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COVID-19, School District Operations, and Student Academic Performance in Virginia

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We use longitudinal student-level data and interrupted time series methods to examine the impact of the COVID-19 pandemic on mathematics achievement among 3rd-8th grade students in Virginia, a state that offered particularly low levels of access to in-person learning in the school reopening period. We find notably large negative initial effects on math in 2020-21, much greater in magnitude than estimates of the nationwide impact. The recovery in 2021-22 and 2022-23 was substantial but students remained well-behind pre-pandemic levels. We also observe differential impacts across subgroups, exacerbating inequality based on socioeconomic background and race but not on receipt of special education or English Learner services. Initial negative impacts were larger in districts with lower levels of access to in-person learning in 2020-21, however, these same districts saw the greatest recovery by 2022-23. We observe suggestive evidence that districts providing greater learning needs supports (e.g., tutoring, extended time) saw somewhat smaller achievement declines, but no strong evidence of differences in pandemic effects (or sometimes mixed evidence) based on other district operational decisions such as their emphasis on assessment use, technology, social-emotional supports, family engagement, health protocols, or teacher development. Findings suggest the continued need to address the pandemic's long educational shadow.

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Abstract

We use longitudinal student-level data and interrupted time series methods to examine the impact of the COVID-19 pandemic on mathematics achievement among 3rd-8th grade students in Virginia, a state that offered particularly low levels of access to in-person learning in the school reopening period. We find notably large negative initial effects on math in 2020-21, much greater in magnitude than estimates of the nationwide impact. The recovery in 2021-22 and 2022-23 was substantial but students remained well-behind pre-pandemic levels. We also observe differential impacts across subgroups, exacerbating inequality based on socioeconomic background and race but not on receipt of special education or English Learner services. Initial negative impacts were larger in districts with lower levels of access to in-person learning in 2020-21, however, these same districts saw the greatest recovery by 2022-23. We observe suggestive evidence that districts providing greater learning needs supports (e.g., tutoring, extended time) saw somewhat smaller achievement declines, but no strong evidence of differences in pandemic effects (or sometimes mixed evidence) based on other district operational decisions such as their emphasis on assessment use, technology, social-emotional supports, family engagement, health protocols, or teacher development. Findings suggest the continued need to address the pandemic's long educational shadow.

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Introduction

The COVID-19 pandemic represents the most significant disruption to the U.S. K-12 public school system and the families it serves in our collective lifetimes. One indicator—among many—of this disruption was the substantial decline in test-based academic achievement among K-12 students, especially in mathematics. These impacts were felt unequally in ways that have exacerbated educational inequality along familiar lines of race and social class. Although widening gaps were not due only to educational policy choices, the declines in achievement were indeed larger among those communities with less access to in-person learning during the school reopening period (CITE). However, much of the research documenting these trends focuses more on the initial impact in the first year of testing after the start of the pandemic and relies on crude measures of access to in-person learning (CITE). Furthermore, very limited attention has been paid to operational decisions school districts made beyond those relating to learning modality, and whether and how those operational decisions were associated with differential impacts.

We study these issues in the context of Virginia, which was an outlier in that it provided very limited access to in-person learning during the reopening period relative to other states (Goldhaber et al., 2023). Virginia is also a valuable context for research because of the availability of a unique original data source on district operational features beyond learning modality, gleaned from reopening plans districts submitted to state policymakers. These data capture the extent to which individual school districts emphasized assessment use, expectations, family engagement, health protocols, learning needs support, social-emotional learning support, technology support, and teacher professional development during the first full reopening school year (2020-21). We use statewide, longitudinal, student-level, administrative data and interrupted time series methods to address the following research questions:

1. Did Virginia's student math achievement outcomes in the first three years after the March 2020 shutdown (2020-21 through 2022-23) differ from pre-shutdown trends?
2. Did student demographic characteristics explain variation in the pandemic's impact on math outcomes?
3. Did school district operations in the first reopening year (2020-21) explain variation in the pandemic's impact on math outcomes?

We find large negative overall pandemic effects on math achievement among Virginia's students, much greater in magnitude than the average effect of COVID-19 nationwide. The recovery in 2021-22 and 2022-23 was substantial but students remained well-behind pre-pandemic levels. We observe differential impacts across subgroups, which exacerbated inequality based on socioeconomic background and race but not based on receipt of special education or English Learner services. Initial negative impacts were larger in districts with lower levels of access to in-person learning in 2020-21, however, these same districts saw the greatest recovery by 2022-23. We observe suggestive evidence that districts providing greater learning needs supports (e.g., tutoring, extended time) saw somewhat smaller achievement declines, but no strong evidence of differences in pandemic effects (or sometimes mixed evidence) based on other district operational decisions such as their emphasis on assessment use, technology, social-emotional supports, family engagement, health protocols, or teacher development. Findings suggest the continued need to address the pandemic's effects and provide guidance for identifying the student groups and districts in greatest need of ongoing intervention. The results also provide helpful bounds on the expectations policymakers should have for the impacts of future educational disruptions due to global events from disease outbreaks to climate change.

Background

The COVID-19 pandemic had direct and ripple effects on a wide range of policy domains and resulting social and economic indicators, and the educational arena was no exception. These disruptions have been reflected in documented negative impacts of the pandemic period on student test-based academic achievement in the U.S., especially on mathematics assessments (Cohodes et al., 2022; Fahle et al., 2024; Goldhaber et al., 2022-a; Jack et al., 2023; Kuhfeld et al., 2022; Lewis et al., 2021; Miller & Schueler, 2022). Overall, economists estimate that these disruptions to learning could generate 2 to 9 percent lower lifetime incomes for impacted students and yield an average annual GDP that is 0.6 to 2.9 percent lower than pre-pandemic years for the remainer of the century (Hanushek, 2022). Therefore, these impacts remain a cause for grave concern, despite the limited sense of urgency among members of the general public (Polikoff, Rapaport, Saavedra & Silver, 2023; Peterson, Houston & West, 2022). These effects were not limited to the U.S., as other scholars have documented negative impacts internationally as well (e.g., Jakukowski et al., 2024).

Beyond the large average negative impacts on student academic achievement, particularly troubling are the ways in which the pandemic appeared to cause disproportionate harm for already vulnerable groups, exacerbating educational inequality. Achievement declines were substantially greater for lower- than average-achieving students (Callen et al., 2024; Peters et al., 2023), and were larger for communities serving greater shares of Black, Hispanic, and low-income students (Cohodes et al., 2022; Fahle et al., 2024; Kuhfeld et al., 2022; Strunk et al., 2023; Goldhaber et al., 2022-a; Jack & Oster, 2023; Lewis et al., 2021). Therefore, not only did COVID-19 result in declines in average student achievement overall but also widened gaps between more and less advantaged students on a number of dimensions.

These differential effects likely represent a bundle of "treatments" during the pandemic period that varied by student characteristics, including but also well beyond the education policy choices that school systems made during the height of the outbreaks. For example, we know that the direct public health impacts of the pandemic—including orphanhood and caregiver fatalities—were higher for children of color (e.g., Hillis et al., 2021; Millett et al., 2020). The pandemic also brought economic disruptions that disproportionately impacted low-wage workers (e.g., Chetty et al., 2024), and increased food insecurity (Niles et al., 2020), domestic violence (Piquero et al., 2021), and mental health challenges (de Figueiredo et al., 2021; Vindegaard & Benros, 2020) in ways that only reinforced preexisting racial and economic inequalities.

That said, educational policy also seemed to play a role. School districts were called on to make very difficult choices with imperfect information, weighing public health risks for children, educators, and their families, against the potential downsides of school closures during a period of uncertainty and turmoil. Without making a judgement about whether and which districts made the "right" decisions, the empirical research documents that communities with higher levels of remote learning saw larger achievement declines than those with greater in-person learning opportunities (Bruhn et al., 2023 ; Darling-Aduana et al. 2022; Fahle et al., 2023; Goldhaber et al., 2022-b; Jack et al., 2023; Jakukowski et al., 2024). We also know that in-person learning access and take up was lower among students in economically disadvantaged communities and in districts serving greater concentrations of families of color (Camp & Zamarro, 2022; Kurmann & Lalé, 2023; Ross et al., 2024).

Despite these documented empirical facts, there are several limitations of the existing literature regarding the pandemic's effects on academic achievement that we address in this paper. First, much of the work focused on the initial impact in the first-year testing resumed after

the pandemic's onset. The smaller number of studies examining achievement in more recent years have generated somewhat inconclusive or mixed results, depending on the assessments and methods used, sometimes showing quite limited recovery (Curriculum Associates, 2023; Lewis & Kuhfeld, 2023) and in other cases documenting a substantial bounce back as of 2022-23 (Fahle et al., 2024). Furthermore, some prior work comparing across states has relied on proficiency rate outcomes with known limitations given variation across states in the definitions of proficiency, among other challenges (Ho, 2008). Here, we examine achievement patterns for three post-pandemic years, through 2022-23, and report out results for scale scores and pass rates to both avoid the methodological limitations of exclusive reliance on a binary proficiency rate outcome while also providing the more policy-relevant and easily interpretable pass rates.

We make additional methodological improvements beyond some of the existing research. For example, given that we rely on longitudinal, student-level administrative data, we are able to separate out COVID-19 effects from known compositional changes to the student population in the aftermath of the pandemic (e.g., Dee et al., 2021; Schueler & Miller, 2023). Additionally, much of the work on the relationship between access to in-person learning and achievement outcomes has relied on relatively crude measures of in-person learning. Often this construct is operationalized as a binary measure of whether or not schools re-opened in the fall in an in-person modality, sometimes as a categorical measure (fully in-person, hybrid, or fully remote), and still other times as a measure of time spent within a given modality. However, these approaches all mask considerable variation in access to in-person learning, particularly when it comes to the "hybrid" modality which could represent anything from one to four days per week learning in person (Sachs et al., 2022). We, therefore, collected daily data on learning modality

for all districts in the state of Virginia to generate a more granular continuous measure of the percent of days in the 2020-21 school year that were offered in person (Sachs et al., 2022).

Another limitation of the work on education policy and pandemic effects on student learning is that nearly all of this research has focused on variation in learning modality, despite the fact that there were a host of other policy decisions that districts were making during this reopening period. We explore some of these other key policy decisions during the first full reopening school year (2020-21)—ranging from the extent to which districts emphasized assessment use, expectations, family engagement, health protocols, learning needs support, social-emotional learning support, technology support, and teacher professional development. We examine whether this emphasis predicted differential initial academic impacts and/or differential recovery as of 2022-23. We are able to do this for Virginia because the state required every district to submit reopening plans detailing their decisions prior to the start of the 2020-21 school year (Lane, 2020). This is a particularly important hole to fill in the literature give recent national research showing that the mechanisms driving achievement declines in this post-pandemic period appeared to operate at the school district or community level rather than the individual student or household level (Fahle et al., 2023). While this research identified some district level factors with explanatory power, such as broadband access, disruptions to social and economic activity, and trust in institutions, there remained substantial unexplained variation in the pandemic's effects worth exploring further.

