Does Increasing Access to Technology Provide Benefits to Students? Considering Socioeconomics, Broadband and One-to-One Computing

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Abstract

With the move to online learning given COVID-19, concerns over broadband access and students' technology capacity has once again come to the forefront of the education discussion. While the concerns over individual student access and capacity are very real, there is a lingering question regarding access and capacity, does it yield benefits for students? Using data from the Federal Communication Commission and 81 school districts across South Carolina, this study examines the overall effects of broadband access, the speed of that access, and experience with one-to-one computing on student outcomes. The findings suggest that the increasing ubiquity of access and capacity does little to address the broader effects of socioeconomics on student outcomes.

Background

In the era of COVID as schools move to online learning and parents, as well as many in the community, question the equity of online learning due to access to high speed broadband, one must question whether such concerns have merit. On the surface one may absolutely agree that individual students with access to high speed internet will perform better. However, it may also be the case that access is endogenous to the same socioeconomic priors that predict other education outcomes and therefore broadband is simply a value add for those who already have means. In this case, broadband would simply be another indicator of economic status. However, it could also be the case that broadband access and experience with technology provides benefits to students writ-large and is therefore at least a moderate value-add for students regardless of socioeconomic status.

Some previous studies have shown that broadband access and the speed of that access is a key determinant of success in online courses (Beckford, 2015; Atkinson, 2007). Others have shown no effect or moderating effects (Harris and Al-Bataineh, 2016; Tay, Nair, and Lim, 2017). However, we seek additional nuance outside of just access. Since digital nativity along with increased information and communication technology (ICT) literacy have been shown to improve online learning performance (Rauh, 2011), this begs the question of whether students in areas with access to high speed broadband and more technology usage in-school show better outcomes in the traditional classroom after controlling for socioeconomic status? If it is found that they do, then this reinforces the question of equity given the abovementioned relationship between online learning and broadband access. Put plainly, if student in areas with access to high-speed broadband – 100 Mbps for households per the Federal Communication Commission (2010) and more experience in computer usage in school (1:1 computing) perform better in the traditional classroom setting, then this should raise serious concerns about how well students without those benefits will do when forced into virtual learning due to COVID. Ostensibly, this would provide a value add for students with those benefits at the expense of the educational attainment of students without those same benefits.

The question of net benefits from broadband and 1:1 computing is complex and is encapsulated within several layers of geographic and socioeconomic priors. For example, a 2019 study by Kim, McVee, & Faith examined the effects of extramural internet access and found that rates of in-home internet access were higher for higher for children who were older and whose parents had higher levels of education and higher incomes. Additionally, Whites, Asian/Asian Americans, and Mixed-race students were significantly more likely (10% - 15%) to have internet in their homes than minority students. Therefore, simply from an access standpoint we can see that internet access in the home is significantly skewed towards upper income, better educated, families.

Of course, internet access in the home is not the only matter of connectivity at issue. As assignments increasingly require access to technology (Frey & Faul, 2005; Davies & West, 2014; Dzekoe, 2021), issues of equity become not just a matter of access but of information and communication technology (ICT) literacy. As shown by Rauh (2011), (Scherer & Siddiq, 2017) and (Handel, Gläser-Zikuda, Kopp, Bedenlier, & Ziegler, 2020) though, as students from higher income families have higher comfort levels in ICT, i.e. those most likely to have internet access are also those with greater comfort in using technology. This raises a question of equity, one not just of access but ability to engage in learning on an equal footing with one's peers.

This is not a problem that is novel to the era of COVID or even to the 21st century. Access to, and comfort with, technology, was noted as an equity issue as far back as (1975) with Harry Silberman's seminal work raising concerns as education moved from a labor intensive to a technology intensive endeavor. Curriculum, pedagogy, and the use of technology to combine the two has come a long way from Silberman's initial concerns over comfort with computers and the efficacy of using computers rather than slide rules. With schools increasingly moving to 1:1

computing (each student receives their own device), the effects of technology access may be exacerbated. Schools that move to 1:1 models tend to have higher funding bases than schools without 1:1 computing ((Warschauer, Zheng, Niiya, & Farkas, 2014; Fleischer, 2012; Holcomb, 2009), e.g. the issue of equity raises its head again, not in broadband but in access to computers to gain technical skills. This inequitable distribution of resources may have multiplicative effects. Not all students who attend a school with a 1:1 model are middle to upper income, e.g. they would fall into the camp of students who can enjoy the benefits of a school with a larger tax base for the school but still not have the same digital nativity as their median to upper income peers. This, of course, is juxtaposed at the far end of the inequity scale with those students who do not have access to the internet all, broadband or not, and do not have a school with 1:1 computing.

