From Disruption to Recovery

March 2022

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Abstract

This study investigates the effects of the COVID-19 pandemic on students' achievement in reading and math across the US. Data were collected from the 2018-2019, 2019-2020, and 2020-2021 school years. Istation's Indicators of Progress (ISIP™) Reading and ISIP Math assessments were used. Results from a piecewise growth model with three intercepts and three slopes show that students performed well before the COVID-19 pandemic. Students experienced a summer learning loss in both reading and math depending on grade level before the pandemic. All students experienced a combination of summer learning loss and COVID-19 learning disruption during the pandemic. Students' academic performance was lower during the pandemic.

Keywords: COVID-19, learning disruption, summer learning loss, reading achievement, math achievement

Introduction

It has been two years since pandemic-induced school closures were implemented across the US in March 2020. There have been several studies on the impact of COVID-19 pandemic on students, teachers, learning, and assessment. DeWitt (2020) conducted online surveys in March 2020 and found that teachers consistently indicated they were not prepared to teach online and that a significant percentage of their students did not even log in to complete assignments. Teachers also taught less new material, especially in high-poverty schools. This lack of preparation unquestionably impacted teaching ability, which in turn impacted student learning. This difference may be due to a lack of knowledge of technology or of evidence-based approaches to teaching online, family or personal issues, illness, or many additional reasons. Michel's research (2020) explores the issue of technology access:

> During COVID-19, disparate access to technology (computer, laptops, and internet access) led to unequal access to the testing opportunities, leading institutions to either temporarily suspend testing for the year (e.g., not requiring a standardized test for admissions or states to seek exceptions for state-mandated end-of-year tests) or find ways to implement remote testing. There was a rush to a remote "at-home" solution without fully vetting the solution or the extent to which technology-related issues would disrupt the testing conditions. (pp. 28–30)

Learning Disruption During the COVID 19 Pandemic

Bansak and Starr (2021) used data from the U.S. Census Bureau's Household Pulse Survey on 200,000 households with K-12 students to examine how school systems shifted, how parents and caregivers stepped up and spent time helping children learn, how parental time inputs varied with parent education, and how education changes intersected with other pandemic shocks, including job loss and food insecurity. They

found that parents and children spent significantly more time in learning activities when their schools provided diversified educational inputs, especially live contact time with teachers. Given the type of alternative schooling, less educated parents spent the same amount of time helping children as more educated parents, although they faced significantly more problems with computer and internet access. Thus, parents and caregivers generally tried to help children continue learning in the pandemic given the resources they could supply to mitigate the drop in learning.

Lambert and Schuck (2021) also conducted a qualitative study on teaching math to students with disabilities during the COVID year. The study was conducted before and during the COVID year and followed three teachers, but the presented findings focus on one teacher. The teacher teaches a self-contained special education class of primarily students with Individualized Education Programs (IEPs) for specific learning disabilities and a few students with IEPs for autism. They found that before the pandemic-induced interruptions to education, this teacher provided her students daily opportunities to tackle challenging mathematical problems and taught self-regulation strategies for students to better understand themselves as learners. After the shift to online learning in the spring of 2020, teaching mathematics online became far more challenging due to various barriers, especially inequitable access, social- and emotional-focused teaching, supporting self-regulation, and tensions in planning instruction. It is clear that students, teachers, and school administrators had a difficult time shifting from face-to-face classroom environments to virtual learning environments.

The Office for Civil Rights of the US Department of Education (2021) announced that for K-12 and postsecondary students "emerging evidence shows that the pandemic has negatively affected academic growth, widening pre-existing disparities. In core subjects like math and reading, there are worrisome signs that in some grades students might be falling even further behind pre-pandemic expectations."

Spitzer and Musslick (2021) conducted a study to see how school closures in the spring of 2020 influenced the performance of German students using curriculum-based

online learning software for mathematics. They analyzed data from more than 2,500 K-12 students who completed over 124,000 mathematical problem sets before and during the school shutdowns. Results from a linear mixed model show that students' performance improved during the shutdown of schools in 2020 relative to the year before. They also found that low-achieving students showed greater improvements in performance than high-achieving students.

Yan et al. (2021) conducted a province-wide survey on the online learning experience. The survey was sent to all 15 million K-12 students in the Guangdong province of China. A total of 1,170,769 students completed the survey. After cleaning up the data, a total of 1,048,575 students were included in their analysis, which accounts to approximately 7% of the total K-12 student population. Chi-square analysis showed that students' online learning experiences differ significantly across grades. They also found that student success in K-12 online education was substantially lower than in regular face-to-face classroom environments. Students experienced various difficulties related to the delivery of online learning.

It is clear that students, teachers, administrators, parents, and caregivers had a difficult time once the pandemic started in the spring of 2020. Many students could not access virtual platforms for a variety of reasons, especially students from families with low socioeconomic statuses. Some students, on the other hand, got help from siblings and parents/caregivers on their assessments, and Locke et al. (2021) successfully detected this. They found that students who took assessments from home scored significantly higher than students who took assessments from school.

Locke et al. (2021) and Patarapichayatham et al. (2021) also found negative impacts of COVID-19 school closures on students' achievement in both reading and math. They both used large data sets of students across the US. Results from a piecewise growth model showed that students performed as expected in the 2018-2019 school year and in the 2019-2020 school year from the September to February assessment months. Student performance significantly changed once they moved to online learning

in March 2020. Students' scores were significantly lower than their performance from September to February in the 2018-2019 school year.

