Supported by
The ROCKEFELLER FOUNDATION

Mathematica
Progress Together

Early Insights and Recommendations for Implementing a Covid-19 Antigen Testing Program in K-12 Schools: Lessons Learned from Six Pilot Sites

January 2021

Divya Vohra, Patricia Rowan, Ravi Goyal, John Hotchkiss, and So O'Neil

Submitted to:

The Rockefeller Foundation
420 Fifth Avenue
New York, NY 10018
Project Officer: Leah Perkinson
Contract Number: 10656

Submitted by:

Mathematica
505 14th Street, Suite 800
Oakland, CA 94612
Project Director: Divya Vohra
Reference Number: 51104

This page has been left blank for double-sided copying.

Acknowledgments

Many people and organizations across the country contributed to this report. First, we acknowledge the invaluable guidance and support of those at The Rockefeller Foundation, especially Leah Perkinson and Sarah Hanck, who fostered close connections with key personnel in pilot sites and helped connect our work with other efforts to identify emerging best practices for Covid-19 testing in schools. We are also grateful for thoughtful input and feedback from Christina Silcox and David Anderson at the Duke-Margolis Center for Health Policy.

We express the deepest gratitude to the key personnel in participating pilot sites who were willing to speak with us, invited us to listen in on key decision-making meetings, and shared data and insights from their unique experiences. These individuals found time to provide the data used in this report while they are also focused on the critical task of operating their schools safely and standing up new testing programs. We are grateful to them for finding time to contribute to this report while also managing such important roles in their communities.

Finally, at Mathematica, we thank Aimee Lansdale, Kenneth Lim, and Emily Cross, who contributed to data analysis; Sheena Flowers, who created the report graphics and produced the report; and Cindy George, who copyedited this report.

This page has been left blank for double-sided copying.

Contents

This page has been left blank for double-sided copying.

Exhibits

This page has been left blank for double-sided copying.

Executive summary

The Covid-19 pandemic has required many students across the United States to begin the 2020 school year online. Experts estimate the impact on students' learning to be significant, with long-term learning losses potentially shaping children's educations for years to come. It is thus critical to identify strategies to keep schools open in a safe way that minimizes the risk of outbreaks. With this goal in mind, The Rockefeller Foundation has partnered with Duke-Margolis Center for Health Policy (DM), Johns Hopkins University (JHU), and schools in six pilot sites to pilot the implementation of Covid-19 testing in schools based on their Risk Assessment and Testing Protocols for Reducing SARS-CoV-2 Transmission in Selected K-12 Schools. The Foundation also engaged Mathematica as a learning partner for this effort to better understand and generate evidence about the acceptability, feasibility, and effectiveness of adding a testing program to schools' existing Covid-19 related plans.

Pilot sites are taking four key steps to initiate their school-based testing programs: (1) program planning and design, (2) mobilization and set-up, (3) operations, and (4) evaluation (for more details, see the Testing For America playbook, which provides advice and guidance on implementing testing programs in educational settings). All sites began designing and planning their testing programs in October 2020 and began to mobilize and set up the resources necessary to implement them shortly thereafter. At this early stage, pilot sites have generated key insights to inform schools and districts across the country on how to implement point-of-care antigen testing in K-12 school settings. This report discusses early learnings and recommendations generated by pilot sites in their first four months of planning and implementing testing programs, based on a review of sites' documentation, key informant interviews, and agent-based modeling (ABM), a statistical modeling approach used to examine the potential effectiveness of testing programs on in-school infections and in-person learning. Based on analysis of these data, we developed a detailed profile of each pilot site and identified cross-site common implementation themes, as well as key questions being considered by multiple sites and early recommendations for how to design and implement a feasible, acceptable school-based testing program. Based on these initial insights, we identified cross-cutting considerations and implications to guide other schools and districts across the country that are considering implementing antigen testing (Exhibit 1).

Exhibit 1. Early insights, recommendations, and implications to guide other schools

Acceptability: Program planning and design	
Insights	**Recommendations and implications**
• Clear communications, delivered by trusted leaders in the community, are needed to build community members' understanding of the program and encourage participation. • The testing approach should be designed using both evidence-based guidance and on-the-ground knowledge of what will be acceptable to students, parents, teachers, and staff. • Engaging early with district administrators and local partners can help gain their buy-in and support for identifying resources.	• A strong communications plan can inform community members of the limitations and implications of antigen testing, and support acceptance of and enthusiasm for school-based testing. • Planners must balance the value of implementing an ideal testing program with community members' needs and comfort levels; finding this balance may introduce a risk that testing will not be robust enough to inform decision making. • In designing a testing program, school leaders should collect input about the wraparound supports community members may need, and identify partners accordingly.

Early insights about feasibility: Mobilization and set-up	
Insights	**Recommendations and implications**
• The logistical and regulatory requirements for conducting point-of-care antigen testing in schools are complex, and beyond what school officials are accustomed to dealing with. • Trained health care workers are needed to administer tests, and additional staff are required to read test results, communicate them to tested individuals, and report them to public health authorities.	• School-based antigen testing requires more than just a supply of tests; to be feasible at a large scale, it also requires significant support and coordination from local, state, and national education and public health authorities. • In communities that already have a robust testing program, school leaders should consider whether they need a school-based program or they could encourage students and teachers to have regular testing at existing community sites.
Early insights about effectiveness: Evaluation	
Insights	**Recommendations and implications**
• Weekly screening of all students, teachers, and staff can reduce in-school infections by 50 percent, making it more effective than masking but less effective than social distancing. However, less frequent or widespread testing adds limited value above and beyond other mitigation strategies. • Frequent testing can substantially reduce in-person learning because of the resulting isolation and quarantine requirements. • Many teachers, students, and parents felt more comfortable returning to in-person learning if they knew that their school would provide testing.	• School officials should continue to promote the adoption of other mitigation strategies in tandem with testing and should work to prevent school-based testing efforts from drawing resources or attention away from those strategies. • The isolation and quarantine measures that limit in-person learning resulting from testing efforts is valuable from a public health perspective to stop outbreaks in school settings, but has other implications for the well-being of students and their families, and school officials will need to be prepared to address these. • School-based testing programs have value beyond measures of their effectiveness—they can provide the comfort that students, parents, teachers, and staff need to resume or continue in-person learning.

The early insights and recommendations in this report reflect the experience of a small number of unique pilot sites captured at a relatively early stage in testing implementation. A future report will update the findings in this report as pilot sites continue to refine their testing plans and conduct testing in their schools, and as pilot sites are able to supply the data required for additional ABM work.

I. Introduction

The Covid-19 pandemic required many students across the United States to begin the 2020 school year online. 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). It is thus critical to identify strategies to keep schools open in a safe way that minimizes the risk of outbreaks. With this goal in mind, The Rockefeller Foundation has partnered with Duke-Margolis Center for Health Policy (DM), Johns Hopkins University (JHU), and schools in six sites to pilot the implementation of Covid-19 testing in schools based on their Risk Assessment and Testing Protocols for Reducing SARS-CoV-2 Transmission in selected K-12 schools. The Foundation also engaged Mathematica as a learning partner for this effort to better understand and generate evidence about the acceptability, feasibility, and effectiveness of adding a testing program to schools' existing Covid-19 related plans. This report discusses early learnings and recommendations generated by pilot sites in their first four months of planning and implementing testing programs, based on a review of sites' documentation, key informant interviews, and initial planning and data collection to support statistical modeling.

The Covid-19 Testing Protocol Demonstration Project

Six pilot sites are participating in the Covid-19 Testing Protocol Demonstration Project: Central Falls, RI; Los Angeles, CA; Louisville, KY; New Orleans, LA; Tulsa, OK; and Washington, DC. All pilot sites have engaged with The Rockefeller Foundation since March 2020 and were selected to participate in this initiative based on motivation, need, and a track record of strong partnership with The Rockefeller Foundation. All pilot sites are also members of the Pandemic Solutions Group (PSG), a network of public officials spanning 52 U.S. cities, states, counties, and tribal nations and representing 66 percent of the U.S. population. The PSG is devoted to rapidly scaling Covid-19 testing, tracing, and tracking in their communities. Pilot sites also participate in the Cross-City Learning Group (CCLG), a subgroup of the PSG that meets regularly for in-depth discussion and knowledge sharing around school-based testing.

In October 2020, The Rockefeller Foundation partnered with the U.S. Department of Health and Human Services (HHS) to make 20,000 Abbott BinaxNOW rapid antigen tests available for K-12 schools in each pilot site. Each pilot site is using these tests to implement school Covid-19 testing programs aligned with guidelines developed by JHU and DM (Rivers et al. 2020). These testing protocols include an assessment for determining

Testing types and purposes

Clinical diagnostic testing is needed for people who have symptoms and/or a history of close contact with an infected individual. These tests require a high level of accuracy.

Screening testing is routine testing of individuals without any symptoms or exposure to identify infected people sooner and reduce transmission. Timeliness is more important than high levels of accuracy; people with a positive screening test may require a follow-up diagnostic test.

Surveillance testing is used to measure population prevalence; different kinds of tests can be used, depending on desired accuracy and turnaround time to inform decision making.

Adapted from: A National Decision Point: Effective Testing and Screening for Covid-19.

the level of risk of Covid-19 transmission in schools and the consequences of transmission, and guidelines for developing a program to regularly test students, teachers, and staff based on a site's risk level. The rapid antigen tests are intended to be used in addition to any other Covid-19 related policies and mitigation strategies put in place by each school, including requirements for making polymerase chain reaction (PCR) diagnostic testing available to diagnose suspected cases. The range of potential testing strategies discussed in the JHU/DM protocols is described in Exhibit 2.

Exhibit 2. Illustrative testing strategy purpose and approach, by school risk level

Example objectives of testing	Testing strategy
Risk level: Very low	
• Identify or rule out Covid-19 in students and staff using clinical diagnostic testing	• Continued mitigation measures in schools • Clinical diagnostic testing offered to students and staff • Testing and quarantine of close contacts of positive cases, including pod members
Risk level: Low	
• Monitor Covid-19 rate increases using surveillance testing • Monitor individuals with higher risk of transmission using routine screening • Offer accessible and actionable clinical diagnostic testing	• Routine surveillance testing of school pods, for example through pooled testing • Routine screening for staff in close contact with a significant number of people throughout the day • Clinical diagnostic testing offered to students and staff • Testing and quarantine of close contacts of positive cases, including pod members
Risk level: Moderate	
• Reduce likelihood of transmission within the school using routine screening • Offer accessible and actionable clinical diagnostic testing	• Routine screening program that balances test frequency, accuracy, and result turnaround time for all students and staff • Clinical diagnostic testing offered to students and staff • Testing and quarantine of close contacts of positive cases, including pod members
Risk level: High	
• Monitor Covid-19 rate increases using surveillance testing • Offer accessible and actionable clinical diagnostic testing	• No in-person learning for students • Twice-monthly surveillance testing for essential staff who work on site • Clinical diagnostic testing offered to students and staff

Source: Rivers et al. "Risk Assessment and Testing Protocols for Reducing SARS-CoV-2 Transmission in K-12 Schools." October 2020.

