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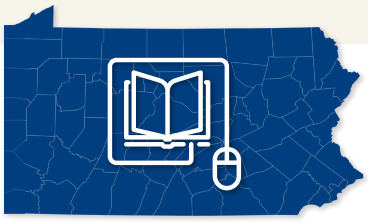
Education Research Brief

Stephen Lipscomb, Duncan Chaplin, Ijun Lai, Alma Vigil, and Hena Matthias
Contributions from Candy Miller, Rhonda Johnson, and Rosemary Riccardo

Did Remote Learning Lead to Different Education and Health Outcomes in Pennsylvania?

Key findings for the 2020–2021 school year

- Vulnerable groups of students were more likely than students overall to attend local education agencies (LEAs) where the predominant instructional modes included remote learning.
- The same groups of students were also more likely to be in LEAs where larger shares of the student population had trouble accessing reliable internet.
- More remote learning was associated with lower assessment performance in grades 5–8, especially in schools with higher levels of economic disadvantage. It was also associated with lower suspension rates in grades 6–12 and did not appear to harm or help graduation rates.
- Remote learning in high school was associated with lower subsequent COVID-19 rates within an LEA's boundary, suggesting it had an important public health benefit.



The COVID-19 virus brought on a public health emergency that massively disrupted school systems and learning nationwide. During the 2020–2021 school year, many LEAs in Pennsylvania and other states adopted remote learning to help slow the virus's spread. However, remote learning came with challenges for students, families, and LEAs. These challenges included very practical ones like not having a reliable internet connection or the correct link to log into classes, as well as fatigue from so many remote meetings and feelings of social isolation. Most Pennsylvania LEAs resumed in-person learning at least partially by the end of the 2020–2021 school year, albeit with masking and other COVID-19 safety protocols that made the learning experience different than in the past. All LEAs resumed fully in-person learning by the fall of 2021 and COVID-19 safety protocols have since eased, but concern about student outcomes has continued.

This brief examines remote learning in Pennsylvania and its role in shaping education and community health outcomes during the 2020–2021 school year.[1] The findings contribute to a growing evidence base on the effects of remote learning during the pandemic that has predominantly focused on assessment outcomes. This brief also explores suspension, high school graduation, and high school dropout outcomes, as well as whether remote learning helped reduce COVID-19 case rates in local communities.

Data for the brief come primarily from administrative records maintained by the Pennsylvania Department of Education (PDE), the Pennsylvania Department of Health, and the Pennsylvania Department of Human Services. The brief also uses survey responses from a large, representative set of LEAs about their use of remote learning during 2020–2021.[2] Exhibit 1 explains the methods.

Exhibit 1. Methods

Research questions and approach. The brief addresses three research questions, listed below, about the remote learning students received based on the predominant instructional modes their LEAs used during the 2020–2021 school year. Our aim is to understand how outcomes changed in response to remote learning and our approach adjusts for various other factors to help isolate remote learning's effects. However, as a non-experimental study, the results may not be causal due to unobserved factors.

1. **How did exposure to remote learning vary across groups of students in Pennsylvania?** We described the predominant amounts of remote learning and the extent of synchronous remote instruction and connectivity challenges for students, as reported by LEAs, and how those amounts varied across groups of students.
2. **How was remote learning associated with student education outcomes?** We estimated the relationships of remote learning with various student outcomes, adjusting for students' 2019 outcomes from before the pandemic and other student and school characteristics. We also examined how those relationships differed based on a school's share of students facing economic disadvantage.
3. **How was remote learning associated with the subsequent COVID-19 rates of communities?** We estimated how an LEA's predominant instructional mode for high school grades at three points in time during the 2020–2021 school year related to the COVID-19 case rate in its attendance boundary the following month. Our approach controlled for prior COVID-19 case rates, prior instructional modes, and indicators for each time point and LEA. We focused on high school grades because concern about virus transmission rates was greatest in these grades.

Remote learning. LEAs reported their predominant instructional mode (fully remote learning, hybrid learning, or fully in-person learning) through a study-administered survey for the first 30 days of the school year, the 30 days after winter break, and the last 30 days of the school year. LEAs that used hybrid learning also indicated how many days of remote learning per week their hybrid model included. LEAs responded separately for elementary, middle, and high school grades. Our remote learning measure for most analyses was a weighted average, within each grade band, of the number of days of remote learning per week each LEA provided across the three periods. For the analysis of COVID-19 case rates, we used a separate remote learning measure for each of the three 30-day time periods.

Outcomes. We measured the following outcomes during the 2020–2021 school year:

- **Assessment performance:** Indicates if a student in grades 5–8 demonstrated at least (1) proficient performance or (2) basic performance on the Pennsylvania System of School Assessment in English language arts (ELA) and math
- **Suspension:** Indicates if a student in grades 2–5 or a student in grades 6–12 received an out-of-school suspension during the school year
- **Graduation:** Indicates if a student in grade 12 earned a high school diploma or GED by the end of the school year
- **Dropout:** Indicates if a student in grades 9–12 dropped out of high school by the end of the school year
- **COVID-19 case rate:** The number of COVID-19 cases per 100 people living within an LEA's boundary in October 2020, February 2021, and July 2021

Sample and representation. The study covers public school students in grades 2–12 in Pennsylvania during the 2020–2021 school year, although the specific grades covered differ by outcome. The analysis samples come from 148 LEAs (traditional school districts and brick-and-mortar charter schools in this research) that provided remote learning data. For the student-level analyses, we limited the samples to students within the specified grade levels for each outcome who had pre-pandemic data from the

2018–2019 school year (when they were in grades K–10). About 42 percent of Pennsylvania's 1.4 million students in grades 2–12 in 2020–2021 were included for at least one outcome. The availability of remote learning data was the main factor limiting the size of analysis samples. We weighted the data by LEA size, urbanicity, and charter status to represent all public school students in the relevant grades.

Appendix A provides more detail on the data and methods. Appendix B provides supplemental results.

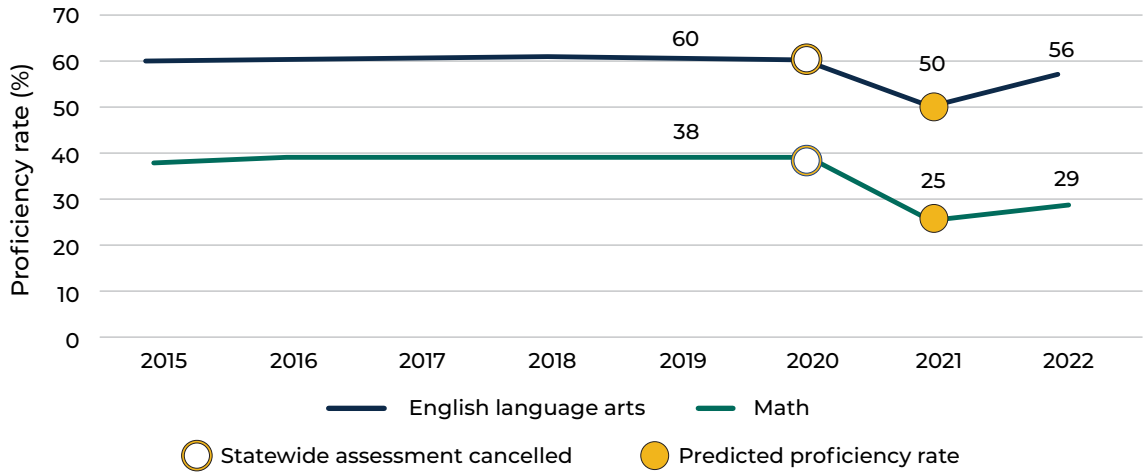
Context for remote learning and outcomes during the pandemic

Existing research and data from Pennsylvania and other states are beginning to shed light on education during the pandemic. Notable results that provide context for this brief's findings include the following:

- **Use of remote learning varied across Pennsylvania LEAs and throughout the 2020–2021 school year, and it became less common as the school year progressed.** About half of Pennsylvania students in each of the elementary, middle, and high school grade bands were in LEAs that began the year in fully remote learning (Lipscomb et al. 2021). The other half of students were split about evenly between LEAs that used fully in-person learning or hybrid learning (a mix of remote and in-person learning that, in Pennsylvania, typically included three remote days and two in-person days per week). Following the winter break, LEAs serving about 10 percent of students in each grade band had switched from fully remote learning to hybrid learning. By the last month of school, 93 percent of elementary and middle school students and 83 percent of high school students were in LEAs that offered hybrid learning or fully in-person learning.