This study further investigates the impact of COVID-19 on students by expanding the studies of Locke et al. (2021) and Patarapichayatham et al. (2021) with more test events. This current study specifically looks at students' ability in reading and math using complete data from three academic years. The goals of this study are to investigate (a) the learning disruption due to the COVID-19 pandemic and (b) how long it may take for students to fully recover and achieve performance levels similar to those seen before the pandemic began. While a piecewise growth model with one intercept and multiple slopes is appropriate for Locke et al. (2021) and Patarapichayatham et al. (2021) research questions, a piecewise growth model with multiple intercepts and multiple slopes is more suitable and is applied in this study.

Methodology

Measures

The ISIP Reading and ISIP Math assessments are used in this study. ISIP assessments are derived using the two-parameter item response theory model and operate under a fully computer-adaptive testing environment. ISIP gathers and reports frequent information about student progress in the critical domains throughout and across academic years (Mathes, 2011). The purpose of ISIP Reading is to measure reading ability and identify deficits in critical areas in order to provide continuous differentiated instruction. ISIP Reading is designed for students in prekindergarten through eighth grade. ISIP Math is designed for students in prekindergarten through eighth grade (Istation, 2018). Both ISIP Reading and ISIP Math scores are computed from different sub-skills depending on grade level. Overall reading scaled scores and overall math scaled scores are used for the analyses. Note that ISIP Reading and ISIP Math are not on the same scale, and these two scores cannot be directly compared. For

example, if a third-grade student takes both ISIP Reading and ISIP Math assessments and achieves an overall score of 500 on ISIP Reading and an overall score of 500 on ISIP Math, each score of 500 has a different meaning and represents a different percentile rank. Therefore, it would be incorrect to assume that this particular student has the same ability in both reading and math. While the scales used in ISIP Reading and ISIP Math cannot be compared across subjects, each assessment's scale does span all grades. The ISIP Reading scaled scores can be compared across all grades from prekindergarten to eighth grade, and the same is true for the ISIP Math scaled scores.

Nationally Stratified Sample

The data for this study came from the Istation database. We selected students across the US who took ISIP assessments in the 2018-2019, 2019-2020, and 2020-2021 school years. Within each school year, there were millions of students in the database. While Istation provides ISIP Reading and ISIP Math assessments for prekindergarten through eighth grade, we have chosen to focus on specific grades for each school year. We constructed the reading data file and math data file separately but in the same manner. First, we chose students in the kindergarten through fifth grade cohort in the 2018-2019 school year. These students were in first through sixth grade in the 2019-2020 school year, and they were in second through seventh grade in the 2020-2021 school year. While Istation provides progress monitoring assessments monthly throughout the school year as well as three benchmarking assessment months per year, this study focuses on the three benchmarking assessment months per school year. These are the beginning-of-the-year assessment month (BOY), middle-of-the-year assessment month (MOY), and end-of-the-year assessment month (EOY). Typically, September is BOY, January is MOY, and May is EOY for most schools across the US. For this reason, the September, January, and May assessment months were chosen for this study. Students in kindergarten through fifth grade in the 2018-2019 school year who had

either two or three test events in September, January, or May of the 2018-2019 school year were selected.

Because COVID-19 school closures were implemented across the US around March 2020, Istation made the assessment and the curriculum available for students at home, and some students continued using the Istation program in April and May of 2020 during the pandemic. Most students had ISIP scores up to the March assessment month, and only a few students had scores up to May 2020. As a result, we decided to select September, January, and March assessment months for the 2019-2020 school year. Students in first through sixth grade in the 2019-2020 school year who had at least one test event in the September, January, and March assessment months of 2019-2020 were selected for this study.

Since the COVID-19 pandemic was not under control at the beginning of the 2020-2021 school year, many schools across the country allowed students to take classes through either a virtual platform at home or in person at school. Some students took ISIP assessments at home, and others took them at school. We found that there were significant differences in scores when students assessed at home compared to when students assessed at school (Locke et al., 2021). To control for a possible assessment location effect, students who took the assessment at home were dropped from the analysis. The September, January, and May assessment months for the 2020-2021 school year were chosen. In each assessment month, only students who took an assessment at school were chosen. Students in second through seventh grade in the 2020-2021 school year who had at least one test event in the September, January, and May assessment months were selected.

The 2018-2019, 2019-2020, and 2020-2021 data were merged to create one longitudinal data file across three academic years with nine test events. Students' IDs in the 2018-2019 data file were used to combine these three-year data together so only students with a score in the 2018-2019 school year were selected from the 2019-2020

and 2020-2021 data. Again, we created separate datasets for ISIP Reading and ISIP Math. Within each data file, there were six different cohorts of students (see Table 1). The first cohort was in kindergarten during the 2018-2019 school year, first grade in 2019-2020, and second grade in 2020-2021. The second cohort was in first grade during the 2018-2019 school year, second grade in 2019-2020, and third grade in 2020-2021. Several cross-sectional comparisons could be computed and compared as well, and they are highlighted in Table 1. For example, second grade students' performance in 2020-2021 could be compared with other second grade students' performance in 2019-2020 and in *2018-2019.*

Table 1: *Sample Cohort by School Year*

Cohort	2018-2019	2019-2020	2020-2021
Kindergarten	Kindergarten	G1	G2
G1	G1	G2	G3
G2	G2	G3	G4
G3	G3	G4	G5
G4	G4	G5	G6
G5	G5	G6	G7

Similar to the Locke et al. (2021) and Patarapichayatham et al. (2021) studies, we applied post-stratification measures and sampled without replacement according to socioeconomic status (SES) at the school level. Stratification is a process of dividing members of the population into homogeneous subgroups before sampling. A stratified sample could thus claim to be more representative of the population than a simple random sampling or systematic sampling. We created four categories for SES, using categories from the National Center for Education Statistics (NCES). SES category 1 consists of schools that have 75% or more of their students enrolled in the free or reduced-price lunch (FRPL) program. SES 2 schools have 50% to 74.9% of students enrolled in FRPL, and SES 3 schools have 25% to 49.9% of students enrolled in FRPL. SES 4 schools have less than 25% of students enrolled in FRPL. Next, we calculated the percentage of enrolled students in each of the four SES levels according to enrollment data available from the NCES for public and public charter schools and used this

information to create sample targets. Within each grade, 36% of students were from SES 1, 16% from SES 2, 20% from SES 3, and 28% from SES 4.

