Summer Slide Is Bad, COVID-19 Slide Is Even Worse:

Online Assessment Perspective

April 2021

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Citation: Patarapichayatham, C., Locke, V. N., & Lewis, S. (2021, June 8-11). *Summer Slide Is Bad, COVID-19 Slide Is Even Worse: Online Assessment Perspective* [Paper Session]. National Council on Measurement in Education (NCME) Virtual Annual Meeting.

Abstract

This study investigates a summer slide, a COVID-19 slide, and students' performance in reading and math across the United States before and during the COVID-19 pandemic, to determine whether learning losses or lags were greater in the COVID-19 year. Data were collected from the 2018-2019, 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 show that students' performance in reading and math were consistent before the COVID-19 pandemic. Students performed significantly lower throughout the 2020-2021 school year, when many schools were using remote or hybrid learning. In reading, students experienced a summer slide for some grades, but all students experienced a COVID-19 slide. In math, all students across grades experienced a summer slide as well as a COVID-19 slide. Students lost their math ability more rapidly than their reading ability, and the magnitude was larger in the upper elementary grades.

Keywords: summer slide, COVID-19 slide, piecewise growth model, student achievement in reading, student achievement in math

Introduction

Student summer learning loss, or summer slide, is the loss of academic knowledge and/or skills over the summer. It has been an issue in reading and math for decades, especially for students from low-income families. Studies on summer learning loss show that there are differences by subject and grade. Quinn and Polikoff (2017) found that students' achievement scores decline over the summer by one month's worth of school-year learning instruction. Students lose their math ability more rapidly than reading, and these losses are greater for students in higher grades. Shafer (2016) found that students from all socioeconomic backgrounds forget more of what they learned in math over the summer than the amount they lose in reading skills.

In March of 2020, schools across the US closed because of the COVID-19 pandemic. Students across the country tried to complete their academic year using educational technology from home. Many students lacked reliable access to the internet and dependable devices and simply terminated from learning activities from March 2020 onward. In fall 2020, many students went back to face-to-face learning environments at school while others continued their new academic year from home. Still other schools across the country followed a hybrid model, with students attending school remotely and in person in the 2020-2021 school year. Some assessment companies provided schools with the ability to conduct progress monitoring at home so that teachers could continue to see how well their students were progressing.

There have been several studies on COVID-19 learning loss since the school closures implemented in March 2020. Kuhfeld, Soland, et al. (2020) and Kuhfeld, Tarasawa, et al. (2020) projected the potential impact of COVID-19 school closures on the academic achievement of five million students. They projected students would begin

the 2020-2021 school year with maintaining 63% to 68% of the learning gains from the previous year in reading and 37% to 50% of the learning gains in mathematics. We investigated COVID-19 learning loss in Texas in reading and math using the Istation's Indicators of Progress (ISIP) Reading and ISIP Math assessments and a piecewise growth model (Patarapichayatham et al., 2021). We found that in ISIP Reading, COVID-19 school closures in spring of 2020 contributed approximately two months' learning loss. In math, COVID-19 school closures contribute approximately 1-2 months' learning loss for students in early elementary grades, and 4-5 months' loss in the upper elementary grades.

We also investigated COVID-19 learning loss in reading and math with a stratified sample of students from across the US using a piecewise growth model (Locke et al., 2021). We found that — similar to the Texas study — learning losses were greater in math than in reading. Learning losses varied by grade and by percentage of students receiving free or reduced priced lunch (FRPL) at the school level, and typically, students enrolled in high- or mid-high poverty schools had learning losses that were lower than, or similar to, students enrolled in other types of schools. Students in higher-poverty schools typically have lower growth trajectories than other students, and their learning losses were lower as well. In reading, most of the learning loss occurred because students did not demonstrate learning gains in April and May. Students started in September at a similar level of achievement that was present in the previous March, indicating that remote learning helped students to maintain their gains from the beginning of the year, but there was not the expected growth in April and May. The situation was somewhat different in math, where there was more loss in the upper

grades. Upper elementary students typically have greater summer slide than younger students, and these results held for the COVID-19 slide as well.

Students' engagement in online learning during this time helped stem some of the learning loss (Lewis et al., 2020). We found that students who engaged with the Istation program in April or May of 2020 following the school closures in the 2019-2020 school year performed better in reading in the fall of 2020 even after controlling for prior year ISIP reading scores, and students in high-poverty schools were able to narrow some of the achievement gaps if they participated in remote learning.