Although we know such inequities exist, distributions of housing, neighborhood location, and the placement of parallel cable/fiber lines is not random; and we know that the resources provided to schools in the form of 1:1 computing is not random. Therefore we can combine the two previous questions into one, 'is it the case that those who have access to broadband and 1:1 computing, but have comparable socioeconomic backgrounds as those without these ad hoc advantages perform better than their similarly situated peers?' If it shown that they do not, then is suggests a deeper issue of equity, i.e. the use of, and access to technology, as a solution to COVID will simply exacerbate the outcomes of lower income and minority student, and may even provide worse outcomes than was the case while being physically in school.

Using a study of all schools across South Carolina (N=871) this study examines how access to broadband and previous experience with online learning affects student performance. It examines factors corresponding to students' Math and ELA scores and previous computer usage to determine if living in an area with higher speed broadband access provides a net positive result for all students, or whether the benefits are distributed to those with greater means. The findings suggest that even with broadband access and experience with online learning, minority students and students from low-income families will still fare worse than White Non-Hispanic students from median to upper income families. South Carolina makes an interesting study since the performance of the state on both its state and national assessments is generally low, e.g. SC was 1.4 (Math) and 0.8 (ELA) standard deviations off from the national average on NAEP and the standard errors for its state test (SC READY) scores were not significantly different that NAEP performance. However, the distribution of scores in SC is polarized, with lower income districts performing significantly below median to upper income districts. Per FCC data, 62.8% of the communities in South Carolina have broadband speeds of 100Mbs or greater, however there is 10.182% correlation between these communities and the poverty levels of the schools serving them. This means that there is significant variation between the areas that traditionally perform poorly on NAEP and state tests and those broadband coverage that meets FCC guidelines. Therefore, we should be able to determine how this variation affects overall performance in the traditional setting.

This paper proceeds with a review of the literature on online learning and students in poverty. From this, hypotheses are derived, followed by a discussion of the methods and analysis used to test those hypotheses. This is followed by results, findings, and conclusions.

Review of the Literature

Before addressing the challenges of technology and online learning, one must account for in-school factors affecting student outcomes. There are several of in-school and administrative factors that have been shown to affect student performance. Among these are principal tenure (Miller, 2013; Branch, Hanushek, & Rivkin, 2012; Azaiez & Slate, 2017), teacher turnover (Adnot, Dee, Katz, & Wyckoff, 2017; Grisson & Bartanen, 2018; Sorensen & Ladd, 2020). Miller (2013), Branch, Hanushek, and Rivkin (2012), and Azaiez & Slate (2017) all show positive results from principal tenure. Azaiez and Slate found higher reading and math scores among similar schools where the principal had six years or more on campus. Miller, in a study of North Carolina public schools, found that average school scores fell for three years following principal turnover. And Branch, Hanushek and Rivkin found that the effects of principal tenure were higher at high poverty schools.

The findings from Branch, Hanushek and Rivkin (2012) also revealed something about the interaction between principal tenure and teacher turnover, e.g. by examining patterns of teacher exits based on principal/school quality revealed that the primary effect of principals was on teacher management. On the question of teacher management and teacher turnover, Adnot et al (2017) found that when teachers were forced to leave for poor performance, student test scores increased by a significant 0.14 standard deviations, although there was no effect based on voluntary exits. These findings are supported by Grissom and Bartanen (2017) who found that involuntary turnover by low performing teachers increases under high performing principals. These results point to strong effects between the principal and the teacher suggesting that longer tenured principals, on average, yield better student performance, and that this performance is reinforced via teacher management and the culling of low-quality teachers. On the specific question of teacher tenure though, the results are more nuanced. It is not just a question of turnover, e.g. Adnot et al (2017). Rather it is a question of tenure. There is ample evidence that teacher tenure positively affects outcomes in a positive manner – which is likely endogenous to the removal of low performing teachers (Ronfeldt, Loeb, & Wyckoff, 2013; Jackson & Bruegmann, 2009; Kraft & Papay, 2014; Sorensen & Ladd, 2020).

There is also some evidence that administrator and teacher salaries affect the quality of instruction. For example, in a study of 3,000 schools in the UK, (20216)found that when teachers are paid 10% less than market rates, student performance decreases by a statistically significant 2%. In the US, performance pay for teachers has been shown to positively affect test scores, e.g. Chetty, Friedan, and Rockoff (2014) and Hill and Jones (2020) both find statistically significant positive results on student performance. In most US schools though, teachers are paid on an automatically increasing scale. This is also true for South Carolina where teachers receive additional pay for level of education and years of experience.