For ISIP Math, we selected 10,000 students per grade in kindergarten through fourth grade (3,600 students from SES 1; 1,600 students from SES 2; 2,000 students from SES 3; and 2,800 students from SES 4) and 5,000 students in fifth grade (1,800 students from SES 1; 800 students from SES 2; 1,000 students from SES 3; and 1,400 students from SES 4). In reading, we selected 15,000 students per grade (5,400 students from SES 1; 2,400 students from SES 2; 3,000 students from SES 3; and 4,200 students from SES 4). Our final sample consisted of 55,000 students in ISIP Math and 90,000 students in ISIP Reading, totaling 145,000 students in this study. Because we use three-year data with a total of nine test events (SEP_2018, JAN_2019, MAY_2019, SEP_2019, JAN_2020, MAR_2020, SEP_2020, JAN_2021, and MAY_2021) within the same observations, we encountered missing data issues. We decided to use predictive mean matching (PMM) in our study using the MICE package in R software. PMM calculates the predicted value of a target variable from all complete cases.

Model and Analysis

A piecewise growth model is used to answer the research questions. It is a type of time series analysis for nonlinear growth with longitudinal data. Growth models examine the development of individuals on one or more outcome variables over time. A model was fit for each cohort using Mplus software. Mplus handles the relationship between the outcome and time by allowing time scores to be parameters in the model so that the growth function can be estimated. This is the approach used in structural equation modeling. In a piecewise growth model, different phases of development are captured by more than one slope growth factor, and this is used when growth is not linear (Muthén & Muthén, 1998-2017).

Many studies revealed that students have decreased performance during the pandemic (e.g., Locke et al., 2021; Patarapichayatham et al., 2021; Yan et al., 2021), meaning students' performance is generally lower than in the pre-pandemic years. In order to better capture students' performance in each year, we used a piecewise growth model with three intercepts and three slopes (see Figure 1). The "i1" is an intercept and "s1" is the slope for the 2018-2019 school year data that incorporates three test events in the model (SEP_2018, JAN_2019, and MAY_2019). The "i2" is an intercept and "s2" is the slope for the 2019-2020 school year data that incorporates three test events (SEP_2019, JAN_2020, and MAR_2020). The "i3" is an intercept and "s3" is the slope for the 2020-2021 school year data that incorporates three test events in the model (SEP_2020, JAN_2021, and MAY_2021).
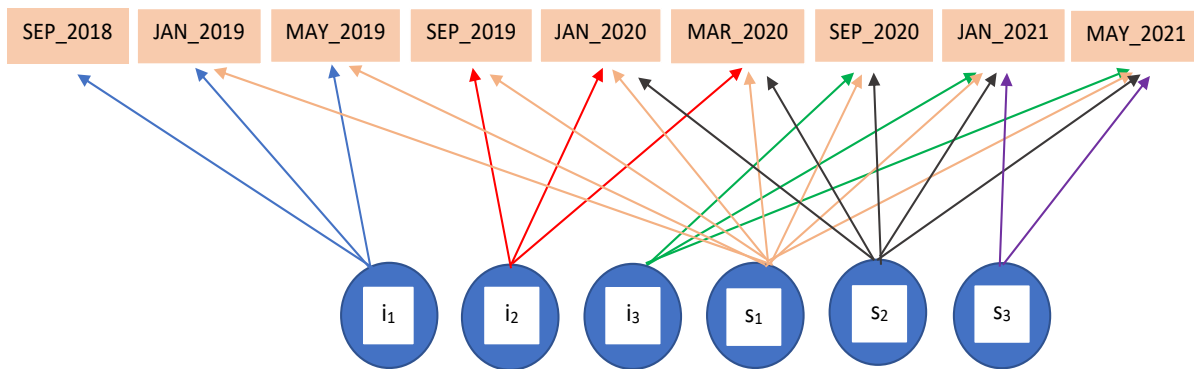

Figure 1: Piecewise growth model

The time interval between each test event is critical to modeling linear growth and to a piecewise growth model. Because these three benchmarking assessment months have the same time interval between each test event, the "s1" and "s3" are modeled as 0, 1, and 2 in Mplus fashion. Because March falls between the January and May benchmarks, the slope of "s2" is modeled as 0, 1, and 1.5 in order to construct equal time intervals across the data. We also extrapolated to estimate May 2020 scores under "s2" with the slope parameter of 2.

Results

Table 2 shows the estimated intercepts and the estimated slopes for ISIP Reading, and Table 3 shows the estimated intercepts and the estimated slopes for ISIP Math. Again, the "i1" shows the estimated ISIP scores in September 2018 (BOY of 2018-2019), the "i2" shows the estimated ISIP scores in September 2019 (BOY of 2019-2020), and the "i3" shows the estimated ISIP scores in September 2020 (BOY of 2020-2021). Estimated slopes are the students' growth trajectories in each segment in the growth model. The "s1" shows the students' growth trajectories in the 2018-2019 school year, the "s2" shows the students' growth trajectories in the 2019-2020 school year, and the "s3" shows the students' growth trajectories in the 2020-2021 school year.

