from New Orleans estimated that working through legal and procurement hurdles with limited state support delayed testing by up to five months. As sites look ahead to the fall, all have noted that stronger coordination from state and federal authorities, especially public health experts, will be critical for ensuring that routine testing is made available in a timely manner in the fall.

A mobile strategy is a feasible approach to offering timely and convenient access to testing. Several sites incorporated some element of mobile testing in their school-based testing programs, proving this to be a feasible strategy for other schools interested in reducing delays in and barriers to testing. New Orleans used vans equipped with testing supplies to conduct mobile screening testing on school grounds using PCR tests while also having BinaxNOW antigen tests available on site in schools for diagnostic testing. Rhode Island sent mobile units to conduct confirmatory PCR tests as needed if an individual tested positive using a BinaxNOW antigen test. The benefit of having some mobile element of the testing program was that it allowed schools to make timely, convenient testing as accessible as possible, even if it did introduce a new layer of scheduling logistics. In New Orleans, for example, the school district partnered with local hospitals to prioritize diagnostic PCR testing appointments for staff and students early in the 2020–2021 school year; later on, the district partnered with a vendor to offer mobile PCR screening testing. Expanding access to mobile testing could be a feasible solution for other pilot sites as well. For example, in Los Angeles, many working parents did not have the ability to wait with their child for 15 minutes to conduct the test at drop-off, or to come back and bring their children home if the test was positive, resulting in some parents choosing not to have their children tested. Mobile testing, offered at times and locations that are more convenient for students and families, could reduce such barriers to participation in routine testing programs.

> **"Folks aren't *going* to get tested or vaccinated. It needs to come to them."**
>
> ***– Testing lead, New Orleans***

Managing resource and staffing needs

> **External vendors and consultants can help with testing implementation, data management, and reporting of test results, thereby relieving some of the operational burden on schools in the fall.**

Summary of findings. Schools need considerable resources to sustain and expand their routine testing programs, as well as tools and guidance to help make decisions about how to deploy these resources. Testing leads at pilot sites took varying approaches to addressing their resource needs as their testing programs were mobilized. For example, Some identified staffing gaps that limited the reach of their testing programs and outsourced components of their programs.

External vendors can help increase staff capacity to sustain or expand testing operations. At least four pilot sites—New Orleans, Tulsa, Washington, DC, and Louisville—contracted with external vendors to take over some component of either administering their testing program or data management and reporting, which relieved some of the burden on staff at the pilot sites and enabled sites to consider expanding their programs. In contrast, Los Angeles and Rhode Island initially used staff employed by the city or state to administer tests and faced capacity issues as they sought to expand their testing programs. In Los Angeles, representatives noted that they had insufficient resources to monitor implementation of their testing programs or provide refresher training in sites with low participation rates. Tulsa also reported a high operational burden for staff in their district related to standing up a data infrastructure that was HIPAA and Family Educational Rights and Privacy Act compliant. Leveraging existing resources to partner with external vendors or consultants could help extend these sites' capacity and ensure smooth testing operations in the fall.

Investing in health professionals to conduct testing: Insights from the field

Washington, DC, implemented school-based testing with medical staff who had pediatric experience. They also handed out stickers to young students and played music in the testing area to create a positive environment for individuals being tested. By using staff with medical training to administer tests, they were also able to do health promotion and education.

Tools to help deploy resources effectively

Tools such as Mathematica's **testing impact estimator** and **When to Test** can help schools consider how best to make use of limited testing resources. For example, the cost of PCR or antigen tests can vary greatly across schools for a number of reasons, including local or state support and access to tests. Because PCR tests, including pooled tests, are often more expensive than antigen tests, many schools may consider antigen-based routine testing programs to be more cost effective. Our ABM results show that, if schools have access to a fixed number of antigen tests, they will achieve a greater reduction in within-school transmission with single -day antigen testing at a higher frequency than with less frequent serial antigen testing. In many of our modeled scenarios, schools achieve greater reduction in within-school transmission with weekly single-day antigen testing (for example, every Monday) than with twice monthly serial antigen testing (for example, Monday and Tuesday every two weeks). Additionally, The Rockefeller Foundation released its **National Covid-19 Testing Action Plan** to support the development of state-led testing plans and also released a **Testing Playbook** to help local sites operationalize testing plans.

IV. Effectiveness of school-based testing

Pilot sites with school-based testing programs generally found few Covid-19 cases among students and staff in their schools. To understand the extent to which school-based testing could contribute to these observed outcomes, Mathematica applied ABM to investigate the potential effectiveness of various routine testing scenarios, the results of which are available on an interactive impact estimator. The impact estimator provides summarized results of thousands of simulations of the potential effectiveness of school-based testing strategies, allowing users to adjust key parameters (such as school type, community incidence rate, and the quarantining policy schools are using) and compare the potential results of different testing strategies. Schools can consider these comparisons, along with factors such as the resources available, the presence of other mitigation strategies in the community, and key stakeholders' appetite for frequent testing, to choose the most appropriate testing strategy for their setting.[7]

The modeling results indicate that routine testing can reduce within-school transmission up to 100 percent under ideal conditions. However, the most effective approaches for reducing transmission can also lead to a significant amount of isolation and quarantine of positive cases and their contacts and thereby reduce the number of in-person school days.

Insights about effectiveness

1. For higher-risk schools relying on testing to reduce within-school transmission, pooled PCR is generally the most effective strategy. Serial antigen testing is a close second.
2. Decisions about test frequency, testing audiences, and a school's quarantine policy along with contextual factors such as the community incidence rate shape the effectiveness of routine testing.
3. Ensuring universal, immediate access to confirmatory PCR testing minimizes the trade-off between within-school transmission reduction and in-person learning.
4. The most effective approaches for minimizing missed in-person school days are those that are less effective at reducing transmission: avoiding quarantining contacts; reducing the frequency of testing; and using antigen tests, which are less sensitive than PCR.

Reducing within-school transmission

Available data indicate that few Covid-19 cases have been identified in pilot sites. ABM results indicate that routine testing can be up to 100 percent effective at reducing within-school transmission, and pooled PCR is an especially effective strategy. Other contextual factors also shape the impact of testing on within-school transmission.

Summary of findings. Available testing data suggest that Covid-19 transmission in pilot sites has been low. In fact, most pilot sites deployed thousands of tests, through their testing pilot programs as well as other sources, and identified very few cases. For example, Los Angeles found only four cases among students in participating testing sites; Washington, DC, found eight in participating schools; and Louisville found none in its learning hubs (Exhibit IV.1; see Appendix A for more details). Although there may be many reasons for the small number of cases found in these schools, the results are consistent with the hypothesis that routine testing may help limit Covid-19 spread. This conclusion is further

[7] ABM results focus on typical primary and secondary schools in the U.S., in terms of number of students, teachers, and staff; therefore, the key findings and insights are applicable to a range of K–12 school settings.

supported by our ABM results, which find that routine testing can reduce within-school transmission by up to 100 percent compared to symptomatic diagnostic testing only. Choice of test type is important: pooled PCR performs at least as well as, and often better than, antigen-based strategies. The effectiveness of routine testing is also influenced by other factors, including testing frequency and audience (students, staff, or both); underlying community incidence; and a school's quarantine policy.

Exhibit IV.1. Covid-19 tests administered and cases identified in pilot sites

Site	Proportion or number of students attending in-person learning (as of 6/11/2021)	Tests administered/ distributed through pilot program	Student Cases Identified[a]	Teacher/Staff Cases identified[a]	Time period
Rhode Island	90% in Central Falls	147,000	8,044	2,655	9/6/20–6/4/21
Los Angeles, CA	High school: 7% Middle school: 12% Elementary school: 30%	10,076	Schools: 1 RAP Centers: 3	Data not disaggregated by student/staff	Schools: 3/29/21–6/4/21 Alternative Learning Centers: 2/22/21-6/8/21
Louisville, KY	School year complete; no students currently attending	20,000 (distributed to all testing sites)	309 0 in learning hubs	66 0 in learning hubs	3/17/21–5/28/21
New Orleans, LA	School year complete; no students currently attending	505 (includes BinaxNOW and PCR)	284	181	9/2020–6/2021
Washington, DC	22%	8,932 (includes BinaxNOW and PCR)	8	6	as of 6/9/21

[a] Students and staff could have accessed testing outside of sites' pilot programs; the reported cases in this table were not necessarily detected by each site's pilot programs. Disaggregated data on how cases were identified were not available.

In most cases, pooled PCR testing is the most effective testing strategy for reducing within-school transmission when community incidence is high. At higher community incidence rates, pooled PCR testing becomes more effective at reducing within-school transmissions than single antigen or serial antigen testing at the same frequency (Exhibit IV.2, top). This is likely because PCR tests produce fewer false negatives than antigen tests (even when used serially) and are thus more effective at identifying cases that might otherwise be missed. At low community incidence rates, different test types perform similarly (Exhibit IV.2, bottom). However, because pooled PCR testing is at least as effective as other test types, and often more effective, it is a good choice for most schools that have the resources to implement it. Serial antigen testing also performs well and could also be a good choice for many schools.

Policy decisions and contextual factors shape the effectiveness of routine testing. Test frequency and audience, underlying community incidence, and quarantine policy all influence the effectiveness of routine testing:

1. **Testing more frequently, and testing more people, reduces within-school transmission.** We find that the reduction in within-school transmissions increases steadily as the testing frequency increases from monthly to twice weekly (Exhibit IV.2). In all cases, universal testing (meaning testing both students and staff) is more effective than testing only students or only staff.

2. **At low levels of community incidence, routine testing appears to have little impact on within-school transmission.** In low-incidence settings (for example, at or below 10 total cases per 100,000 people in the last seven days), routine testing has no impact on within-school transmission in at least half of the simulations run for certain testing strategies. In these simulations, one of the following occurred: (1) there were no within-school transmissions to begin with because of the other mitigation measures in place, or (2) symptomatic diagnostic testing alone was enough to reduce within-school transmissions to zero. These results indicate that the underlying level of Covid-19 spread is so limited in some scenarios that routine testing may not provide much additional benefit. However, schools may still choose to implement routine testing in order to strengthen or maintain community trust, track the incidence of infections within the school population for informed decision making, or provide additional protection as they consider relaxing other Covid-19 mitigation measures such as masking and distancing.

