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Access, Digital Writing, and Achievement

The Data in Two Diverse School Districts

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Abstract: Students must compose texts using keyboards for college and career success. This study focuses on writing done in two school districts by students in Grades 4-11 on Google Docs to understand the relationships among digital device access, digital writing time, and standardized English language arts assessment scores. Our data cover three academic years: 2014-15, 2015-16, and 2016-17. We describe the amount of time spent writing in this mode and how it changed over grade levels and the relationship between Google Docs writing time and access to digital devices. Using fixed-effects regression, the amount of time spent writing digitally increased significantly during this time. Males and English learners spent fewer minutes writing in Google Docs compared to females and fluent English speakers. Students of color tended to spend more time writing in this mode than our White students. Device density (the number of school-provided digital devices per student) predicted the number of writing minutes in the first two, but not the third, years of our data. This study increases our foundational knowledge about the time spent by students on writing in this modality during a time in which these districts began to significantly adopt digital technology.

Keywords: writing, digital writing, writing analytics, technology, secondary students

Writing is a necessary skill whether a person is headed to college or the workforce (Benjamin & Wagner, 2021; Brandt, 2015; Graham, Bollinger, et al., 2012); writing continues across a person's lifespan (Bazerman et al., 2018), and the inability to write and write well can limit academic, occupational, and personal attainment (Graham, 2019). While K-12 schools should be providing the necessary instruction on this skill, there is evidence that there is insufficient time spent either instructing students on writing or providing students with writing opportunities. Finding research-based support for this statement is challenging at a national level, however, because so little has been done to quantify the instructional time spent on writing in the decade since Applebee and Langer's seminal 2011 study (see the call for proposals by the Institute of Education Sciences [IES] National Center for Education Research [2021] noting this lack of writing research).

The most recent nationwide measure of middle and high school teachers in the U.S. reports a total of less than 30 minutes a day is spent by students writing, across all subjects, with the actual observed practice significantly less than that at 7.7% of class time (Applebee & Langer 2011; Graham et al., 2014). While the quantitative causal data are limited, there is evidence that extra instructional writing time leads to improved writing quality compared to those without additional time (Graham, Bollinger, et al., 2012; Graham et al., 2015). The IES What Works Clearinghouse panel recommended a minimum of 1 hour each day devoted to writing, including at least 30 minutes of instruction time and 30 minutes of writing practice (Graham, McKeown, et al., 2012). However, the majority of teachers studied across 28 studies reveal the typical teacher devoted much less time to writing (Graham, 2019). Unfortunately, writing has been comparatively neglected in K-12 classes as schools focus on reading, math, and science to prepare their students for high-stakes standardized tests in those subjects (see discussion in Miller & McCardle, 2011).

Writing is a critical, lifelong skill that is not being given sufficient instructional time in U.S. K-12 schools. This study increases our foundational knowledge about the actual time spent by students on writing in one modality, Google Docs, at a time when these districts were rolling out significant adoption of digital technology. We specifically look at digital writing (in this case, on Google Docs) because the data can be accessed without self-reporting of time by teachers or students, which allows us to provide data that can then be triangulated with other studies that are based on interviews, surveys, and a handful of classroom observations.

This study focuses on writing done in two school districts by students in Grades 4-11on Google Docs to understand the relationships among digital device access, time spent writing in Google Docs, and standardized English language arts (ELA) assessment scores. Our data cover three academic years: 2014-15, 2015-16, and 2016-17. To understand how much time is spent on digital writing, as well as to examine some of the possible factors that lead to more or less time writing, we describe the amount of time spent writing in this mode and how it changes over grade levels, and we explore the relationship between Google Docs writing time, and access to digital devices. Unlike most prior studies involving focused interventions that introduce digital devices into specific classes for a specific period, this research advances the field by looking across two entire districts, over multiple grade levels, including all schools and teachers, for multiple years. We also look at student achievement on pre-existing standardized assessments as one of our measures, rather than researcher-designed assessments that are generally more closely aligned to the specific intervention. The standardized ELA assessments provide a window into achievement on standardized assessments often used by schools, districts, and states to drive decisions on instructional goals and resources, relative perceived quality of schools (even impacting housing prices to a modest extent; Kane et al., 2006; see also Reardon et al., 2019), and a perceived objective understanding of students' literacy skills. Indeed, with respect to racial and ethnic differences which cannot be attributed to racial differences in academic potential, "differences in average test scores must be understood to represent local racial differences in the average availability of opportunities to learn the tested material" (Reardon et al., 2019, p. 1166). This paper gives us a window into the opportunities students have in these two districts to engage in digital writing for school.

Literature Review

The majority of U.S. students are not strong writers as measured by standardized assessments, and students of color are particularly challenged (Miller & McCardle, 2011). The most recent national quality measure of how well U.S. K-12 students write is the 2011 National Assessment of Educational Progress (NAEP). (The 2017 assessment has faced measurement challenges and not been released). There is no international assessment of students' writing like there is for reading, math, science, and even collaborative problem solving (Organisation for Economic Co-operation and Development, 2021). State-reported proficiency rates have gaps and cannot be meaningfully compared across states, grades, subjects, and years because of the difference in assessments and standards (Reardon et al., 2019). This lack of a clear picture of the problem exacerbates the difficulty of attempting to improve students' writing (Graham et al., 2021). The 2011 NAEP assessment showed a serious lack of achievement in writing as measured by the content area and measurement experts constructing the underlying writing framework. We have no reason to believe writing achievement has improved, particularly given the relationship between reading and writing and poor reading scores in recent years (National Center for Education Statistics [NCES], 2012). Our district-level results, described below, are consistent with national concerns.

Results from the National Assessment of Educational Progress in writing (NCES, 2012) indicate that during the time of our study students faced considerable challenges in meeting writing standards. Nationally, only 27% of 8th graders and 18% of 12th graders scored at the proficient level or above in writing. Further, large disparities exist between the performance of White (35% proficient), Hispanic (11% proficient), and Black (9% proficient) students. Male scores (on average 140 scaled score) are notably lower than female scores (160), with 27% of male students below basic proficiency compared to 12% of females and 16% of male students proficient compared to 32% of female students. Most alarming is that only 1% of English learners (ELs) at both Grades 8 and 12 scored at proficient or above in writing. Students remain underprepared as writers in post-secondary school and their careers (Miller & McCardle, 2011).

For purposes of this article, we adopt a broad definition of digital writing to "encompass all forms of communication, expression and creativity taking place through, on or with digital technologies and digital platforms"—in this case, the platform of Google Docs (Pandya & Sefton-Green, 2021, p. 113). We believe that time spent writing in Google Docs is a rough proxy for time spent digitally writing for school. Google Docs is also practically relevant; by 2017, more than half of the K-12 students in the U.S. used these Google Apps (Singer, 2017), and in 2018, 60% of all laptops and tablets purchased for U.S. K-12 classrooms were Chromebooks that include Google Apps (Leswing, 2019). Google Docs, in particular, is widely used in schools and is the predominant word processing tool we have encountered in our research with K-12 students. This article examines time spent by students writing on Google Docs in the course of their standard curriculum. Although it is possible that students did additional digital writing using other word processing applications, other applications (e.g., Microsoft Word) often carry additional cost, and our prior work has found teachers tend to stick to a single word processing application for convenience. According to our districts, the bulk of digital writing during the time of the study was done on Google Docs. While occasional writing may have been done in other applications, most digital writing of any length was done in the Google Docs application, and while most of the writing is likely to be traditional text-based, the Google Docs platform allows for multimodal expressions as well.

New technologies present new cognitive challenges and opportunities (Bazerman, 2011; Leu et al., 2015) that students and teachers need to address. Practice negotiating the use of the tools and marshalling them for the purpose of writing leads to improved writing achievement (Kim & Schatschneider, 2017). Writing achievement can be measured a number of ways—writing fluency (quantity), holistic determinations of writing quality, and standardized writing assessments. An early meta-analysis by Bangert-Drowns (1993) found an average effect size of 0.52 for word processing on length of composition; in other words, students wrote more digitally than by hand. The use of word processing for writing instruction had an effect size of 0.47 on the quality of students' writing as well (Graham, McKeown, et al., 2012). The IES Practice Guide (Graham, Bollinger, et al., 2012) specifically calls for students to be taught how to write with digital tools, but digital technology has not been an integral part of most writing instruction in schools during the last decade (Graham, 2019). However, digital tools have a number of advantages over writing by hand, including the ability to easily revise text, legibility, and access to tools like spelling checkers. A meta-analysis found the increased use of word processing as a tool for composing predicted improved writing quality in students in Grades 1-8 in 83% of studies, with the greatest positive impact found in the higher grades (Graham et al., 2015). In addition, digital writing is authentic and a relevant skill as students move beyond K-12 settings. Most writing in college and in the workforce is done digitally (Bruce et al., 1985; Graham et al., 2016). Thus, students need to successfully write digitally in order to access college and career options (Applebee, 2011; Graham, 2012; Leu et al., 2015) and succeed on the high-stakes assessments that are migrating to computer-based formats (e.g., Smarter Balanced and PARCC assessments of the Common Core State Standards and the GRE). Students need to be prepared for these evolving digital literacy practices (Graham, Bollinger, et al., 2012; Graham et al., 2016).

Looking at the impact of digital writing practice and general ELA assessment results, researchers have seen that prior exposure to computers predicted writing performance in the NAEP computer-based writing pilot studies (Horkay et al., 2006; Sandene et al., 2005; White et al., 2015; Zhang et al., 2016). Students reporting more frequent digital writing for school had higher writing achievement scores on the 2011 National Assessment of Educational Progress (Tate et al., 2016, 2019), with student reports of prior computer use predicting both students' writing quality directly and indirectly through the number of keypresses during the test. Interestingly, prior computer use for writing predicted achievement even on non-computer-based assessments. O'Dwyer et al. (2005) found students who reported greater frequency of technology use at school to edit papers had higher total ELA test scores and higher writing scores on the Massachusetts Comprehensive Assessment System, a paper- and pencil-based test.

