The COVID-19 Pandemic and Oral Reading Fluency

Abstract

The COVID-19 pandemic disrupted school, work, and daily life on a global scale. In the wake of this unprecedented health crisis, schools across the United States were forced to abruptly adapt their educational delivery models. Understanding how student learning trajectories shifted throughout the ongoing pandemic is critical for equipping educators, policymakers, families, and other vested partners to respond to and serve students going forward. Using a national sample of oral reading fluency (ORF) scores, we estimated trajectories of literacy development for students in Grades 1 to 5 before and during the pandemic. Results showed that students began fall 2020 (post-pandemic-onset) with lower average ORF scores than their same-grade peers from the prior (i.e., pre-pandemic) year. Additionally, this disparity in reading fluency between cohorts widened between the beginning and middle of year benchmark periods. Limitations and implications of these widening disparities are discussed.

Keywords: COVID-19, early literacy, assessment, achievement, oral reading fluency, school closing

The COVID-19 Pandemic and Oral Reading Fluency

The onset of the SARS-Cov-2 virus, which drove the COVID-19 pandemic, initiated a once-in-a-century disruption in school, work, and daily life across the globe (Gates, 2020). By mid-March 2020, in person instruction had been suspended worldwide, and large-scale school closures intended to curb the viral transmission affected more than 90% of the world's student population (UNESCO, 2020). In the US, all 50 states required or recommended that school buildings close for some period (Auger et al., 2020). Closures of this magnitude spur tremendous social, emotional, and economic impacts (Armitage & Nellums, 2020), and although the effects of these disruptions will be felt for years to come, considerable efforts are already underway to better understand and mitigate their negative effects (Buonsenso et al., 2021; Cachón-Zagalaz et al., 2020). Indeed, a number of researchers have analyzed available data to describe the current learning landscape to mixed results (e.g. Bielinski et al., 2020; Domingue et al., 2021; Dorn et al., 2020; Huff, 2020; Kuhfeld & Tarasawa, 2020; Reimer et al., 2021). This paper contributes to those efforts by linking learning trajectories before and during the pandemic to meaningful risk categories and describing the variable learning experienced by students across the achievement spectrum.

Impacts of Instructional Discontinuities

Historically, substantial discontinuities in standard classroom instruction (e.g., due to natural disasters or summer breaks) are associated with disruption in academic skill growth (Atteberry & McEachin, 2020; Quinn & Polikoff, 2017; von Hippel & Hamrock, 2019), suggesting that the extended disruptions to education delivery during the pandemic has likely had similar effects on academic growth (Kuhfeld & Tarasawa, 2020). One way to conceptualize these disruptions is to borrow from seasonal learning research, which likens access to educational opportunities to a faucet (Entwisle et al., 2000). Optimally functioning school systems provide a full-stream flow of educational resources to all students and families during the school year. The flow of educational resources slows substantially during summer break and other disruptions, with the degree of change depending on several demographic factors (e.g., socioeconomic status, SES; Alexander et al., 2001; Cooper et al., 1996; Quinn et al., 2014). Importantly, the provision of modest instruction throughout a summer break has been shown to mitigate, and, in some cases, reverse widening achievement gaps for schools in low-income neighborhoods (Kim et al., 2016; Zvoch & Stevens, 2015). At different times and in different locations, instruction during the pandemic likely resembled a full-stream flow of services, a stoppered flow, or something in between. Thus, we conceptualize the experiences of student during the pandemic as differential exposures to learning opportunities, both in terms of the quantity and quality of instruction, rather than framing comparisons to pre-pandemic achievement as academic loss or regression.

To effectively understand and respond to instructional disruptions, educational partners (e.g., educators, administrators, policymakers, and allied professionals) need to understand the depth of the problem. Decisions informed by data empower educators to align instruction and intervention to students' needs. However, because instruction during the COVID-19 pandemic required rapid, unplanned adaptations to the traditional teaching model, schools were not prepared to immediately, and in most cases, fully, transition to online learning in the spring of 2020 (Kraft et al., 2020). Consequently, many schools opted to forgo typical data collection (such as spring 2020 assessments), leaving a dearth of data to inform instruction. Only one-third of districts were found to have held teachers accountable for providing instruction, tracking student engagement, or monitoring students' academic progress (Gross & Opalka, 2020).

Further, only one in five schools provided remote instruction in late spring of 2020 that was characterized as *rigorous* (e.g., use of synchronous instruction, expectations of participation and grading, direct contact requirements; Malkus et al., 2020), and the quality of remote-instruction programs was lower in schools with higher proportions of economically disadvantaged students (Malkus, 2020).

Quantifying the Depth of Educational Disruptions

This unprecedented situation highlights the need for a thorough, quantitative evaluation of student academic performance to inform current and future instructional supports for the increasing number of students who are now or are expected to be at risk for failing to reach expected achievement benchmarks. Indeed, multiple reports projecting or describing early literacy growth trajectories from March 2020 and beyond identify a concerning drop in expected and observed growth.

Early forecasts suggested the potential for substantial opportunity loss (Bailey et al., 2021; EmpowerK12, 2020b; Kaffenberger, 2021; Kuhfeld, Soland, et al., 2020), but relied upon extrapolation from prior evidence. Others drew upon observed data to quantify impacts on educational delivery, but findings have been mixed. For example, Engzell et al. (2021) identified an academic achievement loss in the Netherlands of 0.08 SD after just 8-weeks of remote instruction. This finding is concerning given the significant impact following a relatively short duration (8 weeks), particularly given the hypothesis that greater lengths of remote instruction may compound losses. Other work confirms large learning differences for students across the US during the pandemic compared to prior years (Bielinski et al., 2020; Curriculum Associates, 2020; EmpowerK12, 2020a; Kogan & Lavertu, 2021; Pier et al., 2021). Notably, Amplify (2021) found an increased number of students in at-risk categories based on universal screening data compared to the prior year. In contrast, Kuhfeld et al. (2020) observed similar average performance in fall 2020 MAP Growth reading scores in Grades 3 through 8 as in the prior year. Similarly, Renaissance Learning (2020, 2021) reported small or shrinking differences in the cohort of students experiencing the pandemic compared to their peers from prior. The current study builds on the existing evidence by presenting data from a large, national sample of schools who use a common data system to manage and track students' early literacy skills.

The Case for Leveraging Literacy Data

A common standard of success in school systems is the delivery of instructional interactions that lead to students' acquisition of literacy, numeracy, and content knowledge for core disciplines (e.g. science, arts; Schroeder et al., 2007; Stronge et al., 2011). Early literacy skills are uniquely situated as a prime target for capturing the extent of learning disruptions due to their rapid pace of development relative to many other academic skills and their strong association with future academic outcomes (Beach et al., 2021; Domingue et al., 2021; Francis et al., 1996; Juel, 1988, 1993; Lyon & Moats, 1997; Torgesen et al., 1997). Early literacy skills indicate how children manage a first hurdle in their academic career: learning to read proficiently. Literacy is a primary area of focus from school system entry, and typically educators continue tracking student growth until students achieve functional literacy, through elementary or middle school. Underscoring the emphasis placed on early literacy development in the US in particular, the US participates in a decades-long tradition of assessing students' literacy skills in elementary school and reporting results in publicly accessible formats (e.g., National Assessment of Educational Progress, or NAEP) to report the proportion of students who meet the assessment benchmark goal of basic literacy.

Concerningly low literacy achievement data nationally, often disseminated in NAEP reports, offer one justification for significant investment in research and development on interventions and supports for students, families, educators, administrators, and other vested partners in the process of teaching all children to read. Perhaps more critically, success in early literacy is predictive of later success in academics, adaptive capacities, and life success more broadly (Kutner et al., 2007; Lesnick et al., 2010). Students who are not proficient readers by third grade are at increased risk for academic disengagement and broader adverse outcomes, including behavior problems, high school dropout, and incarceration (McIntosh et al., 2006; National Research Council, 1998). A shortlist of benefits accompanying a literate population include increasing access to a pluralistic democracy, tackling pressing global issues such as climate change and economic disillusionment, and developing individuals' skills in synthesizing information to form reasoned evaluation of knowledge (Murnane et al., 2012). Furthermore, remediation of literacy skills requires significantly more time and resources compared to prevention of literacy difficulties (Torgesen, 2000; Torgesen et al., 2001; Vaughn et al., 2011; Vaughn & Wanzek, 2014; von Hippel & Hamrock, 2019).