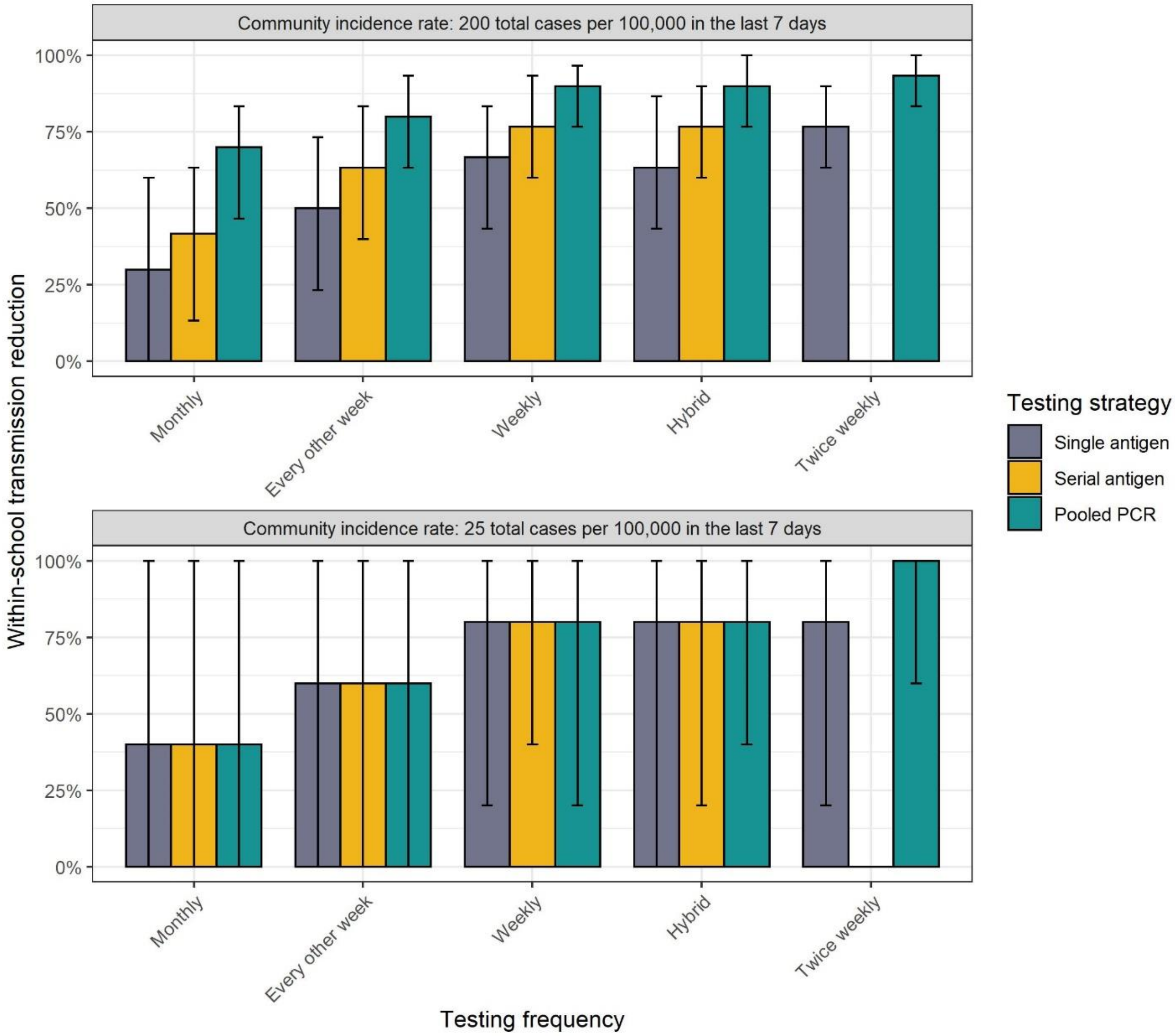
Differences in primary and secondary schools

Throughout this chapter, we focus on ABM findings in secondary schools. Findings in primary schools follow similar patterns, but differ in a few key ways:

- **Testing is more likely to reduce within-school transmission in secondary schools.** Impacts on within-school transmission are smaller in primary schools because of lower rates of susceptibility and transmission compared with older students, the size of the schools, and the smaller number of contacts that primary school students are likely to have.
- **Testing is also more likely to decrease in-person learning in secondary schools.** The impact of routine testing on in-person learning is also smaller in primary schools. Primary school students typically remain in a single classroom for the full day, but secondary school students may have several different classes in a day. Because students, teachers, and staff at a secondary school are therefore likely to interact with more people than those at a primary school, there is a smaller drop in in-person attendance for primary schools compared to secondary schools.

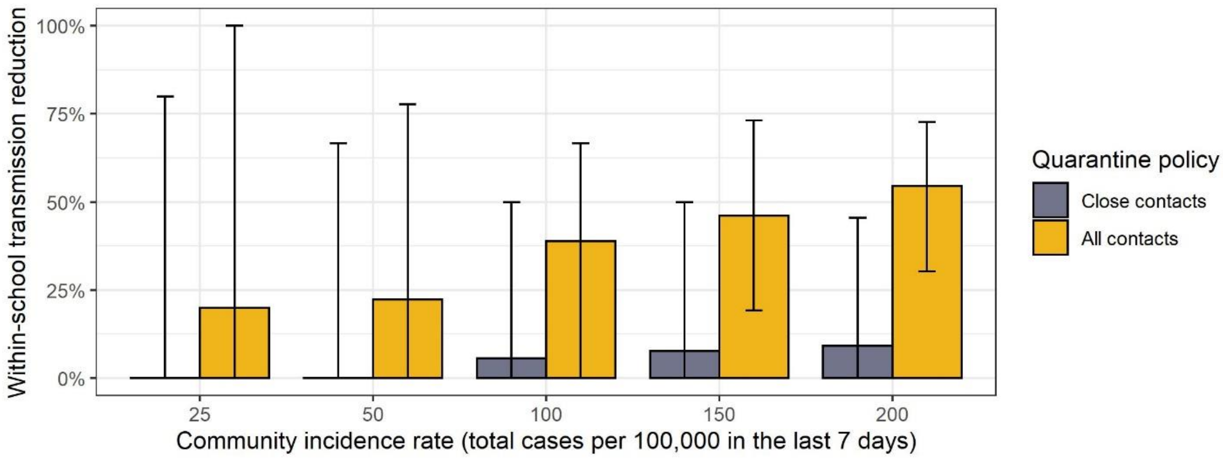
Impacts in primary schools can also be displayed in our interactive impact estimator.

Exhibit IV.2. Testing more frequently reduces within-school transmission



3. **Even without routine testing, symptomatic diagnostic testing paired with expansive quarantine policies can have a large impact on within-school transmission.** At moderate and high community incidence rates, expansive quarantine policies can achieve significant reductions in within-school transmission; for example, offering only symptomatic diagnostic testing (not routine testing) and quarantining all classroom and bus contacts ("all contacts") can reduce within-school transmission by up to 55 percent, whereas quarantining only close contacts ("close contacts") results in a smaller reduction (Exhibit IV.3). If transmission reduction is a school's primary concern and widespread or frequent routine testing is not acceptable or feasible, pairing symptomatic diagnostic testing with an expansive quarantining policy is an effective way to reduce within-school transmission. However, the large amount of in-person learning loss that would result from quarantining so many people may not be acceptable or feasible in many school settings.

Exhibit IV.3. Expansive quarantine policies can greatly decrease within-school transmission; the magnitude of impact increases with community incidence rate



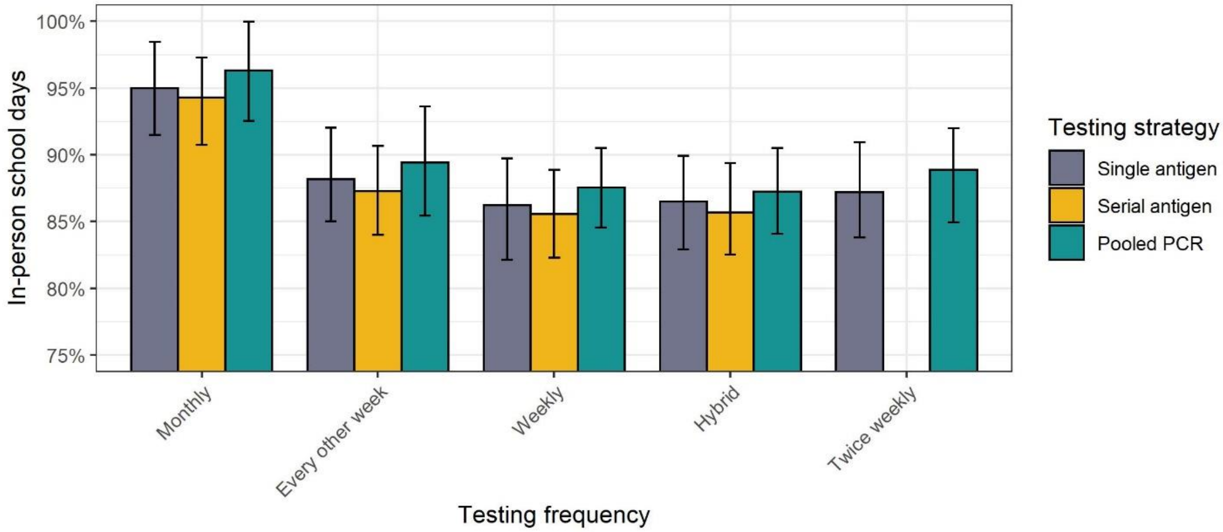
Trade-offs between reducing transmission and missed school days

> **There is a trade-off between within-school transmission and in-person school days. Schools can minimize this trade-off by offering immediate confirmatory PCR testing to avoid unnecessary isolation or quarantine for individuals with false positive routine testing results.**

Summary of findings. The routine testing strategies that are most successful at reducing within-school transmission identify more asymptomatic cases, leading to more people being asked to isolate or quarantine and thus causing more missed days of in-person learning. Because some tests are more likely to produce false positives, some of this in-person learning loss is unnecessary. However, effective routine testing strategies also decrease the risk of outbreaks that may force schools to close. Schools will need to weigh this tradeoff when making testing decisions.