- **Achievement declined during the pandemic, particularly in math, during remote learning, and in schools with high levels of economic disadvantage.** Predicted 2021 proficiency rates for grades 5–8 in Pennsylvania, adjusted for lower participation particularly among lower-performing students and differences in test timing[3], were 10 percentage points lower in ELA and 13 percentage points lower in math than their 2019 levels, before partially rebounding in 2022 (Exhibit 2). Proficiency rates in 11 other states declined by similar amounts on average (Jack et al. forthcoming).

Exhibit 2. Actual and predicted proficiency rates in grades 5–8 in Pennsylvania, 2015–2022



Source: Data from 2015–2019 and 2022 are from PDE. The 2021 data are predicted proficiency rates from Lipscomb et al. (2022a). This exhibit originally appeared in Lipscomb et al. (2022b).

Outside of Pennsylvania, remote learning led to larger drops in achievement than in-person learning, particularly in schools with large shares of students facing economic disadvantage who tended to receive the most remote learning (Cohodes et al. 2022; Darling-Aduana et al. 2022; Goldhaber et al. 2022; Jack et al. forthcoming). Most students made some learning gains, but their gains were less than those made in prior years by students in the same grades (Cohodes et al. 2022; Kuhfeld et al. 2022).

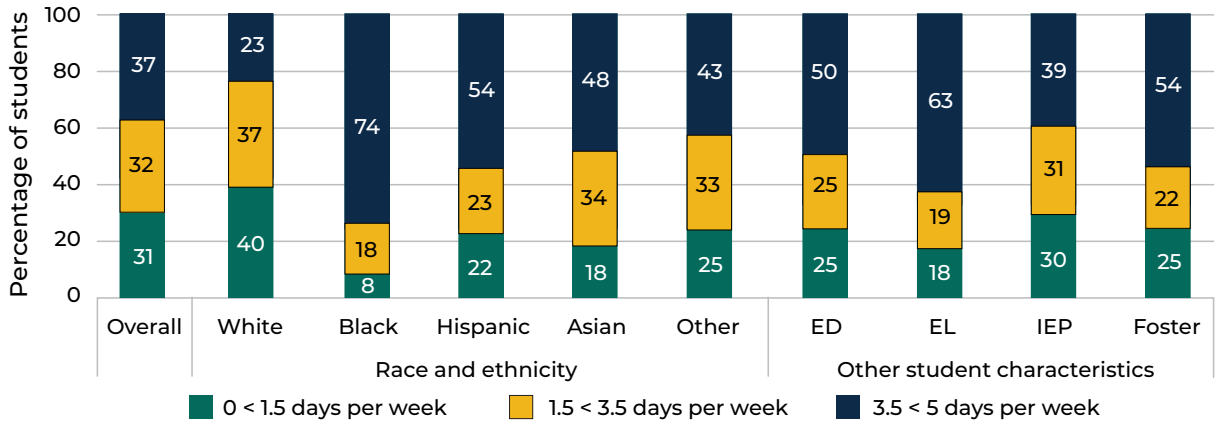
- **COVID-19 rates were higher in counties where school districts implemented less remote learning, especially when they had high prior rates of COVID-19.** Evidence from Washington and Michigan suggests that COVID-19 rates rose more quickly in counties where school districts used less remote learning in the fall of 2020. This was especially true in counties with high prior COVID-19 rates (Goldhaber et al. 2021). Pennsylvania's COVID-19 rates in fall 2020 were higher than in Michigan and Washington[4], suggesting that COVID-19 rates in Pennsylvania might also be affected by remote learning if similar conditions existed. National evidence also suggests that COVID-19 rates rose with in-person learning, especially for high school students, though not when schools used larger numbers of mitigation measures like masking and social-distancing (Lessler et al. 2021).

Findings about remote learning experiences

In this section, we describe how exposure to remote learning differed across groups of Pennsylvania students based on the predominant instructional modes their LEAs offered to all students.

- **Black students, English learners, and other vulnerable groups received more remote learning, on average, than students overall.** Across Pennsylvania, 37 percent of students in grades 2–12 were mostly in remote learning throughout the 2020–2021 school year (at least 3.5 days per week) and 31 percent were mostly in person (fewer than 1.5 days per week of remote learning) (Exhibit 3). These amounts varied considerably across student groups. For example, 74 percent of Black students were in remote learning at least 3.5 days per week, compared to 23 percent

Exhibit 3. Average number of days of remote learning per week based on the predominant instructional modes that LEAs used for grades 2–12 during the 2020–2021 school year



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: Exhibit B.2 shows findings for students not in the ED, EL, IEP and foster care groups. Remote learning was reported at the LEA level. Data were weighted to represent students.

ED = economically disadvantaged; EL = English learners; IEP = had an individualized education program; Foster = involved in the foster care system prior to 2020–2021.

of White students. Most students who were English learners (63 percent), Hispanic (54 percent), or involved in the foster care system (54 percent) averaged this much remote learning, too. This variation may partly reflect implications of state COVID-19 policies or guidelines that LEAs followed to help determine which instructional modes to use given their community case rates. Across schools and LEAs, receiving primarily remote learning was most common in schools with high levels of economic disadvantage (Exhibit B.1) and in urban LEAs (Exhibit B.2).

- **Groups of students who received the most remote learning also averaged the fewest hours per week of synchronous instruction during periods with hybrid or fully remote learning.** Instruction that teachers deliver live to students, either remotely or in person, is called synchronous instruction. Other instruction is asynchronous, for example, when teachers assign students learning activities to complete on their own. On average, students received 19 to 20 hours of synchronous instruction per week in hybrid or fully remote learning (Exhibit 4). Across grade bands, this was about 70 percent of their typical weekly instruction based on state required total instructional hours (Lipscomb et al. 2021).[5] Black students and English learners averaged less synchronous instruction in these modes than White students. Similarly, students in schools with high levels of economic disadvantage averaged fewer synchronous hours in these modes than students in schools with low levels of economic disadvantage (Exhibit B.1).

- **The same groups of students were also more likely to be in LEAs where larger shares of the student population had limited access to reliable internet.** For example, 71 percent of Black students were in LEAs that reported at least 10 percent of their enrollment did not have reliable internet, compared to 44 percent of White students (Exhibit 5). LEAs implementing remote learning may have had better information than they otherwise would on the extent of technology challenges among families. Across schools and LEAs, connectivity challenges were most prevalent in schools with high levels of economic disadvantage (Exhibit B.1) and in urban LEAs (Lipscomb et al. 2021).

Exhibit 4. Average hours per week of synchronous instruction based on the predominant instructional modes that LEAs used in grades 2–12 during fully remote and hybrid learning

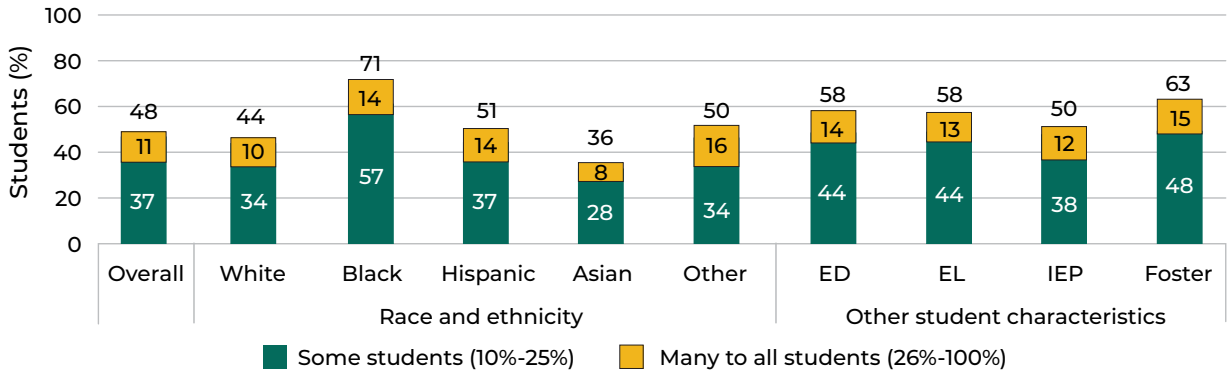
Mode	Overall	Race and ethnicity					Other characteristics			
		White	Black	Hispanic	Asian	Other	ED	EL	IEP	Foster
Hybrid	19	20	14	19	18	19	18	17	19	17
Fully remote	20	21	16	18	20	19	18	18	19	17

Source: Study-administered survey of LEAs.

Note: Data were weighted to represent students.

ED = economically disadvantaged; EL = English learners; IEP = had an individualized education program; Foster = involved in the foster care system prior to 2020–2021.