Current implementation status in pilot sites

The pilot sites have been taking several steps to initiate a school-based testing initiative, which generally has four key components: (1) program planning and design, (2) mobilization and set-up, (3) operations, and (4) evaluation (Testing for America 2020). To date, all sites have designed and planned their testing programs and have begun to mobilize and set up the resources necessary to implement them. In addition, four pilot sites (New Orleans, Tulsa, Washington, DC, and Central Falls) are implementing testing programs using their BinaxNOW tests (Exhibit 3).

Exhibit 3. BinaxNOW testing purpose and status in pilot sites, as of January 13, 2021

	Testing overview	Testing location	Testing purpose	Current status
Central Falls, RI	Rhode Island has a robust off-site testing program for K-12 students and families. They are using the BinaxNOW tests to pilot on-site testing in Central Falls, which has a consistently high test positivity rate and serves a high needs population. Lessons learned from the pilot sites will be used to expand asymptomatic testing in K-12 settings.	2–3 schools in Central Falls District	Screening students and staff	Began in November 2020
Los Angeles, CA	The Office of the Mayor, County Health Department, and University of Southern California are partnering to develop a community-based testing protocol for public schools. The University is leading key stakeholder interviews to develop the testing protocol. Once the protocol is complete, it will be piloted in several schools. Another goal of the pilot is to develop evidence on the accuracy of antigen tests in children.	3–4 schools outside of LAUSD	Screening students and staff	Expected to begin in February 2021
Louisville, KY	Although schools are not meeting in-person, the district partnered with community organizations to launch learning hubs to facilitate distance learning for families that cannot stay home with their students. Louisville piloted an asymptomatic antigen testing program in these learning hubs that will be scaled up when schools reopen.	3–4 learning hubs that serve Jefferson County Public School students	Surveillance of all students and staff	Expected to begin in January 2021
New Orleans, LA	New Orleans Public Schools is made up of over 70 public charter schools. The district is adding antigen testing to its existing school-based testing program which includes mobile PCR testing. To date, they have distributed 20,000 tests to 80 school sites.	All interested schools in district (~75)	Diagnostic for students and staff	BinaxNOW testing to begin as early as January 2021
Tulsa, OK	The school district partnered with the county health department to test elementary school teachers. Nearly 850 teachers opted in to this voluntary testing program during the pilot phase. Lessons from that pilot are being used to launch asymptomatic testing at all schools once in-person learning resumes for all grade levels.	All schools in district (70)	Diagnostic for all students and staff; screening students and staff at some locations	Staff testing in 16 locations in December 2020; screening of students & staff at 3-4 schools to begin in February 2021
Washington, DC	The Friendship Public Charter School network piloted regular asymptomatic testing for all students and is planning to expand to the other sites in its network.	7 learning hubs that serve Friendship Public Charter School students	Screening students and staff	Began in December 2020

Even in this early stage, pilot sites have generated key insights to inform schools and school districts across the country on how to implement antigen testing in K-12 school settings. The variation in each pilot site's context and approach to deploying the BinaxNOW tests provides lessons learned for a broad set of school settings as they plan and start to mobilize testing programs. A future report will update findings and recommendations as pilot sites continue to roll out their testing programs.

Methods used in this report

This report draws on information generated by participating pilot sites between October and mid-December 2020, and seeks to answer three key learning questions:

1. **Acceptability: Program planning and design.** How do participating schools obtain buy-in from key stakeholders (e.g., 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 for pilot sites to mobilize the capacity and capabilities needed to implement a Covid-19 testing program in selected K-12 schools?
3. **Effectiveness: Evaluation.** What is the potential impact of implementing such programs on in-school infections and in-person learning (as measured by attendance)?

To answer these questions, we drew on three data sources:

1. **Documentation.** Mathematica reviewed notes from sites' meetings with The Rockefeller Foundation and weekly CCLG gatherings hosted by the Foundation, as well as additional documentation sites shared detailing their testing approach and experiences with testing from September 2020 to mid-December 2020.
2. **Key informant interviews.** The Mathematica team conducted eight in-depth, semi-structured key informant interviews with key stakeholders in each pilot site from October 2020 to mid-December 2020.[1] These initial interviews captured insights and learnings from the people serving as key decision makers and testing leads in their sites, and focused on three key topics: (1) design and scope of each school's or district's testing initiative, including details of the planning and design process; (2) experiences with testing implementation, communications, and encouraging tested individuals to comply with necessary next steps; and (3) emerging successes, challenges, and lessons learned from the design and (where relevant) early implementation of the testing program. Decision makers interviewed included local education and public health officials, medical experts, and communications and data specialists (Exhibit 4). In most cases, respondents were members of the CCLG and thus were able to comment on learnings and insights that they believed would be of broader relevance to other CCLG members, as well as other schools and districts.

   Each key informant interview lasted between 30 and 60 minutes. Interviews were recorded and detailed notes were taken. To gather more information about implementation of the testing program, the Mathematica team will conduct follow-up interviews with these key informants at critical junctures in their sites' testing programs, as well as interviews with additional key informants identified by this first round of informants. These interviews are currently planned for January and February 2021.

[1] Some interviews were conducted individually, and others were group interviews conducted with multiple key informants from the same pilot site.

Exhibit 4. Stakeholders interviewed by pilot site

Site	Stakeholders interviewed
Central Falls, RI	• Medical director
Los Angeles, CA	• Principal investigator from USC leading qualitative study of pilot schools that will implement testing effort • Key informant interviews with school administrators, focus groups with teachers and parents
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	• Staff from NOLA Public Schools leading the testing effort* • Physician consultant
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

*In New Orleans, Mathematica observed existing NOLA Public Schools planning meetings and training sessions in lieu of a formal interview.

3. **Administrative data on testing.** To date, one pilot site—Rhode Island—and a school in New York City that is not participating in the broader pilot initiative have engaged with Mathematica to provide data for an agent-based modeling (ABM) effort, which can predict the likely spread of Covid-19 in schools and answer questions about the effectiveness of testing on reducing transmission relative to other mitigation measures such as masking and distancing. In addition, we used the information provided by each pilot site on the details of their testing approach and their use of other Covid-19 mitigation strategies to inform the development of the models.

Qualitative analysis. We abstracted information from documentation and interview notes along the four testing program components, and identified themes accordingly. Based on the analysis, we developed a detailed profile of each pilot site and

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 increasing 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 an early indication of whether a testing program can help reduce infections in schools and keep schools open
- Help decision makers decide whether their testing program should be modified

identified cross-site common implementation themes as well as key questions multiple sites were considering and early recommendations for designing and implementing a feasible, acceptable school-based testing program.[2]

Quantitative analysis. We used the information provided by pilot sites to construct agent-based models. We used these models to investigate differences in in-school Covid-19 infection rates and in-person learning that might be expected across ten different testing scenarios under consideration by pilot schools. We used these models to assess the 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. More details about the methods, assumptions, and inputs for the ABM can be found in Appendix B.

II. Acceptability of school-based antigen testing

Given that many schools across the country remained closed for much of the fall, including those in pilot sites, pilot sites have limited implementation experience of their testing programs at this stage. However, all pilot sites engaged in program planning and design, and their experiences offer insights into successful approaches for promoting acceptability of school-based antigen testing programs. These insights include how to engage the school community (students, parents, teachers, and staff) as well as policymakers and school administrators in designing a program within available resources, and how to estimate infrastructure and other resource needs. Pilot sites found that school-based testing programs are well-received by the school community and other partners in the abstract, but key audiences could find some of the program details unacceptable.

Early insights about acceptability

1. Clear communications about the testing program, delivered by trusted leaders in the community, are needed to help the school community understand the strengths and limitations of the program and encourage them to participate.
2. The testing approach should be designed using both evidence-based guidance on the most appropriate testing strategy and on-the-ground knowledge of what will be acceptable to students, parents, teachers, and staff.
3. Engaging early with district administrators and local partners can help gain their buy-in and support for identifying the necessary resources.

This section delves further into the specific facilitators and barriers related to acceptability of testing programs throughout the planning and design phase, as discussed by key informants in each pilot site. Exhibit 5 summarizes key themes and early recommendations corresponding to the three components under the program planning and design phase that have been addressed by pilot sites to date: (1) communicate with key stakeholders, (2) define testing approach, and (3) estimate school resource needs.

[2] [2] 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).

Exhibit 5. Key themes and early recommendations on program planning and design

Communicate with key stakeholders	
Messengers	• Use local principals or other trusted voices in the community to convey the testing strategy • Connect messengers with state officials to develop and deliver messages aligned with public health guidelines
Community experience with testing	• Tailor the level of detail offered in communications based on the community's comfort and familiarity with testing
Collecting feedback and addressing concerns	• Provide forums to understand and address community members' questions and concerns
Define testing approach	
Testing plan	• Try to design components of the testing plan (test type, purpose, audience, frequency, and location) simultaneously, but be prepared for test availability to influence other decisions about the plan • Develop a testing plan that uses evidence-based guidelines about risk level and appropriate testing strategies—but tailor the testing audience and frequency based on community needs and available resources • Consider off-site testing if on-site testing is prohibitively expensive or complex—but make off-site testing accessible to students and staff
Opt-in or opt-out	• Seek legal guidance on whether testing can be mandated and what accommodations are required for those who opt out
Consent	• Use existing staff and tools to develop informed consent procedures quickly, and plan to collect written consent
Integration with other mitigation strategies	• Continue to put resources and effort into other mitigation measures (e.g., masking, distancing, improving ventilation), which are proving to be effective
Estimate school resource needs	
Procuring supplies	• Clarify with district administrators the procedures and available resources for procuring supplies
Partnerships	• Leverage local organizations to serve as partners to provide testing-related wraparound supports
Equity	• Develop a plan to mitigate any equity concerns resulting from antigen testing

Communicate with key stakeholders

The messengers, content, and responsiveness of key messaging to community members' concerns can influence the acceptability of a K-12 testing program.

Three pilot sites—Louisville, Tulsa, and Washington, DC—leveraged different types of stakeholders to deliver information about their testing program. These messengers have a common characteristic—they are all trusted community leaders (Exhibit 6). The community's underlying familiarity and comfort with Covid-19 testing also influenced the acceptability of the testing program among stakeholders. Lousiville and Washington, DC emphasized the importance of collecting feedback from community members, either through regular town hall meetings, short pulse surveys, or conversations with community partners, to understand and alleviate any concerns. Sites' experiences offer several early recommendations on how to communicate with key stakeholders.