The estimated intercepts and estimated slopes in Table 2 are used to derive the estimated ISIP Reading scores for each benchmarking assessment month and are shown in Table 4. The estimated intercepts and estimated slopes in Table 3 are used to derive the estimated ISIP Math scores in Table 5. The fit indices are not reported here, but all model fit information such as root mean square error of approximation (RMSEA), CFI/TLI, Chi-Square Test of Model Fit for the Baseline Model, and Standardized Root Mean Square Residual (SRMR) show high-quality fit indices, indicating a good fit between observed mean scores and estimated mean scores from a piecewise growth model.

Table 2: *Estimated Intercept and Estimated Slopes for ISIP Reading*

Cohort	i1	i2	i3	s1	s2	s3
K	263.745	259.358	267.117	36.907	33.159	24.372
G1	331.991	337.032	340.616	31.332	25.440	20.203
G2	397.282	400.020	402.799	23.384	20.346	17.525
G3	445.570	451.731	450.189	18.983	19.272	13.853
G4	486.929	491.425	487.605	15.414	15.050	9.629
G5	541.981	545.100	541.200	10.935	11.576	6.078

Table 3: *Estimated Intercept and Estimated Slopes for ISIP Math*

Cohort	i1	i2	i3	s1	s2	s3
K	306.821	284.359	270.771	55.939	40.272	20.778
G1	390.691	364.251	350.169	40.449	23.080	17.663
G2	443.008	434.756	419.007	20.180	19.788	19.862
G3	478.806	460.036	438.978	19.029	16.738	17.382
G4	504.219	477.418	455.017	16.581	18.847	17.566
G5	507.223	487.930	465.246	17.830	16.228	14.942

Table 4: *Estimated ISIP Scores for ISIP Reading*

Cohort	BOY 2018-2019	MOY 2018-2019	EOY 2018-2019	BOY 2019-2020	MOY 2019-2020	EOY 2019-2020	BOY 2020-2021	MOY 2020-2021	EOY 2020-2021
K	264	301	338	333	366	399	391	415	439
G1	332	363	395	400	425	451	441	462	482
G2	397	421	444	447	467	487	480	498	515
G3	446	465	484	490	509	528	517	531	545
G4	487	502	518	522	537	552	541	551	560
G5	542	553	564	567	579	590	580	587	593

Table 5: *Estimated ISIP Scores for ISIP Math*

| Cohort	BOY 2018-2019	MOY 2018-2019	EOY 2018-2019	BOY 2019-2020	MOY 2019-2020	EOY 2019-2020	BOY 2020-2021	MOY 2020-2021	EOY 2020-2021
K	307	363	419	396	437	477	443	464	485
G1	391	431	472	445	468	491	466	483	501
G2	443	463	483	475	495	515	489	509	529
G3	479	498	517	498	515	532	502	520	537
G4	504	521	537	511	529	548	516	534	552
G5	507	525	543	524	540	556	525	540	555

Longitudinal Analyses Results in Reading
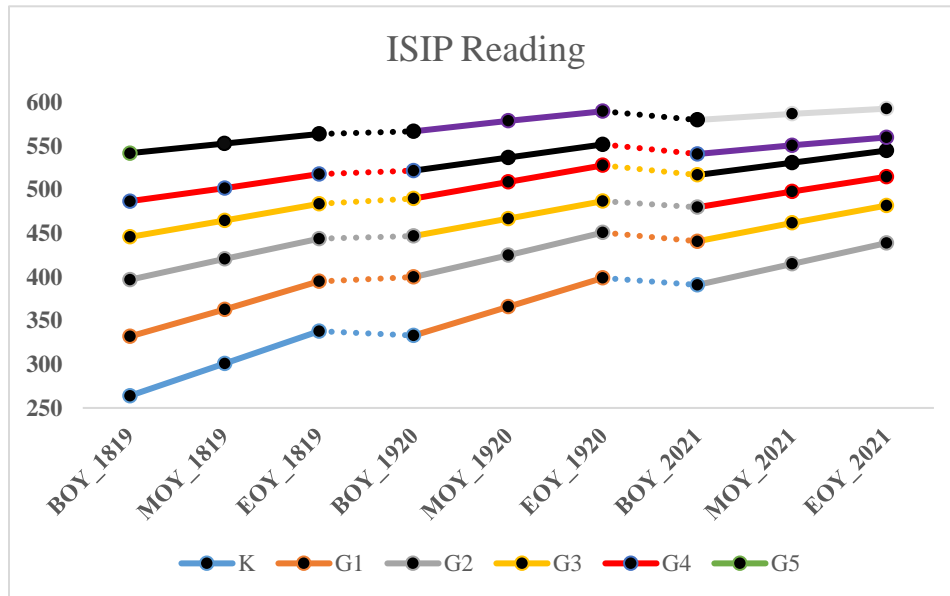
Figure 2: Reading Results

We look at students' progressions in each cohort. Again, kindergarten cohort means they were kindergarteners in the 2018-2019 school year, first graders in the 2019-2020 school year, and second graders in the 2020-2021 school year.