We study these issues in the context of Virginia not only due to the unique data availability on district operational decisions but also because Virginia was an outlier state nationally when it came to learning modality. Goldhaber et al. (2023) show that Virginia was in the highest quartile for average weeks spent in remote learning among all fifty states, with the

greatest number of weeks spent remote across low, medium, and high poverty schools. Similarly, Jack et al. (2023) report that Virginia districts offered in-person instruction for an average of 9.7 percent of the 2020-21 school year—the lowest of the eleven states under study—and compared to 86.5 percent in the highest state (Wyoming).

The resulting research has the potential to inform ongoing recovery efforts by documenting the magnitude of the challenge and helping policymakers identify which groups of students and which communities were mostly negatively impacted and are most in need of additional supports. The work also has the potential to inform policy response to future major educational disruptions, generating theory about which policy choices may support greater academic recovery that should be tested in a more rigorous causal framework in future research.

Data and Methods

Student Math Outcomes. We rely on statewide student-level administrative data covering the 2013-14 to 2022-23 school years provided by the Virginia Department of Education (VDOE). (Henceforth, we refer to years by the spring of a given academic year, such that we refer to the 2022-23 school year as 2023.) Our primary outcome of interest is student math achievement, as measured by statewide math exams used for accountability purposes. These exams are typically administered annually except that no exams were administered in the 2020 school year due to the pandemic. Therefore, our panel includes six pre-COVID years and three post-COVID years. Exams include end of grade exams for grades 3-8, as well as end of course exams for Algebra I, Algebra II, and Geometry. The end of grade (EOG) exams are typically taken by students enrolled in that grade with the exception of a gradually increasing fraction of students who test in the grade level above (e.g., on average 15% of sixth graders take the 7th grade EOG exam and 20% of seventh graders take the 8th grade EOG exam) and a much smaller

fraction (<0.05% or less) taking an assessment with the grade level below. Meanwhile the end of course (EOC) exams are administered to students in a variety of grades at the end of completing a given course. The majority of, but not all, students taking EOC math assessments are in high school. We observe a monotonically increasing fraction of students in sixth through eighth grades taking accelerated math courses and associated EOC assessments (e.g., 38% of eighth graders take the EOC Algebra I exam). Importantly, Virginia administered a new math exam in 2019 which it used in the subsequent years. Therefore, we observe outcomes for one pre-COVID year on the same exam that was administered in the post-COVID period. We explain in the empirical strategy section below how we address this change analytically.

We operationalize math performance in two ways. First, we rely on scale scores which range from 0 to 600. Second, we examine a binary indicator for whether a student scored proficient on the math exam. These two constructs capture related but somewhat different achievement metrics, each with strengths and limitations. The scale scores help us capture effects on the full performance distribution while the proficiency measure only captures movement across the proficiency threshold. Values of these constructs do not always move in the same direction as it is possible to increase proficiency rates without increasing or even while decreasing the overall average score if the scores of the students at the low and high end of the distribution declined (Ho, 2016). The downside of the scale scores is that changes in points scored on a statewide exam are not particularly interpretable nor familiar to the public or to policymakers. Therefore, we report both to better capture and communicate pandemic effects on math achievement. Ultimately, we generate effect size estimates in standard deviation (SD) units by dividing our estimated coefficients by the SD of the scale score outcomes for the pre-pandemic observation years to allow for a comparison of the magnitude of effects across groups,

studies, and contexts beyond Virginia. We do not use z-scores for the main outcomes in our models themselves because to estimate the impact of the pandemic, we are making comparisons across time that would be lost if we standardized scores within years.

Student Demographics and School Context Measures. We also rely on student- and school-level covariates primarily drawn from the administrative data. In determining which covariates to include in our models, we kept in mind that our goal was to isolate the impact of the pandemic on math achievement separate from the impact the pandemic may have had on the demographic composition of Virginia's student population. In Table 1, we describe our overall sample in both the pre-COVID period (averaging across 2014 to 2019) and the post-COVID period (averaging across 2021 to 2023). This table suggests that there were some changes to the composition of the student population after the onset of the pandemic. For example, the share of Hispanic students went from 15% in the pre-pandemic period to 18% in the post period. We see an increase in the share of economically disadvantaged students (43% to 45%), students with disabilities not receiving special education services (7% to 11%), and active English learners (7% to 10%). Prior to estimating the impact of COVID-19 on math outcomes, we estimated models to assess whether the pandemic had an impact on any of the student or school-level covariates we were considering including in our models (using the ITS model we describe in our empirical strategy section below but including no covariates and replacing math outcomes with student and school characteristics, one by one). This allowed us to identify those covariates that the evidence suggested were impacted by COVID. The non-COVID impacted student-level variables included measures of gender, economically disadvantaged status, and assessment taken. The COVID-impacted student-level variables included disability status, race/ethnicity, active EL status, and former EL status. The non-COVID impacted school-level variables

included percent school enrollment by race/ethnicity and disability status, while the COVID-impacted school-level variables included the percent enrollment by economically disadvantaged status, active EL status, and former EL status, as well as overall school enrollment. Finally, for some models (described below) we used time invariant school-level characteristics including school locale (e.g., urban, suburban, town, or rural), school type (e.g., elementary, middle, high, or combined), and a composite index of local ability-to-pay (e.g., a weighted measure of a locality's real property value, adjusted gross income, and taxable retail sales).

School District Operations Measures. We captured several dimensions of school district operations during 2020-21, the first full school year after the pandemic's onset. To do so, we found and coded a variety of publicly available documents created by each of the 132 districts to communicate to the public about both their initial reopening operations and the ways that operations changed throughout the year. We began by coding the mandatory reopening plans districts submitted to the VDOE in advance of the fall reopening. We supplemented these with updated plans submitted later in the year and by searching each district's current website and archive, using The Wayback Machine, to find any documents providing updates to the plans during that year. We also examined districts' Facebook and Twitter posts, but this represented a small share of the documents overall. This generated 1,194 documents for coding and analysis.

We analyzed these documents in two waves–first the initial reopening plans and then the supplementary update documents. In both waves, we generated a priori codes based on a framework from the Center for Reinventing Public Education (CRPE), a national research organization that was unique in its effort to collect early district operations data (for 100 large districts) in real time at the height of the pandemic vis their "COVID-19 Response Database" (Gross et al., 2020). We adapted these codes to fit the Virginia context and refined them as we

went. We detail the full set of codes in appendix Tables A1 and A2 and describe the constructs these codes measure below. The first wave included 72 codes and the second 77 codes.

A team of 19 coders used descriptive coding to record a value for each categorical indicator and to tag segments of text evidencing each coding decision (Saldaña, 2013). We describe the coding process and much more about our methods in another recent paper (Schueler, Reynolds & Miller, 2025). The resulting data were analyzed using Principal Component Analysis (PCA). This process led us to eliminate a small number of items that did not fit in our theorized models, were not capturing much variation, or for which we did not have a strong theoretical basis for including. We ended up with eight constructs representing distinct aspects of district operations each with their own PCA. All PCAs had fairly large, positive loadings for all items, similar magnitudes of loadings for all items, and only a single component with eigenvalue greater than one. We list the full set of constructs and indicators in Table 2 with the item loadings and fit statistics. None of the constructs have correlations greater than 0.37 with any other constructs. For all constructs, higher values represent that the district placed a greater emphasis on that construct in their public communications. For the analyses presented here examining whether variation in district operations predicted differences in math performance outcomes, we generated for each construct an indicator for whether the district was low (< -0.50 SD below the mean), medium (between -0.50 and 0.50 SD around the mean), or high (>0.50 SD above the mean) on emphasizing that construct based.

The final set of constructs are summarized in Appendix Table A3. The first construct "family engagement" captured the extent to which the district emphasized engaging with the family members of their students. For example, one indicator was whether the district recommended check-ins with families at the start of the school year. The second construct was

"SEL support", measuring how much a district emphasized providing social and emotional learning supports to students or staff. Indicators included, for example, whether schools were expected to provide counselors or social workers. The third construct, "assessment use" measured the emphasis districts placed on student assessments, such as whether they stated there was a plan to assess learning in the fall. The fourth was "expectations" assessing how much districts emphasized high expectations for students or staff, such as whether schools were required to provide students with grades. Fifth, "teacher professional development" captured the extent to which districts emphasized instructional supports for teachers, such as instructional coaching in the remote setting. Sixth, the "health protocols" construct captured how much districts emphasized the health precautions they were taking, such as requiring face masks in instructional settings. Seventh, "technology support" included items such as whether the district indicated they would provide home-based internet access for all in need. The final construct, "learning needs support" captured districts' emphasis on providing services to address the negative impacts of pandemic-related learning disruptions on student outcomes, such as tutoring.

Another important aspect of division operations that we examine is related to learning modality. We generated a district-by-grade-by-day dataset tracking changes in the learning modality offered throughout the year (Sachs et al., 2022). This allowed us to ultimately calculate a variable representing the percentage of the year that a district offered students in-person learning—a more granular measure based on daily (versus weekly) changes than most research to date has used. To create this measure, we consulted the same district documents and sources as for the other measures. Three coders recorded the weekly five-day attendance rotation indicating on which day(s), if any, which group of students were offered in-person learning and the date the rotation began. We also tracked days that the district closed entirely, which

sometimes occurred after a COVID-19 outbreak, and relied on the district's public calendar to identify the first and last day of school, as well as holidays and other breaks. These data were used to generate a denominator for the percentage of days in person variable. The average district spent a total of 41% of the 2020-21 school year offering in-person learning (SD=21, Min=0, Max=96). For our analyses here, we generate three categories of low, medium, or high shares of in-person learning. For both the in-person learning variable and district operations measures, in previous work, we provide more detail on the process of developing and evidence of validity for these measures in previously published work (Schueler et al., 2025).