Tate et al. (2019) and O'Dwyer et al.'s (2005) work suggests the importance of digital writing practice goes beyond simple word processing practice, and the skills of composing digitally are of additional value. The writing process is different when done digitally, with affordances such as the speed of production, the legibility of production, and the ability to edit and use tools such as grammar and spell check all impacting the process and eventual product of digital writing (Cochran-Smith, 1991; Daiute, 1986; MacArthur, 1999; McCutchen, 1996). Even the social context of writing can be different digitally—Google Docs, for example, is a simple tool for collaborative writing, and typed text is easier to share with peers and teachers.

Research Questions

This study focuses on students in Grades 4-11 in each of three academic years (2014-15, 2015-16, 2016-17). We begin at fourth grade because instructional focus transitions to learning content areas, rather than developing foundational literacy skills, at this point. Academic demands increase significantly beginning in fourth grade, with a greater emphasis on more complex language and text structures (Carnegie Council on Advancing Adolescent Literacy, 2010; Chall, 1996; Porter et al., 2011); writing also focuses on the use of academic registers of English (Bailey et al., 2007; Scarcella, 2003; Schleppegrell, 2001, 2004; Zwiers, 2006, 2007). Furthermore, students at this age generally use digital word processing sufficiently well for it to be a useful communication tool and typically experience no serious difficulties keyboarding (White et al., 2015). In addition, students face declining motivation during this time (Eccles & Midgley, 1990; Wang & Pomerantz, 2009; Wigfield & Eccles, 2000) and may benefit from the potentially engaging digital technology.

Two school districts—one predominantly White and one predominantly Hispanic—provided us access to these data and student demographic information, state test scores, and information on distribution and use of digital devices. Hapara Analytics provided assistance in gathering the student writing data from the districts' Google domains. The diversity in our districts was of interest because it enabled us to look at historically underperforming groups (English learners and Hispanic students) and those tending to report higher writing achievement (English-only students and White students). The latest reported national scores show White students with a scaled score of 158 compared to Hispanic student scores of 136 (Hispanic B = -.26 [.01]). Even more dramatic, English learners' average scaled score was 108 compared to 152 (not English learner B = .27 [.01]), which is, in each case, significantly different ($p < .05$) (NCES, 2012).

This study draws on data gathered from the Google domain history of students in Grades 4-11 across three academic years to address the following questions:

1. How much time do students spend writing digitally? How does time spent writing digitally change over time (both year-to-year and by grade level)?
2. Does the time spent writing digitally relate to device access?
3. How does time spent writing digitally relate to achievement on standardized English language arts assessments for this population?

Method

Population

We were given access to data by two districts in the southwest United States (SUD) and in the Midwest (MSD). SUD had more than 55,000 students, with over 40% English learners, and more than 90% Hispanic who qualified for free or reduced-price lunch programs. One of the largest districts in the region, over 40% of its students did not meet state ELA proficiency standards, and during the period of the study, it had a dropout rate of over 5%, with about 50% of its students meeting the state's 4-year college enrollment requirements. MSD was also one of the largest school districts in its region with over 40,000 students, but its population was quite different, with only 8% English learners and 13% Hispanic students, and less than half of the students qualifying for free or reduced lunch. MSD has a 4-year graduation rate of 84%, and approximately 90% of its students graduate within 7 years. State assessment scores exceeded the state mean in ELA for Grades 3-8 with 54%–65% of the students scoring proficient. SUD has an annual budget of approximately $483 million ($8,780/student) and MSD of $459 million ($11,450/student). SUD had 35 elementary, nine intermediate, and seven high schools; MSD had 39 elementary, 12 intermediate, and six high schools. Additional descriptive information about the students in our sample (Grades 4-11 only in traditional schools) and in the overall district is set forth in Table 1.

Table 1

Selected Demographics for All Grades and Analytic Sample

Demographics	SUD		MSD	
	Analytic sample	Population (All grades)	Analytic sample	Population (All grades)
Total students	28,200	54,500	16,600	39,400
Male	50%	50%	51%	51%
English learners	32%	40%	5%	8%
Free/reduced lunch	93%	87%		46%
Hispanic/Latino		93%		13%

Note. District numbers rounded to preserve anonymity. Some demographics (e.g., ethnicity) were not provided by either district for privacy reasons.

Only students in Grades 4-8 and 11 had annual state assessment scores in SUD, so for this analysis, our sample was limited to these grades. Similarly, MSD reading assessment results were limited to Grades 3-8 and 11 and writing to Grades 4, 8, and 11. The districts were not only different in their populations, but in their implementation of digital technology. SUD increased the number of digital devices per student over time as funding permitted, moving from computer labs to mobile classroom carts to classroom sets of devices over the 3 years of the study. MSD used the funds from a technology bond to roll out a one-device-per-student plan ("1:1 plan") over 3 years, from 2014 to 2017, across the entire districts in a coordinated fashion.

Data Source

Hapara (www.hapara.com), an educational technology company focused on providing instructional management tools for K-12 educators and administrators, has developed a tool that analyzes usage of Google Apps for Education and Microsoft Office Education 365. Hapara accessed students' Google school accounts using anonymous identifiers and analyzed the time stamps (not the content) for all students' written work on the school domain. This writing was pre-existing and created as part of the standard curriculum. Student writing and other district data were shared with researchers on a de-identified basis and in accordance with FERPA regulations.

Variables

Variables used in the analysis were in four categories: student demographic information, access to digital technology, digital writing time, and ELA assessment scores. Students' demographic information included gender, grade level, school, free/reduced lunch status (SUD only), English language status, qualification for special education, students of color (MSD only, although almost all SUD students are Hispanic), and identification as gifted/talented. Research has shown these demographics relate to both amount and quality of student writing (e.g., Ball, 2006; Fitzgerald, 2006; NCES, 2012; Peterson, 2006; Troia, 2006).

In the case of SUD, access to digital technology consisted of the number of digital devices in the school as shown in the district's records divided by the school enrollment. For MSD, we created a technology variable that indicated the number of years in which the 1:1 plan was implemented (0 = *not implemented*, 1 = *first year of roll out*, 2 = *second year*, etc.). Because a technology implementation is done over time and teachers and students require time to acclimate and successfully use the technology, we would expect the impact of increased access to be higher in Year 2 and subsequent years (see discussion in Warschauer, 2011). We did not have 1:1 implementation details for the high school students, so we indicate their data as missing the first year of the roll out and as in their second year of the roll out from Year 2 on. We did not have information about the nature of student digital access outside of school hours.

Digital writing time is the time a student spent actively writing (including keyboarding and using digital tools like spell check) on a Google Doc during school hours. Note that while we also had information on student digital writing outside of the school day, the data showed extremely limited usage and thus provided little information for our analyses. In addition, we did not have data on students' access to digital technology (hardware, internet, or social resources) outside of school hours and decided to limit our analyses to the time during which we had information about such access.

For our writing achievement measure, we used the relevant state ELA assessment given during the applicable period. After the adoption of the Common Core in many states, researchers have found that three major types of state-level writing assessments have been adopted: multiple-choice tests, traditional on-demand essay assessment, and portfolio assessment (Behizadeh & Pang, 2016). These assessments generally call for students to write from limited sources or general knowledge, with few prompts referencing a truly authentic audience or realistic genre (Graham, 2019). The students in our sample took the state assessments described below, consisting of both multiple-choice sections and short on-demand writing texts. These assessments are limited by the time allotted, type of questions, and writing required as to what they can tell us about students' writing abilities, but because of their use in the educational structure and systems (e.g., for identifying underperforming schools), they are one available data point in the writing our students are able to do (see CCCC Committee on Assessment, 2014).

Student achievement data for SUD consisted of student performance on state assessments for grade-level achievement (Grades 4-8 and 11) on the Common Core State Standards for English Language Arts, specifically the scale score overall in reading, writing, listening and speaking, and research/inquiry. Scale scores were used to provide a common reference over the years. Student achievement data for MSD consisted of annual state assessments in reading (Grades 3-8 and 11) and writing (Grades 4, 8, and 11). Unfortunately, no overall ELA score was available in MSD, and the state assessments changed multiple times over the period for which we have writing data. The scores used were the scale scores with values of 0-200 for reading and 0-70 for writing. While the value of looking at writing scores is obvious, we did not have multiple years of the writing assessment for individual students. Reading scores were considered worth investigating due to the known reading-writing connection (Fitzgerald & Shanahan, 2000).

This study was conducted pursuant to the University of California, Irvine Institutional Review Board, Protocol Number 2017-3534.

Data Analysis

How Much Time Do Students Spend Writing Digitally? How Does Time Spent Writing Digitally Change Over Time?

We began by generating descriptive data of students' digital writing over the course of a school year to answer our first question, "How much time do students spend writing digitally?" We looked at overall data, as well as data by school (for SUD, where the technology implementation was less systematic) and grade level, for multiple school years for trends over time.

Does the Time Spent Writing Digitally Relate to Device Access?

To determine the relationship between device access and time spent writing digitally in SUD, we used fixed effects regression. In MSD, we did not have device number/school, so we instead looked at how many years they had been at one device per student.