For the kindergarten cohort (see Table 2), the "i1" was 263.745, indicating that their 2018-2019 BOY ISIP Reading mean score was 264. The "s1" was 36.907, indicating that these kindergarteners gained 37 ISIP Reading points from BOY to MOY and another 37 ISIP points from MOY to EOY of the 2018-2019 school year. They gained a total of 74 ISIP Reading points in the 2018-2019 school year. Their estimated ISIP Reading scores for BOY, MOY, and EOY in the 2018-2019 school year were 264, 301, and 338 (see Table 4 and Figure 2), respectively. This cohort of students started their first-grade year in 2019-2020 with "i2" at 259.358 and "s2" at 33.159. Their estimated ISIP Reading scores of BOY, MOY, and EOY in the 2019-2020 school year were 333, 366, and 399, respectively. Students gained a total of 66 ISIP Reading points

in the 2019-2020 school year. Going into the 2019-2020 school year, they experienced a small summer slide of 5 ISIP Reading points.

In the 2020-2021 school year, this cohort of students started their second-grade year with "i3" at 267.117 and "s3" at 24.372. Their estimated ISIP Reading scores were 391 for BOY, 412 for MOY, and 439 for EOY. They gained 48 ISIP Reading points total in this school year. Going into the 2020-2021 school year, this cohort of students encountered a combination of COVID-19 learning disruption and summer slide amounting to 8 ISIP Reading points lost from first grade to second grade. Their summer slide before the COVID year (from the 2018-2019 school year to the 2019-2020 school year) was 5 ISIP Reading points, and 8 ISIP Reading points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year). A summer slide or summer learning loss refers to evidence that students often forget some content between the end of one school year and the beginning of the next school year. The greater loss from one year to the next confirms that the COVID-19 pandemic school closures in March of 2020 had negative effects on students' learning.

For the first-grade cohort, the estimated ISIP Reading scores were 332 for BOY, 363 for MOY, and 395 for EOY in the 2018-2019 school year, indicating that they gained a total of 63 ISIP Reading points in this school year. Their estimated ISIP Reading scores were 400, 425, and 451 in the 2019-2020 school year, and they were 441, 462, and 482 in the 2020-2021 school year, respectively. They gained 51 ISIP Reading points total in the second grade and 41 points total in the third grade. This cohort of students did not experience a summer slide before the pandemic (from the 2018-2019 school year to the 2019-2020 school year), but they experienced a combination of COVID-19 learning disruption and summer slide of 10 ISIP Reading points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

For the second-grade cohort, the estimated ISIP Reading scores were 397 for BOY, 421 for MOY, and 444 for EOY in the 2018-2019 school year, indicating that they gained a total of 47 ISIP Reading points in this school year. Their estimated ISIP Reading scores were 447, 467, and 487 in the 2019-2020 school year, and they were 480, 498, and 515 in the 2020-2021 school year, respectively. They gained 40 ISIP Reading points total in the third grade and 35 points total in the fourth grade. Again, this cohort of students did not experience a summer slide before the pandemic, but they experienced a combination of COVID-19 learning disruption and summer slide resulting in 7 ISIP Reading points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

For the third-grade cohort, the estimated ISIP Reading scores were 446, 465, and 484 for BOY, MOY, and EOY of the 2018-2019 school year, indicating that they gained a total of 38 ISIP Reading points in this school year. Their estimated ISIP Reading scores were 490, 509, and 528 in the 2019-2020 school year and 517, 531, and 545 in the 2020-2021 school year, respectively. They gained 38 ISIP Reading points total in the fourth grade and 38 points total in the fifth grade. Again, this cohort of students did not experience a summer slide before the pandemic (from the 2018-2019 school year to the 2019-2020 school year), but they experienced a combination of COVID-19 learning disruption and a summer learning loss resulting in 11 ISIP Reading points lost during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

For the fourth-grade cohort, the estimated ISIP Reading scores were 487, 502, and 518 for BOY, MOY, and EOY of the 2018-2019 school year, indicating that they gained a total of 31 ISIP Reading points during this school year. Their estimated ISIP Reading scores were 522, 537, and 552 in the 2019-2020 school year and 541, 551, and 560 in the 2020-2021 school year, respectively. They gained 30 ISIP Reading points total in fifth grade and 19 points total in sixth grade. Similar to the third-grade cohort, the fourth-grade cohort did not experience a summer slide before the pandemic, but

they experienced a combination of COVID-19 learning disruption and summer slide resulting in 11 ISIP Reading points during the COVID year.

For the fifth-grade cohort, the estimated ISIP Reading scores were 542, 553, and 564 for the three benchmarking assessment months in the 2018-2019 school year, indicating that they gained a total of 22 ISIP Reading points in this school year. Their estimated ISIP Reading scores were 567, 579, and 590 in the 2019-2020 school year and 580, 587, and 593 in the 2020-2021 school year, respectively. They gained 23 ISIP Reading points total in the sixth grade and 13 in the seventh grade. This cohort of students did not experience a summer slide before the pandemic, but they experienced a combination of COVID-19 learning disruption and summer slide resulting in 10 ISIP Reading points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