The previous studies provide useful information on summer and COVID-19 learning loss. This study investigates summer slide, COVID-19 slide, and student performance in reading and math across the US before and during the COVID-19 pandemic, using three academic years with nine test events. We are particularly interested whether students were able to make up some of the learning losses, if their learning continued to lag, and if these differences varied by grade or subject matter. To do this, we used data from Istation from the 2018-2019, 2019-2020, and 2020-2021 school years.

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 operates under a fully computer-adaptive testing (CAT) 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 to provide continuous differentiated instruction. ISIP Early Reading (ER) is available for prekindergarten through third grade, and ISIP Advanced Reading (AR) is available for fourth through eighth grade. The ISIP Reading scales do not have a lowest or highest score. However, students in the first percentile of pre-kindergarten in the fall have ISIP ER scores of 134 or less, while students in third grade in the 99th percentile or above in spring have an ISIP ER score of 290 or more. Similarly for ISIP AR, students in fourth grade in the first percentile in the fall have an ISIP AR score of 1463 or less, while students in eighth grade in the 99th percentile or above in the spring have an ISIP AR score of 2796 or higher. ISIP Math is designed for students in prekindergarten through eighth grade (Istation, 2018). Here, the lowest possible score is 100, while the highest possible score is 900. Students in the first percentile in prekindergarten in the fall have a score of 118 or less, while students in the 99th percentile in the eighth grade in the spring have a score of 731 or greater.

Constructing A Nationally Stratified Sample

The data for this study came from the Istation database. We selected students across the US that 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. Three-year longitudinal data was created to answer research questions in this study.

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 to fifth grade cohort in 2018-2019 school year. These students were in first to sixth grade in the 2019-2020

school year, and they are now in second to seventh grade in the 2020-2021 school year. While Istation provides both progress monitoring assessments monthly throughout the school year as well as three benchmarking assessment months per year, this study focuses on 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. Kindergarteners to fifth graders in the 2018-2019 school year who had at least one data point 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, some students had scores up to April, and only a few students had scores up to May 2020. To avoid selection bias that may occur by selecting students with complete data through May, we selected September, January, and March assessment months for the 2019-2020 school year. Students in first to sixth grade in the 2019-2020 school year who had at least one data point in the September, January, or March assessment months of 2019-2020 were selected into this study.

Because 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 from either a virtual platform from 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 the students were assessed at home compared to 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. September, January, and March assessment months for 2020-2021 school year were chosen. In each assessment month, only students who took an assessment at school were chosen. Students in second to seventh grade in the 2020-2021 school year who had at least one data point in the September, January, or March 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. Because we wanted to use 2018-2019 data as a baseline in this study, students' IDs in the 2018-2019 data file were used to combine these three-year data, so only students with a score in the 2018-2019 school year were selected from the 2019-2020 and 2020-2021 data. 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, in first grade in 2019-2020, and in second grade in 2020-2021. By using this data format, several cohort comparisons could be computed and compared.

Table 1: Sample Cohort

Cohort Name	2018-2019 School Year	2019-2020 School Year	2020-2021 School Year
K	K	G1	G2
G1	G1	G2	G3
G2	G2	G3	G4
G3	G3	G4	G5
G4	G4	G5	G6
G5	G5	G6	G7

Studies show that students from higher-poverty schools (based on free or reduced-price lunch (FRPL) participation rates) tend to have lower achievement scores than students enrolled in lower-poverty schools (Lewis et al., 2019; Locke et al., 2021). Since the data in the Istation database are slightly skewed toward schools that have higher percentages of students receiving FRPL, an indication of lower socioeconomic status (SES), and this may impact the results. In order to minimize the impact, we applied post-stratification measures and sampled without replacement according to 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.

For this study, 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 FRPL program. SES 2 schools have 50% to 74.9% 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 students that were enrolled in each of the four SES levels according to enrollment data available from NCES for public and public charter schools and used this information to create sample targets. Within each grade, 36% of these students were from SES 1, 16% from SES 2, 20% from SES 3, and 28% from SES 4.

In reading, we selected 15,000 students per grade. In math, we selected 10,000 students per grade in kindergarten to third grade, 8,000 students in fourth grade, and

2,000 students in fifth grade. Our final sample consisted of 90,000 students in ISIP Reading and 50,000 students in ISIP Math, totaling 140,000 students for this study. Each student had three school years of data. Because we use three-year data with a total of nine test events within the same observations, there was some missing data.