Exhibit 6. Communications approaches pilot sites are using

	Key messengers	Availability of testing in broader community	Approach to collecting feedback and addressing concerns
Louisville, KY	Community-based organization	Widespread, but limited availability for children	Conversations with community-based organization
Tulsa, OK	Local health department, mayor, community partners	Widespread	Conversations with community leaders and organizations; school board meetings
Washington, DC	Local campus principal and administrators	Widespread	Town hall meetings, weekly e-newsletters, and videos

Use local principals or other trusted voices in the community to convey the testing strategy. Stakeholders absorbed and retained information that came directly from trusted sources better than information from a district administrator, such as a superintendent or city health department official, who may be less embedded in the local community. Administrators in Washington, DC noted, based on experience with previous school initiatives, that parents and students trusted and respected their local campus leaders, who were often members of their community and had a deep understanding of local children's needs. To leverage these trusted relationships, the leadership of the participating charter school network met regularly with principals at each campus to prepare them to deliver accurate messages about the testing program.

Key questions: Communicate with stakeholders

Messengers. Who do the families and students trust? How can support from school and community leaders influence comfort levels and adherence to testing policies? How will school leaders make their messages consistent with laws and public health guidance?

Community experience with testing. Have students/staff generally experienced being tested before? What can schools do to reassure families and staff and mitigate their concerns?

Collecting feedback and addressing concerns. How will schools gather feedback from staff and families on testing? What can schools do to anticipate and prepare for reactions, questions, and concerns?

Connect messengers with state officials to develop and deliver messages aligned with public health guidelines. To promote acceptability of the program among state and local officials and increase local leaders' comfort with leading any communications efforts, pilot sites aligned messaging across schools or testing sites and with legal requirements and higher-level guidance from state public health authorities. Respondents from Tulsa noted that school administrators needed guidance from their legal team and local health department to confirm that their messaging complied with official guidelines. The executive director of the local health department was also in frequent communication with the state Department of Health, Department of Education, and governor. Tulsa testing leads noted that a benefit from seeking guidance and support from state-level officials is that they can help school leaders and key messengers feel comfortable with their communications approach and confirm that these messengers convey appropriate guidance and information about testing.

"Our school staff are important ambassadors of information, so our communications start with the leadership of learning hubs."

– Testing lead, Washington, DC

Tailor the level of detail offered in communications based on the community's comfort and familiarity with testing. In communities where Covid-19 testing is widespread, community members tended to be comfortable with school-based testing because the experience was normalized. In Washington, DC, many parents and students reported having previous experience with testing and there was overwhelming community support for school-based testing. In Louisville, testing is common but testing of children has been limited. As a result, some students, parents, and school staff had expressed trepidation about the seemingly invasive testing procedure. To address these concerns, Louisville school leaders developed detailed guidance on what to expect from the testing experience.

Provide forums to understand and address community members' questions and concerns. Listening sessions, community meetings, short pulse surveys, and collaboration with community-based partners (where applicable) offered school leaders insights into potential concerns and indicated the kinds of messages most likely to resonate within their communities. Based on feedback from town hall meetings and previous citywide experiences with testing, Washington, DC school administrators framed their school-based initiative as an effort to keep the entire community safe. In Louisville, a representative from the community-based organization supporting the testing initiative has provided daily feedback and insight into the questions and concerns that children and parents have raised, and the communications liaison from the participating school district has tailored the district's communications to address them. Taking these community-informed approaches to designing communications for pilot sites has facilitated the early acceptability of their testing programs among students and families.

"What we've heard from parents is enthusiasm and gratitude. They really appreciated that we accommodated their needs."

– Testing lead, Washington, DC

Define testing approach

Testing leads in the pilot sites identified four key components of a testing approach: (1) a testing plan that details the types of tests to be used as well as the purpose, audience, frequency, and location of testing; (2) guidelines for whether key testing audiences can opt into or out of testing and how to handle those who opt out; (3) procedures for collecting informed consent; and (4) strategies for integrating testing with other Covid-19 mitigation measures.

Because all pilot sites were provided with BinaxNOW rapid antigen tests and had received guidance to use these tests for screening when possible, they designed other components of their testing plans around these resources and recommendations (Exhibit 7). This experience that is likely to be common in other schools and districts where tests or testing supplies are donated or made available at reduced cost.

In deciding on testing audience and frequency, pilot sites had to balance the guidance and recommendations laid out by the JHU/DM testing protocols with community comfort with testing. They also had to consider whether on-site testing at schools, which provided maximum convenience for students, could be conducted with little or no disruption to in-person learning, and whether off-site testing could be made accessible to testing audiences if on-site testing was not possible. Pilot sites have also had to design their testing approach to account for the fact that students and staff can opt out of testing, and have had to leverage existing staff and other resources to obtain written informed consent. Finally, as pilot sites have begun to learn that other measures to mitigate the spread of Covid-19 in schools are proving to be very effective, they have had to implement testing programs without drawing resources away from these mitigation measures. Below, we discuss early recommendations for how to design an appropriate testing approach based on pilot sites' experiences.

Exhibit 7. BinaxNOW testing approach in pilot sites

	Testing plan						
	Purpose	Audience	Frequency	Testing location	Opt in or out	Consent required?	Other mitigation measures?
Central Falls, RI	Screening	Students and staff	TBD	Testing conducted on site in pilot schools; students and staff at other schools encouraged to get tested at sites across the state due to space constraints at schools	Opt-in	Yes, written	Yes
Los Angeles, CA	Screening	Students and staff	Twice weekly	Initial validation study conducted at walk-up site; expect to implement on-site testing soon	Opt-in	TBD	Yes, in theory; implementation varies
Louisville, KY	Surveillance	All students and staff	Once weekly	Testing takes place at learning hubs while schools are closed	Opt-in	TBD	Yes
New Orleans, LA	Diagnostic	Symptomatic students and staff and close contacts	As needed	Testing on site in schools	Opt-in	Yes	Yes, widespread
Tulsa, OK	Screening	Teachers, students	Once weekly	Testing on site in schools	Opt-in	Yes, written	Yes, widespread
Washington, DC	Screening	Students and staff	Once weekly	Testing takes place at learning hubs; space constraints at schools	Opt-in	Yes, written	Yes

Try to develop components of the testing plan simultaneously, but be prepared for test availability to influence other decisions about the plan. The key components of a testing plan—types of tests to use, testing purpose, audience, and testing frequency—are closely intertwined and administrators should consider them simultaneously. Under this pilot initiative, however, decisions about test type and testing purpose were sometimes driven by the BinaxNOW antigen tests provided by the initiative piloting their use for asymptomatic screening.

Because these factors were pre-defined, pilot sites focused their testing plan development on the most appropriate testing audience, frequency, and location, as discussed below.[3] Schools in Central Falls and New Orleans had already begun implementing a testing program with other test types when the BinaxNOW tests were made available and they had to adjust their testing plans to make the best use of these new tests. Other sites had not yet begun testing when the BinaxNOW tests were supplied to them and thus they designed their plan around these tests—which may have made planning easier, but did not allow them to examine how other types of tests might have worked. Many school districts across the country may be in similar positions—the availability of tests may be the defining factor that influences other aspects of the testing plan.

Key questions: Define testing approach

Testing plan. How will the testing approach address the following components:

- **Types of tests.** What type of test will be used (PCR or antigen)?
- **Purpose.** Will testing be done for diagnosis, screening, or surveillance? Will a combination of strategies be used?
- **Audience.** Who will be tested? Will only a sample of individuals be tested? How will that sample be chosen?
- **Frequency.** How often will individuals be tested? Are parents and families comfortable with the testing frequency?
- **Testing location.** What kind of infrastructure and space is needed to implement on-site testing? Should off-site testing be considered instead? How can schools make off-site testing accessible to students and staff?

Opt-in or opt-out. Will participation in testing be mandatory or will students have the opportunity to opt out of the testing program? Are there consequences to opting out?

Consent. How can informed consent procedures be implemented quickly? Must consent be written, or can it be verbal?

Integration with other mitigation strategies. What other mitigation measures are in place in schools to reduce the risk of within-school transmission? What resources are required to sustain these measures even as testing ramps up?

[3] Perhaps partly due to this unique situation of receiving BinaxNOW tests at no cost, no pilot sites reported undertaking the kind of systematic risk assessment recommended by the DM guidance.

 **Consider off-site testing if on-site testing is prohibitively expensive or complex—but make off-site testing accessible to students and staff.** Testing sites have considerable space and infrastructure requirements. Although offering testing on school grounds is likely to be most convenient and acceptable to school communities, key stakeholders at many schools across the country may not be willing to meet these requirements because it could interfere with in-person learning or because the necessary infrastructure changes are too complex or expensive to implement. Moving testing off site can help alleviate these pressures. However, many community members already face significant barriers to access testing, and some families may not be able or willing to seek regular testing if it is moved off school grounds. Pilot sites have, therefore, sought creative ways to ensure that testing remains accessible even if it moves off school grounds. Rhode Island has used 15 established testing sites for K-12 students and their families located across the state; ambulance companies also provide on-site testing for schools in Central Falls. Louisville has used learning hubs that technically exist outside of school grounds but still make testing accessible in places where students spend a significant amount of time. Los Angeles offered testing at walk-up sites as part of its initial implementation.

"If people don't have cars, they are not going to go to the site to get tested. They need it to come to them."

– Testing lead, New Orleans

 **Develop a testing plan that uses evidence-based guidelines about risk level and appropriate testing strategies—but tailor the testing audience and frequency based on community needs and available resources.** JHU/DM's testing guidance recommends that sites first assess their level of risk and then select a testing plan accordingly. In sites with moderate or high levels of risk, the entire school community (students, teachers, and staff) should be tested twice weekly using rapid antigen tests to overcome the tests' lower sensitivity compared to PCR tests. Pilot sites did not believe they could follow this guidance, either because such frequent testing would be unacceptable to the community or because they did not have access to the tests or other resources required to sustain this testing frequency. In Tulsa, parents were amenable to once weekly testing but pushed back against twice weekly testing because they "felt like we were using their children as test subjects." New Orleans testing leads noted that this concern could be driven by the fact that BinaxNOW tests are not officially approved for use in children or asymptomatic cases, even though HHS has permitted their use for this pilot. Similarly, testing leads in Louisville received early feedback that many parents would not consent to twice weekly testing due to the discomfort of the nasal swabs used. Leaders in these pilot sites, as well as in Rhode Island and Los Angeles, did not expect to have access to the tests or personnel required to sustain such frequent testing. These areas considered narrowing the testing audience by testing only a sample of students or staff, or limiting testing to a small number of schools, to address this concern. At the same time, frequent testing holds appeal for many key stakeholders. Teachers and staff in Los Angeles, Tulsa, and

"While we can hypothesize that antigen tests can solve the cost and time limitations of PCR testing, we have no idea how well the tests work in children."

– Testing lead, New Orleans

"Schools have closed down because of teachers. They don't feel safe [without testing]."

– Testing lead, Tulsa

Rhode Island have all indicated that regular testing is one of the few mitigation measures a school could implement that would make them feel comfortable returning to in-person learning.