Thus, given the importance and historical context around teaching, assessing, and intervening on early literacy skill acquisition, we argue that examining student reading performance data in the current context provides an appropriate and meaningful barometer for the impact of a global health crisis on students' academic well-being. Given the widespread adoption of universal screening for risk (January & Klingbeil, 2020) and progress monitoring practices in literacy (Clemens et al., 2019), and the fact that relatively few students were assessed using standardized tests in the spring of either 2020 or 2021, the availability of seasonal early literacy data provides a unique opportunity to conduct more timely evaluations of and better understand the association of the COVID-19 pandemic response and learning. As noted, that understanding is critical to facilitating more responsive, targeted policies and instructional decisions.

To maximize the utility and accuracy of such an evaluation, it is essential to leverage, as much as possible, data that are representative of schools across the nation, are valid and reliable, and were collected both before and during the pandemic. In the current study, we examine changes in oral reading fluency (ORF) data from one such measure, the Dynamic Indicators of Basic Early Literacy Skills 8th Edition (DIBELS 8), to estimate the association of COVID-19 pandemic response with literacy growth for students. DIBELS 8 is a suite of freely available, curriculum-based measures that assess student fluency in critical areas of literacy development and are typically administered multiple times during the school year to all students in a school or district in a systematized manner (e.g., students receive ORF passages at their grade-level and then educators track ORF growth over time). Universally screening all students allows districts to make informed decisions about the health of their curricular systems and about the service delivery needs of their students. Nearly 12,500 schools, representing almost four million children across all 50 states and the District of Columbia use online data systems to warehouse DIBELS data, allowing for a large, national sample of early literacy data. Importantly, DIBELS 8 has been available for use throughout the pandemic, including embedded guidance and support for remote testing protocols that were developed early in the pandemic and disseminated widely to DIBELS users.

Acknowledging Varied Responses

Although early literacy skills are likely to provide a robust description of the depth of disruption for the nation's students' learning, it must be acknowledged that responses to and impacts from the global pandemic varied widely across families, schools, regions, and beyond. On March 27, 2020, the US Congress passed the Coronavirus Aid, Relief and Economic Security (CARES) Act, providing grants to states to support the response to COVID-19, including funds for education. Despite this support, state and regional policies more directly governed pandemic response (Storey & Slavin, 2020). While most states did not mandate school closures until mid- to late-March, some schools closed earlier due to positive cases (Forgie, 2020), and school superintendents petitioned the Centers for Disease Control (CDC) for guidance as early as February (Binkley, 2020).

Similarly, the short turnaround between mandated school closures and the initiation of online learning required an immediate shift to the use of videoconferencing tools, revised curricula and assessment, and other instructional adaptations (Storey & Slavin, 2020), and this shift looked very different depending on the state, district, school, and even teacher. While some areas of the country chose to focus on reviewing learned materials (e.g., Cleveland; Gewertz, 2020), others focused on serving students' physical or emotional needs (e.g., Salt Lake City; Stauffer, 2020), while still others sought to strengthen community supports, such as partnering with local broadcasting to produce educational programs for students (e.g., Los Angeles; Goldsmith & Goldsmith, 2020; Li & Lalani, 2020).

In addition, the distribution of technology resources that enabled students to remotely access and engage in their instruction was variable and made more difficult by existing economic conditions for students (Gewertz, 2020; Storey & Slavin, 2020), with one survey suggesting that up to 40% of economically disadvantaged students in K-12 educational settings accessed remote learning only once a week (Kamenetz, 2020). Similarly, leaders in schools that serve a high proportion of students from low-SES backgrounds more frequently expressed concern about their ability to provide technology resources to their students (Herold, 2020), with some reports suggesting that only about half of such schools were able to provide a device to each student (Bielinski et al., 2020).

Beyond the onset of the pandemic, schools, regions, and states adopted diverse long-term responses to the health crisis from the start of the 2020-2021 school year and beyond (Parolin & Lee, 2021). Reports suggest that between one half and two-thirds of students attended school remotely in the fall of 2020, with the rest roughly split between in-person or hybrid models (Irwin et al., 2021; Verlenden et al., 2021). In essence, the educational response to the pandemic has been diverse and uneven (Carpenter & Dunn, 2020; Garet et al., 2020; Malkus et al., 2020). Thus, one obvious challenge in attempting to describe instruction across the nation is how circumstances vary across numerous, overlapping geographical tiers (i.e., state, region, district) as well as critical decision points (i.e., policies, standards, safety protocols, etc.; Reynolds & Chu, 2020).

Schools and families also varied widely in their approach to education during the health crisis. In-person, hybrid, and online learning decisions evolved constantly based upon local and national contexts, and often varied even within and across neighboring schools and districts (Dibner et al., 2020; Hamilton et al., 2020; Kraft et al., 2020). Where one school may have allowed all younger elementary students to attend in person for a time, a nearby school may have had students demonstrating the highest needs of all ages attend in person. Unsurprisingly, school closures were more frequent for schools serving higher proportions of students (a) from diverse backgrounds; (b) of limited English proficiency; and (c) who were more economically disadvantaged, had lower achievement, or higher rates of homelessness (Parolin & Lee, 2021). Thus, national data that measures student achievement across a range of geographic boundaries and the remote-to-in-person instructional spectrum is needed to better understand the educational trajectories associated with the pandemic.

The Current Study

Despite the significant and uneven disruptions to typical education during the COVID-19 pandemic, instruction is still occurring (Goldhaber et al., 2021). Like the recouping of skills following a summer break, we hypothesize that instruction during the 2020-2021 school year was qualitatively different from both typical instruction and the instruction provided during the initial and sudden disruption in spring 2020, but that systems adjusted to serve students despite the circumstances. Of potentially more utility than understanding the depth of learning disruption due to a pandemic is understanding the extent of the recovery.

Our intention is to provide one picture of that disruption and rebound, using a national sample of public-school students who participated in screening assessments that typically occur throughout the academic year, despite the disruption and challenges associated with learning during a global health crisis. We examine the initial hypothesized plateauing or loss in skill acquisition from the onset of the pandemic, followed by the subsequent gains as educators and school systems pivoted to online, hybrid, or adapted in-person learning during and, in some cases, throughout the 2020-2021 school year. As a basis of comparison, we use a consistent assessment (DIBELS 8) across two school years (2019-2020 and 2020-2021) within the same sample of public schools to offer a temporal contrast of ORF trajectories pre- and post-COVID-19 pandemic. Specifically, our research questions were:

1. How do the distributions of Oral Reading Fluency (ORF) scores in Grades 1-5 change over the course of the 2019-2020 and 2020-2021 school years?

2. How do the ORF scores of students in fall and winter of the 2020-2021 school year compare to the scores for same-grade students in the prior year?
3. Do student gains from fall to winter in the 2020-2021 school year resemble gains from the previous year?

We acknowledge that although differences observed between the two cohorts cannot be causally attributed to the pandemic, they remain our best estimate of its effects given how universal learning disruptions were. Moreover, these differences may constitute an underestimate of effects given that they are naturally constrained by students who were present for assessment in 2020-2021.

Method

The current study utilized an accelerated cohort-sequential design to compare change in oral reading fluency for students in Grades 1-5 during the 2019-2020 (Year 1; pre-pandemic) and 2020-2021 (Year 2; post-pandemic-onset) school years (see Table 4). Data were drawn from schools that used one of two online data systems for the DIBELS measures: the DIBELS Data System (DDS) and Amplify mCLASS. Together, the two systems represent a substantial proportion of U.S. K-5 schoolchildren: before applying the inclusion criteria described below, the total K-5 sample between 2019 and 2021 across both systems was 1,447,632 children from 7,045 schools (including both public and private schools). Of the 5,924 schools for which National Center for Educational Statistics (NCES) identifiers were available, 4,073 were public or charter schools. Given the almost complete absence of data in the spring of 2020, we focused on schools that entered data at the beginning and middle of both the 2019-2020 and 2020-2021 school years. Notably, because DIBELS 8th Edition was not yet fully released until the start of the 2019-2020 school year, users during the 2018-2019 school year represented a much smaller sample of schools (i.e., early adopters), so we are unable to make comparisons to cohorts prior to the 2019-2020 school year without dramatically restricting our sample.