Missing data is not unusual in educational research, especially for longitudinal data. It is normal that some students do not assess every single assessment month for a variety of reasons. There are many ways to deal with missing data, including the regression imputation method, mean imputation, list-wise deletion, keeping missing data as they are, or the last observation carries forward method, where the missing data are replaced by the last observation. All these methods may introduce some bias into the sample. 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. By using PMM, all imputed values are plausible. We generated 5 different data sets using this method.

Model and Analysis

We used a piecewise growth model to answer the research questions. This technique 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. The outcome variables can be observed or continuous latent variables. A model was fit for each cohort using Mplus software (see also Table 1). Mplus handles the relationship between the outcome and time by allowing time scores to be parameters in the model so that a growth function can be estimated. This is the same approach used in structural equation modeling. In a piecewise growth model,

different phases of development are captured by more than one slope growth factor, which allows for growth that is not linear (Muthén & Muthén, 1998-2017).

Kamata et al. (2013) demonstrated ways to model nonlinear growth using three testing occasions. They demonstrated the growth models in the context of curriculum-based measurement with the fall, winter, and spring reading fluency benchmark assessments using a linear growth model, a piecewise growth mixture model, a growth mixture model, and a growth model with an estimated time score model. They concluded that a piecewise growth mixture model performed well even with three test events. We also used a piecewise growth model to estimate students learning loss in Texas as well as across the US (Patarapichayatham et al., 2021; Locke et al., 2021). Therefore, we applied a piecewise growth model with our longitudinal data with nine test events over three academic years of data to estimate the effect of summer slide, COVID-19 slide, and students' performance in reading and math.

Figure 1 shows the statistical model used in this study. The model shows the intercept of the growth factors and the slopes for students' learning progress. The "i" is an intercept that incorporates all nine test events in the model (September 2018, January 2019, May 2019, September 2019, January 2020, March 2020, September 2020, January 2021, and March 2021). The "s1" is the slope for 2018-2019 school year that includes three test events (September 2018, January 2019, and May 2019). 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 slope is modeled as 0, 1, and 2 in Mplus fashion. The "s2" is the slope between the last assessment month of the 2018-2019 school year and the first assessment month of 2019-2020 school year. It is the

slope between EOY of 2018-2019 and BOY of 2019-2020. The “s3” is the slope for the 2019-2020 school year that includes three test events (September 2019, January 2020, and March 2020). The “s4” is the slope between the last assessment month of the 2019-2020 school year and the first assessment month of 2020-2021 school year. The slopes s2 and s4 are modeled as 0 and 1. The “s5” is the slope for 2020-2021 school year that includes three test events of 2021 school year (September 2020, January 2021, and March 2021). Because March falls between the January and May benchmarks, to construct equal time intervals across the data, the slopes of s3 and s5 are modeled as 0, 1, and 1.5. We also extrapolated to estimate May 2020 scores under s3 with slope parameter of 2.

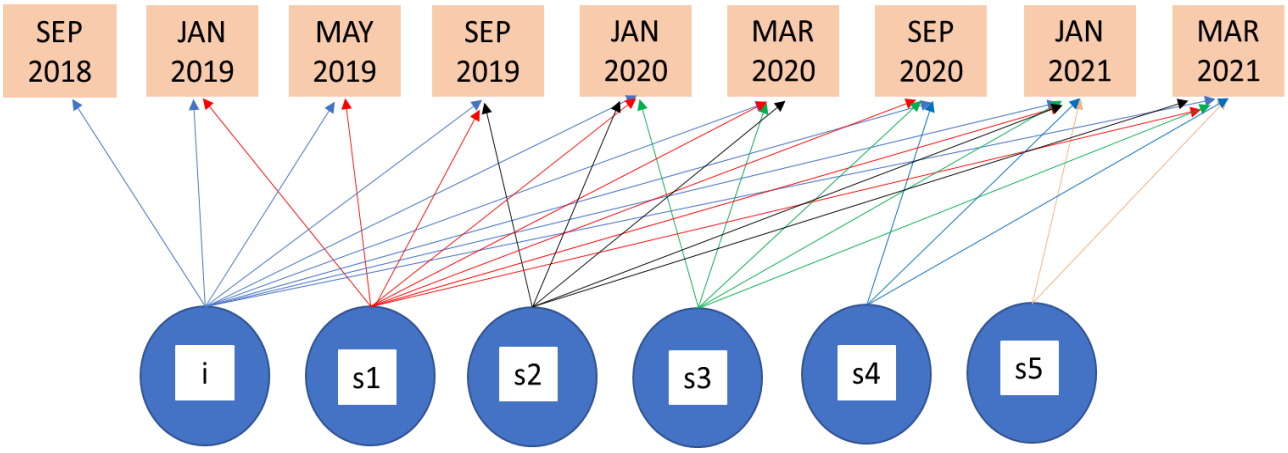

Figure 1: Piecewise growth model

While Istation has several assessment products, some assessments share the same scaling across all grades while others have different scaling in the upper grades. ISIP Math is the only assessment that has one scaling across all grades. ISIP Reading has two different scales for ISIP ER and ISIP AR. Kindergarten to third grade share the same ISIP ER scaling whereas students in higher grades are scored according to ISIP AR