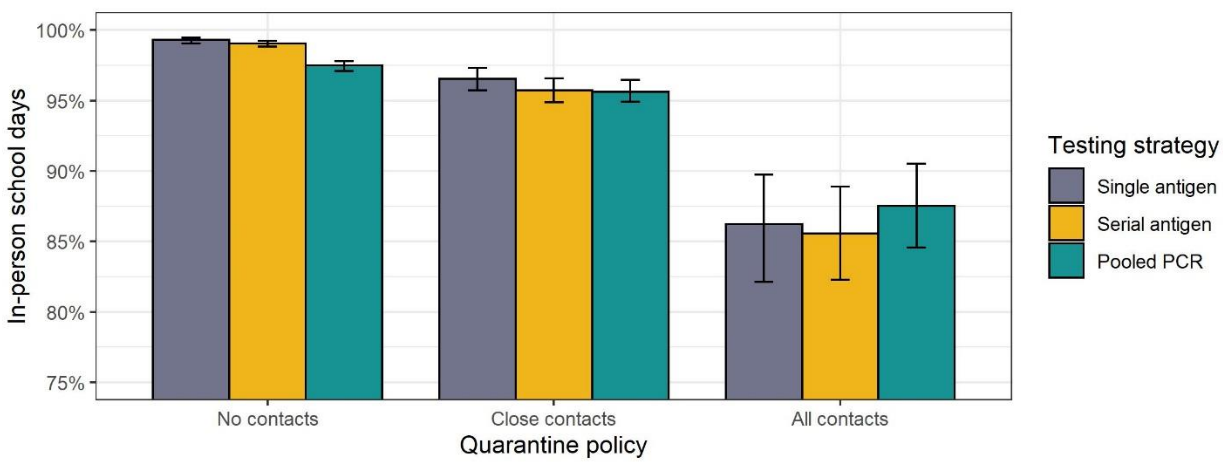
Ensuring universal, immediate access to confirmatory PCR testing minimizes the trade-off between within-school transmission and in-person learning. Routine testing helps identify infections that would otherwise remain undetected, requiring isolation and quarantining that would not take place without routine testing. However, routine testing can have relatively high false positive rates, resulting in unnecessary isolation and quarantine for those who receive a false positive test result and their contacts. If all positive routine test results are checked via an additional immediate confirmatory PCR test (when it is not already built in, such as reflex testing for pooled PCR), then isolation, contact tracing, and subsequent quarantining only occur for confirmed positives and their contacts, mitigating that trade-off considerably. For example, when confirmatory PCR testing is universally available, routine testing in a high school with a community incidence rate of 200 total cases per 100,000 in the last seven days and quarantining of all classroom and bus contacts decreases attendance by a maximum of 14 percent compared to diagnostic testing only (Exhibit IV.4).

Exhibit IV.4. Routine testing with confirmatory testing does not greatly decrease in-person school days compared to diagnostic testing only



Using an antigen-based testing strategy and avoiding quarantining contacts can help minimize missed in-person school days. As mentioned, pooled PCR is often more effective than antigen-based strategies at identifying infections that may otherwise go undetected, which means that schools using this approach will likely have to ask more students, teachers, and staff to isolate or quarantine. Similarly, expansive quarantine policies minimize the risk of transmission but also require many students and staff to miss school. Applying an antigen-based testing strategy and eliminating quarantine for contacts of infected individuals can minimize missed in-person school days that result from routine testing (Exhibit IV.5)—even though these strategies are less effective than pooled PCR testing and expansive quarantine policies at reducing within-school transmission and preventing outbreaks.

Exhibit IV.5. Not quarantining contacts can help minimize missed in-person school days



Another measure of effectiveness

To monitor their testing programs, pilot sites are collecting data such as participation rates, test positivity rates, and number of tests administered. As an added benefit, sharing this information has also helped build trust among students, staff, and their families that in-school learning poses minimal risk—a useful measure of testing programs' effectiveness. For example, Los Angeles' survey of parents and staff indicated that routine testing plays an important role in gaining parents' trust and comfort in sending their children to school. Louisville's learning hubs have not identified a single positive case through its school-based testing, which has helped parents buy into the importance of testing and other mitigation measures and feel safe sending their children to the learning hubs.

V. Key considerations for 2021–2022 school year

The disruptions to the 2020–2021 school year caused by the Covid-19 pandemic have had significant and wide-ranging impacts on students. Given the significant learning losses that the Covid-19 pandemic has already caused, the Centers for Disease Control and Prevention (CDC) is urging schools across the country to fully reopen in the fall.[8] As more students, teachers, and staff gather in schools, and as other mitigation measures such as mask mandates are removed, public health experts have acknowledged that routine testing can offer a critical layer of protection[9] and allow schools to safely remain open in the coming year. Ongoing routine testing will also be key to ensuring that schools remain relatively safe from Covid-19 transmission as new variants emerge and young children await access to vaccines. Below, we discuss overarching considerations and implications that can help guide other schools or school districts interested in applying lessons learned and emerging promising practices to the design and implementation of routine testing programs in the 2021–2022 school year.

Acceptability

Routine testing is most valuable when most people participate and when schools can use creative ways to reduce barriers to participation. Low and declining participation rates in routine testing programs are consistent with broader nationwide declines in testing as vaccinations have become available and case rates have fallen. At the same time, routine testing only effectively reduces transmission if a large fraction of the population participates. If routine testing can be made less burdensome for students, staff, and their families, they may be more willing to participate. Schools should also consider targeted opportunities to apply opt-out approaches to boost participation rates in some subpopulations, such as athletes or musicians. Furthermore, if testing policies can be set in advance of the 2021–2022 school year, providing students and families with time to digest the information and ask questions, more stakeholders may find these opt-out approaches acceptable. Where feasible, schools can also consider requiring that teachers and staff be tested in order to teach in person.

Even as the pandemic evolves, routine testing will be a key strategy for keeping schools safe in the fall—and trusted messengers and testing advocates should continue to emphasize this message before the fall. Many schools have already deployed trusted messengers, such as principals and other locally known school leaders, to communicate the details of their testing programs. These same messengers can now be used to proactively make the case for why routine testing still matters, to answer questions or address common misconceptions about testing before the next school year begins, and to set the stage for high participation in routine testing in the fall.

Feasibility

Schools can take advantage of new resources and supports by shifting the responsibility for school-based testing to local and state public health agencies. State departments of health across the country received a portion of the $10 billion in federal funding under the American Rescue Plan through the CDC Epidemiology Laboratory Capacity Reopening Schools awards to establish routine testing programs in schools.[10] Rather than

[8] https://www.nytimes.com/2021/07/09/health/cdc-schools-reopening-guidelines.html
[9] https://www.wsws.org/en/articles/2021/07/12/scho-j12.html
[10] https://www.cdc.gov/ncezid/dpei/pdf/guidance-elc-reopening-schools-508.pdf

continue to attempt to address the complex logistical and regulatory barriers to implementing school-based testing on their own, school administrators can increasingly rely on local and state public health officials to make coordinated decisions about testing and to leverage these new federal resources to provide funding and technical assistance to support ongoing testing. At least three pilot sites—Los Angeles, Rhode Island, and New Orleans—are partnering with their state departments of health to shift the oversight and authority for school-based testing to leverage this funding. Many pilot sites have advocated for this approach, noting that state and local public health authorities are better positioned to develop and run school-based testing programs than are individual school administrations. As public health officials take on more of the responsibility for school-based testing, tools such as our K–12 testing impact estimator can help them provide overarching guidelines and recommendations for the testing strategies that individual schools should implement.

To prepare for possible surges or other emerging needs in the fall, schools should consider keeping testing-related infrastructure and capacity in place to conduct surge testing or creating other contingency plans to rapidly scale up access to testing. Because case rates have fallen considerably in many communities, some schools and school districts are considering scaling back their routine testing programs in the fall. Although it may make sense for schools in some contexts to offer reduced testing at the start of the 2021–2022 school year, schools should consider maintaining testing capacity in the event that case rates rise. It remains unclear whether the U.S. will experience another wave of Covid-19 cases in the fall as new variants emerge and vaccination rates stabilize, but schools should be prepared for this possibility in order to avoid major disruptions to in-person learning. Los Angeles, New Orleans, and Rhode Island are all planning to keep a supply of BinaxNOW tests and testing sites on hold that they could quickly and easily access if needed. If maintaining testing capacity at school-based sites is infeasible, schools could also explore opportunities to partner with pharmacies or urgent care centers, which have more resources and lab capacity, to conduct surge testing.

Effectiveness

There is no one-size-fits-all approach to choosing the right testing strategy; schools must find their own balance between reducing within-school transmission and reducing in-person learning loss. The most effective routine testing strategies for reducing within-school transmission, feasibility and acceptability notwithstanding, also result in the greatest number of lost in-person school days. Each school district will have to consider the underlying level of risk in its community in order to decide which testing strategy to use. For example, if a community's risk level is very low in the fall, testing strategies that maximize in-person school days, like symptomatic diagnostic testing, may be preferable to strategies that reduce transmission more significantly but result in fewer in-person days. As the pandemic evolves and as schools' priorities shift, schools may find it necessary to revise their testing strategy. Although Mathematica's ABM results offer some general guidelines and considerations, we recognize that every individual school district's community context, access to resources, connections with public health experts and authorities, and capacity to implement testing will shape its decisions about whether and how to approach routine testing.

Schools may also need to account for the fact that, in many cases, routine testing is a key factor in building students' and staff's comfort with returning to in-person learning; even if the other benefits of testing are limited, schools may consider continuing to offer routine testing in the fall as a way of building goodwill and providing peace of mind to key stakeholders in the school community.

Looking ahead

Covid-19 presented all pilot sites, and many other schools across the country, with their first opportunity to develop and deliver health services in a school-based setting. Many school administrators and testing leads now see an opportunity to leverage this experience to provide other health services, such as flu shots, Covid-19 vaccinations or boosters, or other routine immunizations, to students, teachers, and staff in the future. Sites noted that schools are in a unique position to easily reach students if they have the necessary resources and tools. For example, in Washington, DC, the medical staff administering Covid-19 tests at the schools were also able to provide education on disease prevention and sexual health in conversations with students and staff. In other sites, school administrators' experience with Covid-19 testing strengthened their relationship with local health authorities; the stronger ties may allow them to offer additional school-based health services in the future. As school administrators and testing leads begin to look beyond the Covid-19 pandemic, they should capitalize on opportunities to apply the skills, capacity, and infrastructure developed through the pandemic to support and complement other important public health efforts.