Exhibit 5. Percentages of students in grades 2–12 whose LEA reported that shares of the student population had limited access to reliable internet



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: Exhibit B.4 shows findings for students not in the ED, EL, IEP and foster care groups. Data were weighted to represent students.

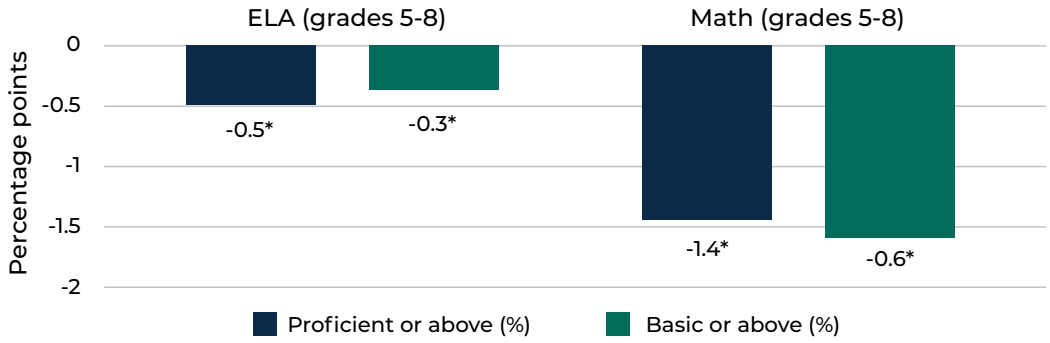
ED = economically disadvantaged; EL = English learners; IEP = had an individualized education program; Foster = involved in the foster care system prior to 2020–2021.

Findings about remote learning and student education outcomes

In this section, we estimate the relationships between remote learning and assessment and non-assessment outcomes, controlling for background characteristics.

/ **Grade 5–8 students who received more remote learning had lower rates of proficient and basic academic performance, particularly in math, compared to similar students.** Estimated rates of proficiency for test takers[6] were 0.5 percentage points lower in ELA and 1.4 percentage points lower in math for each additional day of remote learning per week, controlling for other factors (Exhibit 6).[7] Because students attended five days per week, each additional day of remote learning meant one fewer day of in-person learning. When we compared

Exhibit 6. Estimated difference in the probability of test takers in 2021 achieving at least proficient performance or at least basic performance for each additional day of remote learning per week



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: This exhibit shows estimated regression coefficients for remote learning. The regressions adjusted for students' 2019 achievement and other student, school, and LEA characteristics (see Appendix A).

*Differs by a statistically significant margin from zero at the .05 level, two-tailed test.

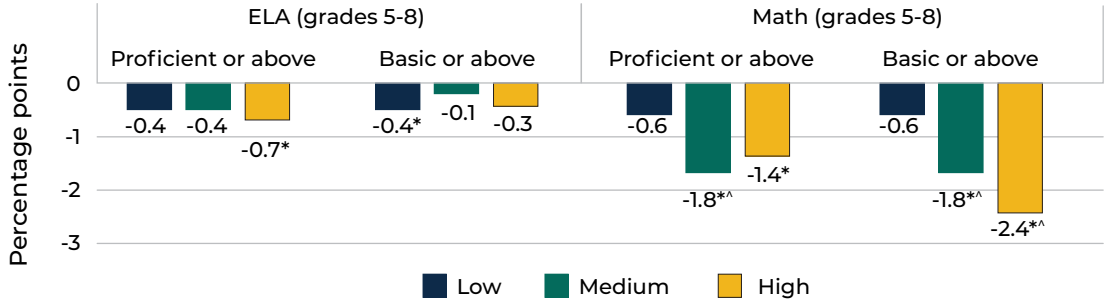
students with five days of remote learning per week to those with none, the implied differences in proficiency rates were 2.5 percentage points for ELA and 7.0 percentage points for math.

The probabilities of achieving at least basic performance, the category below proficient, were lower too (by 0.3 percentage points in ELA and 1.6 percentage points in math for each day of remote learning per week). The probabilities of below basic performance, the lowest category, increased by the same amounts they decreased for basic performance.

- **Relationships between remote learning and assessment performance in grades 5–8 were more negative in schools with higher levels of economic disadvantage, particularly in math.** More remote learning was associated with lower probabilities of proficient and basic performance in math regardless of a school's level of economic disadvantage, but the estimates were larger and statistically significant for students at schools with medium and high levels (Exhibit 7). The findings suggest an additional day of remote learning per week in schools with a medium or high level of economic disadvantage lowered the probability of math proficiency by 1.4 to 1.8 percentage points and the probability of at least basic performance by 1.8 to 2.4 percentage points. The estimates for ELA tended to have smaller magnitudes and fewer were statistically significant. These results suggest remote learning may have exacerbated gaps in math assessment scores based on school-wide household income. Remote learning may have contributed to both increased and reduced inequality between groups of students attending schools with similar characteristics as well, but there were no clear patterns (Exhibit B.5).

- **Students in remote learning were rarely suspended.** Suspension rates fell precipitously during the pandemic (Welsh 2022). In Pennsylvania, the suspension rate of grades 6–12 students decreased from 5.3 percent in 2018–2019 to 1.1 percent in 2020–2021 (Exhibit B.6). Remote learning appeared to play an important role in this trend. Our estimates suggest that the probability of receiving an out-of-school suspension was 0.3 percentage points lower for each additional day

Exhibit 7. Estimated difference in the probability of achieving proficient or basic performance for each additional day of remote learning per week, by school share facing economic disadvantage



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: This exhibit shows estimated relationships between remote learning and assessment performance for three levels of schoolwide economic disadvantage based on regression models run with appropriate interaction terms. Low, Medium, and High indicate schools' shares of students facing economic disadvantage below the 25th percentile statewide, between the 25th and 75th percentiles, and above the 75th percentile, respectively. Appendix A provides more detail.

*Differs by a statistically significant margin from zero at the .05 level, two-tailed test.

^Differs by a statistically significant margin from schools with a low share of students facing economic disadvantage at the .05 level, two-tailed test.

of remote learning per week in grades 6–12, after controlling for background characteristics (Exhibit 8). The implied difference between students with five days of remote learning per week and those with none was 1.5 percentage points, more than enough to reduce the average suspension rate in these grades in 2020–2021 to zero. Remote learning was not related to the probability of suspension in grades 2–5, where the suspension rate is much lower than in grades 6–12.

A sharp decline in suspensions was an almost automatic result of students not being in school buildings during remote learning. Nevertheless, the across-the-board nature of the reduction is important given the longstanding focus of policy and research efforts on addressing persistent disparities in suspension rates between student groups (see Welsh & Little 2018 for a review). In Pennsylvania, 13.5 percent of Black students and 3.2 percent of White students in grades 6–12 were suspended in 2018–2019. Remote learning effectively eliminated this disparity by driving rates for both groups to about 1 percent in 2020–2021. As in-person learning resumes, it will be important to actively consider and adopt strategies that can help prevent the return of these disparities.

/ **High school students in remote learning might have had a lower high school dropout rate than similar students, but there was no apparent difference in graduation rates.** High school dropout and graduation rates fell during the pandemic, albeit by less than suspension rates did. Between 2018–2019 and 2020–2021, the annual dropout rate (grades 9–12) declined from 1.9 percent to 1.4 percent and the graduation rate (grade 12) decreased from 90.4 percent to 89.7 percent (Exhibit B.6). We recommend interpreting these changes with caution because the pandemic probably made it harder for LEAs to define and count dropouts and graduates in ways comparable to previous years. For example, many LEAs use student attendance to help determine dropouts. Since LEAs may have had varying ways of measuring attendance during remote learning, dropout statistics might represent something different than during pre-pandemic years (Shen-Berro 2023). Additionally, some LEAs across the country relaxed graduation requirements and some teachers lowered classwork expectations (Harris and Chen 2022; Harris et al 2020). With these cautions in mind, our estimates suggest that remote learning may have lowered the probability of dropping out. On average, an additional day of remote learning per week was associated with a 0.1 percentage point lower dropout probability (Exhibit 9).[8] Remote learning's association with high school graduation rates was not statistically significant.