Empirical Strategy. We rely on interrupted time series (ITS) methods (Bloom, 2003) to estimate the pandemic's effect on math achievement. We fit a trend through the pre-pandemic math test scores for six years (2014 to 2019) to predict what math scores would have been between 2021 and 2023 had the pandemic not occurred. We interpret the difference between these predictions based on pre-pandemic trends and the observed math achievement levels as the pandemic's impact. This includes the pandemic and all its related effects on health, the economy, schooling, etc. Although we cannot fully rule out the possibility that our estimates capture additional non-pandemic related changes that occurred at the same time as the pandemic, COVID-19 was the most significant source of change to public schooling during this time and therefore likely to be the primary driver of any differences between predictions and observed outcomes. We use the following primary specification where Y_{isdt} represents the math achievement of student *i* in school *s* in district *d* observed at time *t*:

$$Y_{isdt} = \beta_0 + \beta_1 Time_t + \beta_2 2021_t + \beta_3 2022_t + \beta_4 2023_t + \beta_5 NewTest_t + \Theta' Student_{isdt} + \Phi' School_{sdt} + \eta_s + \varepsilon_{isdt} \quad (1)$$

The outcomes are modelled as a function of the linear passage of time ($Time_t$) and a set of three binary indicators for each of the post-pandemic school years (e.g., 2021_t) which capture COVID's impact. We also include a binary indicator ($NewTest_t$) for whether the outcome was measured with the state's new math exam (equal to 1 in 2019 and later years). This allows us to isolate pandemic effects from testing changes that could have also influenced student math performance. We also control for vectors of time-varying student-level ($\Theta' Student_{isdt}$) and school-level ($\Phi' School_{sdt}$) covariates that were not impacted by the pandemic, as described above. Finally, in some models, we include school fixed effects (η_s) to control for any observed or unobserved time-invariant school-level characteristics.

To assess the robustness of our results, we estimate six additional specifications. Model 2 layers in vectors of student- and school-level covariates that did appear to be impacted by the pandemic. Model 3 includes COVID-impacted student-level covariates as well as school-level covariates fixed at their 2019-20 (pre-pandemic) levels. Model 4 includes raking weights which weight our post-pandemic observations to mirror the observed characteristics of the pre-pandemic Virginia student population, to assess whether compositional changes to the student body as a result of the pandemic seem to be driving any results. Model 5 includes a quadratic time trend to test the robustness of our estimates to the choice of functional form in the pre-period. Model 6 replaces school fixed effects with a set of observable school- and district-level time-invariant covariates. Finally, Model 7 is estimated after omitting end-of-course (EOC) test outcomes which are associated with courses into which there is likely more endogenous sorting than for the end-of-year exams. This is meant to test the extent to which our estimates might be driven by changes in the patterns of sorting into these courses before versus after the pandemic.

We adjusted Model 1 to assess the heterogeneity of COVID's impact across student groups as well as across districts that operated in different ways. To measure these heterogeneous effects, we add interactions between a student characteristic or division operation with the time trend variable and the post-pandemic year indicators. We estimate separate models for each student characteristic (i.e., race/ethnicity: interactions with indicators for White, Black, Hispanic, and other race) or division operation (i.e., learning modality: interactions with indicators for below average, average, and above average). The interactions with the time trend variable estimate a separate post-pandemic performance expectation (in the absence of COVID) for each group of students or districts. The district models require an additional specification tweak. We omitted the school fixed effects because the measures of district 2021 operations did not vary across time and replaced them with indicators for school locality, school level, and the district's local ability to pay index calculated and used by the state as part of its school funding system.

For ease of interpretation, some of the results are presented as initial effects in 2021 and the extent of recovery by 2023. This is calculated by subtracting the initial effects from the third year. We sometimes express this recovery as a percentage of the initial effect.

Findings

COVID Negatively Impacted Mathematics Achievement. COVID suppressed student math performance in each of the first three years of the pandemic, although students recouped just over half of these losses by 2023. We have displayed the effects on math scale scores in Table 3 and on the math passage rate in Table 4. In 2021, the average math score of students in grades 3 through 8 was almost 38 points (57% of a SD) below what our preferred model predicted it would have been in the absence of the pandemic (Table 3, column 1). Average scores

in 2022 were 22 points (34% of a SD) lower than expected and 18 points (27% of a SD) lower in 2023. All annual effects were significant at the .001 level. By 2023, students on average had recouped 52% of the initial losses (1 - 2023 effect/2021 effect). This can be seen graphically in Figure 1. The lower average test scores resulted in fewer students passing the math test (Table 4, column 1). Specifically, the passage rate was twenty-six percentage points lower in 2021 than was expected, 16 percentage points lower in 2022, and 13 percentage points lower in 2023. Therefore, recovery was greatest in 2022 and appeared to begin to level off by 2023.

We also present in Tables 3 and 4 the results from five alternative model specifications. Findings from these models show that the results from our preferred model are robust to the inclusion of potentially COVID-impacted covariates (column 2), including those covariates fixed at their pre-pandemic values in all three pandemic years (column 3), weighting students in the years after the pandemic's onset so, as a population, they look similar to students in the last pre-pandemic year (column 4), replacing the time-invariant school characteristics with school fixed effects (column 5), and excluding students who took the end-of-course exams (column 6). These results provide greater confidence that our findings are not due to compositional changes in the student population or the tested population in the post-COVID onset period.

COVID Differentially Impacted Students by Demographic Characteristics. Although all subgroups of interest were negatively impacted by COVID, the pandemic did not impact all student groups equally. We report estimated impacts by year and subgroup using SD units in Table 5. Starting with gender, although both male and female students saw declines in the aftermath of COVID's onset, the effects were slightly larger for female students in all of the post-COVID-onset years. By 2021, female students were performing 59% of a SD lower than expected relative to male students who were performing 54% of a SD lower, on average. A

gender gap of 5% of a SD remained as of 2023. In Figure 2, we show that male students had made a slightly greater recovery by 2023 than female students.

Students of all races and ethnicities experienced average declines in math scores. However, Black and Hispanic students were both somewhat more negatively impacted initially than White students. More specifically, in 2021, Black students were scoring 60% and Hispanic students 61% of a SD lower than expected while White students were scoring 56% of a SD lower than they would have been in the absence of the pandemic. As of the most recent year, Black students had recovered more than Hispanic students, on average, in terms of their scale scores. White and Black students had recovered more than Hispanic students in terms of their pass rates by 2023. We show these differences in Figure 2. As of 2023, Black students were scoring a quarter of a SD lower than expected while Hispanic and White students scored 29% and 28% of a SD below expected, respectively.

Economically disadvantaged students were more negatively impacted by the pandemic than their more economically advantaged peers, across all three years after the pandemic's onset. In the first year, economically disadvantaged students were scoring 61% of a SD lower than expected while non-economically disadvantaged students were scoring 53% of a SD lower. As we show in Figure 2, non-economically disadvantaged students saw a greater share of these declines recovered by 2023 while economically disadvantaged students were still performing somewhat farther behind expectations (-0.30 SD) than non-economically disadvantaged students (-0.25 SD), as shown in Table 5.

When it came to disability status, non-disabled students experienced greater declines than disabled students, both initially and through 2023. In 2021, non-disabled students were performing 60% of a SD lower than expected while disabled students receiving SPED services

were performing 43% of a SD below and disabled students not receiving SPED services were performing 53% of a SD below expectations. Non-disabled students saw the greatest recovery in the following years, as illustrated in Figure 2 but, as of 2023, were still performing lower than expectations relative to disabled students who were receiving SPED services (30% versus 19% of a SD below, respectively). In 2023, disabled students not receiving SPED services were performing similarly to non-disabled students (28% of a SD below expectations), as we report in Table 5.

We do not observe major differences in the initial impact of COVID on math performance by English Learner (EL) status. However, non-ELs had a shallower recovery than EL students. As shown in Figure 2, EL students recovered roughly 62% of their initial COVID declines by 2023 while non-ELs recovered just over 50%. As a result, non-ELs were still performing 27% of a SD lower than expected as of 2023 while ELs were performing only 14% of a SD lower than we predict they would have in the absence of COVID (see Table 5). EL students had the greatest recovery of any subgroup we examined here.

Although there is some variation in the effects from grade level to grade level, we do not see a consistent pattern in the variation by grade either in the initial post-COVID year nor in the recovery years to suggest, for example, that students in higher or lower grades were more impacted by COVID, on average. Those taking the End of Course (EOC) exams appeared to experience smaller negative impacts and greater recovery than students taking End of Grade (EOG) exams, however, it is difficult to draw strong inferences about this since there is non-random selection into course-taking which may have also been impacted by the pandemic.

COVID Differentially Impacted Students by School District Operations. All groups regardless of their district's operational decisions in 2020-21 experienced declines in math test

scores beyond what would have been expected in the absence of COVID, on average. However, we do observe variation in the size of these impacts based on some categories of district operational responses. The patterns for a district's emphasis on in-person learning and learning needs support were more monotonic while others—such as assessment use and technology support—were not. For some categories, the patterns were different for initial effects versus recovery. We describe the findings by district operational characteristic below.

First, students in districts with lower access to in-person learning in the first reopening year saw larger declines in math achievement. As we show in Table 6, students in districts with below average in-person learning were scoring 60% of a SD below expectations in 2021 while students in districts with average access were performing 58% of a SD behind, and students in districts with above average access were performing 52% of a SD behind expectations. As we show in Figure 3, the districts that offered below average access to in-person learning were already on a downward trend in math performance prior to the pandemic relative to districts that ended up offering average or above average access to in person learning. However, the baseline trends between the average and above average groups appeared parallel ($p=0.861$), providing more confidence in our comparisons of the post-pandemic outcomes. Interestingly, as shown in Figure 4, students in the districts with below average access to in-person learning saw a more dramatic recovery in the subsequent years, making up nearly 65% of the losses by 2023 while the students in average districts made up 42% and in above average districts made up 35% of the losses. The result was that by 2023, students in districts that offered an average amount of in person learning were actually slightly outperforming students from districts that offered above average in person learning in 2020-21, on average.

We also observe differential pandemic effects depending on the extent to which districts reported offering learning needs support to address pandemic-related learning disruptions, such as tutoring or extended learning time. As reported in Table 6, children in districts providing below average learning needs support saw the greatest initial declines (performing 60% of a SD below expectations in 2021 versus 55% for those in above average districts on this dimension). These students also saw the lowest rates of recovery. In Figure 4, we show that students in the below average group recovered about 40% of the initial losses by 2023, while students in the average group recovered 57% and in the above average group 52%. In Figure 3, we show that although the average group appeared to be on a somewhat different pre-pandemic trajectory than the other two groups, the above and below average pre-trends were roughly parallel. However, all of the baseline trends for each of the three groups were statistically significantly different from each other when we tested this more formally, limiting our ability to interpret post-pandemic differences between the groups as pandemic effects.

The patterns of COVID's impacts were not monotonic for a district's emphasis on assessment use. The largest math achievement declines were experienced by students in districts with either above or below average focus on assessment. In other words, we observe a u-shaped relationship between emphasis on assessment and pandemic impacts. Students in the average group were performing 55% of a SD below expectations in 2021 while the students in below average districts were scoring 61% below expectations and in the above average districts 60% below (see Table 6). Additionally, the recovery was greatest among students in the average assessment use districts. In Figure 4 we illustrate that students in average districts made up 59% of the losses by 2023 while students in below average districts had made up only 45% and students in above average districts had made up about 47% of the initial declines. However, the

baseline trends appeared parallel when comparing the below versus above average groups (p=0.649), the average group was not on a parallel trajectory pre-COVID to the other groups, complicating our ability to draw causal inferences when contrasting this group with either the below or above average groups.