To answer our research questions, we focused on schools that used DIBELS in both years as intended (e.g., used the appropriate forms at the appropriate time of year). We thus applied the following sequential multi-step inclusion criteria: (a) a given observation's assessment date must reflect screening at the appropriate time of year (e.g., beginning of year (BOY) assessments must have been administered between August 1st and December 1st); (b) schools must have collected data at each of the four modelled timepoints (i.e., the beginning and middle of 2019-2020 and 2020-2021); (c) a school's median assessment date must have been within six weeks of the overall sample's median assessment date for that timepoint; (d) students must have attended only one school and moved to the next grade in 2020-2021; (e) schools must have assessed at least 10 students in a grade at each timepoint; (f) each grade within a school must have been assessed at all four timepoints; and (g) each student must have at least two of the four observations. Changes in the sample size at each step are summarized using a consort diagram in Figure 1.

Participants

The final analytic sample included 471,456 students from 1,684 schools. School characteristics for the sample, including proportions of students in various demographic categories, are summarized in Table 1. As an estimate of how well our sample reflects national characteristics, we also report the same data based on all public schools in the 2019-2020 Common Core of Data that offered at least one of Grades 1-5. The school-level race/ethnicity percentages for our sample are similar to national averages, although the sample slightly overrepresents Hispanic/Latino students (i.e., 34.87% vs. 24.73%) and underrepresents white students (i.e., 39.20% vs. 49.76%) relative to the U.S. population. Additionally, our sample is over-representative of states in the western census division (i.e., 44.52% vs. 24.81%) and of schools in city locales (i.e., 46.72% vs. 28.77%). In part, this is likely due to the popularity of the DIBELS and mCLASS data systems in the western US and its use among large, urban districts in that region during the 2019-2020 and 2020-2021 school years.

Measures

DIBELS is a suite of curriculum-based measures that helps teachers identify students at-risk for reading difficulties and monitor their progress toward grade-level reading goals in Grades K-8. Subtests are administered three times, at the beginning (BOY), middle (MOY, and end of year (EOY). The Oral Reading Fluency (ORF) subtest is a timed measure of students' fluency and accuracy in reading connected text that is administered in Grades 1-8. Students read a passage aloud for one minute, and their score represents the number of words read correctly. In Grades 1-5, DIBELS ORF has a concurrent alternate-form reliability ranging from .87 to .97 and test-retest reliabilities ranging from .87 to .94. Concurrent validity coefficients relative to the Iowa Assessment of Reading – Total Reading (University of Iowa, 2015) range from .58 to .82.

To identify students at-risk for reading difficulties, DIBELS 8 utilizes nationally normed criterion-referenced scores (i.e., benchmarks) that are intended to maximally differentiate students who are expected to reach specific levels of proficiency on an end-of-year summative reading assessment from students who are not on-track to do so. For DIBELS 8, achieving at grade-level expectations (i.e., meeting benchmark goals) in Grades 1-5 is associated with scoring at or above the 40th percentile on the Iowa Assessment in Reading at the end of the year (Biancarosa et al., 2020). Scoring above the benchmark is associated with relatively low risk, as 80% or more of students who scored in this range in the norming sample achieved at or above grade-level at the end of the year.

DIBELS 8 also incorporates an additional cut score (i.e., intensive range) to distinguish the severity of risk for reading difficulties for students performing below benchmark scores. In Grades 1-5, this additional cut score is intended to identify students who are likely to perform at or below the 20^{th} percentile on the Iowa Assessment in Reading at the end of the year (Biancarosa et al., 2020). Students who fall below the benchmark goal but exceed the cut-score for the intensive range are recommended to receive strategic supports to supplement their core instruction, while students that fall below both cut scores are recommended to receive intensive supports.

Analyses

To examine differences in longitudinal change before and during the pandemic, we estimated a three-level piecewise mixed effects model using the lme4 package for the R programming language (Bates et al., 2015; R Core Team, 2021). Student data was modelled across two years using a cohort-sequential design and a maximum of four observations per student, with two exceptions noted below (i.e., $\text{Cohort}_{K\text{-}1}$ and $\text{Cohort}_{5\text{-}6}$). The first two observations represent the BOY and MOY of Year 1 (i.e., pre-pandemic, 2019-2020) and the second two represent the BOY and MOY of Year 2 (i.e., post-pandemic-onset, 2020-2021).

Changes in ORF across these four timepoints were modelled using three unique slopes. The first slope, half-year gain (HYG; b_1) was coded as 0, 1, 1, 1 and is intended to represent the change in ORF scores during the pre-pandemic school year. Changes between Time 2 and 3 are defined by the pandemic slope (b_2), which represents the change in ORF scores between the middle of the pre-pandemic school year and the beginning of the following "pandemic school-year" (i.e., 2020 – 2021). The pandemic parameter across the four timepoints was coded as 0, 0, 1, 1. Lastly, school year gains that occur during the pandemic year were modeled using the pandemic half-year gain slope (P-HYG), which is coded 0, 0, 0, 1 and represents the change in ORF scores between Times 3 and 4 for each cohort. Our complete coding scheme is summarized in Table 2.

Additionally, we modeled grade-level (b_3) as a categorical time-varying covariate (TVC) to allow the intercept, HYG, pandemic, and P-HYG slopes to all vary across grades. Functionally, grade-levels were dummy-coded, such that the fixed effects of grade were static across school years and cohorts. The resulting model is summarized below in Equation 1. Consistent with our research questions, both HYG and the pandemic indicator variable are modeled as random effects. Additional, potentially interesting random effects, such as modeling P-HYG as a random effect, were not possible due to limitations in our degrees of freedom.

$$
\begin{aligned}
Y_{tij} = \; & \gamma_{000} + \gamma_{100}\left(Grade_{2_{tij}}\right) + \gamma_{200}\left(Grade_{3_{tij}}\right) + \gamma_{300}\left(Grade_{4_{tij}}\right) + \gamma_{400}\left(Grade_{5_{tij}}\right) \\
& + \gamma_{500}\left(HYG_{tij}\right) + \gamma_{600}\left(Grade_{2_{tij}}\right)\left(HYG_{tij}\right) + \gamma_{700}\left(Grade_{3_{tij}}\right)\left(HYG_{tij}\right) \\
& + \gamma_{800}\left(Grade_{4_{tij}}\right)\left(HYG_{tij}\right) + \gamma_{900}\left(Grade_{5_{tij}}\right)\left(HYG_{tij}\right) \\
& + \gamma_{1000}\left(Pandemic_{tij}\right) + \gamma_{1100}\left(Grade_{2_{tij}}\right)\left(Pandemic_{tij}\right) \\
& + \gamma_{1200}\left(Grade_{3_{tij}}\right)\left(Pandemic_{tij}\right) + \gamma_{1300}\left(Grade_{4_{tij}}\right)\left(Pandemic_{tij}\right) \\
& + \gamma_{1400}\left(Grade_{5_{tij}}\right)\left(Pandemic_{tij}\right) \\
& + \gamma_{1500}\left(P\text{-}HYG_{tij}\right) + \gamma_{1600}\left(Grade_{2_{tij}}\right)\left(P\text{-}HYG_{tij}\right) \\
& + \gamma_{1700}\left(Grade_{3_{tij}}\right)\left(P\text{-}HYG_{tij}\right) + \gamma_{1800}\left(Grade_{4_{tij}}\right)\left(P\text{-}HYG_{tij}\right) \\
& + \gamma_{1900}\left(Grade_{5_{tij}}\right)\left(P\text{-}HYG_{tij}\right) + u_{00j} + u_{50j}\left(HYG_{tij}\right) + u_{100j}\left(Pandemic_{tij}\right) \\
& + r_{0ij} + r_{5ij}\left(HYG_{tij}\right) + r_{10ij}\left(Pandemic_{tij}\right) + e_{tij}
\end{aligned}
$$

In this model, Y_{tij} represents the ORF score at time *t* for student *i* in school *j*. Table 3 summarizes the interpretation of the parameters that are of primary interest to our research questions. We represent cohorts by their sequence of enrolled grades. For example, $\text{Cohort}_{1\text{-}2}$ represents students who were enrolled in Grade 1 during Year 1 and Grade 2 during Year 2.