scaling. ISIP ER scale score transformation is $20\theta + 200$ whereas ISIP AR scale score transformation is $200\theta + 2,000$.

The scaling issue appears in our analyses when comparing the second and third grade cohorts. In the second-grade cohort, students had ISIP ER scaling in their first two years and their last year of assessments were scored using ISIP AR scaling. On the other hand, the third-grade cohort took the ISIP ER assessment in their third-grade year, and their last two years of data were in ISIP AR scaling in their fourth and fifth grades. We kept these different scales as they are and fit the model as such to make interpretation simpler.

Our longitudinal design allows us to compare students' performance across three years and from cohort to cohort as well. Also, each year's data serves different purposes in this study. The 2018-2019 data is used to investigate students' typical reading and math performance before COVID-19. We calculated baseline summer slide by looking at the differences in scores between EOY of 2018-2019 and BOY of 2019-2020. We also used the 2019-2020 data to investigate students' reading and math performance right before the COVID-19 pandemic and used these to calculate the estimated May scores which are typically the EOY of 2019-2020 school year. COVID-19 slide was estimated using the interval between the EOY of 2019-2020 and the BOY of 2020-2021. The 2020-2021 data was used to investigate students' reading and math performance during the COVID-19 year.

Results

Table 2 shows the estimated intercepts and slopes. The estimated intercept is a cut point on the y-axis, with the ISIP scores on the x-axis. The intercept shows the estimated average ISIP score in September 2018. Estimated slopes are the students'

growth rates in each segment of the growth model. The "s1, s3, s5" represent students' growth rate in the 2018-2019, 2019-2020, 2020-2021, and the "s2" represents a summer slide in this study. The estimated intercepts and estimated slopes in Table 2 are used to derive the estimated ISIP scores for each assessment month using this formula:

$$\hat{y}_i = \mathrm{i} + s_1(time_1)_i + s_2(time_2)_i + s_3(time_3)_i + s_4(time_4)_i + s_5(time_5)_i$$

The estimated mean scores are shown in Table 3.

Because we selected a piecewise growth model for this study and ignored model selection comparison, the fit indices are not reported here. However, 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 good fit between observed and estimated mean scores from this model.

Table 2: Estimated Intercept and Estimated Slopes

Assessments	Cohort	Intercept	Slope 1	Slope 2	Slope 3	Slope 4	Slope 5
Reading	K	180.15	11.49	-1.03	10.07	2.66	6.88
	G1	202.63	9.49	2.01	7.20	1.82	5.98
	G2	223.84	7.12	1.22	6.10	1,563.75	43.58
	G3	246.29	3.69	1,577.75	55.84	-10.24	51.58
	G4	1,830.39	47.13	14.99	43.93	-18.30	10.74
	G5	1,938.36	33.04	5.82	33.08	-13.05	8.01
Math	K	306.46	58.20	-24.56	44.37	-15.30	19.62
	G1	390.03	40.32	-25.44	23.51	-16.11	19.07
	G2	441.30	27.74	-25.55	22.54	-17.20	18.16
	G3	473.79	19.69	-22.13	18.51	-18.39	16.79
	G4	505.74	16.43	-27.82	19.13	-22.20	15.01
	G5	507.27	17.38	-17.65	16.92	-24.19	12.02

Table 3: Estimated ISIP Scores

Assessments	Cohort	SEP 2018	JAN 2019	MAY 2019	SEP 2019	JAN 2020	MAR 2020	MAY 2020	SEP 2020	JAN 2021	MAR 2021
Reading	K	180	192	203	202	212	217	222	220	227	230
	G1	203	212	222	224	231	234	238	236	242	245
	G2	224	231	238	239	245	248	252	1812	1,856	1,878
	G3	246	250	254	1,831	1,887	1,915	1,943	1,905	1,957	1,982
	G4	1,830	1,878	1,925	1,940	1,984	2,006	2,027	1,987	1,998	2,003
	G5	1,938	1,971	2,004	2,010	2,043	2,060	2,076	2,047	2,055	2,059
Math	K	306	365	423	398	443	465	487	450	469	479
	G1	390	430	471	445	469	480	492	464	483	493
	G2	441	469	497	471	494	505	516	488	506	515
	G3	474	493	513	491	510	519	528	500	517	526
	G4	506	522	539	511	530	539	549	517	532	540
	G5	507	525	542	524	541	550	558	526	538	544

Results from Tables 2 and 3 were used to compute students' within-year growth, summer slide, and COVID-19 slide. The results are shown in Table 4.