Seek legal guidance on whether testing can be mandated and what accommodations are required for those who opt out. Testing leads acknowledged that school-based testing programs would be most successful if they could require that all students and staff be tested, with limited opportunities to opt out of the program. However, mandatory testing was not seen as acceptable in most communities, with Rhode Island and Tulsa citing guidance from their legal counsel that they could not require testing as a condition of in-person learning. At most sites, if symptomatic individuals or close contacts of confirmed cases refused to be tested, they were treated as positive cases and were asked not to participate in in-person learning for a 10-day period. This conservative approach may be an effective way to limit in-school Covid-19 transmission, but local laws or regulations may not permit even this temporary restriction on in-person learning in public or charter schools. School districts will have to work with legal experts to meet all students' learning needs, regardless of whether they opt out of testing.

Use existing staff and tools to develop informed consent procedures quickly, and plan to collect written consent. Pilot sites had to quickly develop and initiate a comprehensive informed consent process. They also learned that written consent from students' caregivers, not verbal consent, was most likely required by local and state authorities—adding to the logistical hurdles of collecting consent. One site described the process of gathering consent from parents as "slow and challenging." This site addressed some of these challenges by designating a specific school staff member to answer questions and provide more information as needed to mitigate concerns from parents. Washington, DC drew on their experiences collecting student assent and parent consent for other school-based health initiatives to quickly develop their consent materials for their testing program. Similarly, New Orleans drew on consent materials drafted by other pilot sites, and leveraged school-based partners to identify effective ways to distribute and collect consent forms from parents.

"Our final decision was to use permission slips to collect consent, but that added a barrier to testing. Uptake of the consent forms was not great."

– Testing lead, Rhode Island

Continue to put resources and effort into other mitigation measures—which are proving to be effective. Testing is not a substitute for other Covid-19 safety measures, but rather one of several strategies to reduce in-school transmission. Integrating testing into a suite of other mitigation measures, such as universal masking, social distancing, improved ventilation, and separate lunch periods, is critical to creating a safe environment. Anecdotal evidence from New Orleans, Los Angeles, and Rhode Island pilot testing leads suggests that such mitigation measures are being widely applied in schools and could be effective at reducing the risk of in-school Covid-19 transmission, even in the absence of regular testing. School-based testing can complement these measures but should not replace them. Schools will need to continue to dedicate resources and personnel to ensuring that school communities understand the value of these other mitigation measures and continue to follow them.

Estimate school resource needs

A key step in building the acceptability of school-based testing programs is to help stakeholders become aware of and comfortable with the resources required to implement these programs, and to identify allies and partners who can help secure these resources.

Most pilot sites have begun generating estimates of these resource needs (Exhibit 8). They identified unexpected needs for testing-related supplies, and noted that education and public health authorities needed to provide clearer guidance about how to budget for and procure these supplies. Nearly all sites had identified partners to provide access to related services such as diagnostic or confirmatory PCR testing or telehealth consultations—a key factor in building community members' trust and acceptance of antigen testing. However, families of students who test positive may need additional wraparound services, and no pilot sites have yet identified ways to make these resources available. Early recommendations have emerged from pilot testing leads' experiences with estimating their resource needs to date.

Exhibit 8. Unanticipated resource needs pilot sites have identified

	Other necessary supplies	Partnerships
Central Falls, RI	PPE	Private ambulances, EMTs, National Guard
Los Angeles, CA	PPE	Partners for confirmatory PCR testing
Louisville, KY	TBD	Local health system for telehealth appointments
New Orleans, LA	PPE, Biohazardous waste disposal, test administration trainings	City health department for citywide CLIA waiver
Tulsa, OK	PPE, biohazardous waste disposal	Mobile vendor for on-site PCR testing
Washington, DC	PPE, including N-95 mask fittings, biohazardous waste disposal	Mobile vendor for on-site PCR testing

Clarify with district administrators the procedures and available resources for procuring supplies. Other resources needed to implement the testing initiative include appropriate personal protective equipment (PPE) as well as biohazardous waste collection bins and removal service. One site estimated the total cost per BinaxNOW test administered (inclusive of labor, testing supplies, PPE, and biohazardous waste removal) to be $80. Many school districts were not prepared for these costs and have not implemented clear guidelines for procuring the necessary supplies, introducing uncertainty into many testing programs. If school leaders work with district administrators to build an early understanding of the cost and procurement implications of a testing program, this could help gain administrators' early buy-in and reduce this uncertainty.

Key questions: Estimate resource needs

Testing location & logistics. What kinds of infrastructure and space are needed to implement on-site testing? Should off-site testing be considered instead? How can schools make off-site testing accessible to students and staff?

Procuring supplies. How will schools acquire adequate PPE for administering tests? Are there school district policies related to procurement (of tests and supplies) that need to be waived or updated to help the school implement the testing program quickly?

Partnerships. Which local partners can help meet testing-related wraparound needs?

Equity. How can schools design their testing programs to address equity concerns among students and staff?

Leverage local organizations to serve as partners to provide testing-related wraparound supports. Acceptable school-based antigen testing requires more than just administering these tests; schools must also arrange for confirmatory PCR testing and follow-up care to be made available when indicated. School leaders in Louisville were particularly concerned about the implications of offering less sensitive antigen tests to the very communities that might face the greatest barriers to accessing PCR testing in other settings, and noted that building access to PCR testing into their testing program was a key factor for gaining buy-in from school communities. Local hospitals, health care organizations, and non-governmental organizations may be willing to provide these kinds of wraparound supports, so establishing strong relationships with such partners is critical to a testing program's success; for this reason, nearly all pilot sites have established these kinds of relationships already.

Develop a plan to mitigate any equity concerns resulting from antigen testing. Most students, parents, and staff were enthusiastic about a school-based testing program that could provide rapid results, even though antigen tests are less sensitive than PCR tests. However, Louisville, Tulsa, and New Orleans expressed concern that false positives resulting from these less accurate tests could have negative implications for students, who miss in-person instruction, as well as their caregivers, who may be forced to miss work to quarantine or care for their child.[4] When students and families are faced with these risks, they may be unwilling to participate in testing. Although all pilot sites were considering these implications for equity in their schools, none have yet identified effective ways to mitigate these concerns. Identifying partners who can offer key wraparound supports may be critical, as discussed above. However, these supports will have to go beyond PCR testing and telehealth appointments, and may need to include child care or other services to enable students and caregivers to act on a positive test appropriately with minimal harm to the family.

> **"Parents might be afraid to have a child tested because of what they could lose."**
>
> ***– Testing lead, Louisville***

[4] Concerns about the consequences of positive tests were a key reason why New Orleans opted to use BinaxNOW tests to test symptomatic cases and close contacts only, rather than using them for broader screening.

III. Feasibility of school-based antigen testing

At this early stage in the pilot initiative, all pilot sites have worked towards mobilizing and setting up their testing programs. They have generated insights into the logistical and regulatory steps required to feasibly implement on-site testing in schools, as well as the staff capacity required for antigen testing programs.

Early insights about feasibility

1. Unlike lab-based PCR testing, school-based antigen testing requires planning and resources for both test administration and delivery of results. The regulatory requirements for conducting testing in schools are complex and challenging to navigate, especially for school officials who typically are unaccustomed to dealing with these issues.
2. Trained health care workers are needed to administer tests, and additional staff are required to read test results, communicate them to tested individuals, and report them to relevant public health authorities.

In this section, we examine the resources and other infrastructure required to feasibly set up school-based antigen testing. Exhibit 9 summarizes key findings corresponding to the two components under the mobilization and set-up phase that pilot sites have addressed to date: design collection sites, and staff and train workforce.

Exhibit 9. Key themes and early recommendations on mobilization and set-up

Design sites for specimen collection, analysis, and delivery of results	
Site logistics	• If using antigen tests, design test sites to accommodate both specimen collection and delivery of results
Regulatory permissions	• Seek technical support for obtaining CLIA waivers, how to comply with HIPPA and FERPA, or other regulatory permissions needed for on-site testing
Staff and train workforce	
Recruitment for test administration	• Rely on nurses or other trained health care professionals (rather than lay people) to administer tests • Recruit trained nursing staff early in the design phase
Communicating and reporting results	• Allocate additional staff to read test results, communicate them to tested individuals, and report them to relevant public health authorities • Clearly communicate the protocol for confirmatory PCR testing and isolation

Design sites for specimen collection, analysis, and delivery of results

Antigen testing requires space and infrastructure to collect specimens, analyze samples, and deliver results—which introduces significant feasibility concerns for schools.

Testing leads in pilot sites shared their approaches to, and early recommendations for, addressing logistical hurdles related to space and infrastructure as they implement or prepare to implement antigen testing (Exhibit 10). All pilot sites have observed that on-site antigen testing is particularly complex, given that testing sites must account for both specimen collection and delivery of results. They also noted that the process of obtaining the necessary regulatory permissions to conduct on-site testing has been challenging, raising questions about whether on-site testing is feasible for many schools.

Exhibit 10. Site design considerations pilot sites have addressed

	Specimen collection protocol	Delivery of results
Central Falls, RI	EMTs and clinicians collect specimens	Volunteers and education and public health representatives help with result delivery
Los Angeles, CA	TBD	TBD
Louisville, KY	Testing during normal pickup and drop-off times may be most convenient for parents	Use a large, separate "waiting room" where students and staff can wait for results while distancing safely
New Orleans, LA	In nurses' offices or isolation space for sick individuals	Gyms or auditoriums can work as "waiting rooms"
Tulsa, OK	Testing in areas where regular health screenings are conducted	Dedicated staff on hand to receive results
Washington, DC	Students need space to learn or entertain themselves while waiting to be tested	Streamline delivery of results by reading result immediately and contacting parents/guardians the same day

If using antigen tests, design test sites to accommodate both specimen collection and delivery of results. The BinaxNOW tests are time sensitive – results must be read within 15 to 30 minutes of administering the test or the results become invalid. Unlike testing sites that use lab-based PCR tests, which need only account for specimen collection, BinaxNOW testing sites need to consider how and where to collect test specimens, where to direct people to wait while the test is being processed, and where to read and communicate the results. Some schools have considered repurposing large indoor spaces, such as auditoriums or gyms, for specimen collection or for "waiting rooms" while students await their results. Some pilot sites, such Tulsa and Louisville, have observed that conducting testing at specific times in the day—either at pickup or drop-off times, or outside of normal school hours—may make it feasible to repurpose school areas such as classrooms or lunch rooms for testing. Washington, DC, found that,

Key questions: Design sites

Site logistics. Where will tests be administered? Where will individuals wait for results? What systems are in place to keep track of testing and communicate results?

Regulatory permissions. What permissions must be obtained to conduct on-site testing? Who can support school officials to obtain these permissions?

although BinaxNOW test results must be read shortly after specimens are collected, negative results do not necessarily need to be communicated immediately, and it may be more logistically feasible to inform students and their parents about test results in batches at key moments in the day, rather than communicating each result as it becomes available. Tulsa has similarly opted to notify parents immediately of positive results, but to wait until later in the day to notify parents of negative results.