Functionally, each cohort contributes their Year 1 data to estimating normative gains (i.e., pre-pandemic gains) and their Year 2 data to estimating change in ORF amid the pandemic. For example, data from students in $\text{Cohort}_{2\text{-}3}$ were used to estimate pre-pandemic half-year gains for Grade 2 during Year 1, whereas pandemic half-year gains for Grade 2 is estimated using Year 2 data from $\text{Cohort}_{1\text{-}2}$. The full accelerated cohort design is summarized in Table 4. Note that not all grades have two years of ORF data, because ORF is not administered to kindergarten students and relatively few students in our sample have Grade 6 data, which we attribute primarily to the transition of students in $\text{Cohort}_{5\text{-}6}$ to middle school. Thus, $\text{Cohort}_{K\text{-}1}$ does not have pre-pandemic data and $\text{Cohort}_{5\text{-}6}$ does not have post-pandemic-onset data. However, the inclusion of these cohorts enables a complete design to estimate pandemic effects across Grades 1-5.

Using the model described in Equation 1 and the design represented in Table 4, initial status and half-year gain estimates for students in Grade 1 pre-pandemic can be calculated using the intercept and HYG terms. For Grades 2 to 5, that estimate is modified by its corresponding grade parameter estimate. Initial status and half-year gain estimates during the pandemic period can be calculated using the intercept and HYG terms, as well the pandemic and P-HYG parameters. Similar to the pre-pandemic period, pandemic period estimates for Grades 2 to 5 are modified by a grade-level parameter.

We also conducted several sensitivity checks for our analyses. First, we replicated the model just described using two subsamples of the primary sample: one that included only schools that assessed all Grades 1-5 during the 2019-2020 and 2020-2021 school years, and a second that required that all students had an observation in both school years unless their enrolled grade was not assessed at their school. For example, if a school only assessed students in Grades 1-3, students that would have entered Grade 4 during the 2020-2021 school year were not required to have data from that year. In addition, we estimated our models using both restricted maximum likelihood and full information maximum likelihood (FIML) and with both an unstructured and variance components (VC) variance-covariance structure. We also explored different time-varying coding schemes, including allowing grade level effects to accumulate. Unstructured models resulted in singularities and sometimes did not converge. Otherwise, results differed negligibly across varying approaches. Thus, for parsimony, we report solely on the FIML VC model.

Results

Descriptive statistics for each timepoint are presented in Table 5. Means and standard deviations in Grade 1 highlight floor effects and a positive distributional skew at both BOY and MOY. In Grade 1, MOY scores of zero were reported for approximately 4.25% of students in the pre-pandemic year and 10.03% of students in the pandemic year, indicating that floor effects were more pronounced in the latter. This distributional skew is also reflected in the violin plot in Figure 2, which shows the distributions for each grade, arranged by season and school year. Within each grade and season, the violin plot on the left represents the pre-pandemic year cohort, and the violin on the right represents the corresponding pandemic year cohort, allowing for comparisons across both cohorts and seasons. Within each violin plot, the solid horizontal line displays the mean score, whereas the lower and upper dashed lines represent the 25th and 75th percentiles, respectively. For example, floor effects in Grade 2 can be clearly seen by the wider shape at the bottom of the BOY distributions for both cohorts. The floor effect is less pronounced at MOY, as illustrated by a narrower distribution at the bottom of the corresponding violin plot, although this change is somewhat more pronounced for the pre-pandemic cohort.

Model results are presented in Table 6. We report in detail in Table 7 how point estimates for each timepoint are derived from the coefficients in Table 6 and present fitted trajectories in Figure 3. Without exception, students during the pandemic year demonstrated both lower BOY reading scores and smaller BOY to MOY gains compared to the pre-pandemic year students.

Pre-pandemic Intercepts and Gains by Grade

To derive initial status and half-year gain estimates for Grade 1 students in the pre-pandemic period, the intercept and HYG terms are used. To obtain grade-specific estimates for Grades 2-5, the Grade 1 estimates are modified by the corresponding grade parameter estimates. Estimates are reported for all grades in Table 7.

As illustrated in Table 7, the average BOY ORF score for students who began Grade 1 before the pandemic (i.e., $\text{Cohort}_{1\text{-}2}$) was 20.76 words correct per minute (WCPM) (γ_{000}). Those same students averaged 37.53 WCPM ($\gamma_{000} + \gamma_{500}$) at EOY, which amounts to an average half-year gain of 16.77 WCPM (γ_{500}) from BOY to MOY. As can be inferred from Table 7, from BOY to MOY, Grade 2 students gained an average of 30.54 WCPM ($\gamma_{500} + \gamma_{600}$), Grade 3 an average 27.93 WCPM ($\gamma_{500} + \gamma_{700}$), Grade 4 an average 42.33 WCPM ($\gamma_{500} + \gamma_{800}$), and Grade 5 an average 18.38 WCPM ($\gamma_{500} + \gamma_{900}$).

Pandemic Intercepts and Gains by Grade

To derive initial status and half-year gain estimates for the pandemic period, the intercept and HYG terms are also used, but the pandemic coefficient and pandemic half-year gain (P-HYG) terms also contribute. As before, estimates are modified by the grade parameter estimates for Grades 2-5. For all grades, HYG and the pandemic effect are both coded one at BOY and P-HYG increments to one at MOY.

As illustrated in Table 7, the average ORF score for students beginning Grade 1 during the pandemic (i.e., $\text{Cohort}_{0\text{-}1}$) was 18.19 WCPM ($\gamma_{000} + \gamma_{1000}$). Pandemic first-graders averaged 30.27 WCPM ($\gamma_{000} + \gamma_{500} + \gamma_{1000} + \gamma_{1500}$) at EOY for an average pandemic half-year gain of 12.08 WCPM (γ_{1500}) from BOY to MOY. Compared to pre-pandemic first graders, pandemic first graders scored 2.57 fewer WCPM and by MOY were scoring 7.25 fewer WCPM on average. All differences between pre-pandemic and pandemic at both BOY and MOY were converted to effect sizes by dividing them by the pre-pandemic standard deviation for a given grade level and are also reported in Table 7. In first grade, these differences amount to ES of -0.09 and -0.20 for BOY and MOY respectively. A pattern of these differences increasing from BOY to MOY is apparent and of relatively similar magnitude in every grade, except Grade 4, where the BOY difference ES was -0.16 and EOY was -0.18.

Summary

Without exception, students during the pandemic year demonstrated both lower BOY reading scores and smaller gains from BOY to MOY compared to pre-pandemic year students. Although these differences, which are all statistically significant, may appear small in absolute magnitude, the impact is more obvious when expressed as Cohen's *d* (Cohen, 1992) effect sizes using the pre-pandemic standard deviation for a given time of year. As detailed in Table 7, estimated average differences between pre-pandemic and pandemic performance at BOY ranged from 2.57 WCPM in Grade 1 to 6.29 WCPM in Grade 4, and respective effect sizes ranged from a somewhat modest -0.09 to -0.16. However, by MOY, differences between pre-pandemic and pandemic performance ranged from 6.69 WCPM in Grade 5 to 9.02 in Grade 4, and effect sizes increased and were consistent across grades, ranging from -0.18 to -0.20. Figures 2 and 3 further illustrate important practical ramifications of these small but significant average differences.

First, as shown in Figure 3, average pandemic MOY performance in Grades 2, 3, and 5 falls within the strategic support range of scores. Note, too, how in Figure 2, the median line at pandemic MOY falls at the cut for strategic support (i.e., the top of the yellow portion of the violin plots) in all but Grade 4, and even in Grade 4, the median line is closer to the strategic support cut. Similarly, whereas pre-pandemic the intensive support cut fell at about the 25th percentile of scores in most grades, during the pandemic, more than 25% of scores fell below that cut in those same grades. Taken together, these figures illustrate that larger proportions of students fell into risk categories with more of them requiring intensive support during the pandemic than pre-pandemic. Thus, the relatively small magnitude of mean differences in the current findings masks a substantially increased demand for additional support, which placed an unprecedented strain on schools providing supports based on universal screening results.

Discussion

The COVID-19 global pandemic caused significant disruptions to education delivery. Understanding the depth and nature of differences in student outcomes associated with the pandemic is critical for equipping educators, policymakers, families, and other vested partners with the knowledge they need to serve students going forward. Using a national sample of oral reading fluency (ORF) scores, we compared the trajectories of student literacy development during the pandemic to that of students from the same schools prior to the pandemic.