Demographic Effects on Performance

The evidence of demographic differences in education outcomes has been explored through several lenses, i.e. economics, educational psychology, and critical race theory. The results are consistent though, that demographic effects on education outcomes are real and significant. Note that this is not because of the race or ethnicity of the student, but because of the combination of associated effects that center themselves on non-White student populations both in and out of school. In this vein, a factor that appears in schools is the higher likelihood of being suspended (Kaushal & Nepomnyaschy, 2009; Anyon, et al., 2014; Diamond & Lewis, 2019). Outside of school we see economic deprivation and a lack of social capital affecting students of color. High density minority areas tend to have lower personal and industrial property values (Howell & Korver-Glenn, 2018; Perry, Rothwell, & harshbarger, 2018), are less likely to have broadband access (Mossberger, 2012) and have a lower median level of education than predominantly white neighborhoods (Billings, Deming, & Rockoff, 2014; Quinlan, 2014). Again, there is nothing about race that causes these things, rather these are effects of structural racism.

Broadband, eLearning, and Socioeconomic Status

There is a substantial and growing body of evidence demonstrating that virtual learning benefits those of greater means more than those in low income areas (Rauh, 2011; Ke & Kwak, 2013; Ruthotto, Kreth, Stevens, Trively, & Melkers, 2020). The same factors that predict lower student performance among low-income students in brick and mortar schools also predict outcomes in the virtual environment. One cannot ignore, though, the correlation between low-income areas and high-density minority areas. Evidence from economics, medicine, education, and law all show a high correlation between being in a minority group and being in poverty (Kshirsagar, Manickam, Mu, Jennifer E. Flythe, & Bang, 2017; Banzhaf, Ma, & Timmins, 2019; Whitehurst, Reeves, & Rodrigue, 2016; Atrey & Shreya, 2018). Therefore, when we discuss poverty, we must keep in mind the relationship with race and must control for it in our analysis.

Broadband Access

Early studies of broadband, i.e. the early 2000s, argued that broadband access could provide educational benefits but also that it created potential issues of equity (Firth & Mellor, 2005). Since 2005, these equity issues and the effectiveness of broadband have been exacerbated in the US (particularly in higher poverty areas) relative to the rest of the developed world, and relative to more affluent areas. Per the Federal Communications Commission National Broadband Plan (2010), the goal to maintain a competitive advantage and enjoy the education, health, and societal benefits of broadband, was boosting download speeds to 100 Mbps for households and 1Gbps for schools, hospitals, and libraries. However, the 2018 FCC International Broadband Data Report found that broadband speeds in the US remain are still some of the lowest among OECD countries (still below 100 Mbps when weighting for population density). Studies have examined the effects of broadband and internet access writ large and computer usage on student performance, e.g. Fairlie and London (2012) show that computer access in-home provides benefits after controlling for SES, and Hampton et al (2020) examine the differences in performance based on broadband access among rural middle and high school students (see also Fox & Jones, 2019).

While we can certainly show that an equity gap exists and that some students with access to computers perform better, the literature has largely not addressed the scale of the effects of broadband, or the benefits of broadband across traditional SES and other explanatory variables of student performance. Previous studies of changes in educational performance when students gain access to ultra-fast broadband, e.g. the standard for FCC of 100Mbs for households and 1Gbps for schools, found that students in low-income areas benefitted the most from the new provision of broadband, e.g. Grimes and Townsend (2018). Still other studies find no meaningful effect in broadband provision, e.g. Hazlet, Schwall, and Walltsen (2019).

There are extant studies showing that broadband has a negative effect on student performance. For example, Bello, Ferreira and Telang (2014) in a study of students in Portugal found a 0.78 standard deviation reduction in test scores when broadband was ubiquitous in schools. However, their study also found that when schools blocked websites such as YouTube then performance went up. This is therefore more of an argument for the ways in which broadband is used rather than broadband itself. This is an important point since we may see similar results with 1:1 computing when broadband coverage is at 100%. All of this is to say though that there is no consensus opinion on whether broadband provides positive returns to education. There are also questions of who benefits and when, as well as the circumstances of that benefit (speed of broadband, usage in class, etc.)

eLearning and Socioeconomic Status

Examining the effects between low income students and virtual learning, Rauh (2011) in a study of students in South Carolina, showed that for every 1% increase in students in poverty in a given school (median = 63%) the odds of a student completing an online course decreases by 1.3%. The reasons for this are straightforward. Pew Research Center analysis shows that 25% of students from families making less than $30,000 did not have a computer in the home, compared to 4% of families making over $75,000 (Anderson and Perrin, 2018). Additionally, Morgan (2020) lays out specific family and economic reasons for why students in poverty will be less likely to succeed in online learning than their peers. Specifically, the abovementioned lack of access to technology, parental lack of knowledge around technology, lack of access to broadband, work schedules that prevent parents from working with their student, and general parental frustration with online learning.