Table 4: Estimated Gain Scores, Summer Slide, and COVID-19 Slide

Assessments	Cohort	2018-2019 Gain to May	2019-2020 Gain to March	2019-2020 Gain to May	2020-2021 Gain to March	Summer Slide	COVID-19 Slide
Reading	K	23	15	20	10	-1	-2
	G1	19	10	14	9	2	-2
	G2	14	9	13	66	1	-
	G3	8	84	112	77	-	-38
	G4	95	66	87	16	15	-40
	G5	66	50	66	12	6	-29
Math	K	117	67	89	29	-25	-37
	G1	81	35	47	29	-26	-28
	G2	56	34	45	27	-26	-28
	G3	39	28	37	26	-22	-28
	G4	33	28	38	23	-28	-32
	G5	35	26	34	18	-18	-32

Students' Performance Before COVID-19 and the Effect of COVID-19 Pandemic School Closures

The 2018-2019 data severed as a baseline to investigate students' reading and math performance in a typical academic year. Again, the estimated s1 represents students' growth rate in the 2018-2019 school year. In reading, the s1 were 11.49, 9.49, 7.12, and 3.69 from kindergarten to third grade, respectively (see Table 2). Students grew more in lower grade than in higher grade. These students grew 23 (from 180 to 203), 19 (203 to 222), 14 (224 to 238), and 8 (246 to 254) ISIP ER points from kindergarten to third grade, respectively (see Tables 3 and 4). In fourth and fifth grades, the estimated s1 were 47.13 and 33.04, indicating that fourth grade students grew more than fifth grade students in the 2018-2019 school year. Fourth grade students grew 95 (from 1,830 to 1,925) and fifth grade students grew 66 (1,938 to 2,004) ISIP AR points from September 2018 to May 2019.

In math, the estimated s1 were 58.20, 40.32, 27.74, 19.69, 16.43, and 17.38 for kindergarten to fifth grade, respectively, indicating that students grew more in lower grades than in higher grades. Their ISIP Math estimated scores are shown in Table 3. Students' gain scores in the 2018-2019 were in Table 4. There were 117, 81, 56, 39, 33, and 35 ISIP Math points in kindergarten to fifth grade, respectively.

The 2019-2020 data also represent students' reading and math performance right before the COVID-19 pandemic. The estimated s3 represents students' growth rate in the 2019-20 school year. In reading, they were 10.07, 7.20, and 6.10 from first to third grade, respectively. Students grew 15, 10, and 9 ISIP ER points from September 2019 to March 2020 in first to third grade. Again, students grew more in lower grades than in higher grades. In ISIP AR, the estimated s3 were 55.84, 43.93, and 33.08

indicating that fourth grade students grew more than fifth grade students and these students grew more than sixth grade students. They grew 84, 66, and 50 ISIP AR points from September 2019 to March 2020 students in fourth to sixth grade, respectively.

The estimated gain scores (if the pandemic had not happened at all) from September 2019 to May 2020 would have been 20, 14, and 13 ISIP ER points, and 112, 88, and 66 ISIP AR points for first to sixth grade students, respectively. In other words, first to third grade students missed the opportunity to gain 5, 3, and 3 ISIP ER points from March to May 2020 because of the COVID-19 pandemic school closures. In ISIP AR, students in fourth to sixth grades missed 28, 22, and 17 ISIP AR points of reading ability growth from March to May 2020 because of the COVID-19 pandemic school closures.

Because the COVID-19 pandemic school closures occurred in March 2020 and some students did not engage in remote learning, these students missed the opportunity to improve their reading ability from March to May. If the COVID-19 pandemic school closures did not occur, students' growth in 2018-2019 and 2019-2020 would be expected to be similar to each other as indicating in slopes 1 and 3 as well as estimated ISIP scores. For example, the growth rate of second grade in 2018-2019 was 7.12 and 7.20 in the 2019-2020. In ISIP ER, students grew 19, 14, and 8 ISIP ER points in 2018-2019 and they would likely have grown 20, 14, and 13 ISIP ER points in 2019-2020 in first to third grade, respectively. In fourth and fifth grades, students grew 95 and 66 ISIP AR points in the 2018-2019 school year and they would likely have grown 112 and 87 ISIP AR points in the 2019-2020 school year.