The patterns were also non-monotonic when it came to a district's emphasis on technology support, although in the opposite direction from assessment use. In other words, we observe an upside-down u-shaped relationship between emphasis on technology support and pandemic effects, with the biggest initial declines among students in average districts (-0.61 SDs) and smaller declines among students in below average (-0.55 SDs) and above average (-0.57 SDs) districts. We also saw a greater recovery among the below average (57%) and above average (54%) groups than the average group (45%), as shown in Figure 4. Again, we observed some evidence that the pre-pandemic math achievement trends were parallel between the below versus above average groups (p=0.084) but not between the average group and the other two.

We saw no differences in the pandemic's impact on math based on the extent to which districts emphasized social-emotional learning (SEL) supports, with 2021 effects between -0.57 and -0.58 SD units for all three groups, as shown in Table 6. However, we observe a larger recovery among students in districts with a below average or average emphasis than an above average emphasis on SEL. As shown in Figure 4, students in above average districts had recovered only 45% of their losses while students in average districts had recovered 59% and in below average districts 54% of the declines. Baseline trends between below average versus above average groups were not statistically significantly different from one another (p=0.412).

Similarly, for emphasis on higher expectations, we saw no differences in the pandemic's initial impact, with 2021 effects ranging from -0.57 to -0.59 SD units depending on the group

(see Table 6). However, we saw greater recovery among students in average and above average districts than those in below average districts. In Figure 4, we show that students in below average districts made up about 45% of their losses while students in average districts made up 59% and in above average districts 47%. However, we urge caution in interpreting these differences causally as none of the baseline trends appeared parallel based on formal tests, suggesting post-pandemic differences could have been due to pre-pandemic differences between the districts that opted for different levels of expectations during the recovery year.

The other aspects of school district operations that we could measure did not correlate to major differences in either the initial pandemic effect or the extent of the recovery in more recent years. This included the degree of emphasis on family engagement, health protocols, and teacher professional development. For family engagement and teacher PD, we observed evidence of parallel baseline trends for some of the groups, but not for any of the groups based on the level of health protocols adopted.

Discussion

We examine the effects of the COVID-19 pandemic on student math achievement in the unique context of Virginia–an outlier state in terms of its exceptionally low levels of access to in-person learning in the early period after the pandemic's onset and the availability of unique data allowing us to explore variation in COVID impacts by both student demographics and a wider range of school district operational decisions than has previously been examined. Unfortunately, we find that Virginia was also an outlier in terms of the pandemic's effects on academic outcomes. We observe notably large initial negative impacts on math achievement in the first post-pandemic year on the order of 0.56 SDs or 26 percentage points. The COVID impact we observe in Virginia is between two to three times the magnitude of the overall average first-year

impact on math test scores nationally (Jack et al., 2023; Goldhaber et al., 2022). Our results are consistent with other scholars' findings about the disproportionate pandemic impacts on academic achievement in Virginia relative to other states (Fahle et al., 2024; Jack et al., 2023).

To put the size of these impacts in even greater context, the magnitude of the initial COVID impact in Virginia was the same magnitude as the size of the average gain a typical fourth grade student makes in math over the course of an entire school year. It is about two-thirds the size of the overall national gap in fourth grade math performance between students who do versus do not qualify for subsidized meals (Hill et al., 2007). The pandemic impact would be considered quite large among impacts of educational programs that have been evaluated by randomized control trials (Kraft, 2020). In other words, while students in all states saw math performance declines after the pandemic began, the declines in Virginia were much larger than in most other states and were very large when compared to other policy-relevant benchmarks.

The good news is that we do observe meaningful academic recovery in 2022 and continued recovery the following year. Most groups made up more than half of the initial losses. However, the magnitude of the recovery was more modest in the most recent year than the change we observed between 2021 and 2022, suggesting that recovery leveled off by 2023. This is despite the fact that the average student remained 27% of a SD below pre-pandemic expectations in 2023, indicating there was still substantial room for improvement as of the third post-recovery school year and that the COVID-19 pandemic's shadow is long. In other words, the system had not successfully addressed the significant disruptions the pandemic caused for student achievement, at least by 2023. This is unfortunate given other scholars have estimated these impacts will have substantial lasting effects on long-term outcomes for students and the economy as a whole (Hanushek, 2022).

Not only did the pandemic have large negative impacts on Virginia students overall but also impacted subgroups of students in differential ways. Some of the variation in the pandemic effects appeared to be in a direction that could exacerbate existing inequalities. For example, we saw larger initial negative impacts for economically disadvantaged students, Black and Hispanic students, and female students. It is especially concerning that some of the student groups that absorbed larger initial impacts have in some cases recovered less, including female and economically disadvantaged students. In contrast, when it came to student characteristics based on qualifications for school-based services, we saw smaller negative impacts for students receiving special education services than students with a disability not receiving services and the largest recovery for English Learners.

We also observed some variation in the pandemic's effects depending on various aspects of school districts' operational decisions during the first reopening school year. Consistent with prior work, students in Virginia districts with lower access to in-person learning during that year saw larger initial declines in math achievement in the first year of testing after the pandemic's onset (2021) than those with greater access. However, perhaps surprisingly, those students with the lowest opportunity to learn in person saw the greatest academic recovery in math by year three (2023). Although students in districts providing greater learning needs support saw smaller declines and greater recovery than those in districts with less support, we still observe large declines even among those students in the above-average districts. This is consistent with a related line of research documenting more modest gains from post-pandemic learning support programs adopted at scale than observers hoped (Carbonari, 2024; Kraft, Schueler & Falken, 2024). When it came to SEL supports, we observed no differences in the pandemic's initial impact, but smaller recovery in math achievement among those students in districts with above

average emphasis on SEL. We are unable to determine whether this reflects an effect of SEL supports or the possibility that districts with greater academic challenges simply opted to provide more SEL supports (perhaps SEL and academic challenges were correlated) or some other possibility. Again, we view our results as describing correlational rather than causal relationships between district operational choices and student outcomes, particularly in cases where we do not observe parallel trends in math achievement prior to the pandemic between groups of districts opting into differential levels of operational emphasis. We also want to remind readers that our district operational measures capture what occurred in 2020-21 which may or may not be correlated with district operational choices in 2022, 2023, and beyond.

Future researchers should begin to further this line of research by more credibly isolating the causal impacts of various pandemic-era education policy choices on student outcomes than we are able to here. Perhaps more importantly, future researchers should begin disentangling whether the ongoing statewide impacts are concentrated among students who were of school-age when the pandemic was most acute versus those who entered K-12 school after the height of the pandemic. This would help policymakers understanding whether the K-12 school system is simply working its way through a temporary COVID disruption or whether the pandemic has changed the system in more enduring ways. For example, pandemic-induced challenges with teacher retention may mean that the school system has less capacity to support students, even for those new cohorts of children who entered school in the most recent years. Understanding these dynamics will be essential for policymakers to determine how best to support those students most directly impacted by the pandemic as well as those indirectly affected by the ways in which this national tragedy may have fundamentally changed our nation's K-12 public school system.

References

Bloom, H.S. (2003). Using "short" interrupted time-series analysis to measure the impacts of whole-school reforms: With applications to a study of accelerated schools. *Evaluation Review*, *27*(1), 3–49. https://doi.org/10.1177/0193841X02239017

Bruhn, Campos & Chyn (2023). Who benefits from remote schooling? Self-selection and match effects. EdWorkingPaper No. 23-807.

Callen, Goldhaber, Kane, McDonald, McEachin & Morton (2024). Pandemic learning loss by student baseline achievement: Extent and sources of heterogeneity. CALDER Working Paper No. 292-0224.

Camp & Zamarro (2022). Determinants of ethnic differences in school modality choices during the COVID-19 crisis. *Educational Researcher*, 51(1), 6-16.

Carbonari, M. V., DeArmond, M., Dewey, D., Dizon-Ross, E., & Goldhaber, D. (2024). Impacts of academic recovery interventions on student achievement in 2022-23 (303–0724; CALDER Working Paper). American Institutes for Research.

Chetty, Friedman & Stepner (2024). The economic impacts of COVID-19: Evidence from a new public database built using private sector data. *The Quarterly Journal of Economics*, 139(2), 829-889.

Cohodes, Goldhaber, Hill, Ho, Kogan, Polikoff, Sampson & West (2022). Student achievement gaps and the pandemic: A new review of evidence from 2021-2022. Center for Reinventing Public Education.

Curriculum Associates (2023). "State of Student Learning in 2023" https://cdn.bfldr.com/LS6J0F7/at/x8v8wp2c6j4s4wttsw2nwphb/ca-state-of-student-learningtechnical-report-2023.pdf

Darling-Aduana, Woodyard, Sass & Barry (2022). Learning mode choice, student engagement, and achievement growth during the COVID-19 pandemic. CALDER Working Paper No. 260-0122.

Dee, T., Huffaker, E., Philips, C. & Sagara, E. (2021). The revealed preferences for school reopening: Evidence from public-school disenrollment. Annenberg EdWorkingPaper No. 21-446.

de Figueiredo CS, Sandre PC, Portugal LCL, Mázala-de-Oliveira T, da Silva Chagas L, Raony Í, Ferreira ES, Giestal-de-Araujo E, Dos Santos AA, Bomfim PO. COVID-19 pandemic impact on children and adolescents' mental health: Biological, environmental, and social factors. Prog Neuropsychopharmacol Biol Psychiatry. 2021 Mar 2;106:110171. doi: 10.1016/j.pnpbp.2020.110171.

Fahle, Kane, Patterson, Reardon, Staiger & Stuart (2023). School district and community factors associated with learning loss during the COVID-19 pandemic. Center for Education Policy Research.

Fahle, E., Kane, T., Reardon, S. & Staiger, D. (2024). The First Year of Pandemic Recovery: A District-Level Analysis. https://educationrecoveryscorecard.org/wp-content/uploads/2024/01/ERS-Report-Final-1.31.pdf

Goldhaber, Kane, McEachin, Morton, Patterson & Staiger (2022). The educational consequences

of remote and hybrid instruction during the pandemic. *American Economic Review: Insights*, 5(3), 377-392.

Gross, B., Opalka, A., & Gundapaneni, P. (2020). *Getting back to school: An update on plans from across the country*. Center for Reinventing Public Education.

Hanushek, E. (2022). The Economic Cost of the Pandemic. A Hoover Institution Essay. https://hanushek.stanford.edu/sites/default/files/Hanushek%202022%20HESI%20EconomicCost.pdf

Hill, C., Bloom, H., Black, A. & Lipsey, M. (2007). Empirical Benchmarks for Interpreting Effect Sizes in Research. MDRC Working Papers on Research Methodology.