Fixed effects models, at the school level, allowed us to remove school-level unidentified confounding variables. Our formula was:

$$\text{WritingTime} = \beta 1 + \beta 2\text{DevicesPerStudent} + \beta 3\text{dmale} + \beta 4\text{dlep} + \beta 5\text{dGate} + \beta 6\text{dSPED} + \beta 7\text{dFrl} + \beta 8\text{dgrade} + \beta 9\text{-xSchool} + \varepsilon$$

where DevicesPerStudent indicates the number of digital devices of any type available at the school during the applicable year divided by the total student enrollment of the school in the case of SUD, or years since the grade/school had been one device per student for MSD; dmale is a dichotomous variable for male students; dlep indicates students with limited English proficiency; dGate indicates students identified as gifted; dSPED indicates students with IEPs (special education services); dFrl identifies students receiving free or reduced lunch; dgrade indicates the current grade level of the student; and School indicates the school in which the student is enrolled during the academic year. In MSD, we also had an indication for students of color (i.e., African American, Hispanic, Native American, or Asian American). We checked for interactions between devices per student and student demographic variables to understand if the density of devices impacted the writing time of specific demographic groups differently.

How Does Time Spent Writing Digitally Relate to Achievement on Standardized English Language Arts Assessments for This Population?

To answer our final question, we began by again using a fixed effects regression with clustered standard errors at the school level to model the following for students with achievement scores:

$$\text{ELA Achievement} = \beta 1 + \beta 2\text{WritingTime} + \beta 3\text{dmale} + \beta 4\text{dlep} + \beta 5\text{dGate} + \beta 6\text{dSPED} + \beta 7\text{dFrl} + \beta 8\text{dgrade} + \beta 9\text{-xSchool} + \varepsilon$$

where the amount of digital writing time was substituted for devices per student to predict (a) overall ELA achievement on the annual state assessment in the case of SUD and (b) reading scores and writing scores in the case of MSD. Standard errors were clustered at the class level to account for the non-random assignment of students to classes. Although hierarchical linear modeling (HLM) was considered, a fixed effects regression with clustered standard errors makes a smaller number of assumptions and produces results that are equally reliable as obtained from HLM. In particular, the clustered standard errors methodology is preferred over HLM when, as is the case here, the goals of the study do not involve a decomposition of the residual variance within and between aggregate units (McNeish et al., 2017). Once again, we checked for interactions with our demographic controls to look for heterogeneity.

Table 2
SUD Annual Writing Minutes

Percentile	School year			
	2014-15	2015-16	2016-17	2017-18
1%	0	0	0	0
5%	0	0	0	0
10%	0	0	0	22.82
25%	0	.08	55.73	108.75
50%	0	100.62	194.25	264.60
75%	61.9	282.05	404.42	547.62
90%	172.78	557.58	699.10	933.67
95%	256.13	785.43	935.57	1,230.68
99%	460.18	1,286.37	1,562.83	1,897.08

Results

Descriptive

Annual Writing Time

In the 2014-2015 school year, most students in the SUD did no digital writing for school, increasing to 100.62 minutes for the 50th percentile in 2015-2016, 194.25 minutes in 2016-2017, and 264.60 in 2017-2018 (see Table 2).

MSD students did no digital writing until the 2015-2016 school year, the beginning of the 1:1 plan rollout, when the 50th percentile wrote digitally for 69.42 minutes, increasing to 224.94 minutes the following year when all students had access to a digital device (see Table 3).

Table 3
MSD Annual Writing Minutes

Percentile	School year				
	2012-13	2013-14	2014-15	2015-16	2016-17
1%	0	0	0	0	0
5%	0	0	0	0	0
10%	0	0	0	0	0
25%	0	0	0	0	1.81
50%	0	0	0	69.42	224.94
75%	1.54	39.23	133.33	338.16	620.43
90%	120.35	210.87	321.68	691.80	1,095.13
95%	215.07	312.62	455.03	1,009.73	1,433.28
99%	424.23	567.98	868.35	1,789.12	2,223.67

We also saw differences in annual writing time by grade level (see Table 4 for SUD and Table 5 for MSD). In both districts, we saw statistically significant grade-level differences. Although minutes spent in each grade level generally increased over the 3 years of the study, we see that in SUD sixth and seventh grades, the minutes slightly declined between 2015-2016 and 2016-2017.

Table 4
SUD Annual Writing Minutes by Grade Level, 50th Percentile

Level	2014-15	2015-16	2016-17
Grade 4	0	45.21	143.13
Grade 5	0	134.38	174.78
Grade 6	34.95	197.23	192
Grade 7	37.45	220.18	196.62
Grade 8	49.17	197.03	314.63
Grade 9	50.17	164.87	287.64
Grade 10	13.01	121.40	238.12
Grade 11	0.01	67.56	308.58

Table 5
MSD Annual Writing Minutes by Grade Level, 50th Percentile

Level	2014-15	2015-16	2016-17
Grade 4	28.42	102.33	196.71
Grade 5	40.18	161.22	319.97
Grade 6	284.08	883.97	844.67
Grade 7	225.67	305.08	791.27
Grade 8	206.89	298.18	329.38
Grade 9	195.55	299.93	523.98
Grade 10	208.01	302.34	435.50
Grade 11	121.66	505.78	638.47

Table 6

Device Density in SUD at the 50th Percentile by Grade Level

Level	2014-15	2015-16	2016-17
Grade 4	0.20	0.58	1.16
Grade 5	0.20	0.59	0.76
Grade 6	1.04	1.86	1.98
Grade 7	1.04	1.86	1.98
Grade 8	1.04	1.41	1.98
Grade 9	0.23	0.79	1.24
Grade 10	0.23	0.79	1.43
Grade 11	0.32	0.68	1.24

Some of the increase in minutes for SUD also likely reflect access to digital devices over time, as shown in Table 6.

Correlations Between Writing Time and Other Variables

Focusing first on the data from SUD, as expected, the writing minutes were highly correlated with each other (e.g., 2014 and 2015, .35*; see Table 7), ELA scores for each year were highly correlated with one another (e.g., ELA 2015 and 2014, .79*), and male and free/reduced lunch status was somewhat negatively correlated with writing minutes and ELA scores. More central to our questions, the device density and writing minutes correlations were positive but modest, and the density and ELA score correlations were similar.

Figures 1, 2, and 3)below show the scatterplots for 2014-2015, 2015-2016, and 2016-2017 minutes of digital writing (y-axis) and ELA assessment scores (x-axis) in SUD.

Figures 4 and 5 shows the scatterplots in MSD for reading and writing achievement in the 2015-2016 and 2016-2017 school years.

Focusing on MSD, we ran correlations with either the 2015 or the 2016 writing assessments because students were not tested in concurrent years. In addition, because the 1:1 implementations were done in large groups, the correlations for these indicator variables were not useful. We saw similar correlations to those in SUD, as shown above, with writing showing more of a correlation with writing minutes than reading, as would be expected.

To get a sense of the variation between schools in digital writing minutes, we looked at the 50th percentile each year for each SUD school, separating them into elementary, middle, and high schools. As Figures 6, 7, and 8 illustrate, there was large variation in digital writing minutes between schools, even at the same level (e.g., elementary).

Figures 9, 10, and 11 illustrate the variation in devices per student during the same periods at each level.

Table 7
Pairwise Correlations (SUD)

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	AY 2014 minutes	1.00																
2.	AY 2015 minutes	.35*	1.00															
3.	AY 2016 minutes	.26*	.43*	1.00														
4.	AY 2017 minutes	.23*	.34*	.45*	1.00													
5.	2014 ELA score	.20*	.29*	.34*	.37*	1.00												
6.	2015 ELA score	.18*	.31*	.36*	.36*	.79*	1.00											
7.	2016 ELA score	.24*	.28*	.39*	0.42*	.77*	.81*	1.00										
8.	Male	-.06*	-.10*	-.13*	-.15*	-.14*	.15*	-.13*	1.00									
9.	Free/reduced lunch	-.02*	-.12*	-.04	-.06	-.05	-.13*	-.13*	-.00	1.00								
10.	English only	0.01	.02*	.02*	0.01	.10*	.10*	.09*	0	-.25*	1.00							
11.	Redesignated EL	.13*	.17*	.17*	.20*	.48*	.47*	.47*	-.07*	.07*	-.41*	1.00						
12.	Limited English proficiency	-14*	-.19*	-.20*	-.21*	-.58*	-.56*	.55*	.07*	.09*	-.25*	-.78*	1.00					
13.	Special education	-.04*	-.04*	-.06*	-.05*	-.32*	-.23*	-.22*	.11*	0	.02*	-.30*	.31*	1.00				
14.	Gifted	.15*	.18*	.20*	.20*	.44*	.40*	.39*	-.01	-.09*	.05*	.19*	-.24*	-.07*	1.00			
15.	2014 device density	.19*	.16*	.05*	.10*	.29*	.21*	.08*	-.03	.02*	-.05*	.14*	-.12*	-.02*	.04*	1.00		
16.	2015 device density	.15*	.23*	.11*	.10*	.12*	.27*	.12*	-.01	0.01	-.02*	.07*	-.05*	.03*	.08*	.40*	1.00	
17.	2016 device density	.07*	.14*	.06*	.06*	-.12*	.14*	.09*	-.02*	.03*	-.02*	-.05*	.07*	.08*	.07*	.02*	.49*	1.00

* $p < .05$

Figure 1

SUD Annual ELA Assessment Scores and Number of Minutes of Digital Writing for the 2014 Academic Year