In math, the estimated s3 were 44.37, 23.51, 22.54, 18.51, 19.13, and 16.92 for kindergarten to fifth grade, respectively indicating that students grew more in lower

grade than in higher grade. They grew 67, 35, 34, 28, 28, and 26 ISIP Math points from September 2019 to March 2020 students in first to sixth grade, respectively. The estimated gain scores from September 2019 to May 2020 are 89, 47, 45, 37, 38, and 34 ISIP Math points for first to sixth grade students, respectively. Students missed the opportunity to improve their math ability by 22, 12, 11, 9, 10, and 8 fewer ISIP Math growth points from March to May of 2020 because of COVID-19 pandemic school closures. Like reading, students' growth in math of the 2018-2019 and 2019-2020 school years would have been very similar to each other had the pandemic not occurred. Students grew 81, 56, 39, 33, and 35 ISIP Math points in first to fifth grade in 2018-2019. By comparison, they only grew 67, 35, 34, 28, and 28 ISIP Math points from September 2019 to March 2020. They would have grown 89, 47, 45, 37, and 38 ISIP Math points in 2019-2020 school year.

Estimated Summer Slide

As mentioned earlier, the estimated slope of s2 represents typical summer slide in this study (see Table 2). Another way to compute summer slide is by subtracting the estimated EOY of 2018-2019 in Table 3 from the estimated BOY of 2019-2020 and results are shown in Table 4. In reading, the estimated s2 were -1.03, 2.01, and 1.22 for kindergarten to second grade and 14.99 and 5.82 for fourth and fifth grade. Summer slide was only seen for kindergarten students. These students lose 1 ISIP ER point whereas students in first to fifth grades did not appear to lose any reading ability over the summer of 2019. In math, on the other hand, we found a summer slide across all grades. The estimated s2 were –24.56, -25.44, -25.55, -22.13, -27.82, and -17.65 for kindergarten to fifth grade, respectively. Students lost 25, 25, 26, 22, 28, and 18 ISIP Math points in kindergarten to fifth grade, respectively.

Our results show that the normal summer slide is present in math, but that students have less summer slide in reading, and some students did not lose reading over the summer, pre-pandemic. Assessing summer slide can be difficult, and it is partially explained by when testing occurs. Typically, at EOY there may be several more weeks of instruction, and BOY may occur several weeks after instruction has begun. Quinn & Polikoff (2017) found that students' achievement scores decline over the summer by 1 month of school-year learning instruction. Students lost their math ability more rapidly than reading, and these losses are greater for students in higher grades. Shafer (2016) also found that students from all socioeconomic backgrounds forget more of what they learned in math over the summer than they lose in reading skills.

Estimated COVID-19 Slide

Again, the COVID-19 slide was computed by subtracting the estimated EOY of 2019-2020 scores in Table 3 from the estimated BOY of 2020-2021 scores and results are shown in Table 4. Note that the estimated s4 does not directly represent the COVID-19 slide because March 2020 was not an EOY assessment month. The estimated May of 2020 was used as the EOY of 2019-2020. In reading, while we did not see a summer slide across grades, we did find a COVID-19 slide across grades. Kindergarten and first grade cohort of 2018-2019 lose 2 ISIP ER points whereas third to fifth grade cohort of 2018-2019 lose 38, 40, and 30 ISIP AR points. Our results are consistent in math as well. Students experienced COVID-19 learning loss across grades. They lose 37, 25, 28, 28, 32, and 32 ISIP Math points across the kindergarten to fifth grade cohorts, respectively.

Because the COVID-19 slide is computed in the same way as a regular summer slide during the pandemic, the COVID-19 slide in our study is a compounded effect of

COVID-19 school closures in March 2020 and a regular summer slide. In reading, we found that all of our samples except the kindergarten cohort do not experience summer learning loss in a typical year. All cohorts, on the other hand, experienced COVID-19 learning loss across the country. In math, all cohorts experienced both summer learning loss and COVID-19 learning loss across grades (see also Table 4). The magnitude of COVID-19 pandemic school closures and move to remote or hybrid learning varied by grade level and was greater in upper elementary. The math curriculum in upper elementary becomes more abstract and thus more difficult, so these results are not surprising.