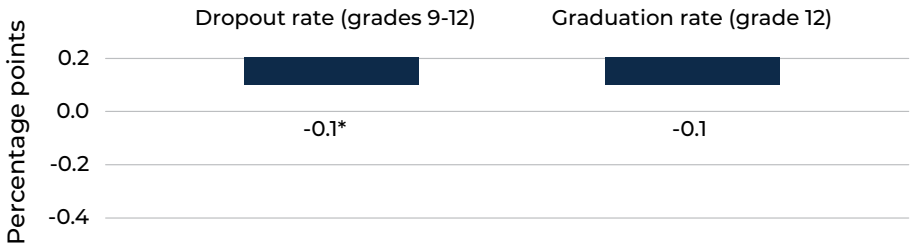
Exhibit 8. Estimated difference in the probability of receiving an out-of-school suspension for each additional day of remote learning per week during the 2020–2021 school year

Source: Study team analyses of data from PDE and a study-administered survey of LEAs

Note: This exhibit shows estimated regression coefficients for remote learning. The regressions adjusted for student, school, and LEA characteristics (see Appendix A).

*Differs by a statistically significant margin from zero at the .05 level, two-tailed test.

Exhibit 9. Estimated difference in the probability of high school dropping out and graduating for each additional day of remote learning per week during the 2020–2021 school year



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: This exhibit shows estimated regression coefficients for remote learning. The regressions adjusted for student, school, and LEA characteristics (see Appendix A).

Students that PDE designated as having dropped out included enrolled students who did not attend any school in 2020–2021 and excluded those who left Pennsylvania public schools and did not drop out.

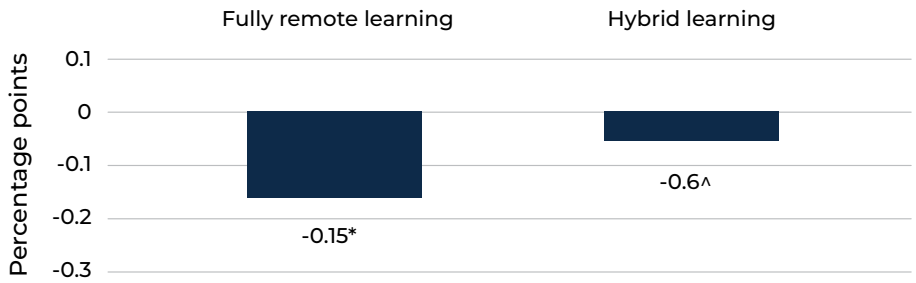
*Differs by a statistically significant margin from zero at the .05 level, two-tailed test.

Findings about remote learning and the subsequent COVID-19 rates of communities

In this section, we estimate the role of fully remote learning and hybrid learning as an LEA's predominant instructional mode in shaping the subsequent COVID-19 case rate within its boundary.

- **LEAs that offered fully remote learning to high school students saw lower COVID-19 case rates in their communities in the following month.** Remote learning in high school appeared to work as a public health strategy for reducing virus transmission. Our data on LEAs' predominant instructional modes covered the first 30 days of the school year, the 30 days after winter break, and the last 30 days of the school year. We analyzed whether changes over time in an LEA's predominant instructional mode for high school grades was associated with changes in the COVID-19 case rate per 100 people living in its boundary during the following months—October 2020, February 2021, and July 2021—adjusting for its past case rate and other factors. We focused on high school grades because concern about virus transmission and infection rates was greatest for these grades. Our findings suggest that switching to fully remote learning in high school led to a reduction in COVID-19 cases by the amount of 0.15 cases per 100 people, relative to fully in-person learning (Exhibit 10). This was 38 percent of the average COVID-19 case rate in our data (0.4 cases per 100 people). The estimated effect of fully remote learning in high school on later COVID-19 case rates was twice as large as for hybrid learning.[9] Our findings suggest remote learning provided a public health benefit, at least during the 2020–2021 school year before vaccines for COVID-19 became more widely available and adopted in the population.

Exhibit 10. Estimated change in community-level COVID-19 case rates (per 100 people) one month after measuring LEA instructional mode for high school students at the start, middle, and end of the 2020–2021 school year, relative to fully in-person learning



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: This exhibit shows estimated regression coefficients for LEAs that used fully remote learning and hybrid learning, relative to fully in-person learning, during the first month of school, the month after the winter break, and the last month of school. COVID-19 case rates in each LEA's boundary are from about one month later—October 2020, February 2021, and July 2021, respectively. The regression adjusted for previous community-level COVID-19 rates and instructional modes, and it included indicators for each period and LEA (see Appendix A).

* Differs by a statistically significant margin from zero at the .05 level, two-tailed test.

^ Differs by a statistically significant margin from fully remote learning at the .05 level, two-tailed test.

Summary and implications

As in other states, the COVID-19 pandemic posed major challenges for Pennsylvania. One of the most difficult decisions was to move students from in-person to remote learning. The findings in this brief suggest that remote learning did harm academic achievement, as feared, but may have also had important public health benefits, highlighting the difficult tradeoffs leaders, educators, and caregivers faced during that time.

About half of Pennsylvania students started the 2020–2021 school year with fully remote learning. Remote learning appeared to lower achievement outcomes, particularly in schools with high levels of economic disadvantage, consistent with research findings in other states (Cohodes et al. 2022; Darling-Aduana et al. 2022; Goldhaber et al. 2022; Jack et al. forthcoming). Students facing economic disadvantage were also more likely than on average to be in LEAs where the predominant instructional mode involved remote learning. Our evidence also suggests that fully remote learning in high school helped lower COVID-19 rates in the local communities during the 2020–2021 school year, a period before vaccines became more widely available and adopted. This is an important finding given that high school students are a small fraction of the population in any of these communities. Another study (Goldhaber et al. 2021) reached similar conclusions by analyzing data from two other states, at least for counties with relatively high COVID-19 rates like those in Pennsylvania during this time. National evidence also suggests that in-person learning increased COVID-19 rates more when used in high school grades than in lower grades (Lessler et al. 2021).

Remote learning may have led to another important, likely unplanned, result. Situations that might have otherwise led to suspensions were far less common online than in-person, and the punishment (staying home) was not relevant when all students were already at home. As a result, remote learning largely eliminated suspensions and, of particular importance, the longstanding disproportionality in suspension rates that existed between different groups of students in Pennsylvania.

In the coming years, educators in Pennsylvania will continue addressing the challenges brought on by COVID-19. Students made some progress on the statewide assessments in 2022, but they remain well behind where they would have been in the absence of the pandemic (Lipscomb et al. 2022b). At the same time, the evidence presented here suggests lower COVID-19 rates and lower suspension rates were two benefits of remote learning. With the return to in-person learning, helping students catch up while preventing the reoccurrence of inequality in suspension rates will likely require ongoing effort and suggests a need to consider alternative policies (Welsh 2022).

Appendix A. Detailed data and methods description

This appendix describes the research questions, data, estimation approach, and samples used in the analyses for this brief. We also discuss limitations of the approach.

Research questions

The brief addresses three research questions about the remote learning that students received based on the predominant instructional modes their LEAs used throughout the 2020–2021 school year.

1. How did exposure to remote learning vary across groups of students in Pennsylvania?
2. How was remote learning associated with student education outcomes?
3. How was remote learning associated with the subsequent COVID-19 rates of communities?

Data

We used several types of data in the analyses for this brief.

- **Student education outcomes.** The Pennsylvania Department of Education (PDE) provided student outcomes data for the 2020–2021 school year. The assessment performance outcomes were whether students in grades 5–8 demonstrated (1) at least proficient performance or (2) at least basic performance on the Pennsylvania System of School Assessment (PSSA) in English language arts (ELA) and math. We also examined three non-assessment outcomes: suspension rates for students in grades 2–5 and 6–12, the graduation rate of students in grade 12, and the dropout rate of students in grades 9–12. Dropout rates included students who enrolled but did not show up in any school during the school year and excluded students who left Pennsylvania public schools and did not drop out.
- **Community COVID-19 rates.** The Pennsylvania Department of Health provided data on COVID-19 cases by month and zip code. We aggregated these data to the local education agency (LEA) level using a crosswalk maintained by the U.S. Department of Education.[10] We calculated the COVID-19 case rate per 100 people living within an LEA's boundary at three points: October 2020, February 2021, and July 2021. We also constructed the COVID-19 case rate for two months before each point and the cumulative case rate from March 2020 through two months before the month of the outcome.
- **Remote learning.** PDE and Mathematica administered an online survey during summer and fall 2021 to a sample of Pennsylvania LEAs. The survey included questions about the modes of instruction the LEAs offered students during the 2020–2021 school year. LEAs indicated whether their predominant instructional mode was fully remote learning, hybrid learning, or fully in-person learning during the first 30 days of the school year, the 30 days after winter break, and the last 30 days of the school year. LEAs that used hybrid learning indicated how many days of remote instruction per week their hybrid model provided. LEAs responded separately for elementary, middle, and high school grades.