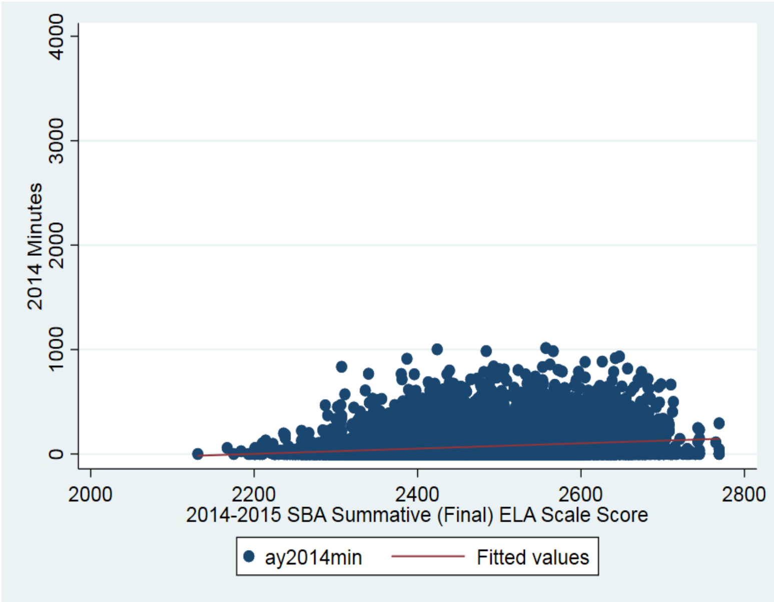


Figure 2

SUD Annual ELA Assessment Scores and Number of Minutes of Digital Writing for the 2015 Academic Year

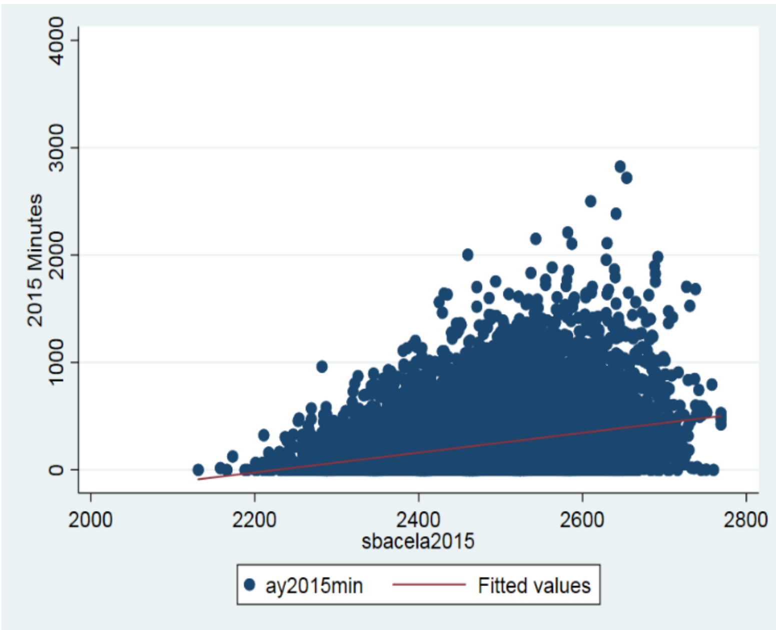


Figure 3

SUD Annual ELA Assessment Scores and Number of Minutes of Digital Writing for the 2016 Academic Year

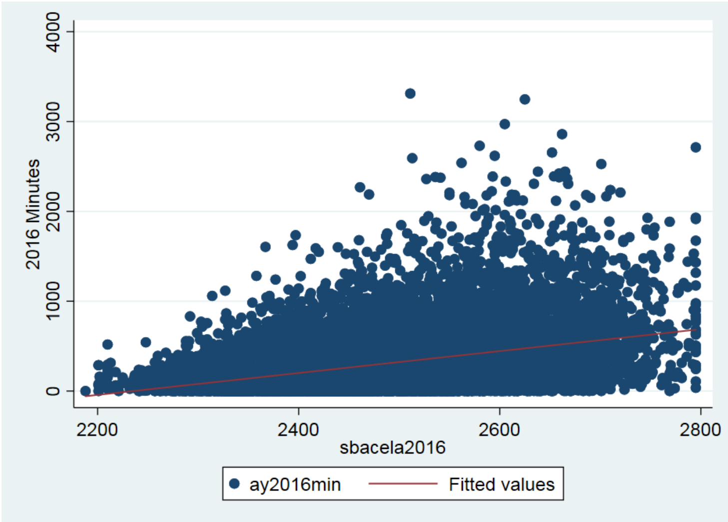
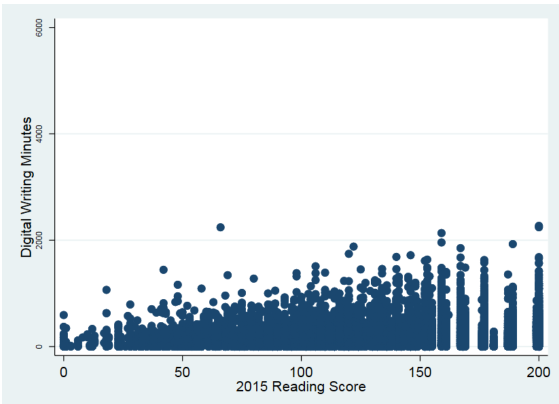


Figure 4

MSD Annual Reading (Top) and Writing (Bottom) Assessment Scores and Number of Minutes of Digital Writing for Each of the 2015 Academic Years



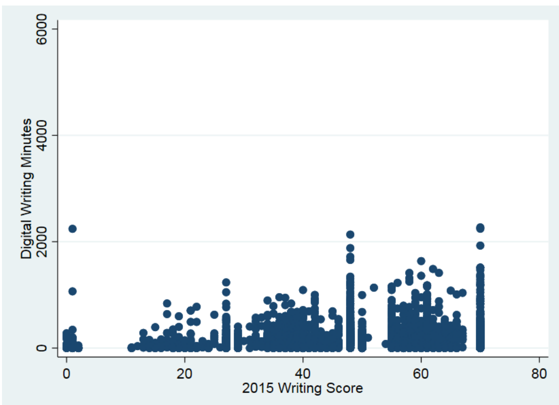


Figure 5

Scatterplots Showing MSD Annual Reading (Top) and Writing (Bottom) Assessment Scores and Number of Minutes of Digital Writing for Each of the 2016 Academic Years

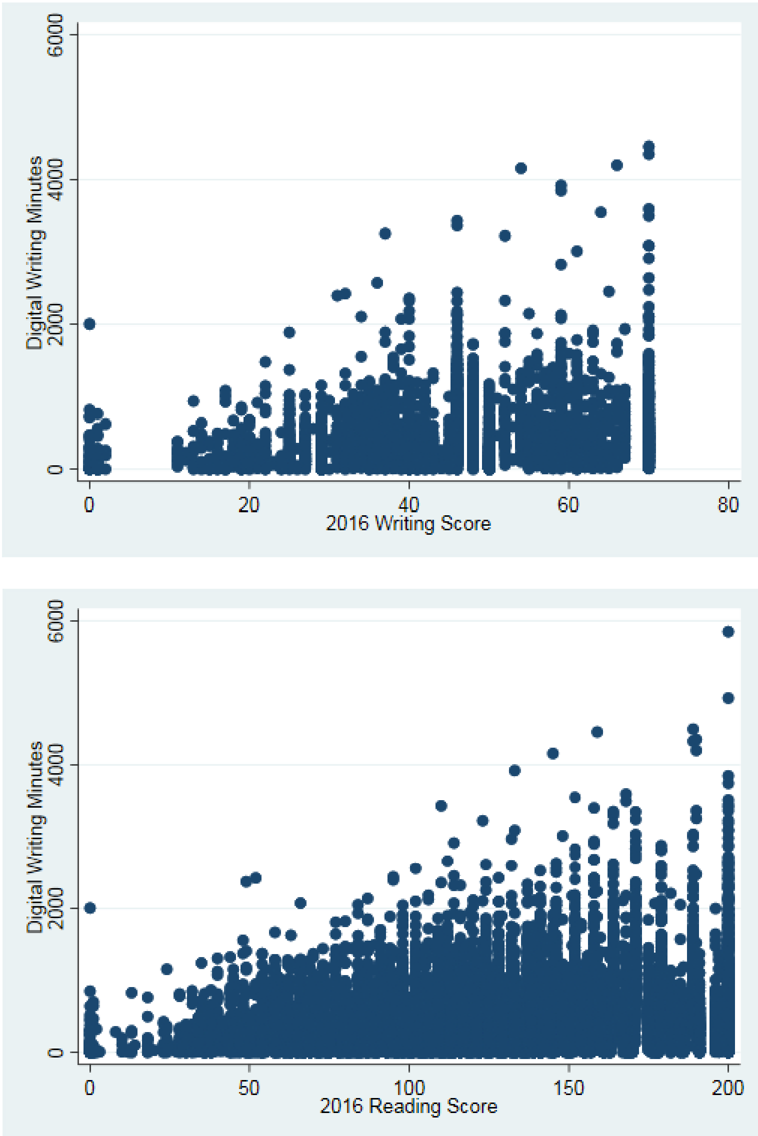


Figure 6

SUD Elementary School Annual Minutes of Digital Writing by School at the 50th Percentile Over Three Academic Years