In all grades studied, students (a) began fall 2020 (post-pandemic-onset) with lower average ORF scores, and (b) experienced smaller gains from the beginning (BOY) to the middle of the school year (MOY) than did their same-grade peers from the prior (i.e., pre-pandemic) year. Particularly striking is that although average differences between the cohorts were only 0.09-0.16 standard deviations apart at BOY, these gaps widened to a noteworthy 0.18-0.20

standard deviations by BOY (Cohen, 1992). Interestingly, of the fives grades analyzed, pandemic year first graders had the smallest BOY difference compared to their pre-pandemic peers (i.e., only 2.57 WCPM less on average) but demonstrated the lowest relative gains from BOY to MOY (i.e., the steepest decrement in the BOY to MOY slope) compared to pre-pandemic gains. One possible explanation for the small BOY difference is the floor effect evidenced by the wide bottom of the violin plot in Figure 2, which showed a clustering of students scoring at zero on the ORF measure at each timepoint. Floor effects may have artificially masked differences between the first-grade cohorts at the beginning of year, where differences became more apparent by the middle of the year. However, absolute differences between the cohorts were more pronounced for Grades 2-5, likely due, in part, to the weaker floor effect seen at the beginning of the year. For example, Grade 4 students showed the largest difference between cohorts, in which the pandemic cohort read an average of 6.29 WCPM fewer at BOY and 9.02 WCPM fewer at MOY. Additional potential explanations include that younger students may have had less access and ability to adapt to remote instruction and that they may have had less ability to practice reading independently than students in upper grades with already-established basic reading skills.

Linking Results to Meaningful Outcomes

A scientist-practitioner may wonder about the clinical significance of these results in the context of identifying and supporting literacy outcomes (e.g., serving students with dyslexia; Peterson & Pennington, 2012). In isolation, the national effects of a global disruption corresponding to an average difference of 10 WCPM or less may not appear clinically important, especially considering that many upper elementary students read more than 100 WCPM. However, these differences in ORF outcomes should be considered in context. Prior research identified cut scores associated with clinically significant differences in outcomes for students (Biancarosa et al., 2020; Gilbert et al., 2012). As shown in Figure 2, the median MOY ORF score for students experiencing the pandemic fell at or below the level that prior research has shown is indicative of a need for additional support in four out of the five studied grades. That is, not only did these students demonstrate lower average literacy skills and smaller gains than their peers from the pre-pandemic year, but these scores are also associated with significantly different outcomes. In essence, more students are demonstrating a greater need for support than in the prior year.

Looking more closely, the average pre-pandemic ORF scores were above the benchmark across timepoints in all grades. Thus, on average, students before the pandemic were likely to be achieving at grade-level. However, the landscape was different for students during the pandemic. By the middle of the year, the average ORF score for four of five grades was just at or below benchmark, indicating that half or more of students in these grades were at some risk and required strategic or intensive instructional supports. Notably, Grade 3 students are the cohort farthest below the benchmark on average. This result is troubling, as third grade typically marks the critical period in a student's educational career when the instructional emphasis shifts from learning reading skills to applying those skills to acquire new content knowledge (Chall, 1983; Stanovich, 2009). Thus, despite relatively small average differences between the pre-pandemic and pandemic years, these differences are likely associated with distinct, significant, and important shifts in the delivery of instruction to students.

Results in the Context of Instruction

Analysis of oral reading fluency scores during the pandemic compared to the year prior highlights the extent of widespread disruption to students' access to literacy-building opportunities. Observed learning trajectories suggest that the educational experience for students during the pandemic differed significantly compared to before the pandemic (pre-March 2020). Elementary students clearly made gains in their literacy acquisition amidst the pandemic, but because the current study does not examine instruction specifically, it is difficult to pinpoint the instructional factors that most impacted student learning during the 2020-21 school year. Still, we contend that because there is sufficient evidence pointing to ORF skill gain for a broad range of students, instruction in various forms can be a protective factor for literacy acquisition. Pointedly, research suggests that schools across the nation undertook substantial efforts to deliver instruction despite the circumstances and challenges (Hamilton & Ercikan, 2022). For example, teachers were tasked with adjusting to entirely novel instructional media requiring a skillset complemented by but disparate from in-person pedagogy (Gurley, 2018; Mari et al., 2021; Trust & Whalen, 2021). By and large, teachers were unprepared to deliver instruction remotely and required substantial support from their schools and districts to grow and enact these new skills (Archambault et al., 2016; Hamilton et al., 2020; Hartshorne et al., 2020; Huber & Helm, 2020; Kennedy & Ferdig, 2018; Lockee, 2021; Reimers & Schleicher, 2020; Shamir-Inbal & Blau, 2021), particularly at the elementary levels (Hvas & Aller, 2020; Jelińska & Paradowski, 2021).

In our view, these data suggest substantial educator resiliency and persistence during the pandemic, which resulted in demonstrable ORF gains despite lower average initial skill at the beginning of the 2020-2021 academic year in almost all grade levels. Despite professional and personal burdens, educators provided instruction and students grew at a greater rate than what has been observed during previous absolute disruptions to educational delivery, such as natural disasters or summer break. High-quality remote instruction may thus be able to foster similar levels of achievement as traditional instruction (Cavanaugh et al., 2004; Means et al., 2009), highlighting the importance of preparedness and expertise moving forward, particularly given ongoing threats to the availability of traditional in-person instruction.

Limitations

The current study inspires several areas for future research. The pandemic affected students, families, and communities differently, and exacerbated existing economic and social inequities (Martínez et al., 2021). To better describe the experiences of all students, future research should investigate the extent to which these results differ by student, family, and school-level characteristics. Further, these and other similar data are unlikely to be missing at random, as those educators who continued to collect and enter DIBELS data amid a pandemic likely prioritize assessment differently than those who did not. Similarly, students may have been missing for a wide range of reasons (e.g., students with more than one school ID in the sample, retained for the 2020-21 school year, schools that assessed outside the typical window, and students without a datapoint before and after the pandemic onset). Lastly, certain regions were over- or under-represented, simply due to the imbalanced distribution of data system use.

Thus, it is likely that the data presented here represent an upper bound for average ORF gains during the COVID-19 pandemic. Many students not represented in the data would be expected to perform more poorly than their represented peers, due to inadequate access to remote resources or instruction, inconsistent attendance, or significant disruptions in their educational context, leading to schools prioritizing other needs over universal screening. In fact, to speak beyond instruction, it is these challenges which have been heightened during the pandemic that may have impacted the ORF performance patterns seen in the current study. Future work should strive to understand the effect of the pandemic response for unassessed students and the relation of other contextual factors on students' learning.

The current study also utilized different "clocks" to estimate gains for students. Students in the sample were assessed across a relatively wide assessment window within a given time of year, which means that the number of instructional days between each assessment period likely varied substantially between students within and across schools. Some evidence suggests that disparities in quality of instruction were exacerbated during the pandemic (DeWitt, 2020; Read, 2020), meaning that the relative quality of instruction between assessment occasions likely also varied substantially. In particular, schools and teachers varied substantially in the extent to which they covered new content during the spring of 2020 (Hamilton et al., 2020) and the expedience with which they transitioned to remote instruction. One figure posits that only 54% of schools had successfully initiated remote instruction within two weeks of ending in-person instruction (Malkus & Christensen, 2020). Had dates corresponding to pandemic related school closures been readily available for the 1,684 schools in our sample, we likely would have opted for an alternative school year clock (e.g., weeks). rather than screening windows or trimesters. Importantly, the current study did not directly measure the classroom context or format of instruction (e.g., virtual, in-person, hybrid). Future research should seek to better understand and account for these differences in instructional context and dosage.

Finally, despite the relationship between early literacy skills, and especially ORF, to overall academic success, these data are but one indicator of the pandemic's effect on student learning. ORF data cannot capture the holistic growth of children, especially during a turbulent and traumatic experience such as a global health crisis. Thus, the magnitude of challenges facing students not represented in universal screening data throughout the pandemic onset may not be known for years, and future literacy outcomes (i.e., when current elementary students are in middle school) may better estimate differences in child skill development (e.g., chronic absenteeism, social withdrawal). Future research can serve our understanding of the effects on children's mental health, physical health, comprehensive skillsets, and lived experiences beyond early literacy skills.