In summary, students in lower grades gained more ISIP Reading points per school year than students in higher grades. For example, kindergarteners gained 74, 66, and 48 ISIP Reading points in their kindergarten, first, and second grades, whereas fifth-grade students gained 22, 23, and 13 ISIP Reading points in their fifth, sixth, and seventh grades. Because students at each grade level have different expectations and subskills to cover, the learning curves may differ between students in lower and higher grades. Also, students who are learning to read may perform differently than students who are reading to learn. Before the pandemic, some students experienced a summer slide. All students faced a combination of COVID-19 learning disruption and summer slide going into the 2020-2021 school year.
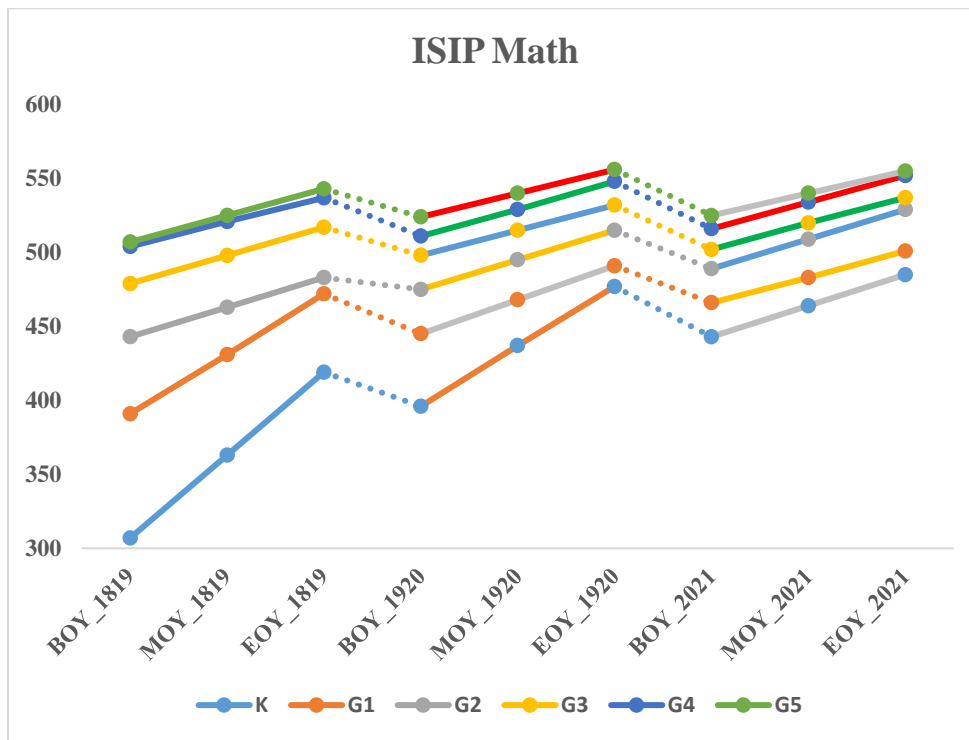
Longitudinal Analyses Results in Math

Figure 3: Math Results

For the kindergarten cohort, the estimated ISIP Math scores were 307, 363, and 419 for BOY, MOY, and EOY of the 2018-2019 school year, indicating that they gained a total of 112 ISIP Math points in this school year. Their estimated ISIP Math scores were 396, 437, and 477 in the 2019-2020 school year and 443, 464, and 485 in the 2020-2021 school year, respectively. They gained 81 ISIP Math points total in the second grade and 42 points in the third grade. This cohort of students experienced a summer slide at 22 ISIP Math points before the pandemic (from the 2018-2019 school year to the 2019-2020 school year), but they experienced a combination of COVID-19 learning disruption and summer slide at 34 ISIP Math points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

For the first-grade cohort, the estimated ISIP Math scores were 391 for BOY, 431 for MOY, and 472 for EOY of the 2018-2019 school year. Their estimated ISIP Math scores were 445, 468, and 491 in the 2019-2020 school year and 466, 483, and 501 in

the 2020-2021 school year, respectively. They gained a total of 81, 46, and 35 ISIP Math points in their first, second, and third grades. This cohort of students encountered 26 ISIP Math points — a combination of COVID-19 learning disruption and summer slide between the 2019-2020 and 2020-2021 school years.

For the second-grade cohort, the estimated ISIP Math scores were 443, 463, and 483 in the three benchmarking assessment months of the 2018-2019 school year. Their estimated ISIP Math scores were 475, 495, and 515 in the 2019-2020 school year and 489, 509, and 529 in the 2020-2021 school year, respectively. They gained a total of about 40 ISIP Math points per year during these three academic years. This cohort of students experienced a summer slide of 8 ISIP Math points before the pandemic (from the 2018-2019 school year to the 2019-2020 school year) and a combination of COVID-19 learning disruption and summer slide at 26 ISIP Math points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

For the third-grade cohort, the estimated ISIP Math scores were 479, 498, and 517 in the 2018-2019 school year. Their estimated ISIP Math scores were 498, 515, and 532 in the 2019-2020 school year and 502, 520, and 537 in the 2020-2021 school year, respectively. They gained approximately 35 ISIP Math points per year. This cohort of students experienced a summer slide of 19 ISIP Math points before the pandemic (from the 2018-2019 school year to the 2019-2020 school year) and a combination of COVID-19 learning disruption and summer slide at 29 ISIP Math points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

For the fourth-grade cohort, the estimated ISIP Math scores were 504, 521, and 537 in the 2018-2019 school year. Their estimated ISIP Math scores were 511, 529, and 548 in the 2019-2020 school year and 516, 534, and 552 in the 2020-2021 school year, respectively. They gained approximately 35 ISIP Math points per year. This cohort of students experienced a summer slide of 27 ISIP Math points before the pandemic (from the 2018-2019 school year to the 2019-2020 school year) and a combination of COVID-

19 learning disruption and summer slide at 31 ISIP Math points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

For the fifth-grade cohort, the estimated ISIP Math scores were 507, 525, and 543 in the 2018-2019 school year. Their estimated ISIP Math scores were 524, 540, and 556 in the 2019-2020 school year and 525, 540, and 555 in the 2020-2021 school year, respectively. They gained approximately 30 ISIP Math points per year. This cohort of students experienced a summer slide of 19 ISIP Math points before the pandemic (from the 2018-2019 school year to the 2019-2020 school year) and a combination of COVID-19 learning disruption and summer slide at 31 ISIP Math points during the COVID year (from the 2019-2020 school year to the 2020-2021 school year).