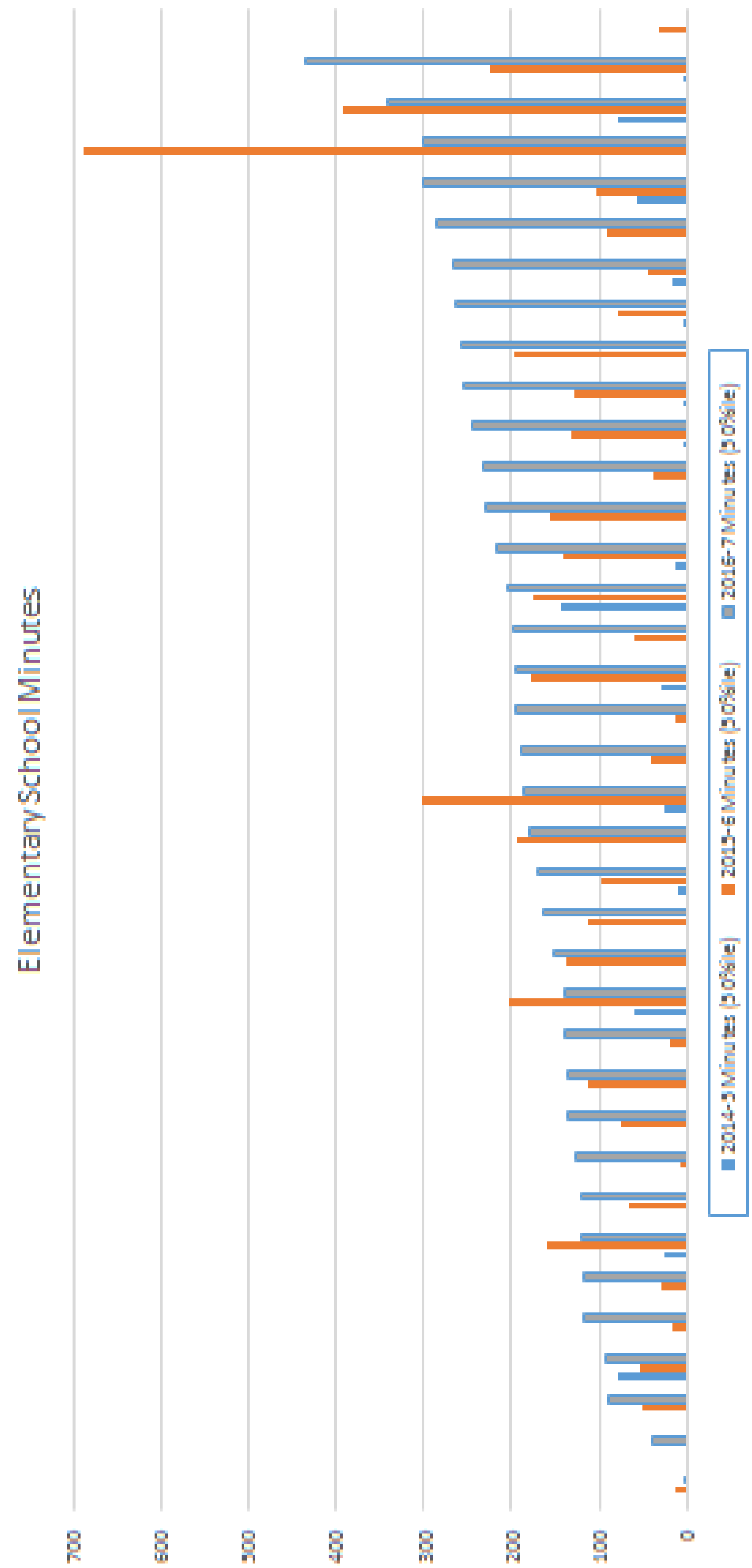


Figure 7

SUD Intermediate School Annual Minutes of Digital Writing by School at the 50th Percentile Over Three Academic Years

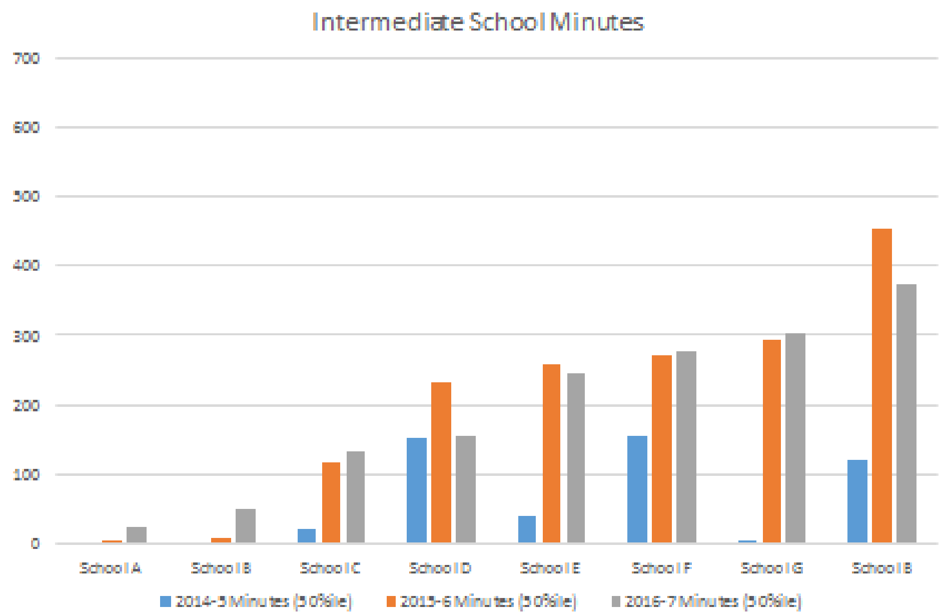


Figure 8

High School Annual Minutes of Digital Writing by School at the 50th Percentile Over Three Academic Years

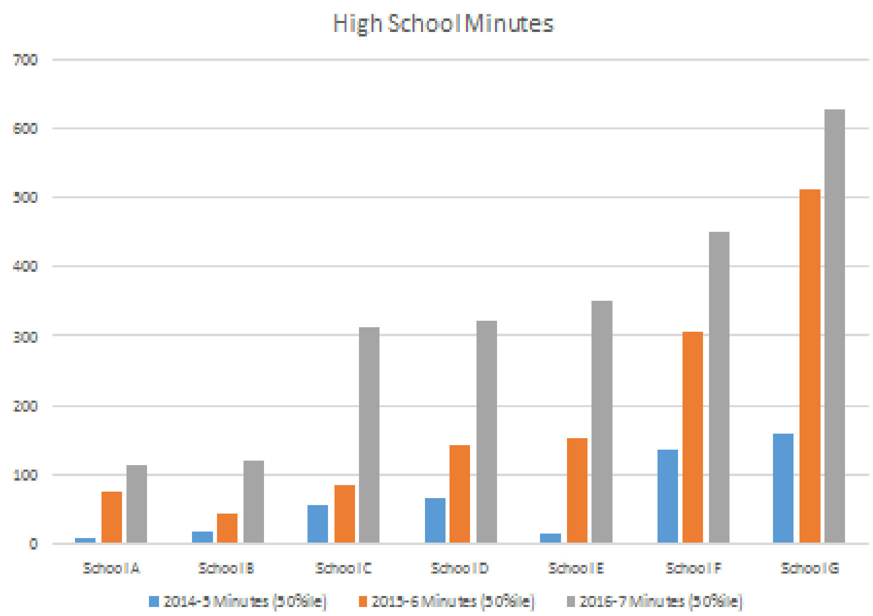


Figure 9

Number of Digital Devices Per Enrolled Student at Each SUD Elementary School (Including K-8 and Similar) Over the Three Academic Years

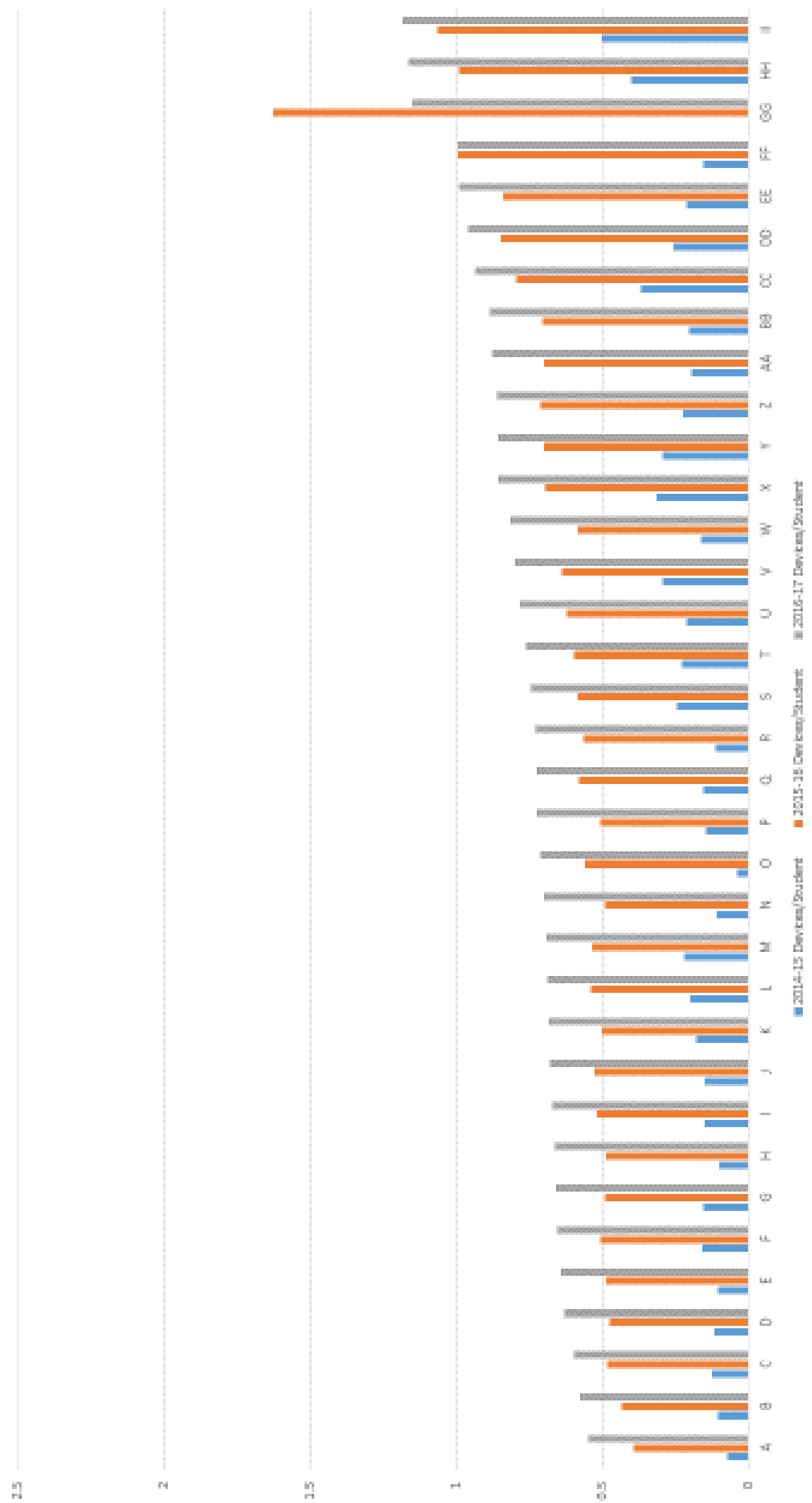


Figure 10
Number of Digital Devices Per Enrolled Student at Each SUD Intermediate School Over the Three Academic Years