Implications

It is clear now that the pandemic was not a one-time disruption experienced by schools and students in early 2020. Rather, the impact is cumulating, with no evidence by the middle of the 2020-2021 school year that a rebound was occurring. In fact, the effect size differences between students at the middle of the 2020-2021 schoolyear and their pre-pandemic peers are comparable to effect sizes most researchers would be heartened to see of an intervention program. In other words, these differences are stark, troubling, and should be monitored into the future. Importantly, the data presented here likely represent a best-case scenario due to discussed limitations, such as the inability to assess all students. Schools must anticipate serving a larger percentage of students who need intensive supports than they typically have. Systems that before the pandemic may have already found themselves strapped for resources to serve their students with intensive needs will be further strained to accommodate even greater numbers of students with greater needs. We must plan for substantially more students who are worse off than schools are used to serving.

The National Association of School Psychologists (2021) recommends that schools reestablish high-quality instruction, with a focus on comprehensive, class-wide supports to serve all learners. To do so, teachers will need continued support and training to differentiate instruction and serve diverse needs even as schools (presumedly) return to sustained in-person instruction. Educators at all levels should become familiar with the content and skills that they may typically assume are mastered in prior years. Formative assessments are a powerful tool in evaluating the extent to which this is true, and their continued use should inform the current and changing needs of students to allow for targeted instruction (Myung et al., 2020). Additionally, the pandemic prompted schools to create or strengthen family-school partnerships to reach home-bound students (Edge Research, 2020). Schools can strategically, but not unduly, provide access to students in need through wraparound mental health supports, targeted homework, computer-based interventions, or flipped instructional approaches.

Lastly, there is consensus among both policy- and decision-makers and, especially, principals (Hamilton et al., 2020), regarding the importance of prioritizing proactive planning for future school closures and other unseen emergencies to minimize disruptions to students. Having infrastructure and trained staff prepared to swiftly pivot to remote or asynchronous instruction has become a necessary part of the proactive planning process when considering the multitude of potential instructional disruptions in future (e.g., natural disasters, pandemic, extended periods of missed school). To recall an earlier metaphor, schools must make every effort to keep the faucet turned on, to ensure uninterrupted access to educational opportunities. One may even question the assumption that remote and hybrid instructional deliveries were simply stopgaps until the nation could generally and safely return to the presumed "ideal" pre-pandemic fully-in-classroom model. We are confident others are and should continue to explore alternative models of the pandemic impact, attending to how we can creatively increase equitable access and growth.

Conclusion

Amid widespread disruptions to typical life during the global health crisis caused by the COVID-19 pandemic, schools were forced to pivot to alternative instructional methods to educate children. Educators were tasked with continuing educational delivery without typical structure or supports, among those the information provided by student assessment data. The current study sought to estimate the change in learning trajectories associated with the pandemic. In Grades 1-5, students during the pandemic began the year demonstrating lower ORF rates. on average, and experienced lower gains by the middle of the year compared to their same-grade peers from the prior year. Interested parties are urged to consider and prepare to serve increased numbers of students at risk for reading difficulties, both now and in the coming years.

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Table 1

Sample Demographics

Characteristic	Study Sample (%)		National Sample (%)	
	Mean	*SD*	Mean	*SD*
Within-School Characteristics				
Gender				
Female	48.63	0.03	48.11	5.79
Race/Ethnicity				
American Indian/Alaskan Native	0.57	2.81	1.58	8.32
Asian	4.12	7.75	4.18	4.36
Black	17.08	27.30	14.68	23.13
Hispanic/Latino	34.87	34.41	24.73	27.01
Native Hawaiian/ Pacific Islander	0.24	1.40	0.36	2.38
Two or more races	3.91	3.88	4.71	4.36
White	39.20	35.60	49.76	32.85
Within-Sample Characteristics				
Title-I Eligible	85.12		78.53	
Charter	6.99		8.59	
Census Locale				
City	46.72		28.77	
Suburb	26.45		32.94	
Town	8.34		11.69	
Rural	17.48		26.60	
Census Division				
Midwest	14.02		24.94	
Northeast	18.19		15.93	
South	23.27		34.32	
West	44.52		24.81	

Note. The national sample represents all public schools in the Common Core of Data for the 2019-2020 school year that offer at least one grade between Grade 1 and Grade 5.

Table 2

Coding Scheme

Time	HYG (b_1)	Pandemic (b_2)	P-HYG (b_3)
1 (BOY 2019-2020)	0	0	0
2 (MOY 2019-2020)	1	0	0
3 (BOY 2020-2021)	1	1	0
4 (MOY 2020-2021)	1	1	1

Note. BOY = beginning of year; MOY = middle of year. Students that begin in kindergarten during Year 1 do not have data until Year 2. For this cohort, half-year gain increments from 0 to 1 at Time 3 and 4, respectively.

Table 3

Interpretation of Coefficients in the Model

Variable	Parameter	Variable description
Intercept	γ_{000}	The ORF score at the BOY in 2019-2020 for the average Grade 1 student in the average school
	r_{0ij}	Variability in BOY 2019-2020 between students nested in schools
	u_{00j}	Variability in BOY 2019-2020 between schools
Grade_2 … Grade_5	$\gamma_{100 \ldots 400}$	Difference in the intercept for average Grade 2 to 5 students compared to the average Grade 1 student in the average school
HYG	γ_{500}	Half-year gain in ORF between BOY and MOY in 2019-2020 for the average Grade 1 student in the average school
	r_{0ij}	Variability in half-year change in ORF in 2019-2020 between students nested in schools
	u_{00j}	Variability in half-year change in ORF in 2019-2020 between schools
Grade_2…Grade_5×HYG	$\gamma_{600 \ldots 900}$	Difference in half-year gain between BOY and MOY in 2019-2020 for average Grade 2 to 5 students compared to the average Grade 1 student in the average school
Pandemic	γ_{1000}	Average pandemic BOY difference from the 2019-2020 intercept for the average Grade 1 student in the average school
	r_{10ij}	Variability in pandemic BOY difference between students nested in schools
	u_{100j}	Variability in pandemic BOY difference between schools
Grade_2…Grade_5×Pandemic	$\gamma_{1100 \ldots 1400}$	Difference in the pandemic BOY difference for average Grade 2 to 5 students compared to the average Grade 1 student in the average school
P-HYG×Pandemic	γ_{1500}	Average pandemic half-year gain difference from the 2019-2020 half-year gain for the average Grade 1 student in the average school
Grade_2…Grade_5×P-HYG	$\gamma_{1600 \ldots 1900}$	Difference in the pandemic half-year gain difference from the 2019-2020 half-year gain for average Grade 2 to 5 students compared to the average Grade 1 student in the average school
Residual	e_{tij}	Error

Table 4

Accelerated Cohort Design

Cohort	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
Cohort K-1	Pandemic				
Cohort 1-2	Pre-Pandemic	Pandemic			
Cohort 2-3		Pre-Pandemic	Pandemic		
Cohort 3-4			Pre-Pandemic	Pandemic	
Cohort 4-5				Pre-Pandemic	Pandemic
Cohort 5-6					Pre-Pandemic

Note. K = kindergarten.

Table 5

Descriptive Statistics of Oral Reading Fluency

	Pre-Pandemic (2019-2020)				Pandemic (2020-2021)			
	BOY		MOY		BOY		MOY	
Grade	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*	*M* (*SD*)	*n*
	Students							
1	21.78 (28.04)	94,484	38.37 (35.51)	96,002	20.09 (29.16)	83,695	32.23 (35.72)	83,695
2	56.65 (36.23)	87,718	87.16 (43.25)	90,559	52.15 (37.13)	79,119	78.57 (44.21)	79,101
3	79.39 (40.25)	65,147	107.02 (41.97)	65,995	75.92 (40.03)	58,736	101.37 (42.08)	58,538
4	94.99 (38.35)	53,415	137.34 (49.80)	53,952	87.75 (37.10)	48,804	129.41 (48.07)	48,867
5	106.85 (39.33)	48,663	125.77 (37.67)	48,663	102.85 (38.56)	45,014	119.04 (37.66)	45,058
	Schools							
1	20.66 (10.31)	1,469	36.99 (14.01)	1,469	19.02 (11.32)	1,469	30.95 (14.72)	1,469
2	54.76 (15.00)	1,402	85.10 (17.88)	1,402	50.28 (15.90)	1,402	76.68 (18.81)	1,402
3	77.71 (16.34)	985	105.61 (16.62)	985	74.61 (16.29)	985	100.46 (16.94)	985
4	93.39 (15.27)	787	135.22 (19.57)	787	88.96 (14.70)	787	128.87 (18.72)	787
5	105.09 (16.16)	718	123.87 (14.99)	718	102.08 (15.47)	718	118.54 (14.59)	718

Note. BOY = beginning of year; MOY = middle of year.