"Schools have been able to demonstrate that, with the right tools and resources, there's this process that can serve schools and communities. How can we take this experience to give kids immunizations moving forward?"

– Testing lead, Washington, DC

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Appendix A.

Site Profiles

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Washington, DC

Site overview: In January 2021, the Friendship Public Charter School network piloted regular asymptomatic testing for all students. At the beginning of the program, Friendship worked with an external testing vendor, but it has since taken over sole responsibility administering tests to students and staff.

School status as of June 11, 2021: Schools have been open for in-person learning since March 29, 2021. Schools are approaching the end of the year and will have a summer testing program in place.

Number of participating schools: 8 Friendship schools.

Site timeline

December 2020
Drive through testing is launched at select school sites

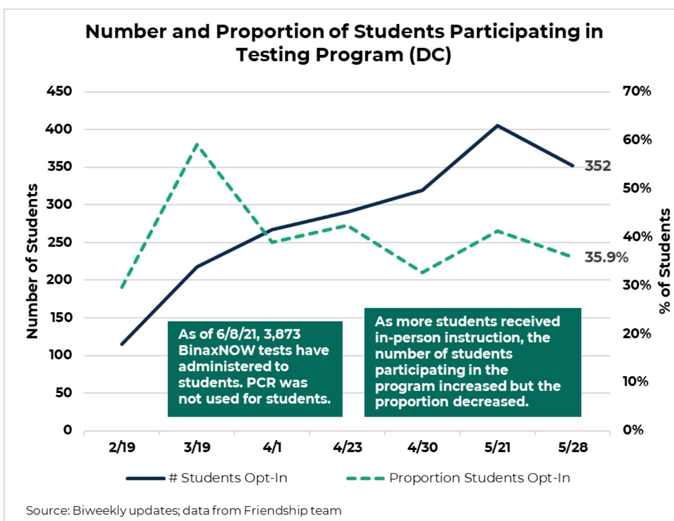
January 2021
Screening testing for students at learning hubs begins

February 2021
Screening testing for staff begins

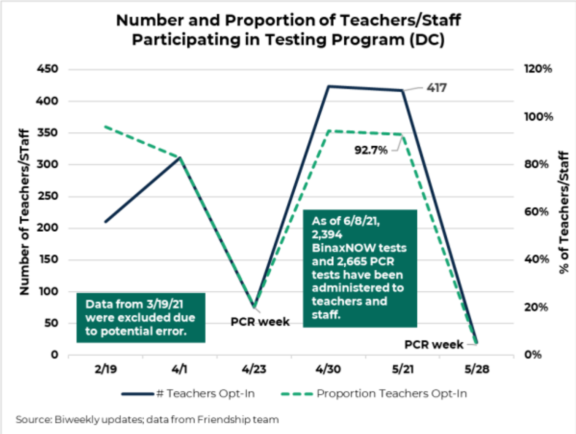
March 2021
All campuses return to in-person isntruction

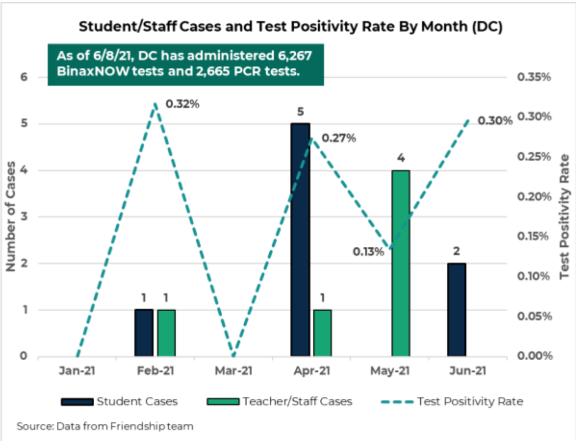
Testing plan	
Strategy	• Screening
Audience	• Students (optional) and staff (mandatory)
Frequency	• Students 1x/week; staff every other week
Location	• Designated testing rooms at participating learning hubs
Administrators	• Contracted nurses

Testing data (as of 5/24/21)	
Tests administered (1/29/21 – 6/8/21)	• BinaxNOW: 6272 • PCR: 2662
Proportion of students opted-in	• 41.3% (405/980)
Proportion of teachers/staff opted-in	• 92.7% (417/450)



Source: Biweekly updates; data from Friendship team





Lessons learned

Biggest wins:

- Students and staff have become familiar with antigen testing and have not shown signs of testing fatigue. Staff mentioned that the program has “created an environment that incentivizes testing.”
- Through its partnership with a testing vendor, Friendship has been able to employ additional health technicians to assist with testing efforts as more students and staff return.
- Friendship’s testing program has served as an example for other LEAs in the city. The team has had an impact at the regional and national levels by sharing lessons learned and logistical strategies with leaders interested in implementing school testing programs.
- Friendship’s approach is also being replicated internationally, in schools in Haiti and India.

Biggest challenges:

- Due to city requirements, large amounts of student data must be retained. Friendship reported that early guidance in procuring a data management system would have been helpful.
- Friendship is working to build trust around testing with families through various efforts, such as advertising campaigns, to increase participation in testing.
- Per DC law, Friendship must store all students’ testing medical records until the child reaches age 21 and is currently working to address this.

The data management side is important. If I had known how big it was going to be, or how long we would have to store the data, I would have advocated that we procure some kind of data management system.

–Testing Lead

Los Angeles, California

Site overview: In fall 2020, the Office of the Mayor, the County Department of Public Health, and the University of Southern California (USC) partnered to develop a community-based testing protocol for schools in Los Angeles. The university conducted key stakeholder interviews to develop the testing plan. In February 2021, due to school closures, the testing plan was piloted in alternative learning centers (ALCs). In March 2021, the pilot was expanded to include schools. Another goal of the pilot was to develop evidence on the accuracy of antigen tests in asymptomatic children.

School status as of June 11, 2021: Most Los Angeles Unified School District schools, and many private and charter schools, have been open for in-person learning. Schools are also required to offer a 100% distance learning option. Los Angeles continues to operate ALCs around the city through the end of the school year on June 11.

Number of participating schools: 60 ALCs (20 in a control group did not test) and 5 public high schools.

Site timeline

November 2020
Walk-up diagnostic testing centers are completed

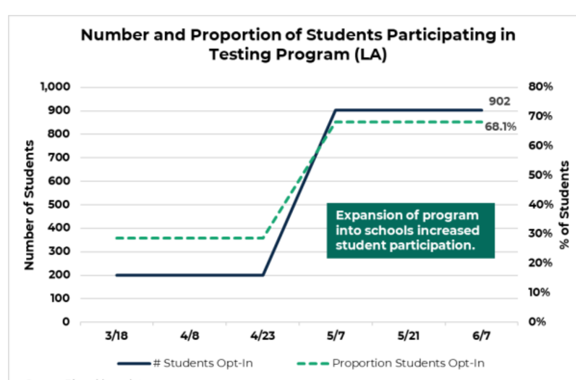
February 2021
Testing program at ALCs begins

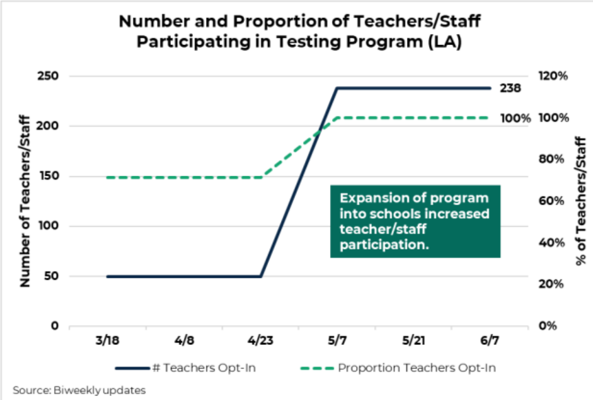
March 2021
Screening testing for student athletes begins

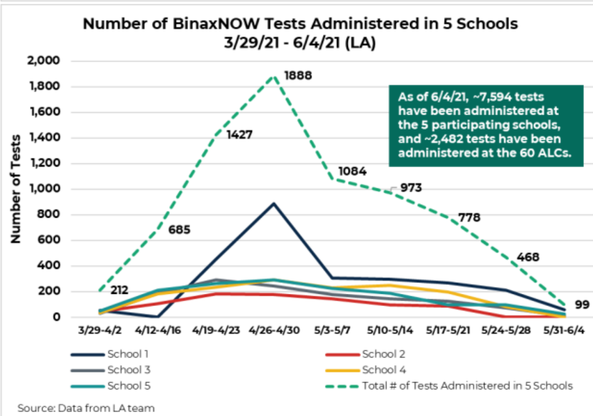
April 2021
Majority of LA schools open for in-person instruction

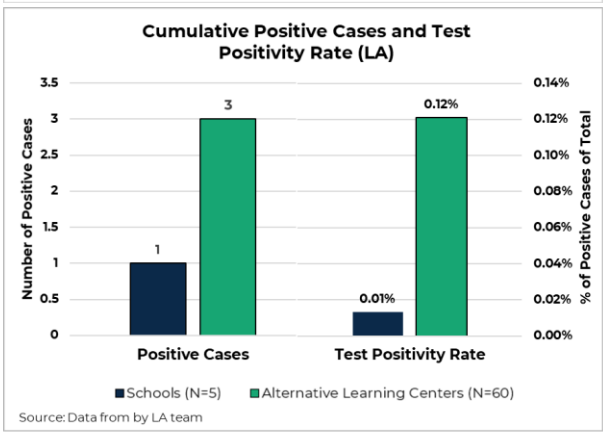
Testing plan	
Strategy	• Screening (complete) and diagnostic pilot program (complete)
Audience	• Students, staff at ALCs; student athletes at schools
Frequency	• 20 ALCs test 2x/week, 20 1x/week (20 also test 0x/week to serve as a comparison group in the pilot); testing frequency for athletes is based on the sport
Location	• ALCs; public high schools
Administrators	• Learning center staff; school staff

Testing data (as of 6/3/21)	
Tests administered	• 100% (20,000/20,000)
Number of students opted-in	• 100% (506/506) for athletes • 48% (396/818) for ALC students
Number of teachers/staff opted-in	• 100% (50/50) for coaching staff • 100% (188/188) for ALC staff









Lessons learned

Biggest wins:

- Significant support from partners, parents, and city government; many parents and students have expressed enthusiasm for testing and its role in promoting public safety.
- USC has obtained a Clinical Laboratory Improvement Amendment (CLIA) waiver for all current and future pilots, which allows for a simpler process to make the testing effort more scalable.
- A validation study on the accuracy of antigen tests in children was recently published as well as a toolkit with instructions and resources to help schools create and implement their own respective screening plans.
- The implementation pilot and the focus groups have allowed the team to understand what works and how to improve future testing efforts. Best practices have been shared with other schools and will inform summer testing programs.