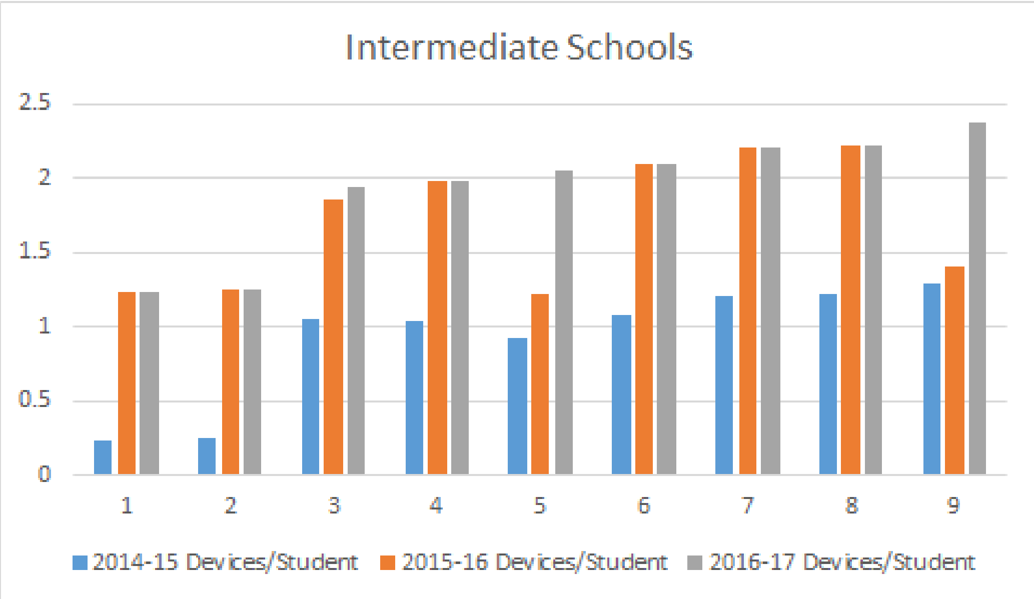


Figure 11
Number of Digital Devices Per Enrolled Student at each SUD Traditional High School Over the Three Academic Years

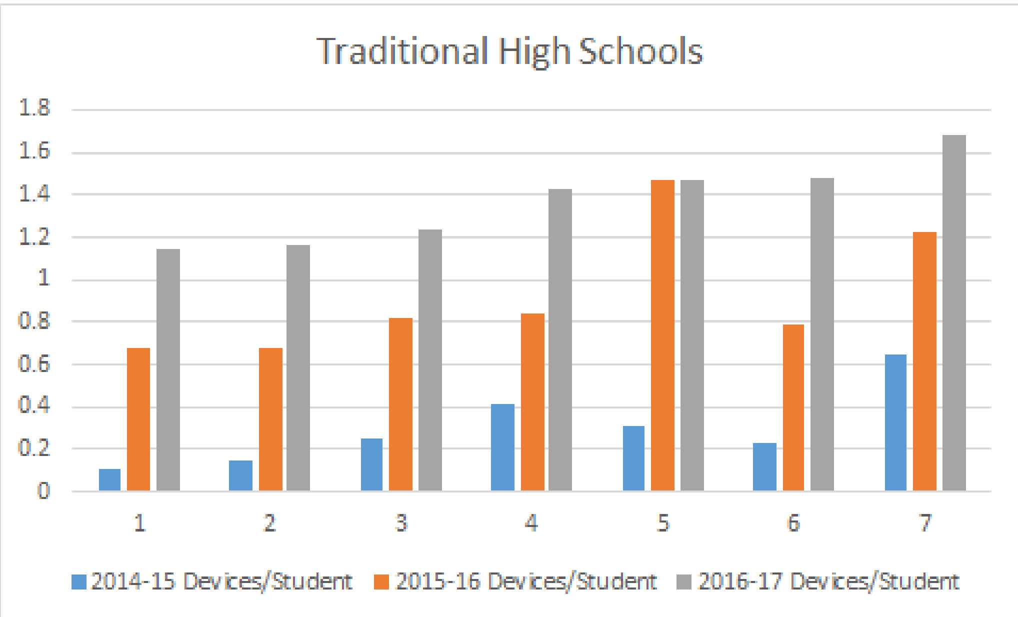


Table 8

SUD Fixed-Effects Regression of Device Density on Annual Writing Minutes, Standardized Minutes, and Devices/Student

Variable	Minutes of digital writing					
	2014-15	2014-15	2015-16	2015-16	2016-17	2016-17
Devices/student	0.22	0.29*	0.24**	0.17*	0.06	0.18
	(0.15)	(0.13)	(0.08)	(0.08)	(0.07)	(0.12)
Grade		0.09		0.03		0.13
		(0.07)		(0.08)		(0.07)
Male		-0.10***		-0.17***		-0.24***
		(0.03)		(0.04)		(0.04)
Free/reduced lunch		-0.01		-0.03		-0.09*
		(0.04)		(0.03)		(0.04)
Limited English proficiency		-0.10***		-0.23***		-0.20***
		(0.03)		(0.05)		(0.03)
Gifted		0.15*		0.21**		0.33***
		(0.07)		(0.08)		(0.06)
Special education		-0.20**		-0.14**		-0.17***
		(0.07)		(0.04)		(0.04)
Constant	0.19	-0.53	0.13	0.15	0.10	-0.21
	(0.11)	(0.36)	(0.11)	(0.39)	(0.12)	(0.42)
n	19,657	18,635	23,761	18,494	24,980	18,383
R2	0.037	0.303	0.054	0.298	0.004	0.286

Note. School dummy variables are omitted from the table, but included in calculation of columns 2, 4, and 6. Standard errors in parentheses.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Because the MSD 1:1 plan was rolled out more uniformly across schools (by grade level), we do not show a similar analysis for MSD.

Fixed Effects Regressions

The Impact of Device Density on Writing Minutes

Table 9
MSD Fixed-Effects Regression of Device Density on Annual Writing Minutes (Standardized)

Variable	Minutes digital writing					
	2014-15	2014-15	2015-16	2015-16	2016-17	2016-17
Years 1:1	2.45***	4.03***	1.39***	0.43***	-0.60**	0.09
	(0.04)	(0.15)	(0.10)	(0.04)	(0.20)	(0.10)
Grade		0.06***		0.02		0.08**
		(0.01)		(0.03)		(0.03)
Male		-0.14***		-0.11***		-0.18***
		(0.03)		(0.02)		(0.03)
Student of color		-0.01		-0.01		-0.07**
		(0.01)		(0.02)		(0.02)
English learner		-0.24*		-0.21**		-0.26***
		(0.10)		(0.08)		(0.06)
Gifted		0.37***		0.54***		0.50***
		(0.05)		(0.09)		(0.08)
Special education		-0.21***		-0.15***		-0.26***
		(0.04)		(0.03)		(0.04)
Constant	-0.03***	-0.52***	-1.47***	-0.90***	1.09**	-0.83**
	(0.00)	(0.05)	(0.20)	(0.09)	(0.40)	(0.25)
n	40928	26314	25413	24200	35890	31426
R2	0.080	0.471	0.030	0.424	0.061	0.428

Note. School dummy variables are omitted from the table, but included in calculation of columns 2, 4, and 6. Standard errors in parentheses.
* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Table 10
Minutes of Digital Writing (Standardized), MSD, With Interactions

Variable	Minutes digital writing		
	2014-15	2015-16	2016-17
Years 1:1	4.35***	0.67***	0.00
	(0.08)	(0.06)	(.)
Grade	0.06**	0.02	0.25*
	(0.02)	(0.03)	(0.11)
Male	-0.13***	0.26***	-0.51***
	(0.03)	(0.06)	(0.08)
Student of color	-0.00	-0.02	-0.12
	(0.02)	(0.04)	(0.10)
English learner	-0.23*	-0.36*	-0.73*
	(0.10)	(0.16)	(0.18)
Gifted	0.34***	0.32	0.34
	(0.06)	(0.23)	(0.27)
Special education	-0.18***	0.33***	-0.72**
	(0.04)	(0.08)	(0.22)
Male* years 1:1	-0.55***	-0.36***	0.08**
	(0.03)	(0.05)	(0.03)
Student of color* years 1:1	-0.25***	0.01	0.18***
	(0.06)	(0.04)	(0.04)
English learner* years 1:1	(-1.39)***	0.15	0.02
	(0.12)	(0.09)	(0.05)
Gifted* years 1:1	1.62***	0.22	0.25*
	(0.37)	(0.15)	(0.10)
Special education* years 1:1	-0.75***	-0.47***	0.09
	(0.05)	(0.07)	(0.13)
Constant	(-0.53)***	-1.14***	-0.54*
	(0.06)	(0.12)	(0.26)
n	26,482	24,200	31,426
R2	0.479	0.425	0.431

Note. Dummy variables for school fixed effects are not shown. Standard errors in parentheses.
* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Device density predicted the number of writing minutes in the first two, but not the third, years of our data (see Table 8).

We also found that grade level was not predictive of writing minutes, but gender, English proficiency, and gifted and special education status were, as expected.