Table 6

Results From Oral Reading Fluency (ORF) Pandemic Change Model

Fixed effects	Coefficient	*SE*	*t*
Intercept, γ_{000}	20.76	0.31	66.84
Grade_2, γ_{100}	34.68	0.18	196.96
Grade_3, γ_{200}	57.92	0.20	291.95
Grade_4, γ_{300}	74.03	0.21	350.99
Grade_5, γ_{400}	85.35	0.21	408.90
HYG, γ_{500}	16.77	0.12	140.76
HYG × Grade_2, γ_{600}	13.77	0.10	132.43
HYG × Grade_3, γ_{700}	11.17	0.12	95.32
HYG × Grade_4, γ_{800}	25.56	0.12	205.61
HYG × Grade_5, γ_{900}	1.61	0.12	13.00
Pandemic, γ_{1000}	-19.33	0.21	-92.19
Pandemic × Grade_2, γ_{1100}	-15.79	0.30	-51.88
Pandemic × Grade_3, γ_{1200}	-13.71	0.28	-48.79
Pandemic × Grade_4, γ_{1300}	-29.28	0.30	-98.65
Pandemic × Grade_5, γ_{1400}	-3.64	0.30	-12.13
P-HYG, γ_{1500}	12.08	0.06	192.32
P-HYG × Grade_2, γ_{1600}	14.38	0.09	153.69
P-HYG × Grade_3, γ_{1700}	13.39	0.10	130.91
P-HYG × Grade_4, γ_{1800}	27.51	0.11	253.87
P-HYG × Grade_5, γ_{1900}	4.20	0.11	37.91
Random Effects	Variance	*SD*	
Student intercept, u_{00j}	1015.30	31.86	
Student slopes			
HYG, u_{50j}	52.28	7.37	
Pandemic, u_{100j}	162.72	12.76	
School intercept, r_{0ij}	131.17	11.45	
School slopes			
HYG, r_{5ij}	13.83	3.72	
Pandemic, r_{10ij}	19.80	4.45	
Residual	166.48	12.90	

Note. HYG = half-year gain; P-HYG = pandemic half-year gain. All coefficients significant at $p < .001$.

Table 7

Comparison of Pre-pandemic and Pandemic Model-Estimated ORF Scores with Estimated Average Differences between Pandemic and Pre-pandemic and Effect Sizes

Year	Time	Cumulating coefficients	Score	Difference	ES
		Grade 1			
2019-20	Beginning	γ_{000}	20.76		
	Middle	$+\gamma_{500}$	37.53		
2020-21	Beginning	$+\gamma_{1000}$	18.19	-2.57	-0.09
	Middle	$+\gamma_{1500}$	30.27	-7.25	-0.20
		Grade 2			
2019-20	Beginning	$\gamma_{000} + \gamma_{100}$	55.44		
	Middle	$+\gamma_{500} + \gamma_{600}$	85.98		
2020-21	Beginning	$+\gamma_{1000} + \gamma_{1100}$	50.86	-4.58	-0.13
	Middle	$+\gamma_{1500} + \gamma_{1600}$	77.32	-8.66	-0.20
		Grade 3			
2019-20	Beginning	$\gamma_{000} + \gamma_{200}$	78.68		
	Middle	$+\gamma_{500} + \gamma_{700}$	106.61		
2020-21	Beginning	$+\gamma_{1000} + \gamma_{1200}$	73.57	-5.11	-0.13
	Middle	$+\gamma_{1500} + \gamma_{1700}$	99.04	-7.57	-0.18
		Grade 4			
2019-20	Beginning	$\gamma_{000} + \gamma_{300}$	94.79		
	Middle	$+\gamma_{500} + \gamma_{800}$	137.12		
2020-21	Beginning	$+\gamma_{1000} + \gamma_{1300}$	88.50	-6.29	-0.16
	Middle	$+\gamma_{1500} + \gamma_{1800}$	128.10	-9.02	-0.18
		Grade 5			
2019-20	Beginning	$\gamma_{000} + \gamma_{400}$	106.11		
	Middle	$+\gamma_{500} + \gamma_{900}$	124.49		
2020-21	Beginning	$+\gamma_{1000} + \gamma_{1400}$	101.51	-4.60	-0.12
	Middle	$+\gamma_{1500} + \gamma_{1900}$	117.80	-6.69	-0.18

Figure 1

Consort Diagram Depicting Changes in Sample Size at Each Step of the Filtering Process