 **Seek technical support for obtaining CLIA waivers or other legal or regulatory permissions needed for on-site testing.** To administer Covid-19 tests on site for screening and diagnosis, schools need a Clinical Laboratory Improvement Amendment (CLIA) waiver. While HHS and The Rockefeller Foundation have provided the pilot sites with guidance on obtaining a CLIA waiver, several sites reported challenges working through this process and none had previous experience obtaining a waiver and operating as a HIPAA-compliant entity (which the CLIA waiver required). In Los Angeles, finding a lab and doctor of record to prescribe tests has been difficult. Tulsa received its CLIA waiver quickly, in doing so is now considered a medical laboratory that must report testing data within 24 hours with little technical support. As Tulsa school officials have noted, school leaders are not necessarily public health experts but are now required to follow complex public health-related regulations regarding HIPAA, biohazardous waste removal, and other issues. Pilot sites' experiences with CLIA waivers raise questions about whether off-site testing might be a more feasible approach for schools that do not feel they can navigate these complexities. New Orleans testing leads learned that multiple schools could be covered under a single CLIA waiver, which facilitated citywide implementation of testing. Tulsa and New Orleans school officials also observed that state authorities could support individual schools in these processes by offering clear guidance ethical, legal, and regulatory requirements and expectations for any schools that wish to implement on-site testing. While New Orleans found that their state set specific reporting requirements, it offered little operational guidance on how to comply with these requirements, requiring the school district to develop and disseminate these guidelines to individual schools. Greater support and coordination at the state level could make it easier for schools and districts to understand and comply with such requirements.

Staff and train workforce

School-based antigen testing programs require significant staff capacity to make them feasible, including trained health professionals to administer tests and additional staff for related tasks.

Although any trained adult can administer BinaxNOW tests, all pilot sites found that nurses or other health care professionals are best suited to this task so they sought to identify staff with appropriate clinical training to administer their tests (Exhibit 11). Pilot sites have identified the need for additional staff to read, communicate, and report results, and three of these sites—Rhode Island, Tulsa, and Washington, DC—have begun to recruit for these staffing needs.

Exhibit 11. Staffing approaches pilot sites have used

	Types of professionals recruited to administer tests	Staffing needs for communicating and reporting results
Central Falls, RI	EMTs, National Guard	Confirmatory PCR test results were also performed; staff needed to read and communicate results of BinaxNOW and manage traffic flow
Los Angeles, CA	School nurses where available; other administrative staff when needed (if they are willing)	TBD
Louisville, KY	Nurse staffing agency; seeking nurses who can incorporate trauma-informed approach	TBD
New Orleans, LA	School nurses	Nurses report results to individuals and the state
Tulsa, OK	School nurses or nurses in training	Additional staff needed to record and communicate results
Washington, DC	Contracted nurses	Nurses with pediatric experience needed; additional staff needed for paperwork

Rely on nurses or other trained health care professionals to administer tests. The BinaxNOW tests can be administered by adults who do not have a health care background. However, school staff who are not trained nurses or other health professionals may be unwilling to administer these tests because they do not want to be put at risk of infection or do not feel comfortable responding to questions or concerns raised by people being tested. School administrators in Los Angeles were particularly unwilling to take on the risks associated with coming to school and conducting tests, both because case rates have been especially high in

Key questions: Staff and train workforce

Recruiting for test administration. Who should staff a testing program? What is the ideal number of staff to administer testing? How will schools identify, recruit, and onboard staff for testing? When should schools start recruiting?

Communicating and reporting results. How will schools communicate the test results and next steps to the individual, school leaders, and health officials? What are the staffing implications?

their area and because many of these administrators have been working from home since March and do not feel comfortable returning to their work sites. In addition, health care professionals are better positioned to provide students, families, and school staff with clinical and public health guidance during test administration. Testing leads in Louisville found that testing can be an intervention in itself, as trained test administrators are able to build testers' awareness of Covid-19 transmission and appropriate mitigation measures at the time of the test. Trained health care providers—especially those who have experience working with children—are also best positioned to build trust and comfort with students. Washington, DC, found that nurses with pediatric experience are capable of relating to students, especially younger students, and putting them at ease, while Louisville has noted that health care providers who provide trauma-informed care may be better able to understand and address any contextual factors that can shape students' fears and concerns.

> **"The BinaxNOW instructions say that you just need a high school degree and training [to administer the test], but that's just not going to fly in our community."**
>
> ***– Testing lead, Louisville***

Recruit trained nursing staff early in the design phase. The current Covid-19 surge in the United States has limited the availability of licensed health care personnel to staff testing programs; schools should therefore begin to recruit staff as early as possible in the design phase of their testing program. Washington, DC, found that working with a temporary staffing agency may not be sufficient, as the personnel identified through these types of agencies may lack the specific expertise to serve children and may be unwilling to engage in Covid-19-related work. Washington, DC, and Tulsa successfully took other creative approaches to recruit qualified staff: Washington, DC, recruited and contracted with retired school nurses, and Tulsa began identifying promising nurses in training who are ready and willing to take on this challenge. Tulsa's approach has been particularly appealing to the nurses in training, who will also gain needed intern hours that they are unlikely to secure in other health care settings given Covid-19 restrictions.

Allocate additional staff to read, communicate, and report test results appropriately. As mentioned, results of BinaxNOW tests must be read within 15 to 30 minutes of specimen collection. Testing sites may therefore need additional staff to read and communicate results appropriately. As Tulsa testing leads learned, asking tested individuals to check test results on a smartphone app at their convenience is not feasible in many schools; schools thus needed to dedicate capacity to communicate results.

> **"Ninety percent of our students are on meal plans and one-third need assistance. The phone app [for communicating results] does not serve our whole population."**
>
> ***– Testing lead, Tulsa***

Staff are also needed to report test results to school and public health authorities. As Tulsa school leaders recently learned, the Navica app, designed originally by Abbott to provide BinaxNOW results on an individual basis, does not allow users to combine data from multiple sites into a district-wide view, which means that results from individuals across multiple schools must be manually aggregated for district leaders to use. School districts must also report results to state public health authorities in compliance with CLIA waivers and any other relevant regulations. These reporting needs can be significant and require a large amount of staff time and expertise.

"Two of our nurses worked in trauma and urgent care so when the tears started to flow, they were right there to wipe them away."

– Testing lead, Washington, DC

Clearly communicate the protocol for confirmatory PCR testing and isolation. Students and staff who receive a BinaxNOW test through a school-based testing program must be informed of their next steps. Individuals who require a confirmatory PCR test should be made aware of this immediately, PCR testing should be offered quickly and easily, and PCR results should ideally be communicated the same day. These steps can help keep students and staff who are truly Covid-19-positive from returning to school while they are infectious. As a testing lead in Rhode Island noted, many entities outside of a school—such as the labs that conduct PCR tests and the agencies that lead contact tracing efforts—must collaborate to take these next steps in a timely manner. Although some of these elements may be outside the control of school officials, school leadership can encourage staff involved in implementing the testing program to become familiar with these protocols and do everything they can to support compliance.

IV. Effectiveness of school-based antigen testing

Mathematica is applying ABM to investigate the effectiveness of antigen testing on improving key outcomes in schools and their communities. The results focus on typical primary and secondary schools in the United States, in terms of number of students, teachers, and staff; therefore, the key findings and insights will be applicable to a range of K-12 school settings.

Early insights about effectiveness

1. Weekly screening of all students, teachers, and staff can reduce in-school infections by 50 percent, making it more effective than masking but less effective than social distancing.
2. Testing only teachers and staff is less effective, with reductions in in-school infections ranging from 5 percent (for monthly testing) to 20 percent (for twice weekly testing).
3. There is a tradeoff between testing frequency and in-person learning; more frequent testing results in more infections being detected, which requires more isolation and quarantining and thus more time away from learning for all exposed or infected students.
4. The impact of testing frequency on in-person learning is more limited in primary schools, in which students and staff typically remain in a single classroom; the impact is greater in high schools, where students typically attend multiple classes in a day.

Pilot sites have been asked to provide information on the types of interactions between school populations, use of other mitigation measures in the school, and testing approaches under consideration (Exhibit 12). Other key data inputs, such as infection rates in the community, are collected from existing literature or, where feasible, city- or state-level resources. These inputs informed the details of our models, including the risk of transmission that arises from different types of interactions, and the likelihood that testing strategies can reduce that risk. We used agent-based models to assess the effectiveness of the testing approaches under consideration on two key outcomes, above and beyond the other mitigation measures implemented in the school: (1) the number of in-school infections, and (2) in-person learning, as measured by attendance. Decision makers can use this information, along with an assessment of the benefits and drawbacks associated with testing and other mitigation measures, to guide decisions about which strategies to implement and whether in-person learning can be conducted safely. Details about the methods, inputs, and model assumptions can be found in Appendix B.

Exhibit 12. Key school populations, interaction types, and mitigation strategies incorporated into ABM based on potential pilot site strategies

Interaction types			Strategies that reduce transmission risk associated with interaction				
School population	Interacts with…	Via…	Testing teachers and staff	Testing students	Pooled testing of population	Social distancing/ masking	Limiting cross-class interactions
Student	Student	Classroom		✓		✓	
Student	Student	Lunch/ recess		✓			✓
Teacher	Student	Classroom	✓	✓	✓	✓	
Teacher	Teacher	Meetings	✓		✓	✓	
Staff	Teacher	Meetings	✓				
Benefits			Identifies positive adults (most likely to transmit) Increases confidence for in-person learning	Identifies positive cases	Identifies positive cases	Minimizes spread to all others	Minimizes spread to other grades and classes
Drawbacks			Time and resource intensive	Time and resource intensive	Multiple tests required to identify positive case	May restrict social interactions	May restrict social and cross-grade interactions

In the remainder of this section, we describe our research questions, modeling approach, and early insights about the effectiveness of school-based antigen testing. As other pilot sites implement their testing programs and gather the data inputs needed for ABM, additional research questions and models may be developed. The details of these additional models, as well as results from all models, will be made available in future reports.