Table 11

SUD Fixed-Effects Regression of Annual Writing Minutes on Annual ELA Assessment, Standardized Minutes, and Assessment Scores

Variable	Annual ELA assessment					
	2014-15	2014-15	2015-16	2015-16	2016-17	2016-17
Annual minutes	0.12**	0.04**	0.11***	0.04***	0.12***	0.06***
	(0.03)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Grade		11.21***		5.38**		9.48***
		(1.92)		(1.59)		(1.89)
Male		-14.34***		-16.97***		-12.93***
		(0.88)		(1.57)		(1.69)
Free/reduced lunch		-12.04***		-13.70***		-19.48***
		(1.95)		(2.29)		(3.09)
Limited English proficiency		-68.04***		-67.27***		-75.31***
		(1.40)		(1.56)		(2.68)
Gifted		83.32***		79.90***		83.54***
		(2.11)		(3.02)		(3.32)
Special education		-44.44***		-47.50***		-46.21***
		(2.00)		(2.43)		(2.72)
Constant	2,445.83***	2,443.65***	2,449.14***	2,473.49***	2,452.85***	2,454.21***
	(0.00)	(7.19)	(6.61)	(14.50)	(6.82)	(12.79)
n	16,153	15,454	16,789	12,444	17,701	12,271
R2	0.189	0.564	0.098	0.504	0.149	0.508

Note. School dummy variables are omitted from the table, but included in calculation of columns 2, 4, and 6. Standard errors in parentheses.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.00$.

Table 12

MSD Fixed-Effects Regression of Annual Writing Minutes on Annual ELA Assessment, Standardized Minutes, and Assessment Scores

Variable	Annual ELA assessment							
	Reading		Writing		Reading		Writing	
	2015	2015	2015	2015	2016	2016	2016	2016
Annual minutes	0.23***	0.11***	0.28***	0.17***	0.24***	0.14***	0.33***	0.44***
	(.03)	(0.01)	(0.06)	(0.04)	(0.02)	(0.02)	(0.06)	(0.06)
Years 1:1		-0.29***		-6.96***		0.02		-0.02
		(0.06)		(0.51)		(0.09)		(0.24)
Grade		0.01		1.59***		-0.13***		-0.04***
		(0.02)		(0.13)		(0.02)		(0.01)
Male		-0.06***		-0.33***		-0.08***		-0.32***
		(0.01)		(0.02)		(0.01)		(0.02)
Student of color		-0.18***		-0.05		-0.17***		-0.06*
		(0.02)		(0.03)		(0.02)		(0.02)
English learner		-1.29***		-1.33***		-1.12***		-0.81***
		(0.07)		(0.13)		(0.07)		(0.10)
Gifted		0.98***		0.58***		0.93***		0.53***
		(0.03)		(0.03)		(0.03)		(0.03)
Special education		-0.90***		-0.84***		-0.87***		-0.71***
		(0.04)		(0.06)		(0.03)		(0.04)
Constant	0.03**	0.21**	-0.14***	-6.15***	0.07***	0.79***	-0.08**	0.52
	(0.01)	(0.08)	(0.03)	(0.50)	(0.01)	(0.11)	(0.03)	(0.28)
n	13,717	13,717	4,231	4,231	16,773	14,168	6,775	4,878
R2	0.183	0.469	0.240	0.451	0.181	0.445	0.164	0.390

Note. School dummy variables are omitted from the table, but included in calculations of all columns 2, 4, 6 and 8. Standard errors in parentheses.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

In MSD, being a pilot school (2014-2015) predicted a large increase in the digital writing minutes, with students in the pilot spending 2.45 more time digitally writing (see Table 9).

However, by Year 2 of the 1:1 roll out (2016-2017), we saw no statistically significant effect of having had the technology accessible for 1 or 2 prior years.

Heterogeneity in the Impact of Device Density on Writing Minutes

There were no significant interactions between device density and the demographic controls except for -.08* for English learner status on 2015-2016 minutes and -.09* for gifted status on 2016-2017 minutes (not tabled). Thus, English learners and gifted students received less benefit from additional device density than students who were proficient in English and those not identified for the gifted program.

Trends with respect to the digital writing time of various demographic groups were similar in both MSD and SUD, with males spending less time writing than females and English learners spending less time writing than students classified as fluent. Looking at the interactions, we found significant effects for most of the demographic groups (see Table 10).

The Impact of Digital Writing Minutes on ELA Scores

Turning to the impact of digital writing on standardized ELA assessment scores, digital writing minutes predicted between .04 ($p < .001$) and .06 ($p < .001$) of the overall SUD annual ELA achievement (note this analysis does not use students in Grades 9 and 10 because they do not take the annual state assessment in SUD; see Table 11).

MSD data were limited to reading and writing scores for 2 school years (see Table 12).

The data show that increased digital writing time predicts improved reading and writing achievement scores, with the impact on writing scores higher, as expected, being a more direct transfer of the skills presumably learned and practiced when digitally writing. Interestingly, we saw a negative relationship between the years the school had one device per student in 2015-2016, the first year of the 1:1 plan roll out.

The impact of digital writing time on ELA scores in SUD was almost erased in 2014-2015 for students with limited English proficiency or classified as gifted or in special education (interaction effects of -.03, $p < .01$; -.03, $p < .01$; and -.04, $p < .001$) but increased for students in special education in 2015-2016 (interaction effect of .04, $p < .001$) and slightly impacted in 2016-2017 for males (.01, $p < .001$) and students with limited English proficiency (-.01, $p < .005$). Interaction effects in MSD were significant for males, English learners, and gifted students (see Table 13).

Discussion

This study draws on data gathered from the Google domain history of students in Grades 4-11 in two very different school districts to understand the relationships among digital device access, digital writing time, and standardized ELA assessment scores. We found students in the first year of our study spent very little time writing digitally, but the digital writing time increased significantly over time, particularly as device accessibility increased. However, we note that the 50th percentile in SUD still only reached a level where they spent about *four hours of the entire school year* writing digitally in 2017-2018, the highest of all years in both districts. We also saw higher digital writing time generally predicted higher scores on standardized ELA assessments.

Table 13

MSD Fixed-Effects Regression of Annual Writing Minutes on Annual ELA Assessment with Interactions Between Demographics and Minutes, Standardized Minutes, and Assessment Scores

Variable	Assessment scores			
	2015		2016	
	Reading	Writing	Reading	Writing
Annual minutes	0.13***	0.20***	0.16***	0.45***
	(0.02)	(0.05)	(0.02)	(0.06)
Years 1:1	-0.38***	-6.54***	0.02	-0.01
	(0.06)	(0.78)	(0.10)	(0.24)
Grade	0.01	1.47***	-0.14***	-0.05***
	(0.02)	(0.19)	(0.02)	(0.01)
Male	-0.07***	-0.33***	-0.08***	-0.32***
	(0.01)	(0.02)	(0.01)	(0.02)
Student of color	-0.18***	-0.05	-0.18***	-0.06*
	(0.02)	(0.03)	(0.02)	(0.02)
English learner	-1.29***	-1.29***	-1.13***	-0.74***
	(0.05)	(0.15)	(0.06)	(0.11)
Gifted	1.03***	0.62***	1.00***	0.57***
	(0.03)	(0.04)	(0.02)	(0.04)
Special education	-0.89***	-0.82***	-0.86***	-0.69***
	(0.03)	(0.06)	(0.03)	(0.05)
Male* minutes	0.04**	0.00	0.03*	0.02
	(0.01)	(0.01)	(0.01)	(0.04)
Student of color* minutes	0.01	0.01	0.03	0.01
	(0.01)	(0.03)	(0.01)	(0.04)
English learners* minutes	-0.16*	0.27	-0.13**	0.18
	(0.06)	(0.29)	(0.05)	(0.16)
Gifted* minutes	-0.08***	-0.07***	-0.09***	-0.14**
	(0.01)	(0.02)	(0.02)	(0.04)
Special education* minutes	-0.03	-0.04	-0.01	0.09
	(0.03)	(0.06)	(0.03)	(0.12)
Constant	0.23**	-5.67***	0.84***	0.54
	(0.08)	(0.78)	(0.11)	(0.27)
n	13,717	4,231	14,168	4,878
R2	0.471	0.453	0.448	0.392

Note. School dummies not shown; standard errors in parentheses.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

We see that over time and with increased access to devices, the amount of time spent writing digitally per year in both districts increased from none in 2014-2015, to between 1 and 1.5 hours in 2015-16, to more than 3 hours in the 2016-2017 school year. Some of this increase could be due to changes over time in the perception of the importance of digital writing and teachers' comfort level allowing students to write on computers instead of solely by hand. It may reflect (limited) curricular changes that take into account the availability of digital devices for writing. Our fixed effects regressions show increased access to digital devices predicts increased writing minutes (.29, $p < .01$ for the 2014-2015 school year in SUD). We also see that in SUD, this effect was reduced to .17 ($p < .01$) in 2015-2016 and was not statistically significant in 2016-2017. Looking at the number of devices per students in SUD over time, we found that by 2016-2017, average device density exceeded 1:1 in all but fifth grade (when every four students shared three devices, most likely located in their ELA class as classroom sets but not in their elective classes, for example). Thus, after a certain level of access is achieved, additional devices do not predict increased digital writing.

We see similar trends in MSD, where the pilot schools entered the 1:1 plan first in 2014-2015, and the students with access to devices spent more than four times more minutes writing digitally. In the main year of the 1:1 plan implementation, the impact was approximately one tenth as large, and by the full implementation in 2016-2017 (and thus the third year of the program), we find no statistically significant impact of how long the student had 1:1 device access. This also shows that in MSD, there was not a large difference between students in Year 1 of device access and Year 2 of access—sometimes access takes a while to show an effect on what is actually happening in classrooms. We would not have been surprised to see minutes increase over the first few years of access as teachers and students integrated devices into the existing curriculum. We suspect the lack of a lag here was due to the quality of the 1:1 implementation plan, with clear and transparent communication among stakeholders, time spent preparing for the roll out, and resources placed into preparing teachers to use the technology effectively. Nonetheless, we would caution districts to not expect such immediate impact and uptake in all instances.