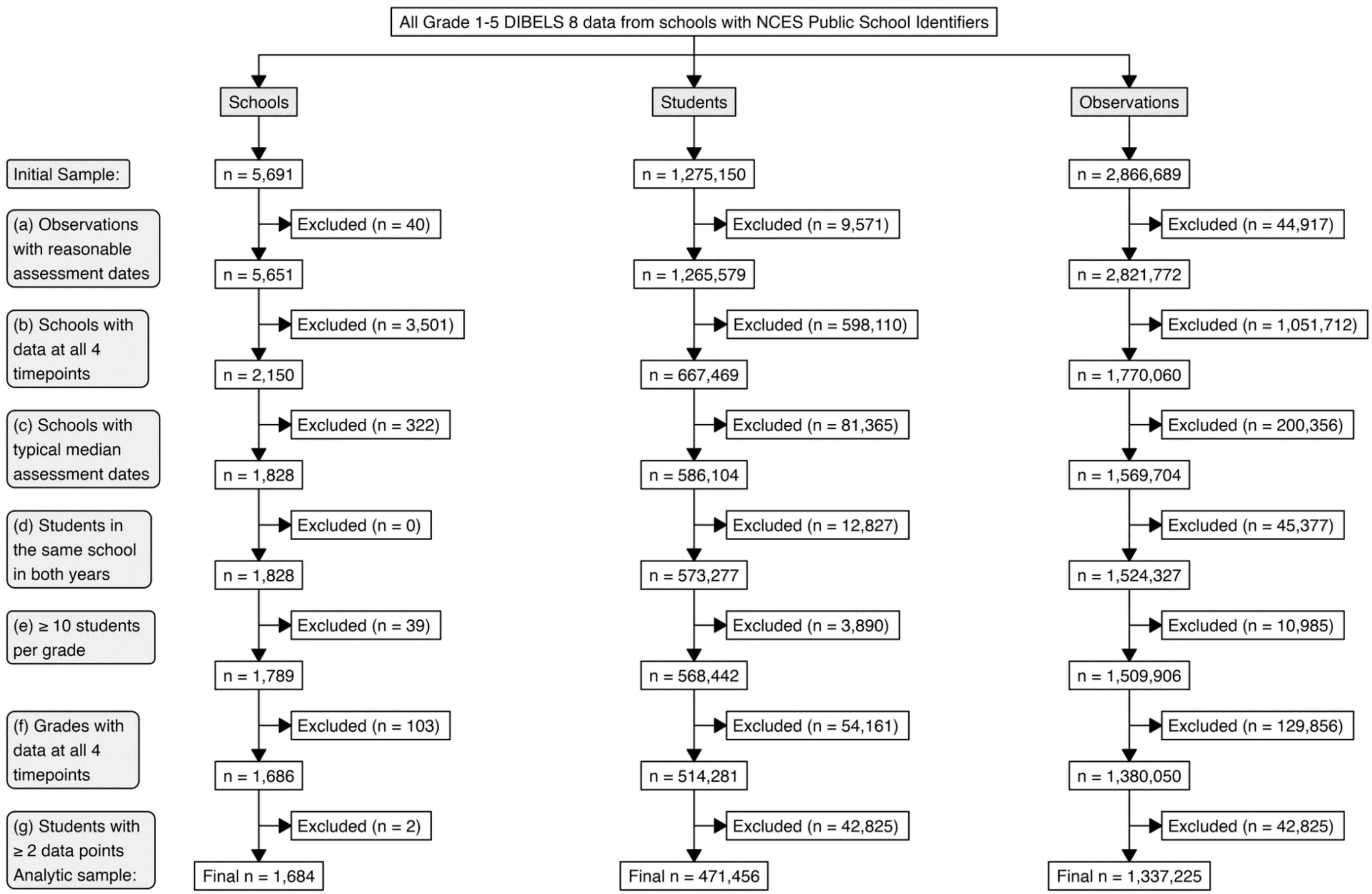
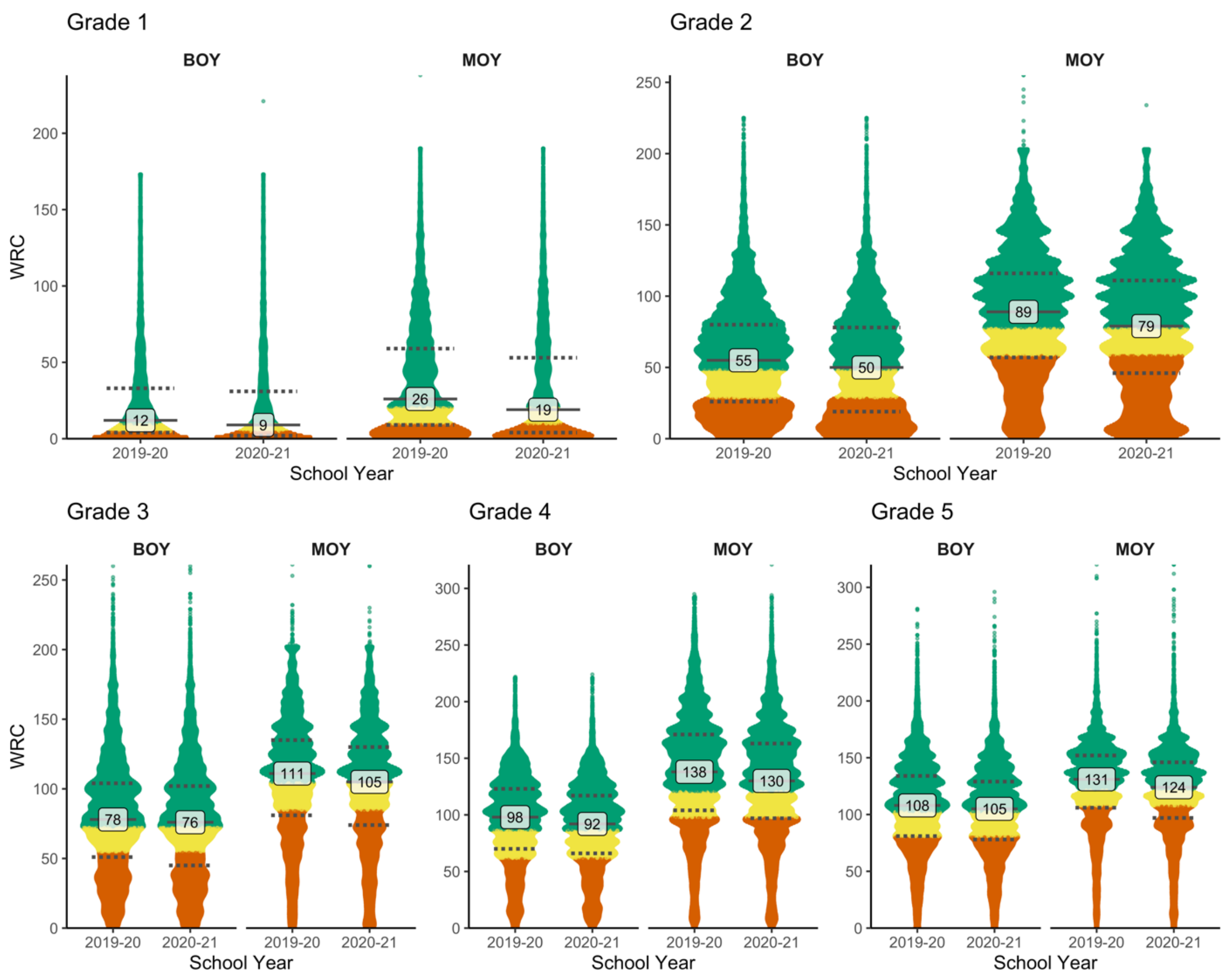


Figure 2

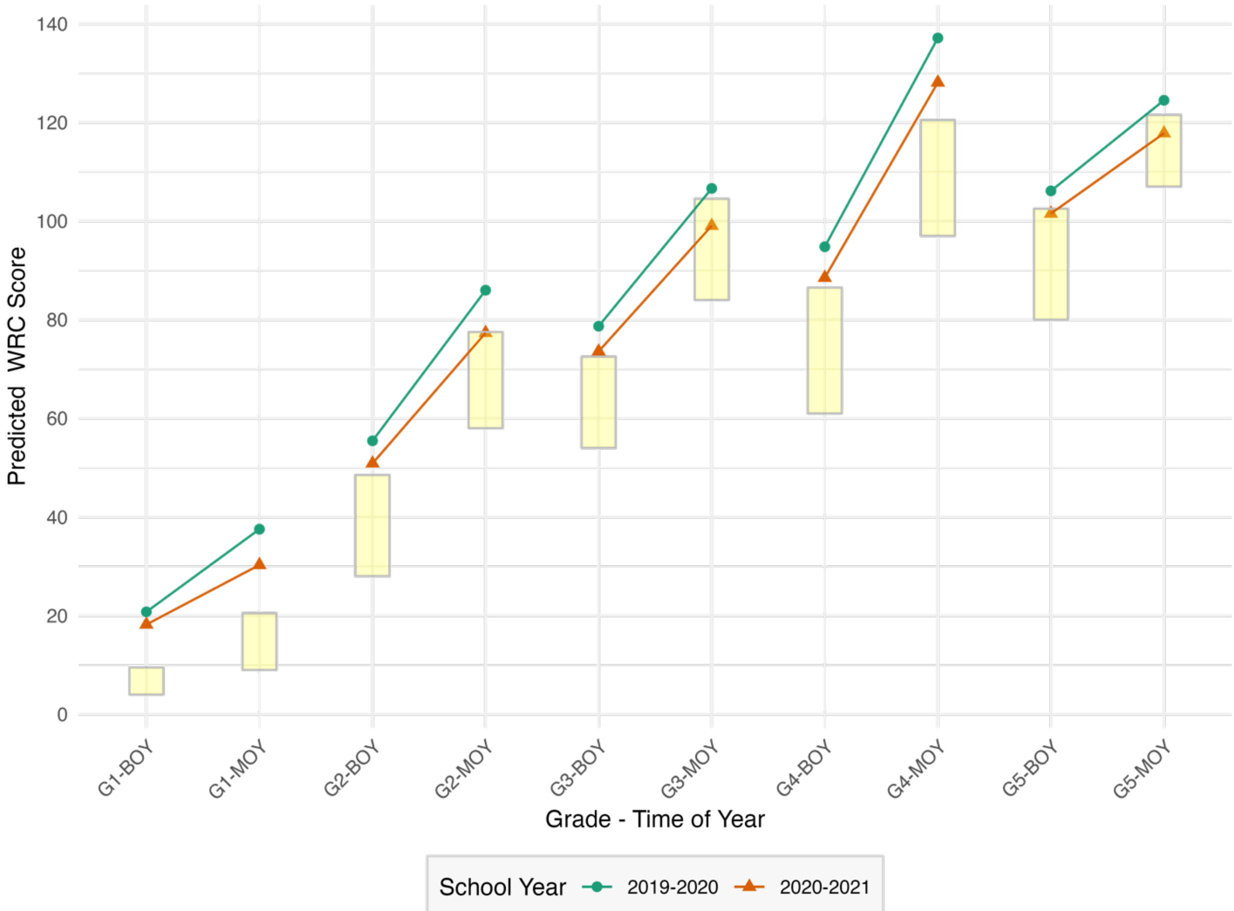
Distribution of Performance Distributions Across Grades, School Year, and Time of Year



Note. BOY = beginning of year; MOY = middle of year; WRC = words read correct. Figure depicts the distributions of scores by representing each observation in the dataset. Distributions vary in width based on the number of observations at a particular score. Labeled lines represent the median and dotted lines represent the 25th and 75th percentiles. Red represents the DIBELS 8th Edition range for students needing intensive support, yellow represents strategic support, and green represents core support.

Figure 3

Model Implied Reading Trajectories



Note. Yellow regions represent the DIBELS 8th Edition range for students in need of strategic support.