Approach

We used ABM to investigate differences in in-school Covid-19 infection rates and in-person learning that might be expected across three testing scenarios (diagnostic testing only; screening of teachers and staff only; universal screening of all students, teachers and staff) and four testing frequencies (monthly, twice monthly, weekly, and twice weekly); these are described in Exhibit 13. The testing scenarios were selected based on consultation with stakeholders involved in this pilot initiative. These are not all of the possible ways that schools might test during the pandemic, but they capture a wide range of different approaches.[5]

Exhibit 13. Testing scenarios used in ABM

Testing audience and frequency		Testing scenarios									
		Diagnostic only	Screening teachers and staff only				Universal screening				
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Teachers and staff	Twice weekly		✓				✓				✓
	Weekly			✓				✓			
	Twice monthly				✓				✓		
	Monthly					✓				✓	
	None (diagnostic only)	✓									
Students	Twice weekly						✓				
	Weekly							✓			✓
	Twice monthly								✓		
	Monthly									✓	
	None (diagnostic only)	✓	✓	✓	✓	✓					

For each set of circumstances, we examined two outcomes:

1. Relative total number of infections among students and staff. The agent-based model simulates infections among the school population over weeks and months, making it possible to compare the estimated cumulative infections. This can help schools assess the extent to which different testing strategies may reduce in-person infections.
2. Percentage of days in the school building for a typical student. We estimate the percentage of school days a typical student is likely to be in the school building over the course of the school year, which

[5] In all scenarios, we made six key assumptions: (1) schools conduct fully in-person instruction; (2) students and staff wear masks on the bus and throughout the school day; (3) students interact with other students only in their class(es); (4) elementary students remain with the same class all day, while middle and high school students take six classes during the day; (5) lunch is eaten in classrooms rather than cafeterias; (6) if recess occurs, it involves only the students who are in class together. In addition, all results reported here are based on an assumed community infection rate of 100 cases per 100,000 people per week. As a robustness check, we also conducted all analyses assuming community infection rates of 50 and 150 cases per 100,000 people per week. More details on methods, assumptions, and inputs can be found in Appendix B.

depends on isolation and quarantine that may result from positive tests. This can help a school predict how much disruption the typical student is likely to experience.

3. Many critical factors affecting disease spread remain highly uncertain, such as the relationship between length of exposure and transmission probability. The model must make assumptions about these factors. Given the uncertainty of these assumptions, we focus on the relative changes in in-school infections or days of in-person learning a school is likely to experience under different operating scenarios and in different circumstances, rather than the absolute number of infections or days.

Impact on in-school infections

School-based screening programs reduce in-school infections, but screening only teachers and staff is less effective than universal screening.

We examine the impact of a school's testing scenario on the relative number of infections among students and staff over several months, and find that the number of infections among the school population falls steadily as the testing frequency increases from monthly to twice weekly.[6]

Weekly screening of all students, teachers, and staff can reduce in-school infections by 50 percent for high schools and 35 percent for primary schools. For universal screening, the number of in-school infections falls steadily as the testing frequency increases from monthly to twice-weekly. Weekly screening of all students, teachers, and staff can reduce in-school infections by 50 percent in high schools (Exhibit 14) and by 35 percent in primary schools (Exhibit 15). The differences in impact across school types are due to the high rates of transmission and susceptibility of high school students compared to primary school students, and due to the greater number of contacts that high school students are likely to have.

Practicing physical distancing (of six feet or more) is estimated to reduce Covid-19 transmission by 88 percent, and universal masking is estimated to reduce Covid-19 by 40 percent (Leung et al. 2020). Therefore, we estimate that weekly screening of all students, teachers, and staff has a smaller impact than practicing physical distancing.

[6] These results assume that schools quarantine close contacts, including everyone in a classroom with an infected individual, but do not shut down entirely when cases are detected.

Exhibit 14. Cumulative Covid-19 infections among students and staff in high schools

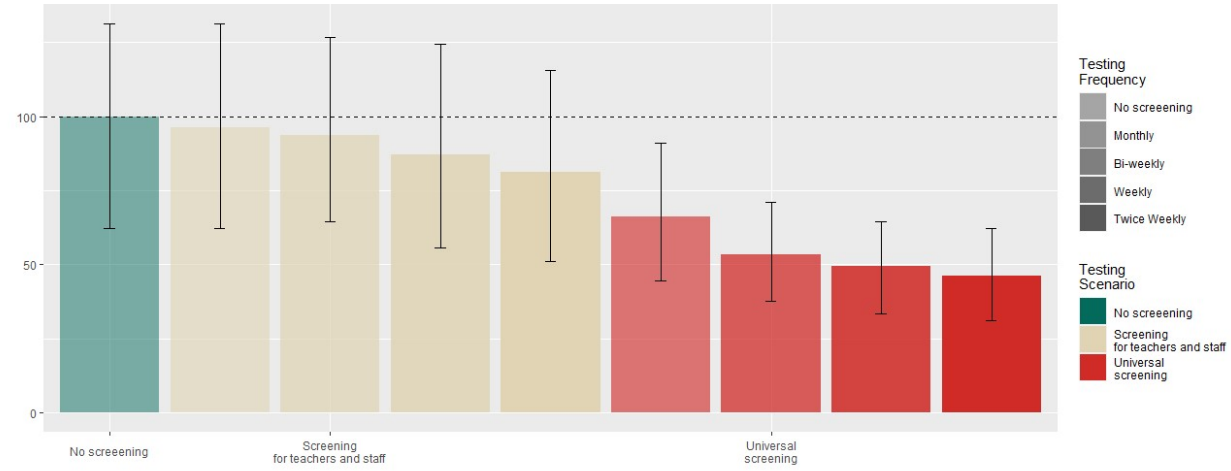
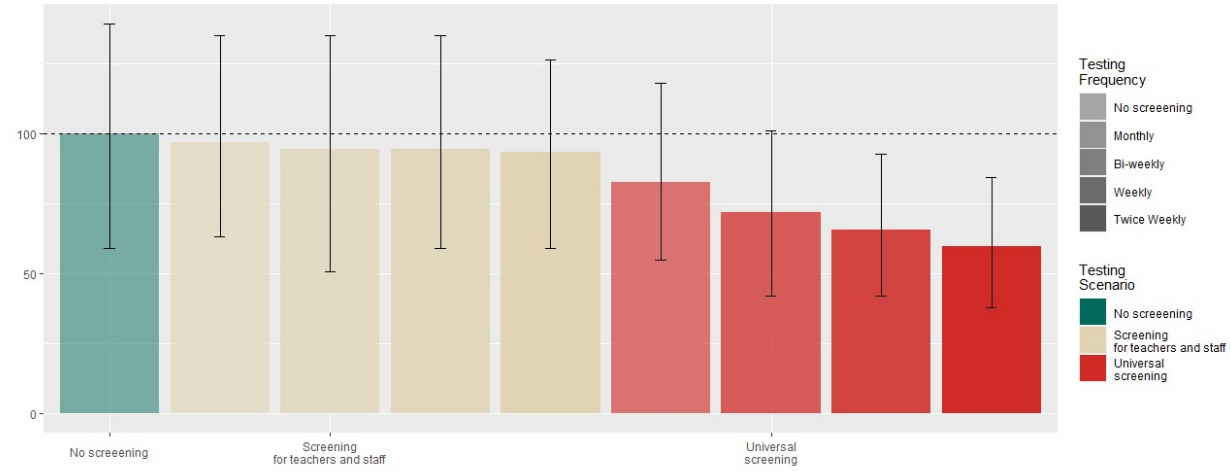


Exhibit 15. Cumulative Covid-19 infections among students and staff in primary schools



Screening only teachers and staff is less effective than universal testing. In high schools, screening only teachers resulted in reductions of infections ranging from 4 percent (for monthly testing) to 19 percent (for twice weekly testing). We estimated smaller reductions for primary schools, from 3 percent (for monthly testing) to 7 percent (for twice weekly testing). Given these limited benefits, screening only teachers and staff may not be an effective way to reduce in-school infections.

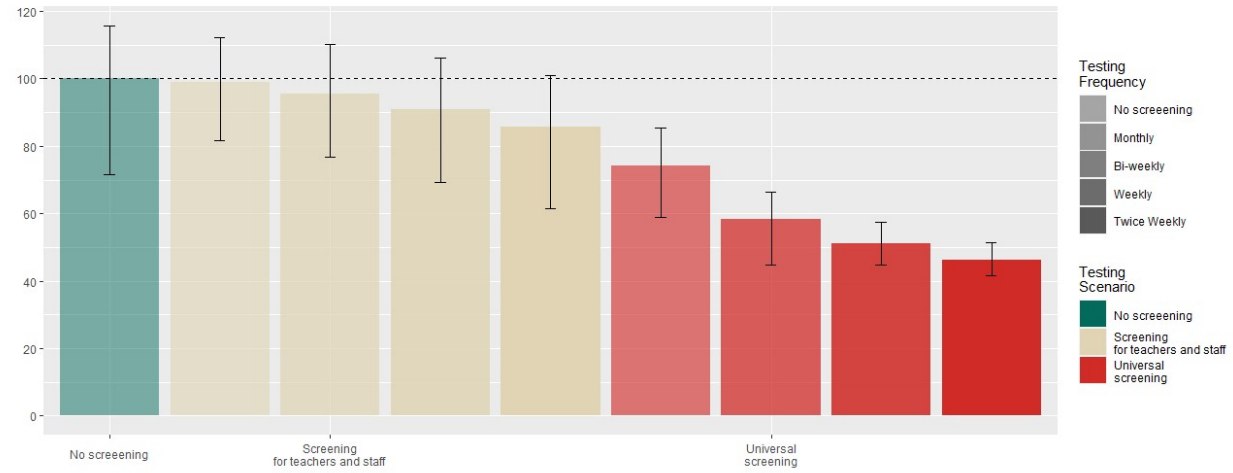
Impact on in-person learning

School-based testing programs reduce in-person learning days as screening coverage increases, because increased testing results in more students, teachers, and staff being asked to isolate or quarantine.

Increases in screening coverage lead to discovery of more CovidCovid-19 infections, which leads to more quarantining of individuals and their classrooms. School type has a strong impact on the strength of that relationship; individuals in a high school have more contact with others than those in a primary school because high school students typically attend multiple classes in a day while primary school students do not.

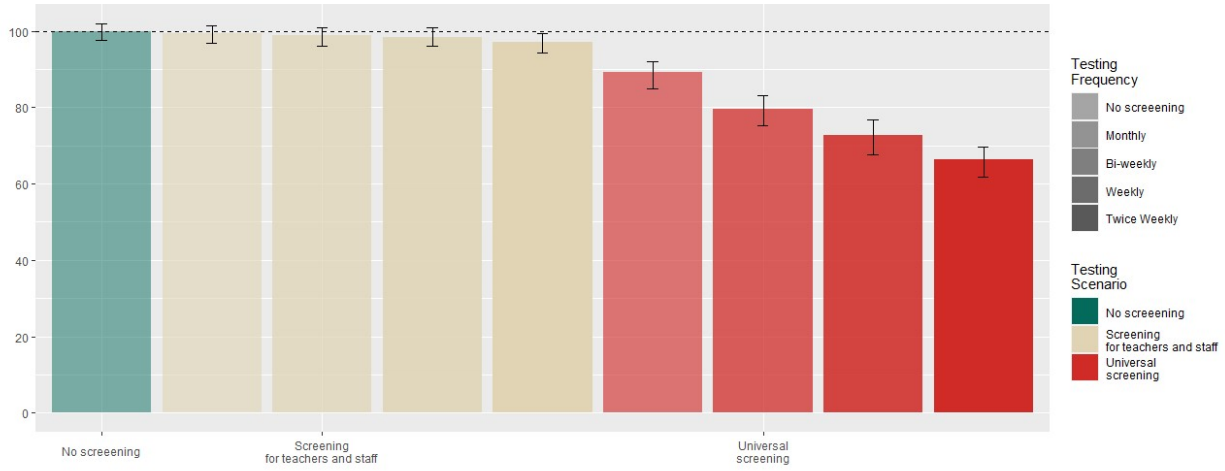
There is a clear trade-off between screening frequency and in-person learning (Exhibit 16). Screening helps identify infections that would otherwise remain undetected, requiring isolation and quarantining that otherwise would not take place. We assume that if a teacher tests positive, individuals in each of the teacher's classes will be quarantined. Screening teachers and staff therefore decreases in-person attendance between 2 percent (for monthly screening) and 15 percent (for twice weekly screening). In addition, if a student tests positive, individuals in each of the student's classes and bus will be quarantined. Universal screening of teachers, staff, and students therefore reduces in-person days between 25 percent (for monthly screening) and 55 (for twice weekly screening).