Hillis SD, Blenkinsop A, Villaveces A, Annor FB, Liburd L, Massetti GM, Demissie Z, Mercy JA, Nelson Iii CA, Cluver L, Flaxman S, Sherr L, Donnelly CA, Ratmann O, Unwin HJT. COVID-19-Associated Orphanhood and Caregiver Death in the United States. Pediatrics. 2021 Dec 1;148(6):e2021053760. doi: 10.1542/peds.2021-053760.

Ho, Andrew D. (2008). "The problem with 'proficiency': Limitations of statistics and policy under No Child Left Behind." Educational Researcher, 37, 351-360. https://doi.org/10.3102/0013189X08323842.

Jack and Oster (2023). COVID-19, school closures, and outcomes. *Journal of Economic* Perspectives, 37(4), 51-70.

Jack, R., Halloran, C., Okun, J., & Oster, E. (2023). Pandemic Schooling Mode and Student Test Scores. *American Economic Review: Insights*, *5*(2), 173–190.

Jakukowski, Gajderowicz & Patrinos (2024). COVID-19, school closures, and student learning outcomes. New global evidence from PISA. *Nature*.

Kraft, M. (2020). Interpreting Effect Sizes of Education Interventions, *Educational Researcher*, 49(4).

Kraft, M., Schueler, B. & Falken, G. (2024). What Impacts Should We Expect from Tutoring at Scale? Exploring Meta-Analytic Generalizability. Annenberg Working Paper No. 24-1031.

Kuhfeld, Soland, Lewis, Ruzek & Johnson (2022). The COVID-19 school year: Learning and recovery across 2020-21. *AERA Open*, 8(1), 1-15.

Kuhfeld, Soland & Lewis (2022). Test score patterns across three COVID-19-impacted school years. EdWorkingPaper No. 22-521.

Kurmann & Lalé (2022). School closures and effective in-person learning during COVID-19: When, where, and for whom. IZA Institute of Labor Economics Discussion Paper Series.

Lane, J. (2021). ARP Act ESSER Local Plans for the Safe Return to In-Person Instruction and Continuity of Services. Superintendent's Memo #302-21.

Lewis, Kuhfeld, Ruzek & McEachin (2021). Learning during COVID-19: Reading and math achievement in the 2020-21 school year. Center for School and Student Progress.

Lewis, K. & Kuhfeld, M. (2023). "Education's long COVID: 2022–23 achievement data reveal stalled progress toward pandemic recovery." https://www.nwea.org/research/publication/educations-long-covid-2022-23-achievement-datareveal-stalled-progress-toward-pandemic-recovery/.

Miller, L. C., Oh, M. & Reynolds, A. (Working Paper). The Impact of the COVID-19 Pandemic on English learners' English Language Proficiency in Virginia.

Miller, L. C. & Schueler, B. (2022). Post-Pandemic Onset Public School Student Test-based

Performance in Virginia. https://education.virginia.edu/documents/post-pandemic-onset-public-school-student-test-based-performance-virginia

Millett, Jones, Benkeser, Baral, Mercer, Beyrer, Honermann, Lankiewicz, Mena, Crowley, Sherwood & Sullivan (2020). Assessing differential impacts of COVID-19 on black communities. Ann Epidemiol. 2020 Jul;47:37-44.

Niles, Bertmann, Belarmino, Wentworth, Biehl & Neff (2020). The early food insecurity impacts of COVID-19. Nutrients. 2020 Jul 15;12(7):2096.

Peters, Langi, Kuhfeld & Lewis (2023). Unequal learning loss: How the COVID-19 pandemic influenced the academic growth of learners at the tais of the achievement distribution, *Journal for the Education of the Gifted*, 48(1).

Peterson, Paul, David M. Houston, and Martin R. West (2022). "Parental Anxieties over Student Learning Dissipate as Schools Relax Anti-Covid Measures" Education Next, 23(1):20. https://www.educationnext.org/parental-anxieties-over-student-learning-dissipate-as-schoolsrelax-anti-covid-measures-2022-education-next-survey-public-opinion/

Piquero, Jennings, Jemison, Kaukinen & Knaul (2021). Domestic violence during the COVID-19 pandemic: Evidence from a systematic review and meta-analysis. *Journal of Criminal Justice*, 74.

Ross, Jiang, Young & Strambler (2024). In-person learning during the pandemic: Student take-up and school-level effects of remote and hybrid instruction on student outcomes, PNAS, 121(33).

Sachs, E. (2023). Measuring in-person learning during the pandemic. https://ies.ed.gov/learn/blog/measuring-person-learning-during-pandemic

Sachs, E. N., Miller, L. C., & Schueler, B. E. (2022). Virginia school division operations during SY 2020-21: In-person learning. https://education.virginia.edu/documents/epwvirginia-school-division-operations-during-sy-2020-21-person-learning202209pdf

Saldaña, J. (2013). *The Coding Manual for Qualitative Researchers* (2nd ed.). London: Sage.

Schueler, B. E. & Miller, L. C. (2023). Post-Pandemic Onset Public School Enrollment and Mobility: Evidence from Virginia. *Educational Evaluation and Policy Analysis*, 46(4).

Schueler, B., Miller, L. C., & Reynolds, A. (Conditionally Accepted). The Politics of Pandemic School Operations for Reopening and Beyond: Evidence from Virginia. *American Educational Research Journal*. Also Annenberg Working Paper No. 23-837.

Vindegaard & Benros (2020). COVID-19 pandemic and mental health consequences: Systematic review of the current evidence. *Brain, Behavior, and Immunity*, 89, 531-542.

Tables

Table 1. Student-Level Sample Descriptive Statistics

	Pre-COVID (2014 to 2019)		Post-COVID (2021 to 2023)	
	Mean	SD	Mean	SD
Test-Based Math Outcomes				
Scale Score	441.45	66.65	416.20	63.63
Passing	0.74	0.44	0.60	0.49
Student Demographics				
Female	0.49	0.50	0.49	0.50
Asian	0.07	0.26	0.08	0.27
Black	0.22	0.42	0.21	0.40
Hispanic	0.15	0.36	0.18	0.39
Other race	0.06	0.24	0.07	0.25
White	0.50	0.50	0.46	0.50
Economically Disadvantaged	0.43	0.50	0.45	0.50
Disabled, no SPED services	0.07	0.26	0.11	0.31
Disabled, SPED services	0.08	0.27	0.07	0.25
Active English Learner	0.07	0.26	0.10	0.31
School Locale				
Rural	0.24	0.43	0.26	0.44
Town	0.07	0.25	0.06	0.24
Suburb	0.46	0.50	0.47	0.50
City	0.23	0.42	0.22	0.41
School Type				
Elementary	0.53	0.50	0.52	0.50
Middle	0.44	0.50	0.44	0.50
High School	0.01	0.07	0.00	0.07
Combined	0.03	0.17	0.03	0.17
District Characteristics				
Local Ability to Pay	0.44	0.16	0.44	0.15
Sample Counts				
Unique Observations	3,394,859		1,492,919	
Unique Students	1,143,834		747,177	
Unique Schools	1,563		1,525	
Unique Districts	132		132	

Note. Statistics reflect the pooled sample of students enrolled in grades 3 through 8 who took a math SOL test with no observations in 2019-2020. Math scale scores range from 0 to 600 and the composite index for local ability to pay ranges from 0.17 to 0.80, and all other variables range from 0 to 1. *SOL* = Standards of Learning; *EOG* = End of Grade; *EOC* = End of Course (Algebra I, Geometry, Algebra II).

Table 2. Items Contributing to District Reopening Operations Characteristics Components in 2020-21

Family Engagement	Wave	Load
Feedback informs plans	Fall 2020	0.53
Guidance provided for learning at home	Fall 2020	0.75
Family check-ins recommended before start of year	Fall 2020	0.73
Learning data will be shared	Fall 2020	0.64
SEL Support	**Wave**	**Load**
Acknowledges SEL needs of students	2020-21	0.88
Provides SEL supports for students	Both	0.88
Schools expected to provide counselors/social workers	Fall 2020	0.55
Acknowledges SEL needs of staff	2020-21	0.92
Provides SEL supports for staff	2020-21	0.90
Partner organizations deliver SEL services	Fall 2020	0.43
Health Protocols	**Wave**	**Load**
Changed building practices for physical distancing	Fall 2020	0.96
Changed building sanitation protocols	Fall 2020	0.94
Provides guidelines for transportation health protocols	Fall 2020	0.83
Provides guidelines for food service health protocols	Fall 2020	0.83
Provides guidelines for behavioral norms for health	Fall 2020	0.93
Supplies PPE for all employees	Fall 2020	0.63
Requires face masks in instructional spaces	Fall 2020	0.78
Plan for determining future rolling school closures	Fall 2020	0.60
Updated sick leave policy for COVID-19	Fall 2020	0.70
Guidance provided for health	Fall 2020	0.54
Health data will be shared	Fall 2020	0.63
Provides staff training for health best practices	Fall 2020	0.67

Assessment Use	Wave	Load
Plan to assess student learning in the fall	Both	0.69
Plan to monitor academic progress through the year	Both	0.91
Specified assessment to be used for monitoring	2020-21	0.85
Expectations	**Wave**	**Load**
Reiterated schools required to take attendance	Fall 2020	0.70
Defines attendance in remote setting	2020-21	0.69
Schools required to provide grades	Fall 2020	0.80
Requires teacher feedback on student work	Fall 2020	0.79
Names required minimum instructional minutes	Fall 2020	0.59
Teacher Professional Development	**Wave**	**Load**
Offered COVID-specific instructional PD	Fall 2020	0.70
Provides coaching to teachers in remote setting	Fall 2020	0.84
School day time set for PD, planning or collaboration	Fall 2020	0.69
Tech Support	**Wave**	**Load**
Provides home-based internet for all students in need	Both	0.77
Majority grades provided devices for students in need	2020-21	0.77
Provides tech support for at-home learning	2020-21	0.57
Learning Needs Support	**Wave**	**Load**
Plans to offer summer school or ELT	Both	0.65
Plans to provide tutoring	Both	0.58
Majority synchronous instruction when remote	Both	0.45
Provides interventions based on diagnostic	Fall 2020	0.64

Note: Each row provides a summary of the item and the reopening plans that contribute to the coding of the item (e.g., Fall 2020 Reopening Plan, 2020-21 Amendments to Reopening Plans, Both), as well as loadings for each item.