  In our analyses of student outcomes, we estimated the average number of days of remote learning per week each LEA provided throughout 2020–2021, based on their predominant instructional modes. Values ranged from zero days to five days. For each grade band, we averaged remote learning days per week across the three time points. We gave the middle point half of the total weight because about half the school year is closer in time to that point than to the beginning and ending periods. The other two time points were given equal weight. In our analyses of COVID-19 case rates, we examined the use of fully remote learning and hybrid learning as the predominant mode in each period separately.

  The selected sample for the survey included the 50 largest LEAs and a random sample of 150 other LEAs (including brick-and-mortar and virtual charter schools) selected in proportion to size. This means larger LEAs had a higher probability of being selected. The response rate to the LEA

survey was 80 percent weighted to the student population; responding LEAs served about half of Pennsylvania's public school students. The sample for this brief included the 148 responding LEAs that were traditional school districts or brick-and-mortar charter LEAs. We excluded eight virtual charter LEAs because they did not experience any changes in instructional mode during the pandemic (as they always provide instruction remotely). The data were weighted to cover all students in the relevant grades for each outcome except those in the virtual charter schools. The weights adjusted for differential sampling probabilities by LEA size and type and for missing data by LEA type. The types included the largest 50 LEAs, charter LEAs (not among the largest 50), rural non-charter LEAs (not among the largest 50), and other LEAs.

- **Other LEA data related to remote learning.** LEAs also used the survey to report on the number of hours per week of synchronous instruction students received in fully remote or hybrid learning, whether they prioritized specific groups of students for in-person instruction, and the extent to which their students had challenges with reliable internet connections.
- **Other student data.** PDE provided data on student gender, race and ethnicity, economically disadvantaged status, English learner status, and individualized education program (IEP) status. PDE also provided 2021 and 2019 PSSA scaled scores for students in ELA and math, which we converted to standardized z-scores based on the distribution of 2019 (pre-pandemic) scores for analyses of assessment outcomes. The Pennsylvania Department of Human Services provided data on student involvement in the foster care system. We created an indicator for whether a student had experience in the foster care system before the start of the 2020–2021 school year.
- **School data.** We constructed indicators for school urbanicity (urban, suburban, rural) and charter school status from the U.S. Department of Education's Common Core of Data for the 2020–2021 school year. Given the flexibility that Pennsylvania LEAs had during 2020–2021 to administer the PSSAs anytime between the spring and fall of 2021, we also used data from PDE to indicate whether the timing of testing at a school was in fall 2021 or was uncertain because data were missing or the school appeared to offer assessments during both periods.

Estimation approaches and samples

Research question 1

We conducted a descriptive analysis of the extent of remote learning and synchronous remote instruction that LEAs provided during the 2020–2021 school year based on their predominant instructional modes, the extent of internet connectivity challenges, and the ways in which those factors varied for groups of students. We reported means for students overall and by student race and ethnicity, economically disadvantaged status, English learner status, IEP status, and involvement in the foster care system. The sample included students in grades 2–12 in LEAs that participated in the survey. Results were weighted to represent all public school students in grades 2–12 in Pennsylvania.

Research question 2

We used multivariate linear regressions to estimate how students' average number of remote learning days per week related to their academic outcomes controlling for other factors, as specified below.

Approach. We estimated Equation 1 separately for each education outcome in Exhibits 6, 8, and 9.

(1) $Y_{i,t} = \beta_0 + \beta_1 R_{i,t} + \beta_2 X_{i,t} + \beta_3 Y_{i,t-2} + \varepsilon_{i,t}$

In this equation, $Y_{i,t}$ is the outcome for student i at time t, where t is the 2020–2021 school year. $R_{i,t}$ is the average number of remote learning days per week that student i's LEA provided through the predominant instructional modes they used. $X_{i,t}$ includes a variety of student characteristics and school characteristics. $Y_{i,t-2}$ includes lagged student-level and school-level measures, mostly from the 2018–2019 school year. β are the estimated relationships between the covariates and the outcome, and $\varepsilon_{i,t}$ is a random error term. We clustered standard errors by LEA.

The regression models for all student outcomes controlled for the following measures:

- **Student-level characteristics.** $X_{i,t}$ included student gender, race and ethnicity, economically disadvantaged status, English learner status, IEP status, prior involvement in the foster care system, an indicator for whether the student was in a group the LEA prioritized for in-person instruction, and grade-level indicators.[11] These measures were from the 2020–2021 school year except for foster care involvement, which included any involvement before the start of 2020–2021 school year.
- **School-level characteristics.** $X_{i,t}$ also included the percentages of students in the school who (1) were facing economic disadvantage, (2) were English learners, and (3) had IEPs during the 2020–2021 school year, as well as school urbanicity (indicators for suburban and rural, relative to urban) and charter school status in that year.
- **Lagged student-level and school-level measures.** $Y_{i,t-2}$ included each student's attendance rate and whether they had been suspended during the 2018–2019 school year. We also included these measures as school-level averages for the student's grade level in 2018–2019.

Additional student and school control variables varied by outcome (Exhibit A.1).

We then examined how remote learning's role in shaping student outcomes varied across student groups. This analysis focused on the assessment performance outcomes because they were the primary outcomes.

We estimated two versions of Equation 2 separately for each assessment performance outcome.

$$(2)\ Y_{i,t} = \beta_0 + \beta_1 R_{i,t} + \beta_2 X_{i,t} + \beta_3 Y_{i,t-2} + \beta_4 (R_{i,t} X_{i,t}) + \varepsilon_{i,t}$$

Equation 2 is like Equation 1 except it includes interactions $R_{i,t}X_{i,t}$ between remote learning and a subset of the characteristics in $X_{i,t}$. We first estimated Equation 2 where $R_{i,t}X_{i,t}$ included interactions with two indicators for schools with medium and high shares of students facing economic disadvantage (with low shares being the excluded group). This specification was informed by prior research that found different relationships between remote learning and student outcomes based on schoolwide poverty levels (Cohodes et al. 2022; Darling-Aduana et al. 2022; Goldhaber et al. 2022; Jack et al. forthcoming). We defined medium percentages to be between the 25th and 75th statewide percentiles and high percentages to be above the 75th percentile. These cutoffs corresponded to values of 26 percent and 63 percent. We also used these two indicators in $X_{i,t}$

Exhibit A.1. Grades covered and additional regression controls, by outcome

Outcome	Grades	Additional student-level controls	Additional school-level controls
PSSA performance in ELA and in math • Proficient or above • Basic or above	5–8	• PSSA score in ELA from 2019 (z-score units)[14] • PSSA score in math from 2019 (z-score units)	• School-grade average ELA score in 2019 (z-score units) • School-grade average math score in 2019 (z-score units) • PSSA test timing was fall 2021 • PSSA test timing was uncertain in 2021
Out-of-school suspension	2–5, 6–12	None	None
High school graduation	12	None	Percentage of students who graduated from the school in 2019
High school dropout	9–12	None	Percentage of students who dropped out from the school in 2019

instead of a continuous schoolwide measure of the share of students facing economic disadvantage. We next estimated a series of regressions based on Equation 2 where the interaction term $R_{i,t}X_{i,t}$ was for different student-level characteristic. The interactions were between remote learning and the race and ethnicity categories (each one separately), economically disadvantaged status, English learner status, IEP status, and having had foster care system involvement, respectively.

The findings from estimating Equation 2 with the school-level interactions are in Exhibit 7. The findings for the student-level interactions are in Exhibit B.5. In each exhibit, the estimated value for each group is the sum of the point estimate for the reference group in the regression and the applicable interaction term.

Sample and representation. The study covered public school students in grades 2–12 in Pennsylvania during the 2020–2021 school year, although the specific grades covered differ by outcome. The analysis samples came from 146 brick-and-mortar LEAs that provided remote learning data through the survey. The samples included traditional school districts and charter schools. For the student-level analyses, samples for each outcome were limited to students within the specified grade levels who had pre-pandemic data available from 2018–2019 (when they were enrolled in grades K–10). About 42 percent of the 1.4 million students in grades 2–12 in 2020–2021 were included in the analysis sample for at least one outcome. We used weights designed to represent all public school students in grades 2–12, including students not covered by the survey. The weights adjusted for the sampling method and nonresponse.

Research question 3

We estimated how an LEA's decision about its predominant instructional mode related to the subsequent COVID-19 case rate in its community using a multivariate linear regression, as specified below.

Approach. We estimated Equation 3 at the LEA-by-month level for findings in Exhibit 10.