Exhibit 16. Average percentage of high school days in-person



The impact of screening on in-person learning is smaller in primary schools than high schools (Exhibit 17). Primary school students typically remain in a single classroom for the full day, while high school students may have several different classes in a day. Because students, teachers, and staff at a high 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 high schools. Primary school in-person attendance drops by between 1 percent (for monthly testing) and 4 percent (for twice weekly testing) when screening just teachers and staff, and between 11 percent (monthly) and 35 percent (twice weekly) when screening universally.

Exhibit 17. Average percentage of primary school days in-person



V. Discussion, implications, and next steps

Based on early learnings from the six pilot sites that have implemented or plan to implement antigen testing in their schools, Mathematica has identified key crosscutting considerations about the acceptability and feasibility of designing and setting up school-based testing programs, as well as the potential effectiveness of these programs. Below, we discuss overarching learnings and considerations that may offer insights for other schools or school districts interested in understanding the potential acceptability, feasibility, and effectiveness of school-based testing, and we discuss their implications for future implementation of school-based testing programs.

Implications of early insights for other schools and districts considering antigen testing

- A strong communications plan can inform community members of the limitations and implications of antigen testing, and support acceptance of and enthusiasm for school-based testing.
- Planners must balance the value of implementing an ideal testing program with community members' needs and comfort levels; this balance may introduce a risk that testing will not be robust enough to inform decision making.
- In designing a testing program, school leaders should collect input about the wraparound supports community members may need, and identify partners accordingly.
- School-based antigen testing requires more than just a supply of tests; to be feasible at a large scale, it also requires significant support and coordination from local, state, and national education and public health authorities.
- In communities that already have a robust testing program, school leaders should consider whether they need a school-based program or they could encourage students and teachers to have regular testing at existing community sites.
- School officials should continue to promote the adoption of other mitigation strategies in tandem with testing and should work to prevent school-based testing efforts from drawing resources or attention away from those strategies.
- The isolation and quarantine measures that limit in-person learning resulting from testing efforts is valuable from a public health perspective to stop outbreaks in school settings, but has other implications for the well-being of students and their families, and school officials will need to be prepared to address these.
- School-based testing programs have value beyond measures of their effectiveness—they can provide the comfort that students, parents, teachers, and staff need to resume or continue in-person learning.

Acceptability

School communities are broadly in favor of school-based testing programs, but they may need support to fully understand their limitations and implications. Given the limited availability of Covid-19 testing in many parts of the country, it is perhaps unsurprising that key school stakeholders—including students, parents, teachers, and staff—are enthusiastic about introducing school-based testing programs. At a high level, these audiences have expressed excitement about the possibility of receiving regular, accessible testing. However, school leaders and public health officials understand that testing programs can have significant drawbacks. In the case of this pilot initiative, testing is being conducted primarily with rapid antigen tests, which are known to be less accurate than PCR tests. School leaders are concerned that some students, parents, and staff may find it challenging to interpret antigen test results and may not be willing to comply with recommendations for frequent testing or with isolation, quarantine, or contact tracing protocols based on the results of these tests. A strong communications plan, informed by community input and delivered by trusted messengers, could help keep community members well informed of the limitations and implications of antigen testing, and maintain high acceptance of and enthusiasm for school-based testing programs.

Modifications to the ideal testing approach may be necessary to make the testing program acceptable to students, parents, and staff—but this may limit the testing program's value. Despite the general acceptability of school-based testing, leaders in pilot sites found that many students and parents were uneasy with the prospect of frequent testing, with concerns about the discomfort of test administration and feeling like "test subjects." Administrators understood that this concern alone could render any school-based testing effort unacceptable to students and their families. Program planners may thus have to modify the ideal testing approach to promote high uptake of testing. These tradeoffs could have significant implications for the value of a testing program; testing too infrequently may make it challenging or impossible to contain spread and glean meaningful information about infections that could guide decision making around school opening or other policies. Although testing less frequently than recommended may help the school community feel safe, it may not be a good use of resources given the limited information it would generate.

To break chains of transmission, people must act on test results appropriately, which requires recognizing and mitigating adverse incentives. The families of students who test positive may need other services to minimize the potential harm of complying with isolation and quarantine protocols. If these services are not available, working families may have an adverse incentive not to participate in testing because of the challenges that could come with a positive test and required isolation or quarantine. To promote acceptability of the testing program, and to encourage compliance with isolation, quarantine, and contact tracing protocols, schools should seek to offer these wraparound services to students and staff. This may be challenging for schools or school districts, which are likely already stretched thin. However, key community partners such as hospitals or health care networks may be willing to offer support. Programs should identify these potential partners early and leverage them whenever possible. In addition, programs could conduct a needs assessment, town hall meetings, or other listening sessions while designing their testing program, to identify the specific supports that community members may need and begin planning for ways to provide these supports.

Feasibility

Setting up on-site antigen testing at schools may prove to be prohibitively complex, expensive, and challenging to sustain for many schools. School-based testing requires a significant amount of space and infrastructure, professional health care workers, and access to tests and related supplies. It also requires compliance with a host of ethical, legal, and regulatory requirements related to informed consent, collecting and processing biological specimens, and reporting test results. Antigen testing is particularly complex, as both test administration and reading of results must be conducted on site. Some schools participating in this pilot initiative have (1) had access to key personnel and logistical support, (2) received expert guidance on their proposed testing approach, and (3) been connected to testing-related service providers. They have also benefited from sharing experiences, guidance, and resources with one another through the CCLG and TSG. However, these schools and districts are unlikely to have access to the necessary resources to sustain regular antigen testing in the long term—and other schools and districts across the country are unlikely to have this level of support at any stage. With vaccines currently being rolled out across the country, it is possible that schools may only need to sustain testing programs until the majority of their population is vaccinated. However, public health experts acknowledge that this process could take many months, and could thus require that on-site, school-based testing programs be functional for at least the remainder of the school year. Several key informants have observed that this may not be feasible at a large scale across the country without significant support and coordination from local, state, and national education and public health authorities.

Schools should consider alternatives to on-site antigen testing when possible, including outsourcing testing responsibilities or relying on existing community sites. Although many key informants in pilot sites were skeptical of their schools' ability to implement and sustain school-based antigen testing, many were far more optimistic about off-site testing. Approaches to off-site testing could include mobile testing sites or contracting with testing providers to offer testing for key school community members at sites that are better suited for this, for example, local parks or sports arenas. In communities that already have a robust and widespread testing program, school leaders should consider whether a school-specific testing program is necessary; it may be possible to encourage students and teachers to obtain regular testing at existing community sites.

Effectiveness

Other mitigation measures appear to be working well, and testing programs should support— and not take away from—these other efforts. Schools in all pilot sites have implemented or plan to implement a robust set of mitigation measures in line with guidelines from the Centers for Disease Control and Prevention for limiting the spread of Covid-19 in schools. To date, evidence suggests that these measures can be effective when students, teachers, and staff comply with them, and that they cannot be replaced by a testing program. The results of Mathematica's ABM work indicate that frequent screening is also an effective way to reduce the risk of in-school infections. However, as testing leads in all pilot sites have noted, testing is more resource-intensive and logistically complex than most other mitigation measures such as masking, distancing, and opening windows. Furthermore, when other mitigation measures are used widely, the expected number of in-school infections may be low to begin with—meaning that a testing program may add relatively little value on top of these other measures. Thus, although testing can be a valuable component of a school's Covid-19 mitigation strategy, robust implementation of other strategies is also important for reducing in-school infections. School officials should continue to promote the adoption of these other mitigation strategies and should work to prevent any school-based testing efforts from drawing resources or attention away from these strategies.

Frequent testing may reduce in-person learning. If students and staff comply with the isolation and quarantine guidelines resulting from positive tests, testing programs can reduce the number of days that students attend school for in-person learning. While this may be advisable from a public health perspective, limiting school attendance could have negative implications for the well-being of students, staff, and their families. School officials will need to be prepared to address these implications if they opt for frequent testing.

Testing programs may provide the comfort that students, parents, teachers, and staff require to resume in-person learning, which could be one way to measure "effectiveness." Even if testing programs alone are not more effective than other mitigation measures at limiting in-school infections and allowing schools to remain open, strong community support for these programs suggests that they still have value. The "effectiveness" of a testing program could be partly defined as its ability to make the school community feel comfortable with in-person learning—and early learnings from pilot sites indicate that testing is especially successful at this. Parents' enthusiasm for school-based testing indicates that offering testing helps build parents' comfort with sending their children to school. Teachers and staff also feel safer with testing, and in some cases may be unwilling to return to in-person teaching without access to regular testing. These findings suggest that testing programs have value beyond quantitative measures of their effectiveness, and the considerable resources and effort they require may be worth the peace of mind they provide.

Next steps

The insights and recommendations in this report are limited to the experiences of the six sites participating in this pilot initiative, all of which have been working on designing and implementing their testing programs for only a few months. This report also captures insights at a relatively early stage in testing implementation. A future report will update the findings in this report as pilot sites continue to refine their testing plans and conduct testing in their schools.

The early insights presented in this report are also limited by the fact that most sites have not yet been able to supply quantitative data to describe their testing or key outcomes such as in-school infections, or to build school-specific agent-based models. Testing leads and other key decision makers in each school and city have been stretched thin as they have sought to quickly implement their testing programs, and thus have had limited capacity to engage with the ABM work or to supply data that they would be comfortable sharing publicly. In a future report, we expect to share more quantitative details of sites' implementation as well as results from the agent-based models being built with participating sites.

As pilot schools prepare to begin the spring semester, and as local public health authorities plan for vaccines to become available, we will continue to follow pilot sites to document their learnings, insights, and emerging best practices and recommendations. We will also assess the feasibility of conducting a longer-term study of the effectiveness of screening in schools, including the possibility of conducting a matched comparison or other quasi-experimental design with any sites that may be willing to participate. The goal of this work will be to provide continued information and evidence to keep schools open while keeping students, families, teachers, and staff safe.