Table 3. The Impact of the COVID-19 Pandemic on Student Math Scale Scores in Virginia

Model	(1)	(2)	(3)	(4)	(5)	(6)
Spring 2021	-37.78***	-39.06***	-38.82***	-38.27***	-37.61***	-38.34***
	(0.11)	(0.10)	(0.11)	(0.11)	(0.11)	(0.12)
Spring 2022	-22.36***	-22.64***	-22.64***	-21.15***	-22.47***	-23.05***
	(0.13)	(0.12)	(0.12)	(0.13)	(0.13)	(0.15)
Spring 2023	-18.16***	-18.94***	-18.58***	-16.61***	-18.40***	-18.68***
	(0.16)	(0.15)	(0.15)	(0.16)	(0.16)	(0.18)
Time	-0.61***	-0.36***	-0.29***	-0.65***	-0.67***	-0.79***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
New Test	5.86***	5.84***	5.79***	5.86***	5.95***	5.83***
	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.09)
Observations	4,887,778	4,885,973	4,865,596	4,887,778	4,887,778	4,362,962
School fixed effects	X	X	X	X		X
Student COVID-impacted covariates		X	X			
School COVID-impacted covariates		X				
School covariates fixed at 2019-20			X			
Raking weights				X		
Quadratic time trend						
School/district time-invariant covariates					X	
Omitting end-of-course (EOC) tests						X

Table 4. The Impact of the COVID-19 Pandemic on Student Math Pass Rates in Virginia

Model	(1)	(2)	(3)	(4)	(5)	(6)
Spring 2021	-0.26***	-0.27***	-0.26***	-0.26***	-0.26***	-0.27***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Spring 2022	-0.16***	-0.16***	-0.16***	-0.15***	-0.16***	-0.17***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Spring 2023	-0.13***	-0.14***	-0.13***	-0.11***	-0.13***	-0.14***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Time	-0.00	0.00***	0.00***	-0.00*	-0.00***	-0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
New Test	0.05***	0.05***	0.05***	0.05***	0.05***	0.05***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	4,887,778	4,885,973	4,865,596	4,887,778	4,887,778	4,362,962
School fixed effects	X	X	X	X		X
Student COVID-impacted covariates		X	X			
School COVID-impacted covariates		X				
School covariates fixed at 2019-20			X			
Raking weights				X		
Quadratic time trend						
School/district time-invariant covariates					X	
Omitting end-of-course (EOC) tests						X

Table 5. COVID-19 Impact on Math Scores by Subgroup, in Standard Deviation Units

Group	Spring 2021	Spring 2022	Spring 2023
Overall	-0.57	-0.34	-0.27
Gender			
Male	-0.54	-0.31	-0.25
Female	-0.59	-0.36	-0.30
Race/Ethnicity			
Black	-0.60	-0.35	-0.25
Hispanic	-0.61	-0.36	-0.29
White	-0.56	-0.33	-0.28
Economically Disadvantaged (ED)			
Non-ED	-0.53	-0.32	-0.25
ED	-0.61	-0.36	-0.30
Disability Status			
Non-Disabled	-0.60	-0.36	-0.30
Disabled, no SPED services	-0.53	-0.33	-0.28
Disabled, SPED services	-0.43	-0.26	-0.19
English Learner (EL) Status			
Non-EL	-0.56	-0.33	-0.27
EL	-0.55	-0.26	-0.14
Math Test Taken			
EOG Grade 3	-0.62	-0.38	-0.32
EOG Grade 4	-0.53	-0.31	-0.21
EOG Grade 5	-0.56	-0.31	-0.24
EOG Grade 6	-0.58	-0.35	-0.29
EOG Grade 7	-0.60	-0.42	-0.36
EOG Grade 8	-0.56	-0.32	-0.28
EOC (Algebra I and II, Geometry)	-0.51	-0.23	-0.19

Note. SPED stands for "Special Education." All within year, between group and within group, between year differences are statistically significant ($p < .05$) with the exception of the following: ELs v. non-ELs in spring 2021 ($p = .19$), White v. Hispanic students in spring 2023 ($p = .07$), non-disabled v. disabled students without SPED services in spring 2023 ($p = .11$), EOG 5 and EOG 8 in spring 2021 ($p = .99$), EOG 4 v EOG 5 in spring 2022 ($p = .45$), EOG 4 v. EOG 8 in spring 2022 ($p = .055$), EOG 5 v. EOG 8 in spring 2022 ($p = .20$), and EOG 6 v. EOG 8 in spring 2023 ($p = .49$).

Table 6. COVID-19 Impact on Math Scores by District Operations, in Standard Deviation Units

Group	Spring 2021	Spring 2022	Spring 2023
Overall	-0.57	-0.34	-0.27
Percent In-Person Learning			
Below Average	-0.60	-0.30	-0.21
Average	-0.58	-0.38	-0.33
Above Average	-0.52	-0.37	-0.34
Assessment Use			
Below Average	-0.61	-0.40	-0.34
Average	-0.55	-0.29	-0.22
Above Average	-0.60	-0.38	-0.32
Expectations			
Below Average	-0.59	-0.40	-0.35
Average	-0.59	-0.31	-0.23
Above Average	-0.57	-0.33	-0.26
Family Engagement			
Below Average	-0.59	-0.34	-0.26
Average	-0.57	-0.33	-0.27
Above Average	-0.58	-0.36	-0.29
Health			
Below Average	-0.56	-0.33	-0.24
Average	-0.57	-0.33	-0.27
Above Average	-0.59	-0.35	-0.30
Learning Needs Support			
Below Average	-0.60	-0.43	-0.36
Average	-0.59	-0.32	-0.25
Above Average	-0.55	-0.33	-0.26
SEL Support			
Below Average	-0.57	-0.34	-0.26
Average	-0.58	-0.32	-0.24
Above Average	-0.58	-0.36	-0.32
Technology Support			
Below Average	-0.55	-0.31	-0.23
Average	-0.61	-0.38	-0.34
Above Average	-0.57	-0.33	-0.26
Teacher PD			
Below Average	-0.57	-0.36	-0.29
Average	-0.58	-0.35	-0.27
Above Average	-0.57	-0.32	-0.26

Figures

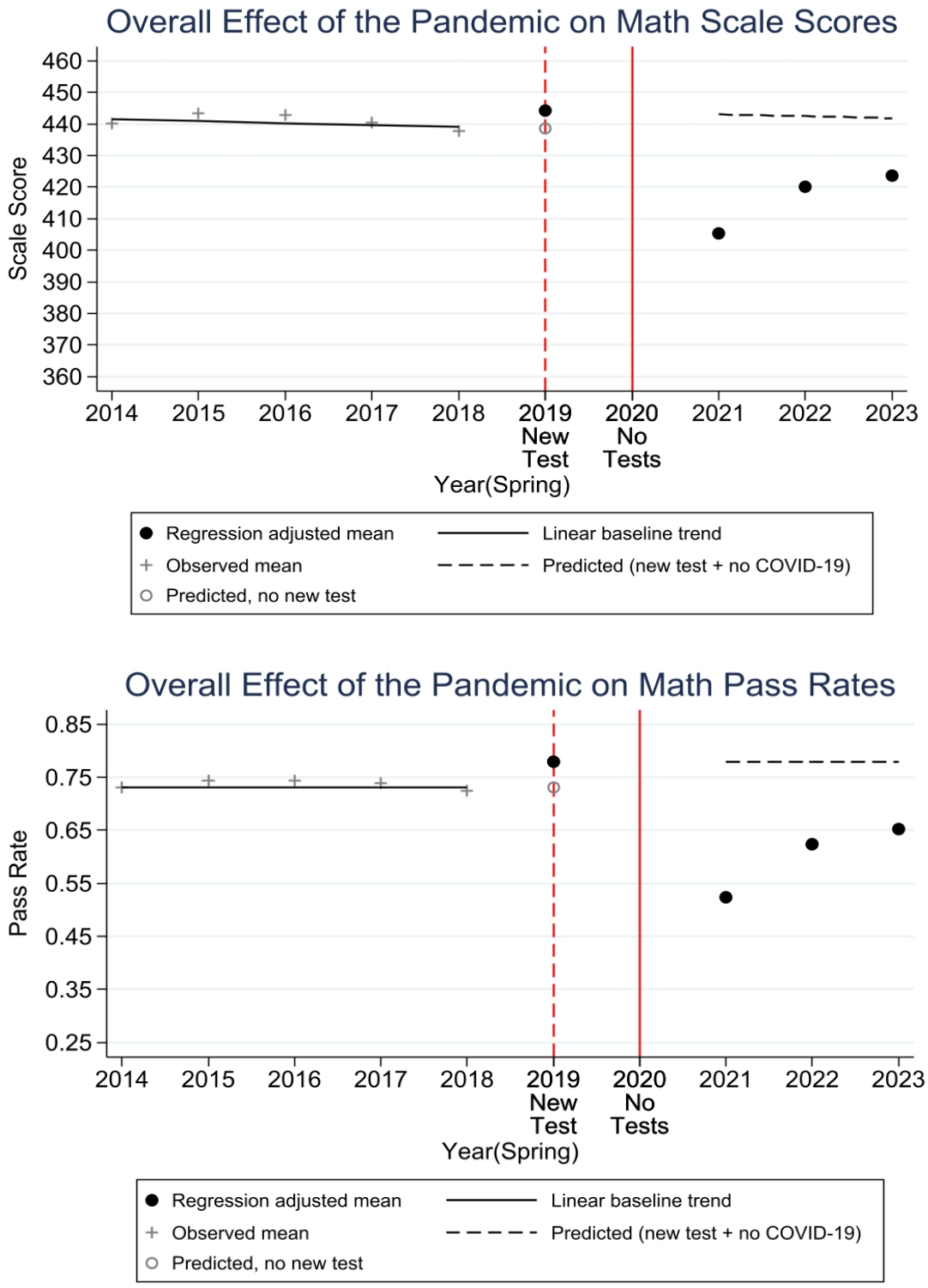
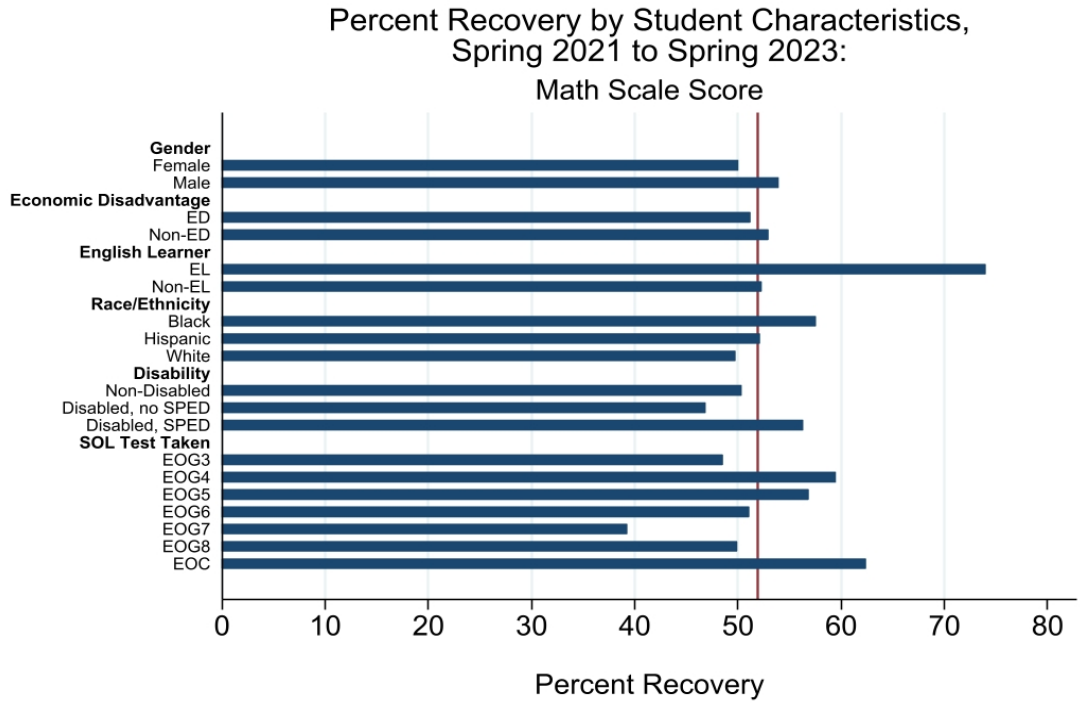
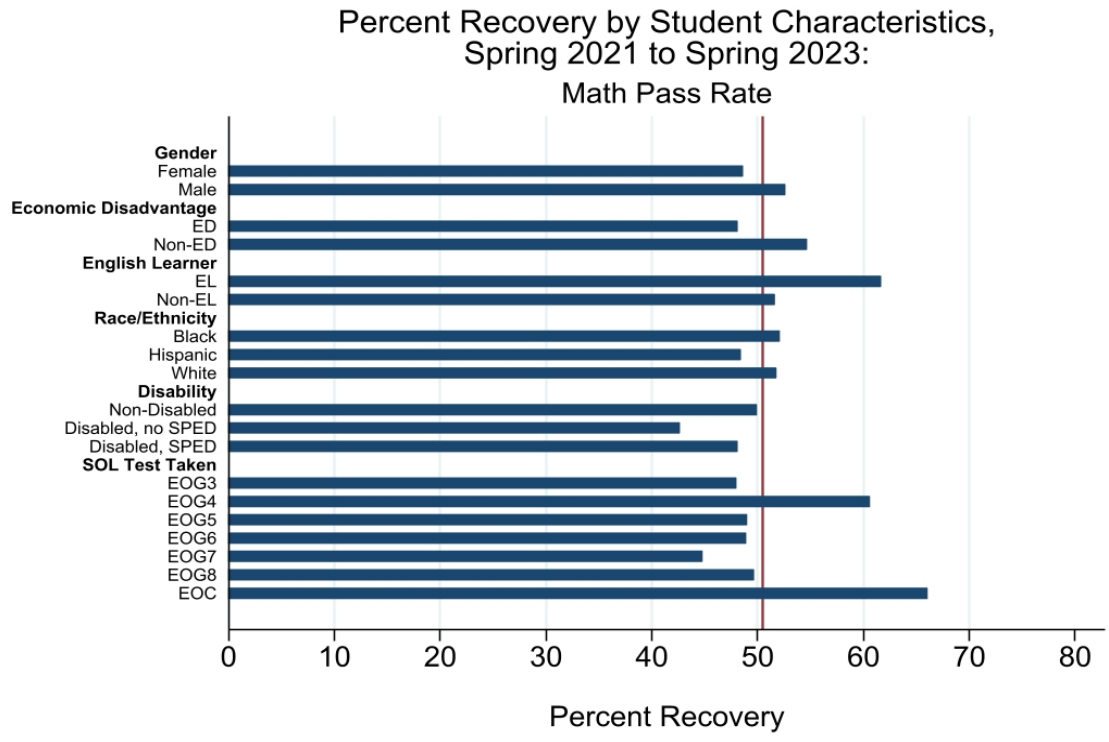