Biggest challenges:

- Logistical barriers (e.g., CLIA waiver, IRB approval, training staff, resource constraints, etc.) were difficult to resolve at the beginning stages of the program.
- The LA team is planning for summer programs which will begin in June 2021. They are still working on the study design for the summer pilot programs, which may impact the IRB approval process and the overall start date.

[Testing] creates the perception of increased safety, especially in underserved communities. It's important to test every week to know it's a safe environment.

–Testing Lead

Louisville, Kentucky

Site overview: In fall 2020, the Jefferson County Public School District (JCPS) partnered with community organizations to launch learning hubs to facilitate distance learning for families that cannot stay home with their students. Louisville originally piloted an asymptomatic antigen testing program in these learning hubs that has since scaled up to include additional regional testing sites in middle and high schools.

School status as of June 11, 2021: In-person hybrid.

Number of participating schools: 12 regional testing sites in middle/high schools, 17 learning hubs; Central Office Nutritional Center.

Site timeline

Fall 2020
JCPS launches learning hubs

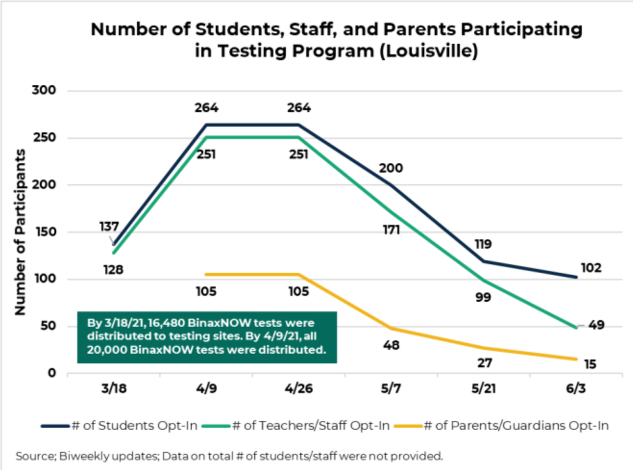
February 2021
Screening testing at learning hubs begins; Surveillance testing for nutritional staff begins

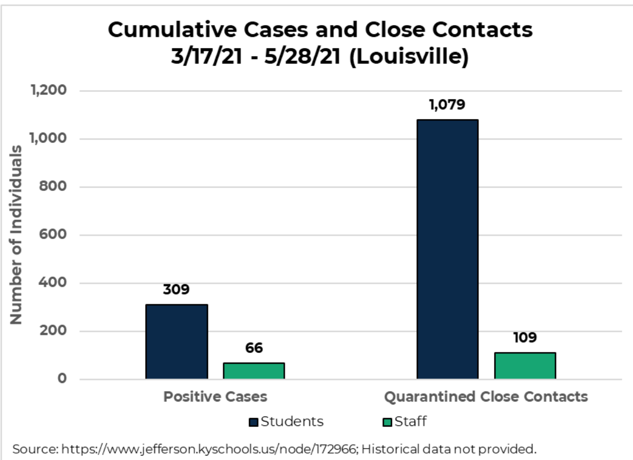
March 2021
Elementary schools return to in-person instruction

April 2021
Middle and high schools return to in-person instruction

Testing plan	
Strategy	• Screening testing for students and staff at learning hubs • Surveillance testing for JCPS nutritional staff
Audience	• Learning hub students and staff; JCPS nutritional staff
Frequency	• Learning hubs/schools test 1x/week; Nutritional Center tests 2x/week
Location	• Learning hubs; Central Office Nutritional Center
Administrators	• External testing vendor

Testing data (as of 6/3/21)	
Tests administered (1/29/21 – 6/9/21)	• 100% (20,000/20,000) have been distributed to sites
Number of students opted-in	• 102
Number of teachers/staff opted-in	• 49
Number of parents/guardians opted-in	• 15





Lessons learned

Biggest wins:

- JCPS has maintained positive relationships with its testing vendor and the community learning hub directors, which has allowed the expansion to the 12 regional sites to run smoothly. Engaging community partners provided a layer of trust and credibility.
- By testing nutrition staff, the school cafeterias could stay open to provide food to students and families as needed. Testing enabled the district to quickly identify and respond to an outbreak among this group.
- There have not been major staff capacity issues in regard to testing administration.

Biggest challenges:

- There is continuing concern from families and staff around issues related to testing and possible need for isolation and quarantine. For example, if families are told to self-isolate or self-quarantine, they might not have access to essential services such as groceries and medication. Louisville Metro Government (LMG) is working to address this by providing wraparound services for affected families.
- There have been decreases in testing throughout the county, which is likely due to increased vaccination rates and reopening efforts. JCPS is currently making updates to the registration site and communications plan to boost testing participation and address parental consent concerns. The city has also developed a video to encourage testing and communicate its importance to families.

> **There are lots of different reasons [people don’t participate in testing.] People are worried about having to quarantine and all the difficulties that go with it. People are worried about the invasiveness of the test. We need strong communication between trusted learning leaders and parents.**
>
> ***–Testing Lead***

Tulsa, Oklahoma

Site overview: In the fall of 2020, the Tulsa Public School District (TPS) began testing a small cohort of elementary school teachers using BinaxNOW. In December they expanded testing to all TPS employees who opted-in to the testing program. About 850 teachers (16%) opted-in to this voluntary testing program during the pilot phase. In December 2020, they had 16 staff testing locations. Lessons from that pilot were used to help launch asymptomatic testing at all schools in the district (70 schools) after in-person learning resumed for all grade levels. The Tulsa Public School (TPS) school board shifted the start of in-person instruction from March 22nd to February 22nd because of input from the community, which impacted the timeline of the program. On March 11th, TPS started doing diagnostic testing of students. In April, TPS signed a contract with a vendor that will assist with data management, Project Beacon.

School status as of June 09, 2021: TPS continues to have 16 screening locations for weekly testing of staff. They also have diagnostic testing available for students and staff at 68 school locations which will be administered by the school nurses as needed. All schools are in-person.

Number of participating schools: 68 school sites.

Site timeline

November 2020 CLIA Waiver applied for and accepted for school testing

December 2020
BinaxNOW diagnostic testing pilot starts with participating staff and teachers in schools

January - February 2021
Schools are virtual post-holidays; fully reopen by February 22

March 2021
Student diagnostic opt-in testing goes live

Testing plan	
Strategy	• Screening and diagnostic opt-in testing for staff before in-person learning started in Spring of 2021 • Screening and diagnostic opt-in testing for student began March 2021
Audience	• All TPS staff and students
Frequency	• Testing was made available daily at 68 school sites from 9 – 11 am and as needed outside of that time frame
Location	• On site across Tulsa metro
Administrators	• School nursing staff

Testing data (as of 6/9)	
Tests administered, students	• 625
Tests administered, staff	• 1,356
Number of students opted-in to testing program	• 600+
Proportion of teachers/staff opted-in to testing program	• 25.3% (1,364 / 5,400)

Lessons learned

Biggest wins:

- Teachers and staff embraced testing early on.
- District has worked closely and strongly with the Tulsa Health Department in the testing program ensuring the safety of kids at every decision made.
- Testing enabled confidence to reopen schools in the safest way possible.
- Successfully launched and integrated the data management vendor's platform (Project Beacon) within TPS procedure. This enabled them to capture testing data and report out test results. The Navica app developed by Abbott was not able to do this effectively since it was designed for single-test use.
- Nursing staff has successfully administered testing at school sites. In addition, they have dedicated nursing staff willing to conduct testing for summer school programs.
- TPS team members have worked well together to implement testing.
- Quickly secure the CLIA lab waiver.

Biggest challenges:

- TPS had to report results to the State Department of Health (one record at a time) within 24-hours of testing. This was a challenge before the Project Beacon platform was put in place.
- Decisions on when to open the schools to in-person wavered back and forth in the spring of 2021. This required changing the timeline for the testing program.
- Back-end of the data aggregation system for the BinaxNOW testing program posed challenges which were solved by the Project Beacon platform.
- Staff turnover has been high.
- Less students opting-in for program testing due to being vaccinated.

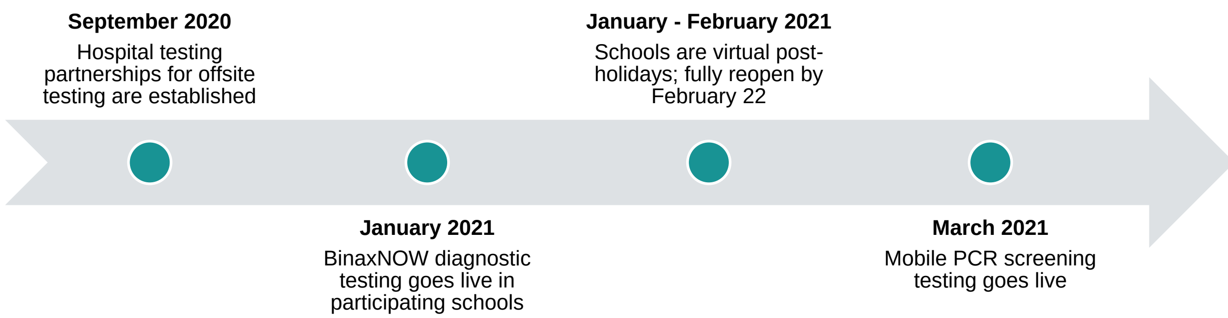
New Orleans, Louisiana

Site overview: New Orleans Public Schools (NOLA PS) is made up of more than 70 public charter schools. The district added antigen testing to its existing school-based testing program in January 2021 in 38 K-12 school sites. In fall 2020, ahead of launching the antigen testing program, the district distributed its allocation of 20,000 BinaxNOW tests to at least 70 school sites. School nurses administer tests to symptomatic students and staff as needed for diagnostic purposes. NOLA PS added a mobile PCR screening testing component to the program at the end of March. The district plans to implement PCR testing for a minimum of eight weeks. An external vendor administers the mobile PCR tests to students and staff every two weeks.