(3) $Y_{d,t} = \beta_0 + \beta_1 R_{d,t-1} + \beta_2 L_d + \beta_3 C_{d,t-2} + \beta_4 R_{d,t-2} + \varepsilon_{d,t}$

In this equation, $Y_{d,t}$ is the COVID-19 case rate per 100 people in the boundary of LEA d at time t, which is October 2020, February 2021, or July 2021. $R_{d,t}$ includes indicators for whether the predominant instructional mode LEA d offered high school students was either hybrid learning or fully in-person learning in the preceding month (that is, in the first month of the school year, the month after winter break, and the last month of the school year). Fully remote learning was the reference group. L_d is a set of indicators for each LEA. $C_{d,t-2}$ includes lagged COVID-19 rates from two months prior (that is, August 2020, December 2020, or April 2021) as well as the cumulative COVID-19 rate from March 2020 through the two months prior. $R_{d,t-2}$ includes indicators for the lagged instructional mode (for example, the LEA's instructional mode from the fall for the winter record). We set the lagged instructional mode to fully remote learning for all LEAs for the record pertaining to October 2020 because all school buildings closed and switched to remote learning in March 2020. β are the estimated relationships between the covariates and the outcome, and $\varepsilon_{d,t}$ is a random error term. We clustered standard errors by LEA.

Sample and representation. The focal population included all Pennsylvania public school students in 2020–2021 (all grades) attending traditional school districts and brick-and-mortar charter LEAs. We used weights designed to represent this population, including students in LEAs not covered by the survey.

Limitations of the approach

The approach to estimating the effects of remote learning in this research has at least three limitations. First, the research design does not, in general, provide the strongest possible evidence of causal impacts. The design attempted to isolate remote learning's role in shaping outcomes by controlling for other observable factors such as

students' pre-pandemic outcomes. However, there may be unobserved factors related to both amounts of remote learning and the outcomes that could result in biased causal estimates. For example, if LEAs that implemented fully remote learning as the predominant mode of instruction were less able to address COVID-related challenges connected to outcomes, even after adjusting for controls in our analysis, this could result in biased estimates. In our analysis of community COVID-19 case rates, where each LEA has multiple observation points, this concern is limited to any unobserved time-varying factors. However, even in that case, it is possible that some LEAs were forced to start using remote learning in September, January, or the last month of school because of increases in COVID-19 that occurred early in each of those months, after our baseline measures. If so, our results might be biased by reverse causality. Second, the findings about how outcomes changed in response to remote learning do not indicate the reasons for those changes. Third, remote learning data were not available at the student level. As a result, the inferences about remote learning in this brief are based on the predominant instructional modes offered in each student's LEA at different points in the school year.

Appendix B. Additional findings

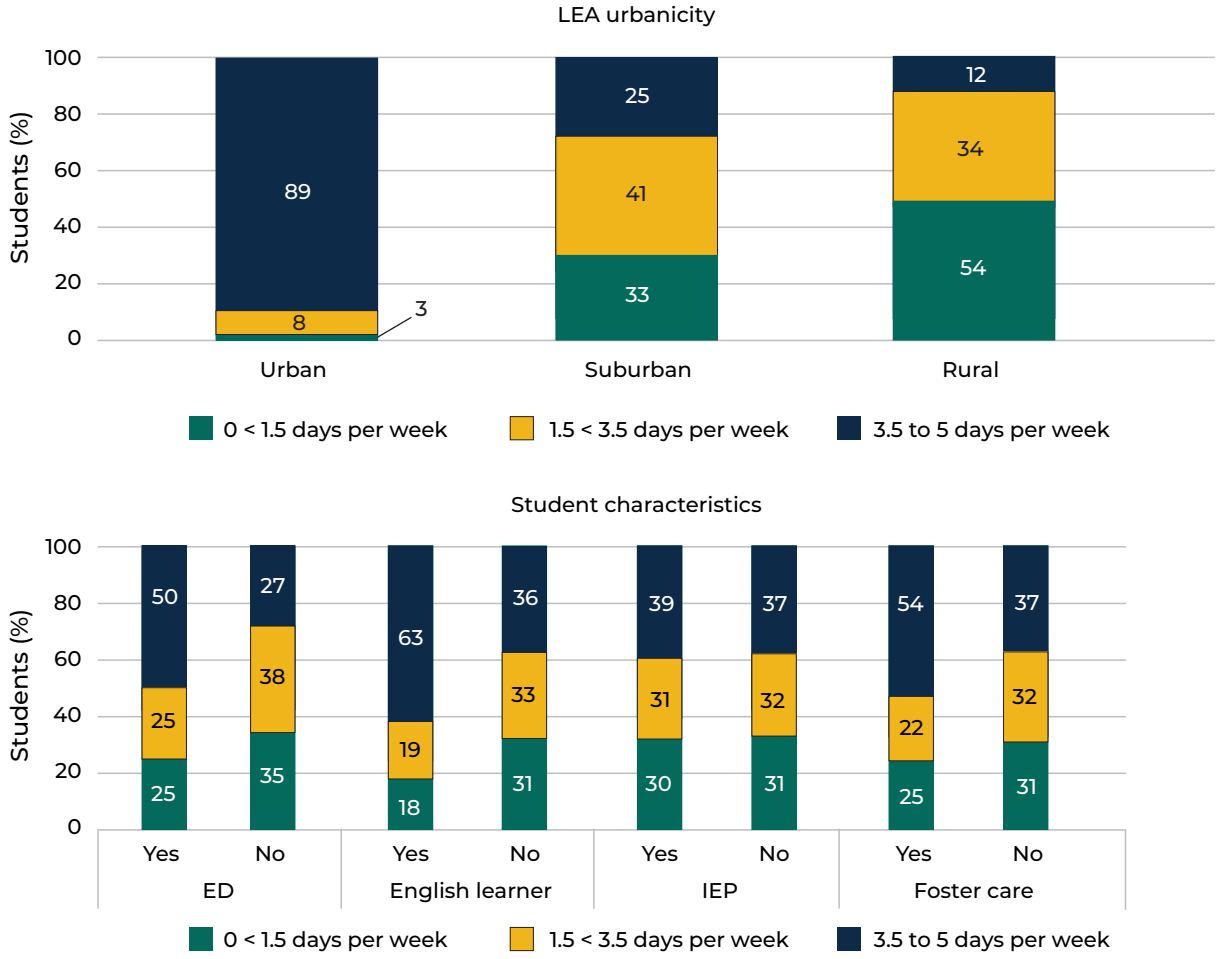
Exhibit B.1. Exposure to remote learning for students in grades 2–12 during the 2020-2021 school year, by school levels of economic disadvantage

		School share of students facing economic disadvantage		
Measure	Overall (Grades 2–12)	Low (<25th percentile)	Medium (25th to 75th percentile)	High (>75th percentile)
Average number of days of remote learning per week based on LEAs' predominant instructional modes				
3.5 to 5	37	19	24	78
1.5 to < 3.5	32	50	34	12
0 to < 1.5	31	31	42	10
Average hours per week of synchronous instruction based on LEAs' predominant instructional modes				
Hybrid	19	22	19	16
Fully remote	20	23	19	17
Percentages of students whose LEA reported different shares of enrollment with limited internet access				
Many students (26% to 100%)	11	9	10	18
Some students (10% to 25%)	37	15	39	56

Source: Study-administered survey of LEAs.

Note: The 25th and 75th percentiles statewide corresponded to school shares of students facing economic disadvantage of 26 percent and 63 percent, respectively. Data were weighted to represent students.

Exhibit B.2. Average number of days in remote learning per week based on LEAs' predominant instructional modes throughout 2020–2021 in grades 2–12, by LEA and student characteristics



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: Data were weighted to represent students.

ED = economically disadvantaged; IEP = had an individualized education program; Foster care = involved in the foster care system prior to the start of 2020–2021.