Just as in ISIP Reading, students in lower grades gained more ISIP Math points per school year than students in higher grades. For example, first-grade students gained 81, 46, and 35 ISIP Math points in their first, second, and third grades, whereas fifth-grade students gained 36, 32, and 30 ISIP Math points in their fifth, sixth, and seventh grades. Before the pandemic, students did experience a summer slide. The learning disruption is even bigger during the pandemic year, when all students faced a combination of COVID-19 learning disruption and summer slide.

Cross-Sectional Analyses Results in Reading

We looked at students' performance cross-sectionally within the school year. It is color-coded in Tables 1, 4, and 5. There were two groups of first-grade students in this study: first-grade students in the 2018-2019 school year and first-grade students in the 2019-2020 school year. There were three groups of second-grade students in this design: second-grade students in the 2018-2019, 2019-2020, and 2020-2021 school years. There were also three groups of third-, fourth-, and fifth-grade students. Sixth-grade students appeared in the study only in the 2019-2020 and 2020-2021 school years.

For the first grade, estimated ISIP Reading scores were 332 at the BOY of 2018-2019 and 333 at the BOY of 2019-2020. This indicates that the first-grade students in these two different school years performed almost identically at the beginning of the 2018-2019 and 2019-2020 school years. These students also gained about 65 ISIP Reading points in their first grade. This also indicates that their performances were very similar to each other before the COVID year.

For the second grade, the estimated ISIP Reading scores were 397, 400, and 391 at the BOY of the 2018-2019, 2019-2020, and 2020-2021 school years, respectively. This shows that these students performed very similarly at the beginning of the 2018-2019 and 2019-2020 school years, meaning that these students performed at almost the same level before the pandemic. They scored 9 ISIP Reading points lower at the BOY of 2020-2021, showing that the pandemic had negative effects on their reading ability. However, students gained about 50 ISIP Reading points in each school year, demonstrating that their reading progressions were about the same across these three groups of second grade students in three different academic years. In other words, these second-grade students started the year with about the same reading ability level, and they shared the same within-year reading growth projections in the 2018-2019 and 2019-2020 school years. The second-grade students in the 2020-2021 school year, on the other hand, had the same within-year reading ability growth, but they started the year 9 ISIP Reading points lower. Given that these second-grade students gained approximately 50 ISIP points on average per academic year, the pandemic created about 20% reading disruption for these students in the 2020-2021 school year.

For the third grade, the estimated ISIP Reading scores were 446, 447, and 441 at the BOY of the 2018-2019, 2019-2020, and 2020-2021 school years, respectively. Similar to the second-grade students, these third-grade students performed almost identically before the pandemic at the beginning of the 2018-2019 and 2019-2020 school years. They scored 6 ISIP Reading points lower at the BOY of 2020-2021 during

the pandemic. Also, they gained about 40 ISIP Reading points in each school year, suggesting that the reading progressions of these third- grade students were about the same across these three groups of students in three different academic years. Third grade students in the 2018-2019 and 2019-2020 school years started the year with about the same reading ability level, and they shared the similar within-year reading growth projections. Third-grade students in the 2020-2021 school year, on the other hand, had the same within-year reading ability growth but started the year at a lower reading ability level. Given that these third-grade students gained 40 ISIP Reading points per academic year on average, students in the 2020-2021 school year were 15% behind grade-level expectations for their reading ability. The pandemic created an approximately 15% reading disruption to their reading ability in the 2020-2021 school year.

For the fourth grade, the estimated ISIP Reading scores were 487, 490, and 480 at the BOY of the 2018-2019, 2019-2020, and 2020-2021 school years, respectively. These fourth- grade students performed very similarly before the pandemic at the beginning of the 2018-2019 and 2019-2020 school years. They scored 10 ISIP Reading points lower at the BOY of 2020-2021 during the pandemic. Also, they gained about 35 ISIP Reading points in each school year, suggesting that their reading progressions were about the same across these three groups of students in three different academic years. Again, students in the 2018-2019 and 2019-2020 school years started the year with about the same reading ability level, and they shared the same within-year reading growth projections. Fourth grade students in the 2020-2021 school year, on the other hand, had the same within-year reading ability growth but started the year at a lower reading ability level. These students in the 2020-2021 school year were 30% behind grade-level expectations for their reading ability, suggesting that the pandemic added a roughly 30% reading disruption on these students in the 2020-2021 school year.

For the fifth grade, the estimated ISIP Reading scores were 542, 522, and 517 at the BOY of the 2018-2019, 2019-2020, and 2020-2021 school years, respectively. Fifth grade students already scored 20 points lower at the beginning of the 2019-2020 school year, indicating students experienced a summer slide before the pandemic. Their reading ability was even lower at the beginning of the 2020-2021 school year. The COVID-19 pandemic caused a reading disruption of about 20% in their 2020-2021 school year.

For the sixth grade, the estimated ISIP Reading scores were 567 and 541 at the BOY of the 2019-2020 and 2020-2021 school years. Sixth grade students scored 26 ISIP Reading points lower at the beginning of the 2020-2021 school year, indicating a large combination of COVID-19 learning disruption and summer slide. The pandemic added a large amount of reading disruption in the 2020-2021 school year.