School status as of June 04, 2021: Elementary schools: in person; middle and high schools: in person/hybrid.

Number of participating schools: 38 (BinaxNOW); 33 (PCR).

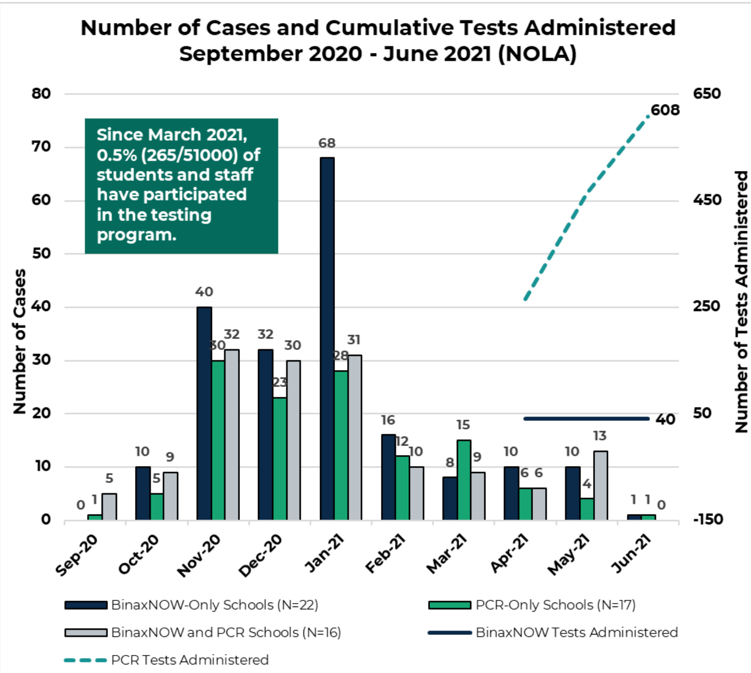
Site timeline



Testing plan	
Strategy	• Diagnostic on site using BinaxNOW tests • Diagnostic off site through defined hospital partnerships • Screening using a mobile PCR test vendor
Audience	• Students and staff for all testing strategies
Frequency	• As needed for diagnostic purposes • Screening testing is every two weeks
Location	• Diagnostic tests (BinaxNOW) administered in school nurse's offices on site • PCR tests for screening offered via mobile testing vendor at rotating locations
Administrators	• BinaxNOW tests administered by on-site school nurses • PCR tests administered at local hospital for diagnostic purposes or by mobile testing vendor for screening program

Testing data (as of 6/4)	
Tests administered, students and staff	• Total BinaxNOW tests: 40 (January to May) • Total PCR screening tests: 465 (March 29 to May)
Number of students and staff opted-in to testing program	• 265 (total population of students and staff attending in person varied significantly across the year)

Note: Disaggregated data showing number and proportion of students and teachers/staff were unavailable.



Source: https://nolapublicschools.com/covidtracker; biweekly updates

Lessons learned

Biggest wins:

- Schools are using one to three BinaxNOW testing kits per week for symptomatic people.
- Demand for mobile PCR testing is high among teachers and staff, especially after vacation days.

Biggest challenges:

- Resolving legal complications of the school district owning implementation of health programming has been challenging, including protecting data privacy and reporting of testing results.
- Student participation has been limited.
- Accessing funding for high quality PCR tests is an ongoing challenge that might limit the district's ability to extend testing into the 2021–2022 school year.
- Facing legal and contractual complications to combine testing program with vaccination services.
- Providers, funders, and state agencies are focused either on testing or vaccination, but not on the holistic approach to the pandemic.

Our overarching goal is seeing what we can do to increase study participation in testing and how we can leverage testing to encourage vaccination. The critical move that needs to happen is that testing and vaccination can't occur in silos but need to be a single strategy and a larger component of your COVID-19 response strategy.

–Testing Lead

Rhode Island

Site overview: Rhode Island has an off-site testing program for K–12 students and families. The state used BinaxNOW tests to pilot on-site testing in two or three schools in Central Falls District that had a consistently high rate of test positivity and serve a high-need population. The lessons learned from the pilot sites helped expand asymptomatic testing in K–12 settings. Rhode Island started its antigen testing program in December 2020 with supplementary tests provided by the state. In early February, it finished onboarding opt-in schools for the BinaxNOW testing program. It continues to support those schools with technical and material support. The number of schools participating in the BinaxNOW testing program increased from 78 to 109 from February to April 2021. Rhode Island onboarded these schools and continues to support them with technical and material support. Starting May 18, they will begin a four-week pooled testing pilot to determine the viability of using this as an additional sentinel testing option for schools. The testing program plans to support summer activities for local education agencies (LEAs) and communities.

School status as of May 23, 2021: Elementary and middle schools: in person and hybrid; high schools: hybrid.

Number of participating schools: 109

Site timeline

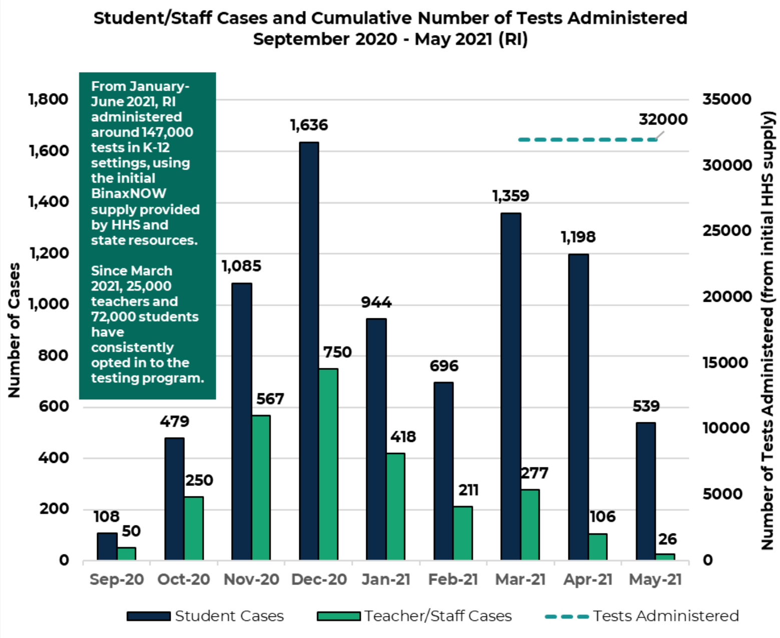
October 2020
Schools reopen for in-person instruction

December 2020
BinaxNOW screening testing begins

May 2021
Begining a pooled testing pilot program

Testing plan	
Strategy	• Screening
Audience	• Students and staff
Frequency	• Weekly and event driven (e.g., school functions, graduations)
Location	• 78 LEAs covering students from 109 participating schools
Administrators	• Emergency medical technicians, school staff, and volunteers

Testing data (as of 5/23)	
Tests administered	• 147,000 tests using HHS supply and state resources (~32,000 of initial HHS supply of 40,000)
Proportion of students opted-in to testing program	• 55.4% (72,000 / 130,000)
Proportion of teachers/staff opted-in to testing program	• 50% (25,000 / 50,000)



Source: Data from RI team; biweekly updates

Lessons learned

Biggest wins:

- Despite continued vaccinations, even among educators, there is still support for continued access to testing.
- School participation increased from 78 to 109 sites. Looking to expand testing to event-based testing (e.g., graduations, athletic events)
- There were no significant outbreaks or disruption in the in-person and hybrid settings, despite decreased testing demand.
- Central Falls School District staff credit its low positivity rate (.21%) and zero in-school transmission cases to strong communications, processes, structures, and commitment to creating safe and healthy learning environments.
- Additional access to BinaxNOW tests through this pilot project allowed Rhode Island to expand the project to support testing in other K-12 schools.
- Schools are conducting an average of 8,000-10,000 BinaxNOW tests per week.

Biggest challenges:

- Decreasing levels of students and staff consenting and participating in ongoing testing efforts is proving to be a challenge.
- Some LEAs still struggle with staffing and workload to support regular screening tests.

Parents are tired of testing and it is occurring in parallel with vaccine rollout and the dropping of the vaccine eligibility age. We are seeing a shift toward testing for specific events like athletic events or graduations versus broader population surveillance.

–Testing Lead

Appendix B.

Supplemental Exhibits

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Appendix Exhibit B.1. Stakeholders interviewed, by pilot site

Site	Stakeholders interviewed
Rhode Island	• Medical Director • Senior Project Manager
Los Angeles, CA	• Principal Investigator from USC leading qualitative study of pilot testing program • Project Director, USC • Deputy Director, Office of the Mayor • Professor and Vice Dean of Research, USC
Louisville, KY	• Manager, District Health Services, Jefferson County Public Schools • Chief, Accountability, Research, and Systems Improvement, Jefferson County Public Schools • Director of Academic Project Management, Jefferson County Public Schools • Executive Consultant, City of Louisville
New Orleans, LA	• Covid-19 Testing Coordinator • Chief School Support and Improvement Officer
Tulsa, OK	• Project Manager overseeing testing effort • Resource Development Manager for local health department • Director of Data Strategy at the school district
Washington, DC	• Chief Executive Officer • Chief of Staff • Director of Health Services • Chief Performance Officer
SHIELD at University of Illinois at Urbana-Champaign	• K–12 School Testing Program Coordinator • Associate Professor, Epidemiology
Johns Hopkins Safe Tribal Schools Program	• Associate Scientist, Center for American Indian Health

Appendix Exhibit B.2. Pilot site dashboards

Pilot site	Description	Source
Rhode Island	RI provided longitudinal data on confirmed student and staff cases from September 2020-May 2021.	Data provided by RI team
Los Angeles, California	LA provided cumulative data on total participation, tests administered, and confirmed cases in ALCs, as well as longitudinal data from participating school sites on cases and tests administered.	Data provided by LA team
Louisville, Kentucky	Louisville's public dashboard is updated every Friday and provides data on number of confirmed cases and quarantined close contacts for both students and staff in Jefferson County Public Schools.	JCPS Covid-19 Dashboard
New Orleans, Louisiana	NOLA's public dashboard is updated every Monday and provides longitudinal data on confirmed cases in the district. It also provides cumulative data on student and staff cases.	NOLA Public Schools Covid Case Tracker
Washington, DC	DC provided longitudinal data on student and staff cases, tests administered, and type of test conducted (BinaxNOW or PCR) from January 25, 2021, to June 8, 2021.	Data provided by DC team

Appendix C.