REFERENCES

Bi, Q., Y. Wu, S. Mei, C. Ye, X. Zou, Z. Zhang, X. Liu, et al. "Epidemiology and transmission of COVID-19 in 391 cases and 1,286 of their closest contacts in Shenzhen, China: A retrospective cohort study." *Lancet Infectious Diseases,* vol. 20, no. 8, August 2020, pp. 911-919. https://doi.org/10.1016/S1473-3099(20)30287-5.

Davies, N., P. Klepac, Y. Liu, K. Prem, M. Jit, Eggo, R., and CMMID COVID-19 working group. "Age-dependent effects in the transmission and control of COVID-19 epidemics." *Nature Medicine,* vol. 26, June 2020, pp. 1205-1211. https://doi.org/10.1038/s41591-020-0962-9.

Dimitrov, N. and L. Meyers. "Mathematical approaches to infectious disease prediction and control." *INFORMS TutORials in Operations Research,* September 2010, pp. 1-25. https://doi.org/10.1287/educ.1100.0075.

Dorn, E., B. Hancock, J Sarakatsannis, and E. Viruleg. "COVID-19 and student learning in the United States: The hurt could last a lifetime." McKinsey & Company, June 2020. Available at https://webtest.childrensinstitute.net/sites/default/files/documents/COVID-19-and-student-learning-in-the-United-States_FINAL.pdf.

Faherty, L.J, B. Master, *et al.* "COVID-19 Testing in K-12 Schools: Insights from Early Adopters." Santa Monica, CA: RAND Corporation. 2021. Available at https://www.rand.org/pubs/working_papers/WRA1103-1.html.

Ferguson, N., D. Laydon, G. Nedjati-Gilani, N. Imai, K. Ainslie, M. Baguelin, S. Bhatia, et al. "Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand." *Imperial College London*, March 2020. https://doi.org/10.25561/77482.

Gill, B., R. Goyal, and J. Hotchkiss. "Operating Schools in a Pandemic: Predicting Effects of Opening, Quarantining, and Closing Strategies." Princeton, NJ: Mathematica. September 2020. Available at https://mathematica.org/our-publications-and-findings/publications/operating-schools-in-a-pandemic-predicted-effects-of-opening-and-quarantining-strategies.

Hoffman, J. and E. Miller. "Addressing the Consequences of School Closure Due to COVID-19 on Children's Physical and Mental Well-Being." *World Medical & Health Policy*, vol. 12, no. 3, September 2020. https://doi.org/10.1002/wmh3.365.

Keeling, M., M. Tildesley, B. Atkins, B. Penman, E. Southall, G. Guyver-Fletcher, A. Holmes, et al. "The impact of school reopening on the spread of COVID-19 in England." *MedRxiv*, June 2020. https://doi.org/10.1101/2020.06.04.20121434.

Lai, S., N. Ruktanonchai, L. Zhou, O. Prosper, W. Luo, J. Floyd, A. Wesolowski, et al. "Effect of non-pharmaceutical interventions to contain COVID-19 in China." *Nature*, vol. 585, May 2020, pp. 410-413. https://doi.org/10.1038/s41586-020-2293-x.

Leung, N., D. Chu, E. Shiu, K. Chan, J. McDevitt, B. Hau, H. Yen, et al. "Respiratory virus shedding in exhaled breath and efficacy of face masks." *Nature Medicine,* vol. 26, no. 5, May 2020, pp. 676-680. https://doi.org/10.1038/s41591-020-0843-2.

Lu, J., J. Gu, K. Li, C. Xu, W. Su, Z. Lai, D. Zhou, et al. "COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020." *Emerging Infectious Diseases,* vol. 26, no. 6, July 2020. https://dx.doi.org/10.3201/eid2607.200764.

Park, Y., Y. Choe, O. Park., S. Park., Y. Kim, J. Kim, S. Kweon, et al. "Contact Tracing during Coronavirus Disease Outbreak, South Korea, 2020." *Emerging Infectious Diseases,* vol. 26, no. 10, October 2020. https://dx.doi.org/10.3201/eid2610.201315.

Prem, K., Y. Liu, T. Russell, A. Kucharski, R. Eggo, N. Davies, M. Jit, and P. Klepac. "The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study." *Lancet Public Health*, vol. 5, no. 5, March 2020, pp. 261-270. https://doi.org/10.1016/S2468-2667(20)30073-6.

R Core Team. "R: A language and environment for statistical computing." R Foundation for Statistical Computing. 2020. Available at https://www.R-project.org/.

Rivers, C., C. Silcox, C. Potter., M. Franklin, R. Ray, M. Gill, M. McClellan. "Risk Assessment and Testing Protocols for Reducing SARS-CoV-2 Transmission in K-12 Schools." October 2020. Available at https://www.rockefellerfoundation.org/wp-content/uploads/2020/10/Risk-Assessment-and-Testing-Protocols-for-Reducing-SARS-CoV-2-Transmission-in-K-12-Schools_Final-10-14-2020.pdf.

Testing for America. "COVID Testing Playbook For Higher Education Institutions." December 2020. Available at https://static1.squarespace.com/static/5eb1ad02f776b52308734838/t/5fcadde9bce7087d1ad17ccd/1607130604703/Testing+for+America_Testing+Playbook+for+Higher+Education+Institutions+12+1+2020.pdf.

Van Kerckhove, N. Hens, W. Edmonds, and K. Eames. "The impact of illness on social networks: implications for transmission and control of influenza." *American Journal of Epidemiology*, vol. 178, no. 11, December 2013, pp. 1655-1662. https://doi.org/10.1093/aje/kwt196.

Willem, L., F. Verelst, J. Bilcke, N. Hens, and P. Beutels. "Lessons from a decade of individual-based models for infectious disease transmission: A systematic review (2006-2015)." *BMC Infectious Diseases,* vol. 17, no. 1, September 2017, pp. 612. https://doi.org/10.1186/s12879-017-2699-8.

Appendix A.

Agent-based model: methods, assumptions, and inputs

This page has been left blank for double-sided copying.

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 the 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).

There are four key components to the ABM: (1) specifying 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 as well as the number of teachers and staff are specified in Appendix Exhibit B.3. Each elementary student is assigned a single class, while high school students are assigned six classes that they attend each day; all classes are assumed to contain the same number of students. High 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 are assigned to ride the school bus. All school buses are assumed to transport the same number of students, randomly distributed across grades and classrooms.

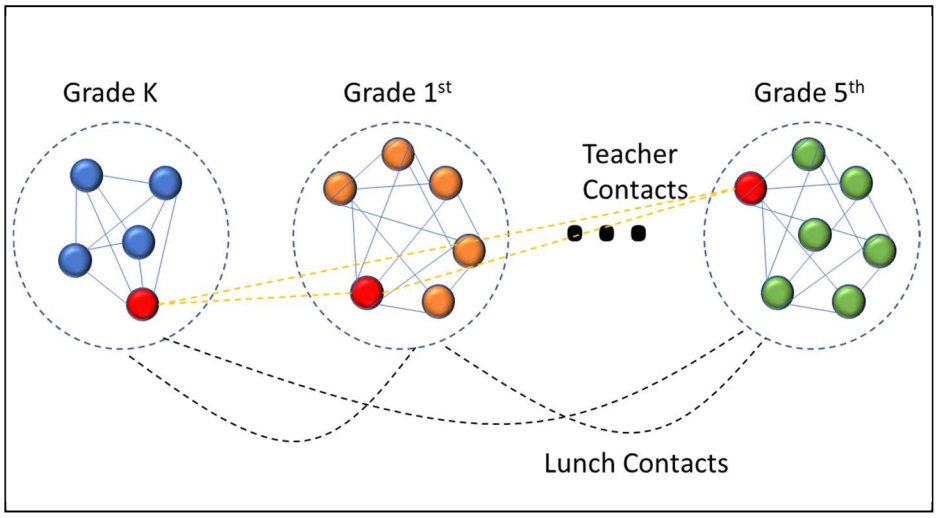
The ABM includes the four types of interactions (second component) listed below.

- **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 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 changes 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 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.

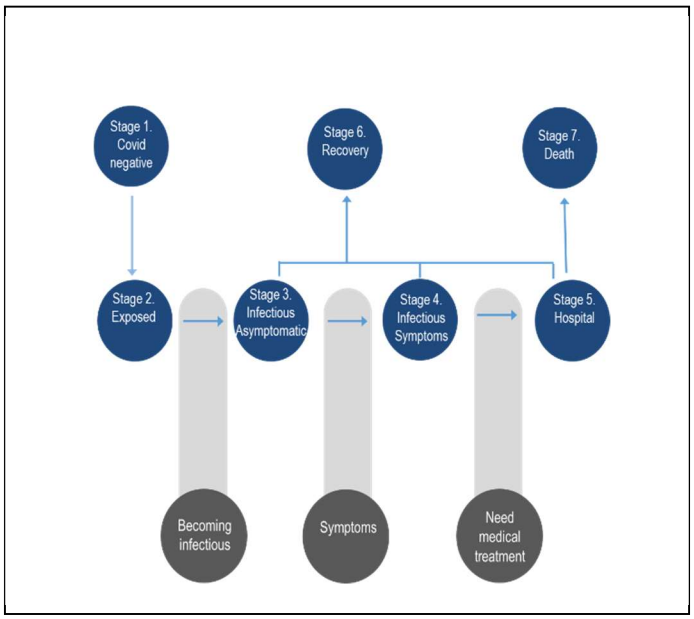
Appendix Exhibit A.1. Illustration of a potential contact network for a K–5 school



Appendix Exhibit B.1 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 B.4, as well as 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 A.2. Model for Covid-19 stages of care and possible transition pathways between stages



Regarding the fourth component, the model 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 B.2 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 B.4. 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.

Integration of 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, it is important for the simulation to know whether an individual is in their 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 average 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. 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 new findings about the relative susceptibility of younger versus older children (Park et al. 2020), secondary students are assumed to be as susceptible as adults, while elementary students are assumed to have half the susceptibility as adults. Appendix Exhibit B.4 provides values for the transmission probabilities used in the model, which are derived from available external evidence on Covid-19 and mitigation factors.

Inputs

Appendix Exhibit A.3. 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. (2016). Half the people working in schools aren't classroom teachers—so what. *Brookings Institution*. Retrieved May, 31, 2017. (https://www.brookings.edu/research/half-the-people-working-in-schools-arent-classroom-teachers-so-what/)

[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 A.4. 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 their specific setting (Lu et al. 2020). However, this estimate is probably high due to 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 is 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, a value of half (50 percent) was selected 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 a 88 percent reduction due to social distancing of 6ft.

[10]Park et al. 2020[7]. Keeling et al. 2020[8] had estimated 63 percent for children across all ages, which is generally consistent with Park et al.'s subsequent finding of 50 percent for young children and no difference in susceptibility for older children.

Mathematica

Princeton, NJ • Ann Arbor, MI • Cambridge, MA
Chicago, IL • Oakland, CA • Seattle, WA
Tucson, AZ • Woodlawn, MD • Washington, DC

EDI Global, a Mathematica Company

Bukoba, Tanzania • High Wycombe, United Kingdom

mathematica.org