Figure 1. COVID-19 Impacts on Math Scale Scores and Pass Rates.



Note. EOG = End of Grade. EOC = End of Course (Algebra 1 or 2, Geometry).
Red line indicates percent recovery in pooled sample.



Note. Red line indicates percent recovery in pooled sample.

Figure 2. Percent Recovery on Math Scale Scores and Pass Rates, by Subgroup.

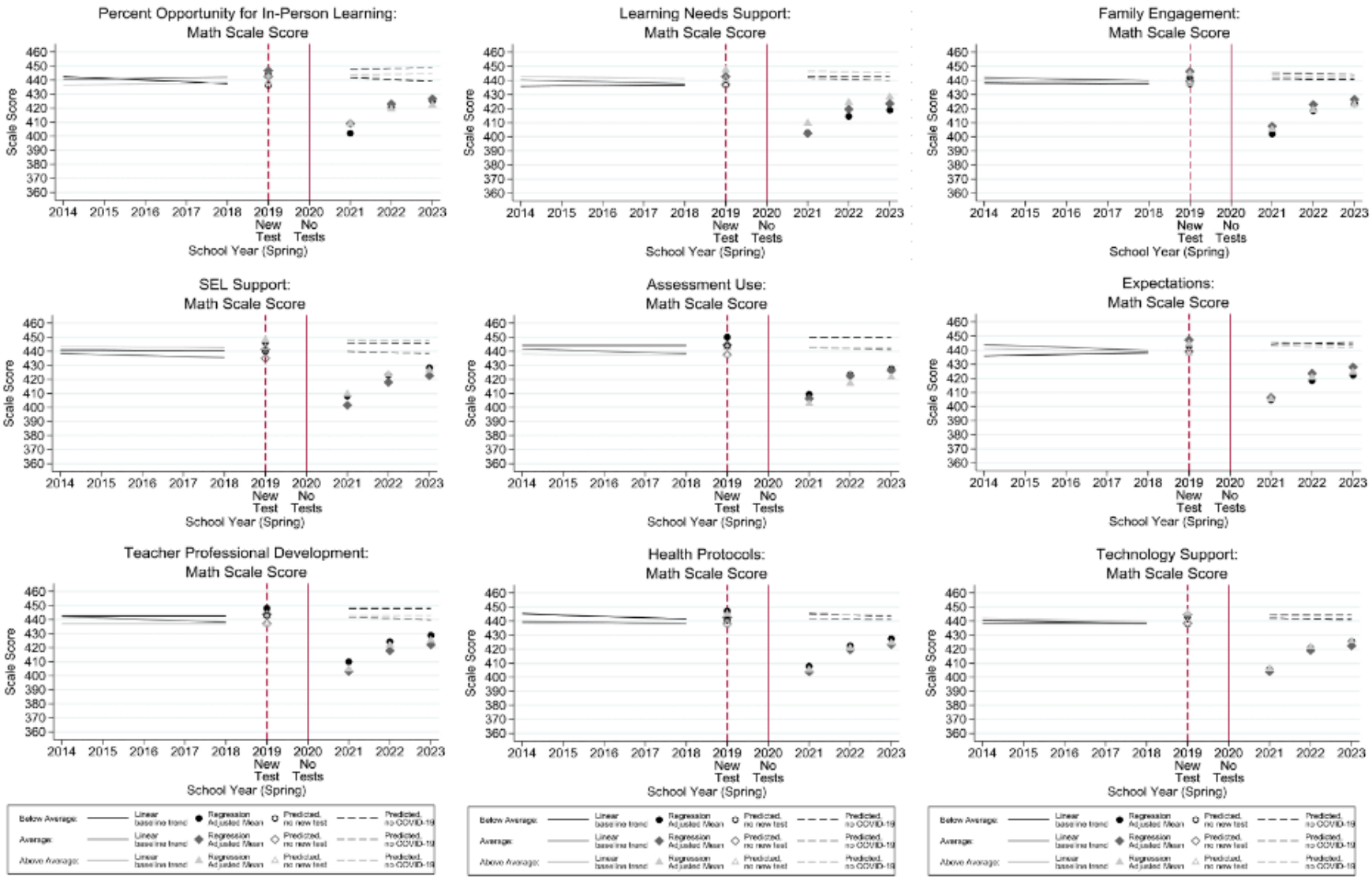
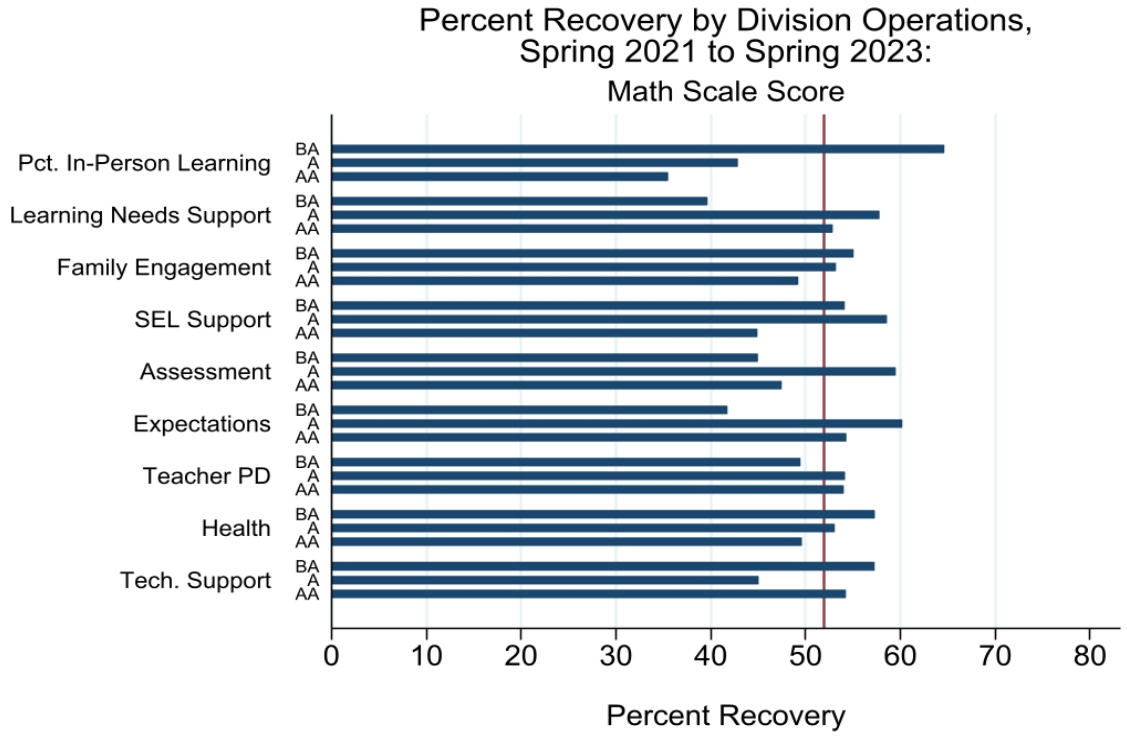
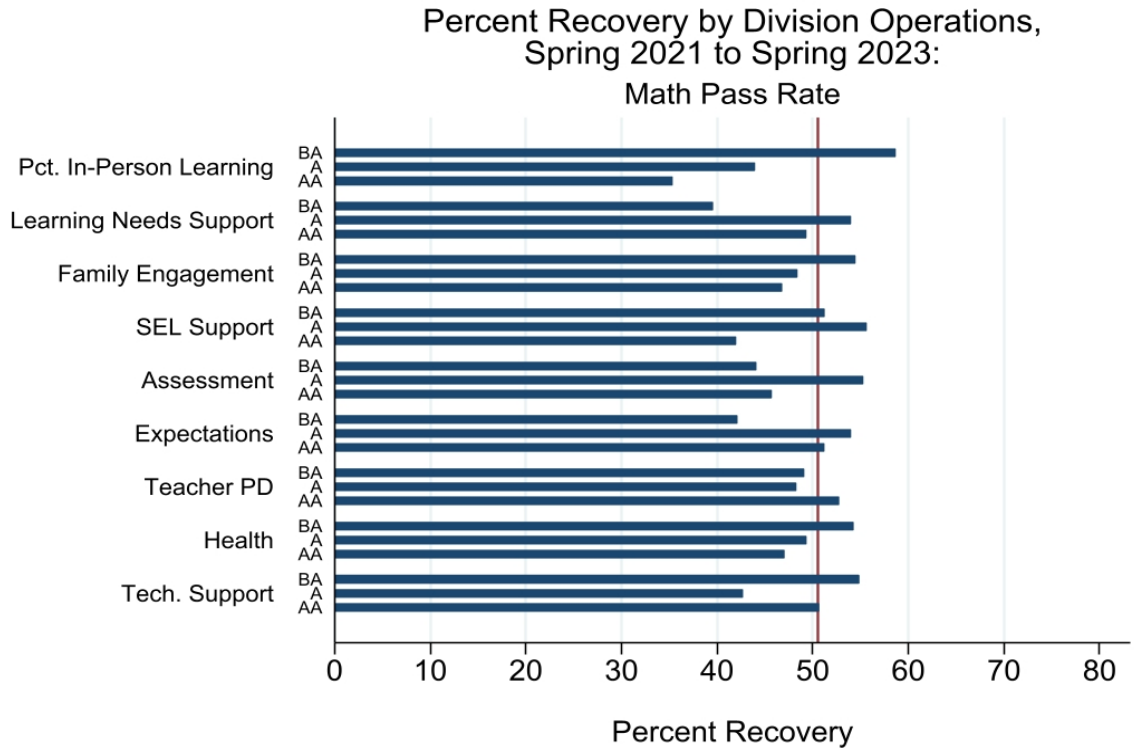