Agent-based Modeling: Approach, Methods, Assumptions, and Inputs

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Approach

Scenarios are defined by a school type, contact quarantine policy, community incidence rate, and testing strategy. Testing strategies are diagnostic testing only or diagnostic testing combined with screening testing where screening testing varies by the population tested, frequency of testing, and test type used. The parameter values for each of these inputs are described in Appendix Exhibit C.1. In total, valid combinations of those parameters led to 924 simulated scenarios.

Appendix Exhibit C.1. Testing scenario parameters used in ABM

Parameter category	Possible values
School type	(1) Elementary (2) Middle/High
Contact quarantine policy	(1) No quarantining of contacts (2) Only close contacts within 6 feet (3) All classroom and bus contacts
Community incidence rate (cases per 100,000 in the past week)	(1) 5 (2) 10 (3) 25 (4) 50 (5) 100 (6) 150 (7) 200
Diagnostic Testing	(1) On
Screening Testing strategy	
Test type	(1) No screening testing (2) Single antigen (3) Serial antigen (4) Pooled PCR
Tested population	(1) Students (2) Teachers, administrators, and staff (3) Students, teachers, administrators, and staff
Testing frequency	(1) Twice weekly (2) Hybrid (3) Weekly (4) Twice monthly (5) Monthly

Methods

ABMs' ability to model complex interactions among individuals differentiates ABMs from top-down epidemic models (Dimitrov and Meyers 2010). Therefore, ABMs are ideal for informing policy decisions that influence complex social systems, such as the interactions among members of a school community and the spread of Covid-19 among them (Willem et al. 2017). An ABM allows investigators to leverage their expertise about complex social systems by enabling the explicit inclusion of important societal structures (such as a high degree of contact among students in the same classroom) into the model. Furthermore, policymakers must consider these societal structures in the measurement and evaluation of interventions targeted at mitigating the spread of Covid-19 (such as physical distancing and self-isolation) to obtain valid results (Lai et al. 2020).

The ABM comprises four key components: specifying (1) the agents, (2) interactions among the agents, (3) transmission between agents, and (4) disease progress of an infected agent. As discussed in the main text, here the agents are categorized into three types: students, teachers, and other staff. The model assumes students attend grades K–5 for elementary school, 6–8 for middle school, and 9–12 for high school.

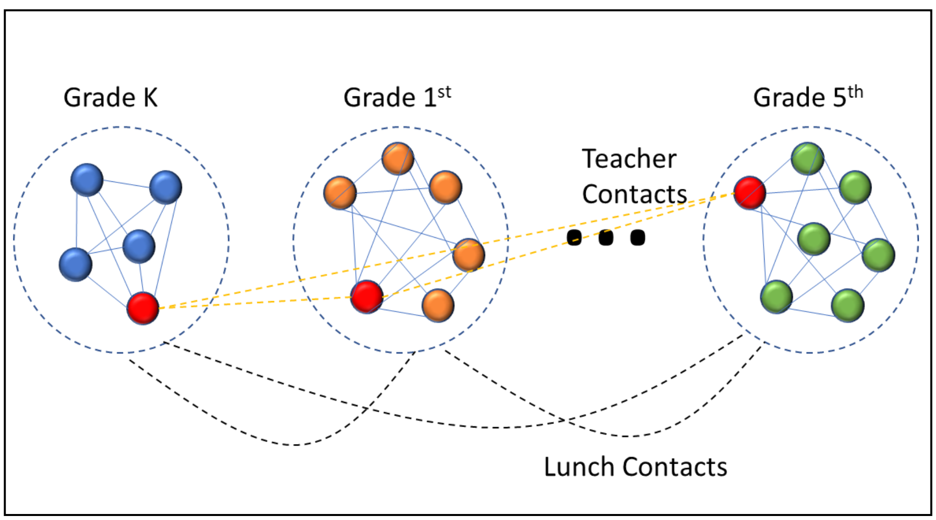
The number of students by grade and the number of teachers and staff are specified in Appendix Exhibit C.4. Each elementary student is assigned a single class, whereas high school students are assigned six classes that they attend each day; all classes are assumed to contain the same number of students. High school students are assigned their six classes and classmates at random (within grade), which results in students of the same grade randomly mixing across their classes. A single teacher is assigned to each of the classes. A percentage of students is assigned to ride the school bus. All school buses are assumed to transport the same number of students, randomly distributed across grades and classrooms.

The ABM includes the four types of interactions (second component) listed below.

- **Classrooms**: During each in-person school day, all students within the same class interact with each other. The students also interact with the single teacher in the classroom. Students in middle or high school interact this way in each of their classes during each in-person school day.
- **School bus**: During each in-person school day, all students within the same bus interact with each other.
- **Lunch/recess**: During each in-person school day, students interact with students in the school. The number of interactions for a student during a day is governed by a negative binominal distribution ($r = 5$; $p = 0.1$). The students that a particular student interacts with change each day. For all results shown, we assume that lunch/recess occurs among a single class.
- **Teachers, administrators, and support staff**: During each school day, teachers and staff can have contact among themselves; this is in addition to teachers interacting with students in their classroom (see classroom interaction above). The number of interactions a teacher has with other teachers is governed by a negative binominal distribution ($r = 5$; $p = 0.625$). The same holds for the number of interactions for a teacher with staff and for a staff member with other staff.

Each individual also has a probability of acquiring Covid-19 from interactions outside the school community (that is, other than in the school or on the school bus). This probability represents the background risk of acquiring Covid-19 from their non-school community and is in addition to the four types of interactions (described above) among the school population.

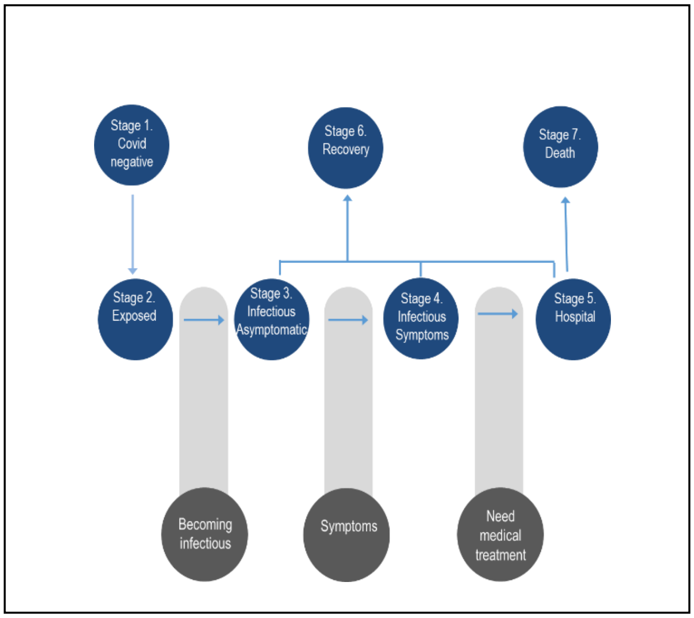
Appendix Exhibit C.2. Illustration of a potential contact network for a K–5 school



Appendix Exhibit C.2 shows an illustration of interactions for a K–5 school for the classroom, lunch/recess, and teacher contacts (bus and administrators/support staff contacts are not shown).

The third component is the transmission of Covid-19 between agents. Each type of interaction has a probability of transmitting Covid-19 from an infected to an uninfected individual; this probability can be modified based on characteristics of the individual (such as student versus adult and asymptomatic versus symptomatic) as well as precautions taken by the individual (such as adhering to six feet physical distance and wearing masks). The transmission probabilities for each interaction are provided in Appendix Exhibit C.5, which also includes modifications based on characteristics and precautions. In addition to the interactions listed above, students, teachers, administrators, and support staff can also acquire Covid-19 outside the school based on a community-level infection rate.

Appendix Exhibit C.3. Model for Covid-19 stages of care and possible transition pathways between stages



The model also simulates an individual's disease progression. The progression is based on a Susceptible-Exposed-Infectious-Recovered epidemic model, which is commonly used to model Covid-19 (Prem et al. 2020). Specifically, an individual progresses through seven stages: (1) Covid-19 negative; (2) Covid-19 positive incubation; (3) infectious but asymptomatic (for individuals that ultimately develop symptoms, this would be their presymptomatic phase); (4) infectious with symptoms; (5) hospitalized; (6) recovery; and (7) death. Individuals contribute to the accrual of the first five infected cases once they transition to Stage 2 from Stage 1. Once an individual transitions into Stages 5, 6, or 7, they do not infect other individuals in the school. Only individuals in Stage 4 are able to self-isolate (that is, remain at home).

Each day, an agent either remains in the current stage or transitions to another stage. Appendix Exhibit C.3 depicts these stages as well as possible transition pathways between stages. Individuals stochastically transition between stages in daily increments. The daily probability of moving from Stage 1 (uninfected) to Stage 2 (exposed) is determined by the values shown in Appendix Exhibit C.5. The daily probabilities of an exposed person with Covid-19 transitioning from Stage 2 to Stage 3 (that is, being asymptomatic but infectious) follows a geometric distribution based on Imperial College London's estimate that the mean time from exposure to infectiousness is 4.6 days (Ferguson et al. 2020). Once an individual enters Stage 3, they can recover (Stage 6), develop symptoms (Stage 4), or remain in Stage 3. The daily probability of transitioning from Stage 3 to Stage 4 is based on a geometric distribution derived from Imperial College London's estimate of an average of half a day from infectiousness to symptoms for those who become symptomatic (Ferguson et al. 2020).

We have relied on estimates from CDC and the Office of the Assistant Secretary for Preparedness and Response to assume that 50 percent of students and teachers/staff are asymptomatic for the entire duration of their infection (CDC 2020b); asymptomatic individuals transition directly from Stage 3 to Stage 6. The remaining 50 percent of students and teachers/staff eventually develop symptoms, which transitions them to Stage 4. If an individual is in Stage 4, they can recover (Stage 6), require hospitalization (Stage 5), or remain in Stage 4. Only if an individual enters the hospital can they move to Stage 7 (death). For children, hospitalization and death are very rare. Additional information on the probabilities related to progression through the stages is available on request.