There is a suggestion in our data of interesting differences in digital writing time by grade level. We were not surprised to see digital writing time increased as students progressed in grade. Presumably, the curriculum and teachers focused on the skill of paper-based writing as a precedent to digital writing. This is not an unusual strategy, particular for those with less exposure to digital writing themselves and for the period under examination. We note two possible items of interest when considering Tables 4 and 5. First, at full device implementation, there is quite a large difference in the time spent writing digitally between our districts, particularly in the later grades. We hypothesize the SUD curriculum maintained a strong focus on reading and math given its standardized assessment scores, spent significant curricular time on English language learning, and, perhaps, fell into some of the socioeconomic disparities described by Warschauer (2004) and Rafalow (2020). We also see a large increase in digital writing time at the middle school level in MSD, even compared to high school. In our school-based research, we have found middle school teachers to be very interested in digital tools to increase student engagement and the authenticity of student work. They also seem to have more curricular flexibility than their high school counterparts, which may allow for increased experimentation and faster adoption of digital technology.

We also note significant differences in digital writing time across school sites in SUD, where the digital implementation was done by site rather than by grade level. While some of this difference would likely be attributable to device access (which itself may have been driven by a local interest in funding device acquisition), we also hypothesize the school site conditions may be providing more (or less) support for digital writing. Within a school site, collaborative teams may support and inspire use by teachers of digital writing in the curriculum. Professional development opportunities and even parental support for digital writing is likely to vary at a site level. Site conditions that support quality digital writing are worth further investigation, especially once the basic device and internet access has been implemented across districts.

Turning for a moment to our various demographic groups, we see that males in both districts spend .10 - .24 times fewer minutes writing digitally. Students of color tended to write less in MSD. (We did not have ethnicity data for SUD, which is almost entirely comprised of Hispanic students.) The reduction in digital writing time for English learners was large in both districts (-.20, $p < .001$, and -.26, $p < .001$, in SUD and MSD, respectively, in 2016-2017) even when access was fully implemented. This could be due to both reduced fluency of the student and reduced class time for digital writing as students work on different language skills to improve their English. Not surprisingly, gifted students tended to spend a great deal more time writing digitally, especially in MSD, and students identified as in special education spent much less time writing digitally in both districts.

Does increased device access impact all demographic groups the same? In SUD, we only found slightly reduced impact on increased minutes for English learners and gifted students (who were already writing more anyway). We found more disparity in MSD, with males, students of color, English learners, and students in special education receiving less benefit from the initial roll out of the devices and gifted students receiving more benefit; but in all cases, once the plan was fully implemented in 2016-2017, the benefits for all groups turned positive—with males, students of color, and gifted students receiving additional benefit from the access in terms of time spent writing and English learners and special education students showing no statistically significant differences. We hypothesize that for groups of students with perceived greater risk of low achievement, writing, particularly digital writing, takes a back seat to the tasks of math and reading, whether because they are viewed as more "fundamental" or because they are more measured by state and local assessments. If resources are seen as limited, it might seem more important to ensure an English learner can increase their English vocabulary, for instance. Of course, an argument could be made for writing as a valuable strategy in the arsenal of teachers of English learners or low achieving students (e.g., writing to learn content).

Digital writing time positively predicted annual state assessment results to a small degree. Annual ELA results are a distal measure of digital writing quality, and practice writing digitally is not an obvious way to improve reading skills, for example, let alone listening skills, which formed part of the SUD ELA assessment. Nonetheless, SUD experienced small increases in the overall ELA scaled scores, and MSD experienced increased scores in reading as well as writing (though not surprisingly, the writing effects were larger). The interaction effects in SUD were unclear, with changes in amount and direction over the 3 years leading to inconclusive results; interaction effects were clearer in MSD, with a slight additional improvement in male reading scores, but negative interactions for English learners erasing the positive effect of digital writing time on the reading assessment (not writing, however) and negative interactions for both reading and writing in the case of students identified as gifted (perhaps caused in part by a ceiling effect).

We also note that increased digital writing time does not necessarily mean increased writing time in general—the digital writing could be in addition to prior levels of handwritten writing or could replace handwritten work. In addition, implementation of technology programs can be distracting, especially in the first few years of implementation, taking up time and other precious resources from the curriculum.

This study looked at 3 years of digital writing data for students in Grades 4-11 in two very different districts. We found digital writing time gradually increased with more access to technology, and greater time writing digitally was correlated with higher standardized literacy test scores, even during the early years of implementation. However, our findings are limited to the specific experiences of those two districts and are not generalizable across all districts. In addition, because we looked at extant data, we did not have exactly parallel information on each of the two districts. Nonetheless, we believe looking at analogous results for two very different districts side by side provides a replication that helps illustrate patterns and issues that may be more widely generalizable and suggests areas worthy of additional systematic study. For instance, it would be interesting to see the impact of the devices on the total writing time—whether done digitally or by hand—and on writing quality, as well as on things such as genre of writing. With the existing data, we cannot tell whether the digital writing time is accretive or replaces handwritten writing time, nor whether the quality changes as students switch modes.

Conclusions

Students need to be able to write digitally to be prepared for success in college and career. Most academic and professional writing today is done digitally (Brandt, 2015), and schools can provide students with experience writing digitally. There are specific affordances and challenges when writing digitally that teachers can instruct students on, so students become effective writers across multiple writing modes.

We found increased digital writing time as students' access to devices approached the 1:1 level and that additional saturation of devices had negligible impact on writing time. However, the additional time was at best 4 hours of writing during the entire academic year. Even if all this time was in addition to, and not replacement of, paper-based writing time, 4 hours of practice is unlikely to prepare students with transferable skills in digital writing for college and career, nor does it reflect any curricular focus on teaching students the affordances of digital writing. Nonetheless, even at this limited amount of time, increases in digital writing time predicted improved ELA achievement on standardized assessments. For those concerned digital writing will actually reduce student writing ability, these data should be comforting. There is even a suggestion in these results that increased digital writing time gained through sufficient device access might be one way to increase writing time for reluctant writers and make inroads on the concerning writing achievement gaps for male students and other demographic groups.

Because we know that digital access remains uneven and inequitable (Tate & Warschauer, in press), schools provide an important means of providing baseline access to functional hardware, robust internet, and social resources. However, we also know that the differences in the quality of instruction with technology play a significant role in educational achievement and that these differences tend to fall on socioeconomic lines (Rafalow, 2021). Quality writing instruction, beyond notetaking and worksheets, is needed to improve writing achievement. Writing in a variety of genres and disciplines will increase the likelihood that students have sufficient opportunities to write and learn transferable skills for their future writing selves. Collaborative writing, a mainstay of much of the writing done in the workplace, needs to be modeled and practiced, so students are able to navigate the nuances of writing and re-writing texts with their peers. As Jennifer Fletcher (2015) so aptly put it, "our students need appropriately rigorous instruction in inclusive classrooms—instruction that invites and prepares them to critically engage arguments in a variety of postsecondary contexts" (p. xxiv). Finally, some of the writing achievement that would be gained with increased authentic writing across genres and content areas would not be visible on current standardized assessments, so continued work on improving writing assessment is vital, so we can accurately measure what matters.

Although this article tells the story of two specific districts several years ago, it may also provide some insight for districts who were not yet at the level of one device per student when emergency distance learning began in March 2020. During the pandemic, progress has been made closing the physical portion of the digital divide so that 92% of households with K-12 students now always or usually have access to a device for learning, and 91% have internet access (U.S. Census Bureau, 2021). How might this digital device access change writing for upper elementary and secondary school students once they return to in-person learning? We optimistically hope this improved access and the forced use of online learning tools (for both teachers and students) will lead to a continued growth in opportunities for digital writing and, particularly, more writing time for males and underrepresented students.

Directions for Future Research

Research is needed that combines measures of time spent writing with the actual types of text being written and the classes in which the writing is taking place. Taking notes is quite different from drafting a well-structured argumentative essay. We also need to be able to evaluate the purpose and quality of these texts for a more robust analysis of what students are currently writing in schools and look for opportunities to improve the teaching and learning of writing in secondary schools. Additional quality measures beyond the standardized assessment measure used in this study, such as holistic scoring, would also be of interest. Out-of-school writing activities are also a fertile ground for increasing writing opportunities, diversifying writing genres, and reaching diverse students (see Vaughan, 2020, for a discussion of out-of-school writing and equitable opportunities).

Another interesting avenue for research would be the evolving availability and use (or non-use) of digital scaffolding tools such as spell check, text-to-speech, and other accommodations. Some are allowed for all students (labeled in California as "Universal Tools"; California Department of Education, n.d.), such as an English thesaurus, highlighter tool, line reader, and spell check; others are for students with designated learning disabilities and needs, including a bilingual dictionary for some portions of the ELA assessment, read aloud text, scribe (a human being writes for the student as the student dictates), and text-to-speech (except for reading passages), and for those with documented accommodations, speech-to-text and word prediction software. We note that even when some of these accommodations are available, as in the 2011 NAEP writing test, students rarely use them (Tate & Warschauer, 2019).

Finally, the amount of remote learning necessitated by the current pandemic also leads to an interesting opportunity to see whether, and how, digital writing has changed in the years between these data from the initial implementation of widespread devices to the present time. Not only have teachers, students, and even the curriculum had time to adapt to the availability of devices since their initial implementation, but the current educational reality has forced teachers and students alike to become more used to digital technology for many purposes including writing. Device and broadband internet availability has improved. There is a fascinating set of data just sitting in the Google Docs platform for future researchers.

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