Exhibit B.3. Average hours per week of synchronous instruction based on the predominant instructional modes that LEAs used in grades 2–12 during fully remote and hybrid learning

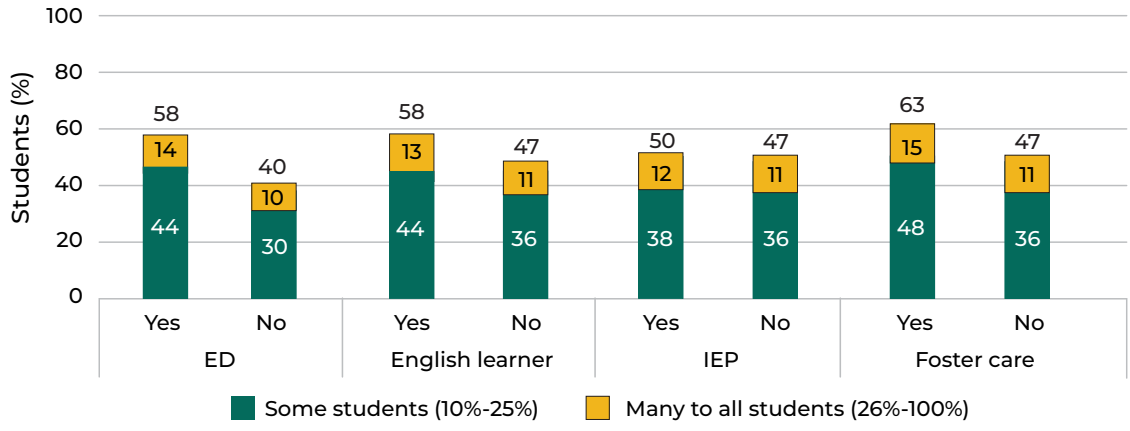
		Race and ethnicity					Other characteristics			
Mode	Overall	White	Black	Hispanic	Asian	Other	ED	EL	IEP	Foster
Grades 2–12										
Hybrid	19	20	14	19	18	19	18	17	19	17
Fully remote	20	21	16	18	20	19	18	18	19	17
Grades 2–5										
Hybrid	18	20	12	18	16	18	16	16	18	15
Fully remote	18	20	14	17	19	18	17	17	18	15
Grades 6–8										
Hybrid	19	20	13	19	17	18	17	16	18	16
Fully remote	20	21	15	18	19	19	18	17	19	16
Grades 9–12										
Hybrid	20	21	18	20	21	20	20	21	20	20
Fully remote	21	21	20	19	23	21	20	21	21	20

Source: Study-administered survey of LEAs.

Note: Data were weighted to represent students.

ED = economically disadvantaged; EL = English learners; IEP = had an individualized education program; Foster = involved in the foster care system prior to 2020–2021.

Exhibit B.4. Percentages of students in grades 2–12 whose LEA reported different shares of enrollment had challenges with limited access to reliable internet, by student characteristics



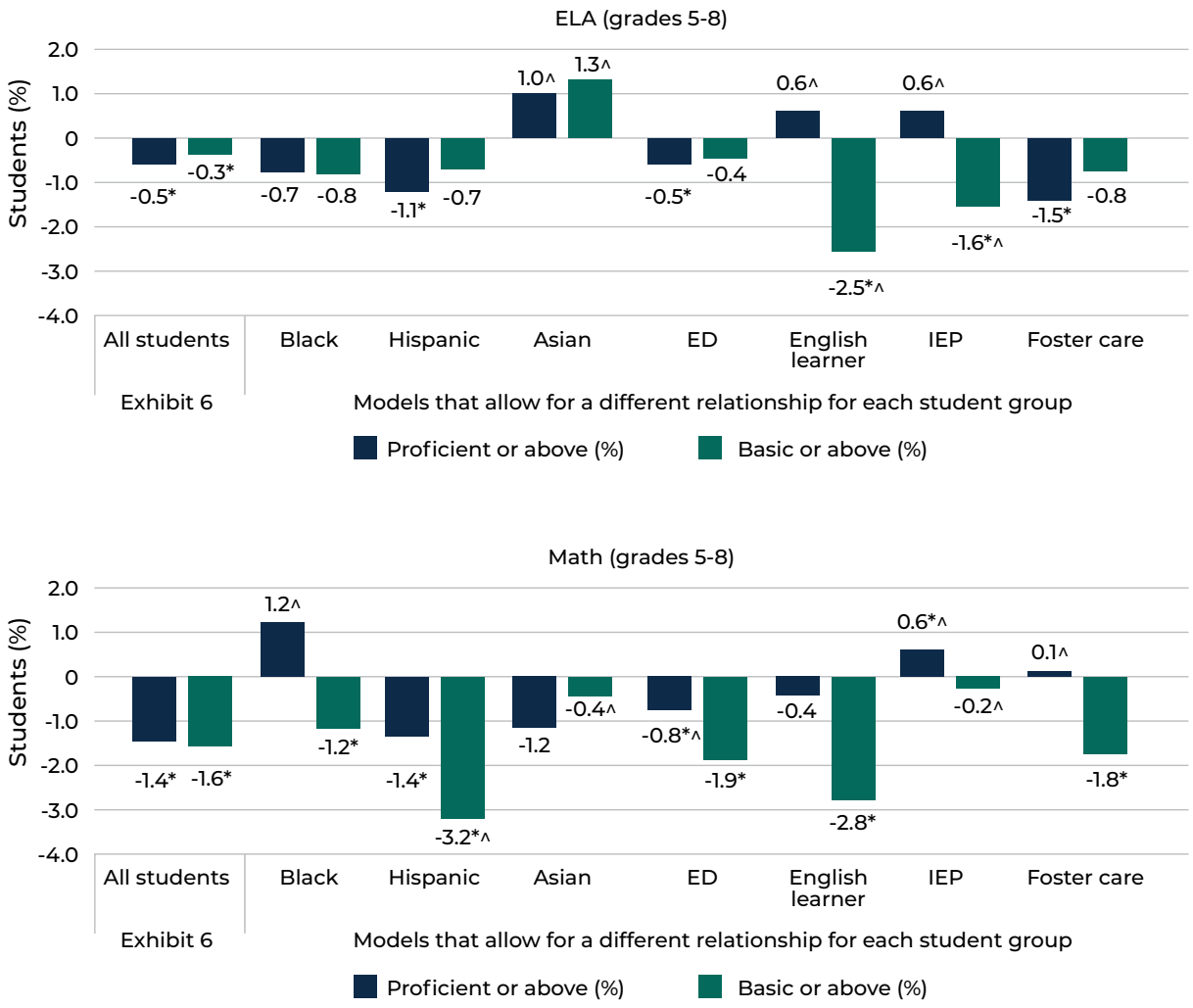
Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: Data were weighted to represent students.

ED = economically disadvantaged; IEP = had an individualized education program; Foster care = involved in the foster care system prior to the start of 2020–2021.

/ **For students in schools with similar characteristics, there were no clear patterns of increased or reduced inequality in assessment performance between student groups from remote learning.** We compared remote learning's associations with assessment performance for groups based on race and ethnicity categories, economic disadvantage, English learner status, IEP status, and having prior experience in the foster care system to other students not in each respective group.[12] Controlling for school characteristics including the level of economic disadvantage, remote learning was typically negatively related to assessment outcomes in both subjects (Exhibit B.5). However, there was no clear pattern of increased or reduced inequality for vulnerable groups of students

Exhibit B.5. Estimated difference in assessment outcomes for each additional day of remote learning per week during the 2020–2021 school year, overall and by student characteristics



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: This exhibit presents the estimated associations of remote learning with assessment performance for students overall from Exhibit 6, as well as for groups of students from a series of regression models where each model has an interaction term for one of the groups.

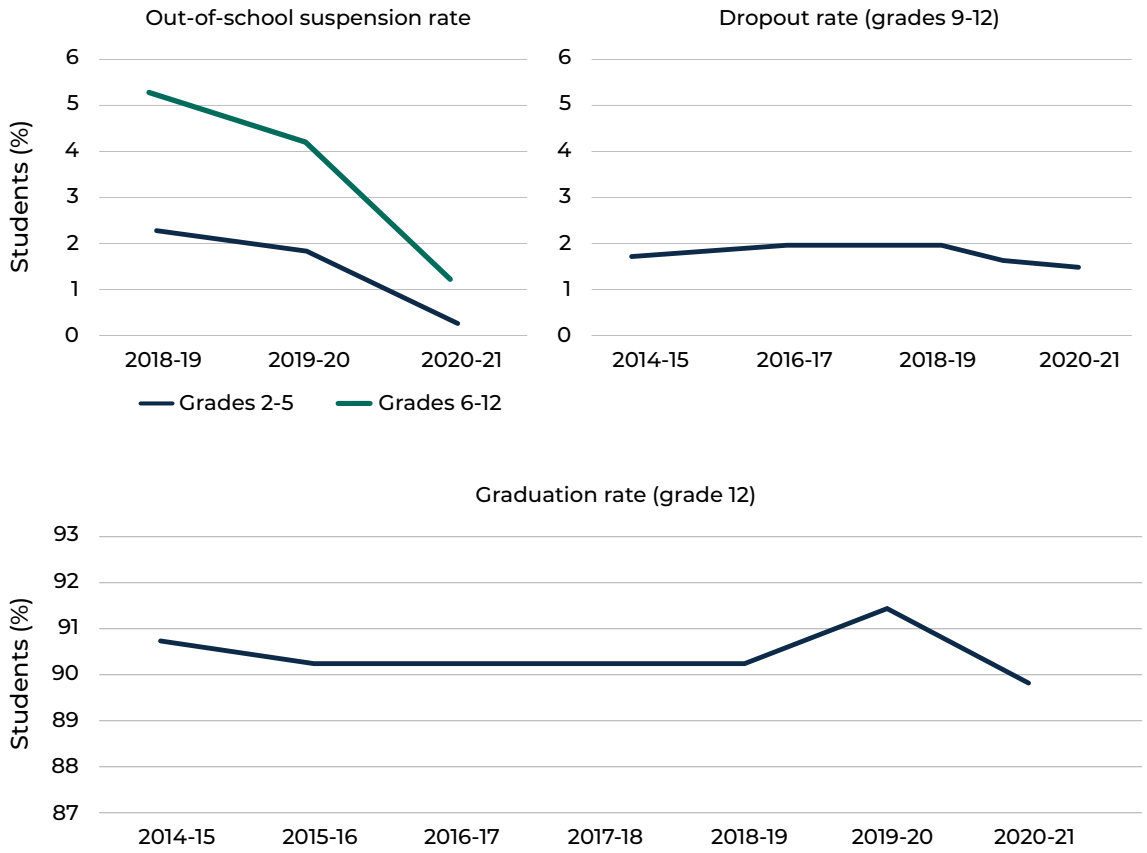
The exhibit excludes students reporting other races or ethnicities. The estimates for that group were not significantly different from zero in ELA. They were statistically significant and negative in math.