Integrating the fourth component (disease progress of an infected agent) with the other three components is necessary to simulate the spread of Covid-19 as well as strategies to mitigate the spread. For instance, the simulation must know whether an individual is in the infectious phase (specifically, Stages 3 or 4) when they have an interaction with other members of the school. All the code and data visualizations were created in R (R Core Team 2020).

Assumptions

Whether an infection occurs in any particular school is partly a function of random factors. One of the advantages of ABMs is that they can incorporate random variation. As a result, multiple simulations of an ABM will produce different results even when scenario parameterizations are identical. To account for random variation in ABM results, we ran 200 simulations of each scenario at each school level for every combination of variables. For each of the combinations of variables, we show median results across the 200 simulations. We also show the upper and lower boundaries for 90 percent of simulations, using the 5th and 95th quantile results of those simulations. These bars provide information on the range of outcomes likely to be experienced by similar schools.

Apart from school characteristics and random variation, the ABM assumes that transmission rates vary systematically by the amount of time spent with an infected person (for example, one class period or bus ride versus a full day); the type of individuals in the interaction (children or adults); and whether masks are worn. The transmission probability is not modified by distance away from the infected person, a conservative assumption based on guidelines from Bazant and Bush (2021). Our analyses assume that both students and staff wear masks on the bus and in school, in a nod to the growing public consensus about the value of masks. In light of findings about the relative susceptibility of younger versus older children (Park et al. 2020), secondary students are assumed to be as susceptible as adults, whereas elementary students are assumed to have half the susceptibility as adults. Appendix Exhibit C.5 provides values for the transmission probabilities used in the model, which are derived from available external evidence on Covid-19 and mitigation factors.

Various testing strategies and contact quarantining policies overlay the base model structure discussed above in order to address the potential effectiveness of testing in the presence of those policies. Pilot sites provided information on the testing approaches and contact quarantining policies considered (Exhibit 13 contains a full summary of those parameterizations). Appendix Exhibit C.6 provides values associated with testing, tracing, and quarantining assumptions.

Testing strategies in the model are composed of three primary components: test type, testing frequency, and target population. Serial antigen testing is implemented as back-to-back single antigen testing (for example, weekly serial antigen testing means single antigen testing on Monday and Tuesday). The pooled PCR scenarios are implemented differently when the target population for testing includes teachers and staff. Students are in fixed pools, defined by student homerooms that are 27 students in size, and teachers and staff receive single antigen tests. Therefore, pooled PCR does not have a scenario targeting just teachers and staff. For each test type and frequency combination, testing is assumed to occur on the first day of the period or equally distributed over the school days of the period (for example, weekly testing always occurs on the first day of the week and that day is considered to be Monday, whereas twice weekly occurs on days 1 and 3, or Monday and Wednesday). Twice weekly serial antigen testing was not considered feasible since it would result in testing four out of five school days each week. The hybrid testing frequency is twice per week testing for adults and weekly testing for students. Following CDC guidelines for screening testing in schools, asymptomatic positive tests are followed by a confirmatory PCR prior to contact tracing and quarantining.[11] Finally, the model assumes 100 percent participation in testing by the targeted population.

Contact quarantining policies vary by the number of contacts quarantined, including none, close contacts only (as defined by the CDC[12] to mean within six feet of an infected person for a cumulative total of 15 minutes within 24 hours), and all classroom and bus contacts. Close contacts are identified in the model as a stochastically defined subset of all classroom and bus contacts of an infected individual. Each contact has a probability of being a close contact each day they interacted with the positive individual up to two days prior to administration of the test with a positive result. Based on pilot site feedback, probabilities for the close contacts only quarantine policy were chosen to target an average of 2 close contacts per class or bus for an overall average of 12 or 14 close contacts per positive case, depending on whether or not the positive individual rides a bus. Based on feedback from pilot sites and experts, all of the primary school scenarios assume quarantining of all class and bus contacts.

[11] CDC: Operational Strategy for K–12 Schools Through Phased Prevention from https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/operation-strategy.html
[12] CDC: Resources for health departments, Contact Tracing: Case Investigation & Contact Tracing Guidance: Appendix A from https://www.cdc.gov/coronavirus/2019-ncov/php/contact-tracing/contact-tracing-plan/appendix.html#contact

Inputs

Appendix Exhibit C.4. ABM inputs for the characteristics of students, teachers, and support staff (reprinted from Gill et al. 2020)

Category	Parameter	Estimates
Elementary school: total number of students in per grade	Kindergarten	71[1]
	1st grade	75[1]
	2nd grade	75[1]
	3rd grade	75[1]
	4th grade	75[1]
	5th grade	75[1]
High school: total number of students in per grade	9th grade	214[1]
	10th grade	214[1]
	11th grade	214[1]
	12th grade	214[1]
Students per class	K–5	21[2]
	9–12	27[2]
Professional and support staff per primary school	Teachers	29[3]
	Administrators and staff	29[4]
Professional and support staff per high school	Teachers	56[3]
	Administrators and staff	56[4]
School bus	Students per bus	29[5]
	Percent riding the bus	55%[6]

[1]Source: National Center for Education Statistics (https://nces.ed.gov/pubs2011/pesschools09/tables/table_05.asp).

[2]Source: Digest of Education Statistics. National Center for Education Statistics. (https://nces.ed.gov/programs/digest/d14/tables/dt14_209.30.asp?current=yes).

[3]Source: National Center for Education Statistics (https://nces.ed.gov/programs/digest/d17/tables/dt17_601.50.asp)

[4]Source: Loeb, S. "Half the People Working in Schools Aren't Classroom Teachers—So What*?"* Washington, DC: Brookings Institution, January 2016. Available at https://www.brookings.edu/research/half-the-people-working-in-schools-arent-classroom-teachers-so-what/). Retrieved May, 31, 2017.

[5]Source: National Center for Education Statistics (https://nces.ed.gov/fastfacts/display.asp?id=67)

[6]Based on assuming that the 500,000 school buses in the United States (https://www.atu.org/work/school) run two routes per day.

Appendix Exhibit C.5. ABM inputs for the transmission probabilities

Category	Parameter	Parameter value
Daily transmission rate for symptomatic adults per contact	Within classroom per period	0.16%[1]
	At lunch or recess	0.16%[2]
	Among teachers, administrators, and staff at meetings	0.22%[3]
	On school buses	0.16%[4]
	Outside of school	Varies depending on local infection rate
Proportion asymptomatic	Children	50%[5]
	Teachers, administrators, and staff	50%[6]
Reduction in transmission	Infected individual is asymptomatic	50%[7]
	Infected and noninfected individual wearing a protective mask	40%[8]
	Infected individual practicing physical distancing (6 feet)	75%[9]
	Relative susceptibility of elementary school children versus adults of acquiring Covid-19	50%[10]
	The proportion of infected individuals that would self-isolate if they present with symptoms	100% of staff; 100% of students
	Proportion of positive test results reported to school	100% of staff; 100% of students

[1]Converted to a daily transmission probability based on a secondary attack rate of 12.8 percent for individuals with frequent close contacts (Bi et al. 2020). Assumes an entire school day is equivalent to having frequent close contacts with an individual.

[2]There is limited data on transmission rates due to contacts during lunch and recess. The only study we identified calculated a daily transmission probability of approximately 12 percent for its specific setting (Lu et al. 2020). However, this estimate is probably high because of selection bias in the settings investigated. To be conservative in estimating the impact of Scenario B, we set the daily transmission probability to be equivalent to estimates for individuals with frequent close contacts.

[3]Converted to a daily transmission probability based on a secondary attack rate of 3.0 percent for individuals with moderate contacts (Bi et al. 2020).

[4]There are limited data on transmission rates due to contacts on public transportation. To be conservative in estimating the impact of Scenario B, we set the daily transmission probability to be equivalent to estimates for individuals with frequent close contacts. We assumed a bus ride has a transmission risk approximately equivalent to a class period.

[5]CDC and the Office of the Assistant Secretary for Preparedness and Response: COVID-19 Pandemic Planning Scenarios from https://www.cdc.gov/coronavirus/2019-ncov/hcp/planning-scenarios.html.

[6]CDC and the Office of the Assistant Secretary for Preparedness and Response: COVID-19 Pandemic Planning Scenarios from https://www.cdc.gov/coronavirus/2019-ncov/hcp/planning-scenarios.html.

[7]At time of analysis, there is no clear evidence comparing the infectiousness of asymptomatic to symptomatic (Davies et al. 2020). For influenza, asymptomatic infections are about a third as infectious per social contact as persons with symptomatic infections (Van Kerckhove et al. 2013). Based on conversations with infectious disease modelers, we selected a value of half (50 percent) as plausible.

[8]Based on a conservative estimate from Leung et al. (2020).

[9]Based on a conservative estimate from https://www.livescience.com/face-masks-eye-protection-COVID-19-prevention.html, which reported an 88 percent reduction due to social distancing of six feet.

[10] Park et al. (2020). Keeling et al. (2020) had estimated 63 percent for children across all ages, which is generally consistent with the Park et al. subsequent finding of 50 percent for young children and no difference in susceptibility for older children.

Appendix Exhibit C.6. ABM inputs for testing, tracing, and quarantining

Category	Parameter	Parameter value
PCR test characteristics	Sensitivity	90.7%[1]
	Specificity	100.0%[1]
Antigen test characteristics	Sensitivity	65.4%[2]
	Specificity	99.0%[2]
Contact probability (by quarantine policy)	No contacts	0%
	Close contacts only (classroom)	4%[3]
	Close contacts only (bus)	3.7%[3]
	All classroom and bus contacts	100%
Contact tracing window before administered positive test	Asymptomatic	2[4]
	Symptomatic	2[4]
Quarantine duration	Asymptomatic	10[5]
	Symptomatic	10[5]

[1]Based on estimate from Kanji et al. (2021).

[2]Pollock et al. (2021) estimates of sensitivity and specificity of Abbot BinaxNOW versus RT-PCR specifically when testing asymptomatic pediatric individuals.

[3]Based on pilot site feedback, probabilities were chosen to target an average of two close contacts per class or bus.

[4]CDC. COVID-19: Contact Tracing from https://www.cdc.gov/coronavirus/2019-ncov/daily-life-coping/contact-tracing.html

[5]CDC. COVID-19: When to Quarantine: Options to reduce quarantine from https://www.cdc.gov/coronavirus/2019-ncov/if-you-are-sick/quarantine.html.

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