Students' Performance During the COVID-19 Pandemic Year

The 2020-2021 data represent students' reading and math performance during the COVID-19 pandemic year. The estimated s5 represents students' growth rate in 2020-2021 school year. It is very clear that students lag behind typical or expected growth. In reading, by comparing estimated s1, s3, and s5 of second grade, the growth rates were 7.12, 7.20, and 6.88 in the 2018-2019, 2019-2020, and 2020-2021. By comparing the gain scores from September to March of 2019-2020 and 2020-2021, it is also very clear that students lag behind typical or expected growth, especially in higher grades. Students grew 10 and 9 ISIP ER points in second and third grade in 2019-2020, they grew at almost the same rate in 2020-2021. In fourth to sixth grade, they grew 84, 66, and 50 ISIP AR points in 2019-2020. They grew 66, 77, and 16 ISIP AR points in 2020-2021 school year.

In math, by comparing the estimated s1, s3, and s5, the growth rate of second grade were 27.74, 23.51, and 19.62 in the 2018-2019, 2019-2020, and 2020-2021. Students' growth rate was small in 2020-2021 compared to their peers in prior years.

They grew 35, 34, 28, 28, and 26 ISIP Math points second to sixth grade of 2019-2020, and they grew 29, 29, 27, 26, and 23 ISIP Math points in 2020-2021 school year. In the 2020-2021 school year, students are behind by 1 to 6 ISIP Math points, depending on grade.

Our findings are consistent with findings from Kuhfeld, Soland, et al. (2020) and Kuhfeld, Tarasawa, et al. (2020), which both projected that students would begin the 2020-2021 school year with 63% to 68% of the learning gains in reading and 37% to 50% of the learning gains in mathematics. Also, Locke et al. (2021) and Patarapichayatham et al. (2021) found that the 2020-2021 cohort of students are behind the previous year cohort. They also found that learning losses were greater in math than in reading and the magnitudes was larger in higher grades than lower grades.

Students' Performance from 2018-2019 to 2020-2021 School Year

Figure 2 shows students' performance in reading and math across three years. Estimated May 2020 scores were included to illustrate students' growth trajectories. The black dotted line represents a summer slide, and the red dotted line represents a COVID-19 slide. ISIP ER and ISIP AR are on different scales making comparisons across these scales impractical. Therefore, the third-year data for the second-grade cohort and the first-year data of the third-grade cohort were ignored because they are on different scales. In reading, students in lower grades (see ISIP ER) share similar growth trajectories across three years in the program. Their reading progression is also stable from kindergarten to third grade. Students in higher grades, on the other hand, share similar growth trajectories in 2018-2019 and 2019-2020 school years. Their growth rate is flat in 2020-2021 school year (see ISIP AR). In ISIP ER, these students performed slightly better in the 2020-2021 school year compared to their own performance in

2019-2020 school year. Sixth and seventh grade students on the other hand had lower performance compared to their own performance in the 2019-2020 school year. In math, students had steeper growth trajectories in 2018-2019 school year. They kept improving their math ability in 2019-2020 but with less growth. The trajectories are flat in the 2020-2021 school year compared with growth in typical school years. Students in lower grades had higher growth rates than students in higher grades. In lower grade students, 2020-2021 performance was about the same as the previous year. Students in higher grades, showed equal or lower performance compared to their own performance in the 2019-2020 school year.