Figure 3. COVID-19 Impacts on Math Scale Scores by School District 2020-21 Operations.



Note. BA = Below Average. A = Average. AA = Above Average. Red line indicates percent recovery in pooled sample.



Note. BA = Below Average. A = Average. AA = Above Average. Red line indicates percent recovery in pooled sample.

Figure 4. Percent Recovery on Math Scale Scores and Pass Rates, by District Operations.

Table A1. Wave 1 Codes by Category: Fall 2020-21 Reopening Plans (continued)

#	Code Description	#	Code Description
4. Structured and meaningful 2020-21 learning plan			
4.1	District sets expectation that remote curriculum be provided for core courses	4.2	District will provide remote curriculum for all grade levels
4.3	District will provide remote instruction for all grade levels	4.4	Type of remote instruction offered to students
4.5	District expects teachers to provide feedback on student work for students engaged in remote learning	4.6	District has a plan to provide interventions or increased supports based on student learning loss diagnostic
4.7	District plans to provide tutoring to students	4.8	District has a plan for supporting high school students with college and career preparation (test prep, counseling, etc.)
4.9	District requires teacher/student check-ins when engaged in remote learning	4.10	District expects schools to diagnose entering student learning loss
5. Educational services for vulnerable populations		5.1	District has a plan to provide specific support to students with language barriers
5.2	District has a plan to provide specific support to students experiencing homelessness/transitional students	5.3	District has a plan to provide specific support to students with disabilities
6. Support to Staff		6.1	District offered COVID-19 specific instructional professional development
6.2	District explicitly states that it has increased time dedicated to teacher PD and/or collaboration	6.3	District provides staff training for health and safety best practices
6.4	District has plan to provide coaching to teachers during the year in remote learning setting	6.5	District sets aside time during the school day for professional learning, planning, and/or collaboration
7. Health and safety measures in place		7.1	District communicates changes to building practices for all schools to ensure physical distancing
7.2	District communicates changes to building health sanitation and protocols	7.3	For in person learning, district communicates guidelines to transportation forms, routes and sanitization practices
7.4	For in person learning, district communicates guidelines to food services to prevent cross-contamination	7.5	For in person learning, district communicates guidelines in expectations for behavioral norms to prevent cross-contamination
7.6	District supplies PPE for all employees	7.7	District requires face masks
7.8	District has a plan or policy for determining future rolling closures if confirmed infection(s) of staff or students	7.9	District's sick leave policy is updated to reflect COVID-19 preferences
8. Equitable access to education is ensured for all students		8.1	Plan commits to provide devices for all students in need
8.2	Plan commits to provide hotspot/wifi access for all students in need	8.3	District recommends or requires home visits or virtual family/student check ins before the start of year

All codes were included in the collapsed codes for the analysis.

Table A2. Wave 2 Codes by Category: Through Year Reopening Operations

#	Code Description	#	Code Description
1. Clear reopening plan			
1.1	District provides full-time remote "home choice" option	1.2	Date by which families needed to make a decision
1.3	For what time period were families selecting from among the available options?	1.4*	Staffing of home choice option
1.5*	District prioritizes serving vulnerable populations for in-person instruction in school buildings	1.5.1	Type of vulnerable populations prioritized for in-person instruction
1.7	District defines "attendance" for the remote setting	1.7.1*	How does the district define attendance in the remote setting?
1.8*	District modified its grading format from pre-COVID year(s)	1.8.1	If the District changed its grading format from previous year(s), what changes were made?
1.9	District changed its grade retention policy from previous year(s)	1.9.1	If the District changed its grade retention policy, what changes were made?
1.10*	District has a plan to assess student learning in the fall (via formative or diagnostic assessment)	1.10.1	How did the district assess learning in the fall - K-2?
1.10.2	How did the district assess learning in the fall - 3rd - 5th grade?	1.10.3	How did the district assess learning in the fall - middle school?
1.10.4	How did the district assess learning in the fall - high school?	1.10.5	Will the fall assessment(s) be administered in-person or online/virtually?
1.11*	District has a plan to monitor students' academic progress throughout the year (via formative or diagnostic assessment)	1.11.1*	Did the district specify which assessments would be used to monitor students' academic progress throughout the year?
1.11.2	Which assessments were used to monitor students' academic progress throughout the year for K-2 students?	1.11.3	Which assessments were used to monitor students' academic progress throughout the year for 3rd-5th graders?
1.11.4	Which assessments were used to monitor students' academic progress throughout the year for middle school (6th-8th grade) students?	1.11.5	Which assessments were used to monitor students' academic progress throughout the year for high school (9th-12th grade) students?
1.12*	District plans to provide tutoring	1.12.1	If yes to 1.12, specify for whom, how they were identified, and what programming was offered to these students
1.13*	District plans to offer summer school instruction or another form of extended learning time?	1.13.1	If yes to 1.13, specify for whom, how they were identified, and what summer programming or extended learning time was offered to these students
1.14*	District acknowledges the social, emotional, and mental health needs of students?	1.14.1*	District discusses services or supports to address social, emotional, and mental health needs of students

(Continued)

Table A2. Wave 2 Codes by Category: Through Year Reopening Operations (continued)

#	Code Description	#	Code Description
1.15	If "Yes" to 1.14.1, identify new services provided to students	1.15.1*	District acknowledges the social, emotional, and mental health needs of staff?
1.15.2*	District discusses services or supports to address social, emotional, and mental health needs of staff	1.15.3	If "Yes, COVID" to 1.15.2, identify new services provided to staff
2. Structured and meaningful 2020-21 learning plan		2.1*	In what format(s) will the district provide remote curriculum?
2.2	District will provide remote curricula for all students	2.2.1	If district DOES NOT provide remote curricula for all students, for which students is remote curriculum provided?
2.3.1 to 2.3.14*	Type of remote instruction offered to *{pre-kindergarten, kindergarten, … 11th grade, 12th grade}* students	2.4*	Were any teachers assigned to teach multiple modes?
2.4.1	IF "Yes" to 2.4: Did district expect teachers to simultaneously/concurrently teach students in-person and online?	2.4.2	If yes to 2.4.1, then for which grades or student groups
3. Equitable access to education is ensured for all students		3.1.1 to 3.11.14*	Plan commits to provide devices for *{pre-kindergarten, kindergarten, … 11th grade, 12th grade}* students in need
3.2*	Plan commits to provide internet connectivity for students in need	3.2.1*	District commits to providing tech support for at-home learning throughout the school year

Codes with an asterisk were included in the collapsed codes for the analysis.

Table A3. Definitions of District Operation Measures

Measure	Definition
Assessment Use	The extent to which the district emphasized assessments (e.g., plans to assess student learning in the fall and/or monitor progress)
Expectations	The extent to which the district emphasized the expectations they had for students and teachers (e.g., teachers required to provide feedback on student work).
Family Engagement	The extent to which the district emphasized engaging with students' families (e.g., check-ins with families, use of family feedback to inform reopening plans)
Health Protocols	The extent to which the district emphasized the health precautions they were taking in the reopening year (e.g., provision of personal protective equipment)
Learning Needs Support	The extent to which the district indicated planning to provide students with services designed to address the negative impacts of pandemic-related disruptions to learning (e.g., extended learning time, tutoring, synchronous instruction)
SEL Support	The extent to which the district emphasized providing social and/or emotional learning supports to students or staff (e.g., acknowledgement of SEL needs among staff)
Teacher PD	The extent to which the district emphasized instructional supports for teachers (e.g., pandemic-specific instructional PD)
Technology Support	The extent to which the district stated to provide technology support (e.g., internet for students in need, devices)
% In-Person Learning	The percentage of the year students were offered in-person learning in each district

Note. For information on the individual indicators for the district operation constructs, see Schueler et al., 2023.
For information on how the percentages of in-person learning were generated, see Sachs et al., 2022.