Our findings show that students in higher grades experienced a larger summer slide as well as a larger COVID-19 learning disruption. Our findings are confirmed by Kuhfeld et al. (2020), Locke et al. (2021), and Patarapichayatham et al. (2021). They found that students encountered larger magnitudes of summer slide and COVID-19 learning disruption in upper elementary grades.

Cross-Sectional Analyses Results in Math

For the first grade, the estimated ISIP Math score was 391 at the BOY of 2018-2019 and 396 at the BOY of 2019-2020. This indicates that these first-grade students in these two different school years performed similarly at the beginning of the 2018-2019 and 2019-2020 school years. These students also gained about 80 ISIP Math points in their first grade, showing that they also had a similar growth rate before the COVID year.

For the second grade, the estimated ISIP Math scores were 443, 445, and 443 at the BOY of the 2018-2019, 2019-2020, and 2020-2021 school years, respectively. These students performed almost identically across these three different academic years and had similar within-year growth rates.

For the third grade, the estimated ISIP Math scores were 479, 475, and 466 at the BOY of the 2018-2019, 2019-2020, and 2020-2021 school years, respectively. These third-grade students scored 4 ISIP Math points lower at the BOY of 2019-2020, suggesting students experienced a summer slide. Their performance was even lower, by 9 ISIP Math points, at the BOY of 2020-2021, indicating a combination of COVID-19 learning disruption and summer slide. Also, they gained about 38 ISIP Math points in each school year, showing that these third-grade students' math progressions were about the same across these three groups of students in three different academic years. The pandemic added approximately 25% to the students' math learning disruption in the 2020-2021 school year.

For the fourth grade, the estimated ISIP Math scores were 504, 498, and 489 at the BOY of the 2018-2019, 2019-2020, and 2020-2021 school years, respectively. These students scored 6 ISIP Math points lower at the BOY of 2019-2020. Their performance was lower, a total of 9 ISIP Math points lower, at the BOY of 2020-2021, indicating a COVID-19 learning disruption and a summer slide combination effect on students. Also, they gained about 35 ISIP Math points in each school year, suggesting that these fourth-grade students' math progressions were about the same across these three groups of students in three different academic years. The pandemic increased the students' math learning disruption by approximately 30% in the 2020-2021 school year.

For the fifth grade, the estimated ISIP Math scores were 507, 511, and 502 at the BOY of the 2018-2019, 2019-2020, and 2020-2021 school years, respectively. Fifth-grade students performed somewhat similarly before the pandemic. Their performance was 9 ISIP Math points lower at the beginning of the 2020-2021 school year, indicating

a combination of COVID-19 learning disruption and summer slide. Similar to fourth-grade students, these fifth-grade students gained about 35 ISIP Math points in each school year. The pandemic increased the students' math learning disruption by approximately 25% in the 2020-2021 school year.

For the sixth grade, the estimated ISIP Math scores were 524 and 516 at the BOY of the 2019-2020 and 2020-2021 school years. Sixth-grade students experienced a large combination of COVID-19 learning disruption and summer slide. They scored 8 points lower in ISIP Math at the beginning of the 2020-2021 school year. The pandemic increased the students' math learning disruption by approximately 25%in the 2020-2021 school year.

Just as in ISIP Reading, students in higher elementary grade levels experienced a larger summer learning loss as well as a bigger COVID-19 learning disruption than students in lower elementary grade levels. Our findings are also confirmed by several previous studies (e.g., Locke et al., 2021; Middleton, 2020; Office for Civil Rights: U.S. Department of Education, 2021; Patarapichayatham et al., 2021).

Conclusions and Recommendations

Learning Disruption

Longitudinal data analyses across three-year data and cross-sectional data analyses across grades demonstrate that students' academic performance was approximately 25-40% lower in their 2020-2021 school years depending on grade level and subject area. Students in higher grade levels experienced bigger learning disruptions than students in lower grade levels. The magnitude was larger in math than in reading. Students had 25-40% less growth in the 2020-2021 school year compared to their peers in the 2018-2019 and 2019-2020 school years.

From Disruption to Recovery and How to Get There

Our results suggest that students will need additional support, such as added on-grade and off-grade instruction, more time and attention paid to learning progress, more studying time, and an increase in school activities, in order to catch up to the typical grade-level curriculum. It is unknown how long it will take for students to return to their pre-pandemic grade-level ability. Given how much of their math and reading ability they have lost in the 2020-2021 school year, our results suggest that it may take at least a few years for students to fully return to their typical grade-level ability. It is possible that students with different backgrounds will need different support and attention to return to their grade-level expectations. Students in different grade levels may need varying amounts of time to fully recover. Students may also recover more quickly or more slowly in different subject areas. All parties will need to work together at policy and practical levels.

At the district and school levels, schools may consider short-term and long-term programs to help students get back to the typical grade-level curriculum, including school-based summer learning programs, one-on-one high-dosage tutoring programs, after-school programs, and programs for additional learning time. Schools may also need to consider vertical and cross-grade curriculum collaboration.

At the teacher and classroom levels, teachers may need to identify the subskills that students may have missed or may have not mastered, and they may need to implement extra reading and math interventions for their students. Adaptive online curriculum may be an option for teachers to implement, as it is available for students whenever and wherever they are ready to study.

At home, parents and caregivers may need to further support their children so that they can get back to their grade-level curriculum as soon as possible. Parents and

caregivers may need to continue working with their children just as they did at the beginning of the pandemic (e.g., Bansak & Starr, 2021).

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DOI: 10.1111/bjet.13102