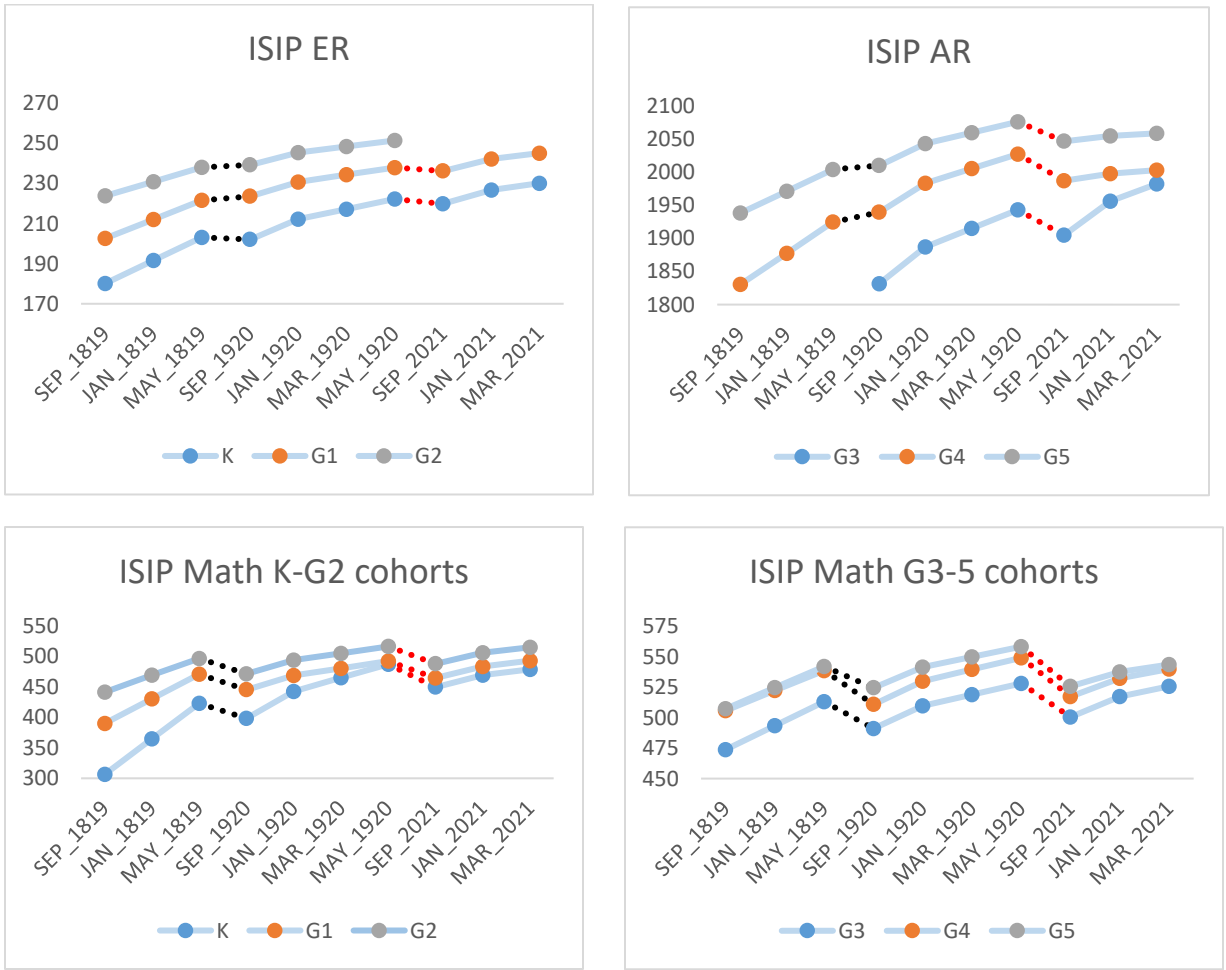

Figure 2: Estimated Mean Scores Across Three Years of Data

Discussions, Limitations, and Future Directions

This study investigates summer slide, COVID-19 slide, and student performance in reading and math across the US before and during the COVID-19 pandemic. Our results confirm that at all students experienced summer slide before the COVID-19 year. However, students across the country experienced COVID-19 learning loss in both reading and math. The COVID-19 pandemic has marked negative effects on students' achievement in both reading and math. Students' performance during the 2020-2021 school year is lower than that of the 2018-2019 and 2019-2020 cohorts in both reading and math across all grades. However, the magnitudes of losses vary by grade and by subject. COVID-19 learning loss was smaller in lower grades but larger in higher grades. Although Istation provides both assessment and curriculum to students, we mainly focused on only assessments. Although there have been several studies show that Istation curriculum has helped students in their reading and math, we did not take Istation adaptive curriculum into consideration in this study.

The results from this study are very useful for teachers, parents, and school district administrators. Our results also suggest that students will need additional on-grade and off-grade instruction, with more time and attention paid to each student's learning progress, more studying time, and an increase in school activities over the upcoming summer to catch up to the typical grade level curriculum. Since each student has a different learning curve, it may take more than one year for some students to fully recover from COVID-19 learning losses, especially for students with learning disabilities and/or disorders. Another limitation is the scaling difference between ISIP ER and ISIP AR. This limits our ability to look at growth across the grades, and future research may need to look at percentile growth as a means to bridge this gap.

We will further investigate students' performance after students complete their 2020-2021 school year. These results will be compared with their peers in the 2018-2019 and 2019-2020 school years. We will also estimate summer slide and COVID-19 slide again in the fall of 2021 as well as investigate students' performance in reading and math after the COVID-19 year.

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