*Differs by a statistically significant margin from zero at the .05 level, two-tailed test.

^Differs by a statistically significant margin from students not in the group at the .05 level, two-tailed test.

relative to other students. For example, in ELA, inequality for English learners and students with IEPs may have narrowed near the cutoff for proficiency and widened near the cutoff for basic performance. In math, remote learning may have increased inequality for Hispanic students near the cutoff for basic performance. It may have reduced inequality for Black students and students with IEPs near the cutoff for proficiency.[13]

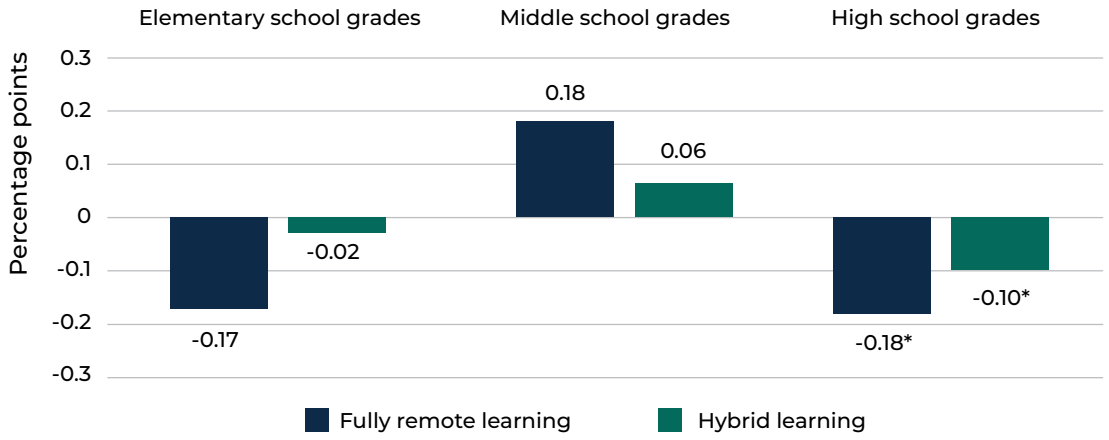
Exhibit B.6. Non-assessment outcomes for Pennsylvania students, 2015–2021



Source: Study team analyses of data from PDE.

Note: The samples for each year are constructed as described in Exhibit 1 except we report unweighted data from all LEAs rather than the weighted data based on LEAs where remote learning data were available. Data on suspensions prior to 2018–2019 are not comparable to later years.

Exhibit B.7. Estimated change in community-level COVID-19 case rates (per 100 people) one month after measuring LEA instructional mode at the start, middle, and end of the 2020–2021 school year, relative to fully in-person learning



Source: Study team analyses of data from PDE and a study-administered survey of LEAs.

Note: This exhibit shows estimated regression coefficients for LEAs that used fully remote learning and hybrid learning, relative to fully in-person learning, during the first month of school, the month after the winter break, and the last month of school. COVID-19 case rates in each LEA's boundary are from about one month later—October 2020, February 2021, and July 2021, respectively. The regression adjusted for previous community-level COVID-19 rates and instructional modes and included indicators for each period and LEA (see Appendix A).

*Differs by a statistically significant margin from zero at the .05 level, two-tailed test.

^Differs by a statistically significant margin from fully remote learning at the .05 level, two-tailed test.

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Endnotes

[1] The brief is part of a partnership between the Pennsylvania Department of Education and Mathematica to understand how the pandemic has shaped education outcomes in Pennsylvania.

[2] PDE and Mathematica administered the survey as part of the study. Findings are reported in Lipscomb et al. (2021).

[3] Pennsylvania LEAs received flexibility to administer the PSSAs anytime between the spring and fall of 2021. As a result, some LEAs postponed the usual spring assessments to the fall of the 2021–2022 school year (Lipscomb et al. 2022a).

[4] Data are from the COVID Data Tracker maintained by the Centers for Disease Control and Prevention.

[5] Pennsylvania LEAs must provide more total instructional hours in secondary grades than in elementary grades (990 hours versus 900 hours across 180 school days). Consistent with this difference, students received slightly more synchronous instruction per week in secondary grades than in elementary grades (Appendix B.3).

[6] The samples for assessment outcomes in this brief are limited to test takers only. Participation rates in Pennsylvania's 2021 statewide assessments were lower than in a typical year (67 percent in grades in grades 5–8, compared to about 95 percent normally; Lipscomb et al. 2022a). Participation rates were particularly low for students who were not proficient before the pandemic and those in LEAs that mainly used fully remote learning in the month following the winter break in early 2021. We used weights to make the sample representative of non-test takers as well as test takers.

[7] We observed a similar pattern for scale scores of the assessments, which capture variation across performance levels.

[8] Remote learning's association with lower dropout rates might be related to increases in reported attendance rates. There was a positive relationship in our data between more remote learning and reported attendance rates, consistent with findings in previous research (Darling-Aduana et al. 2022).

[9] We conducted a sensitivity analysis where we controlled for the instructional modes LEAs offered to students in elementary and middle school grades as well as in high school (Exhibit B.7). The results for fully remote learning in high school grades were like those in Exhibit 10. A statistically significant negative relationship also emerged between hybrid learning in high school and COVID-19 case rates after controlling for the instructional mode variables among elementary and middle schools. However, there were no statistically significant findings for the earlier grades. We believe this was because many LEAs used one instructional mode

for all their students at a given point in time. As a result, there was little remaining variation in instructional modes after controlling for them at the high school level. Consistent with this theory, several point estimates on the instructional mode variables for the elementary and middle school grade bands had large standard errors relative to the high school variables. Additionally, previous studies (for example, Lessler et al. 2021) suggest a stronger relationship between in-person learning and COVID-19 cases in higher grades. Correspondingly, we focused on instructional modes for high school grades in the brief.

[10] This aggregation was approximate because some zip codes crossed LEA boundaries. When that happened, we used weights based on the land area covered by a given LEA and zip code to allocate COVID-19 cases. Details about this crosswalk are available at https://nces.ed.gov/programs/edge/Geographic/RelationshipFiles. For charter LEAs, we used the zip code for their main campus and linked it to total population counts from the 2015-2019 American Community Survey 5-Year Narrative Profile.

[11] We omitted grade indicators for the graduation rate outcome because the sample comprises only grade 12 students.

[12] In 2018–2019, before the pandemic began, the statewide proficiency rate in grades 5–8 was 60 percent in ELA and 38 percent in math (Exhibit 2). Ninety-three percent of students in these grades demonstrated at least basic performance in ELA and 69 percent did so in math. At both performance levels, the percentages for Asian and White students were above the statewide averages, and those for other groups in Exhibit B.5 were below the statewide averages.

[13] These findings for Black students in Pennsylvania differ from other studies that have found negative relationships between remote learning and achievement outcomes for Black students in other states (for example, Cohodes et al. 2022).

[14] We could not use lagged PSSA scores for the other outcomes because scores are not available for students in all grades.

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