Given the circumstances above, the author is skeptical of suggestions that students in poverty will receive an equitable education in online learning during COVID, or in online learning in general, should be examined with skepticism. Snelling and Fingal (2020) provide 10 strategies schools can use to ensure equitable online learning outcomes. However, the first of these is to ensure digital equity, meaning that schools may provide hot spots or ensure that learning apps are available on smart phone or tablets. While laudable, there is ample evidence that screen size affects engagement and overall outcomes in virtual learning. One of the first studies in this regard was Maniar et al (2008) who showed that attempting to learn via video lecture on an average size smartphone screen size inhibited the learning experience. Later studies, e.g. Raptis et al (2013), Dunaway and Soroka (2019), and Sad and Goktas (2014) reinforced these findings. Specifically, Dunaway and Soroka showed that learners with larger screen sizes could access and interpret information more effectively.

Of course, there may also be mitigating factors that may affect the performance of low-income students' success in online courses. If students in poverty are in a school that offers 1:1 computing, then they may show higher outcomes than similarly situated students without 1:1. Some studies have shown that 1:1 computing improves digital literacy (Topper & Lancaster, 2013) suggesting that experience with 1:1 computing and broadband access may provide additional benefits, even if a student is low-income. In terms of the academic effects of 1:1 computing on its own, the evidence is mixed. Williams and Larwin (2016) in a study of 24 schools in Ohio found no effects on academics from 1:1 computing. However, Bebell and Kay (2010) found positive effects on student achievement, as did Rosen and Beck-Hill (2012) and Harris and Al-Bataineh (2016). Still, Tay, Nair, and Lim (2017) found moderating effects of 1:1 computing with mediating effects ICT literacy.

Hypotheses

From the above, we can draw a few hypotheses regarding both broadband and 1:1 computing on student performance.

H1: one-to-one computing has a moderating effect on student achievement given broadband access, or a direct effect regardless of broadband.

For this to be true though, both broadband access and 1:1 computing would need to have independent effects and a combined effect that was explicitly larger than the independent effects.

H2: the positive effects from broadband access, (2a) experience with 1:1 computing, or (2b) both broadband and 1:1 computing, are distributed to White median to upper income students than minority or low-income students.

For this to be the case it may be true in absolute terms (higher test scores with constant effects from broadband, 1:1 or both. It may also be true in relative terms, e.g. effects may not be constant across racial/ethnic groups.

Methods and Data Analysis

The approach to this analysis is to examine school level variation based on broadband access within the school zone, and what percentage of the students in the school have access to 1:1 computing while controlling for socioeconomic and school level effects. Additionally, because school funding is largely a function of variation at the county level with regard to property taxes, but which affects both the per pupil allotment because to the differences in property values, I use a nested multilevel model with per pupil allotment at the district level and median property value at the district level nested within the county. There were 871 schools and 6 demographic categories per school and 6 individual grade levels (3-4 and 5-8) grade levels giving an N of 11,370.

Data were collected from four primary sources: the SC Department of Education, Zillow, the Federal Communications Commission (FCC), and the Bureau of Labor and Statistics (FCC). Data on student performance and student subgroup performance, e.g. performance by race/ethnicity and poverty status. Poverty is defined as TANF, SNAP, WIC, or Medicaid eligibility. Because poverty affects the entire school and not just individual student cohort, the school's poverty index was also used. The SPI is an imputed index of the total share of students in poverty in the school. While the poverty status is binomial variable indicating whether a cohort of test takers is in poverty (0 = No, 1 = Yes), the school poverty index is measure of the percent of students in the entire school who are in poverty. Data were collected for school performance and subgroup performance in each school in South Carolina for the 2018-19 academic year. Data were collected on ELA performance on the state mandated assessment, SC Ready for grades 3-8. Additionally, school level characteristics including the average teacher salary, average administrator salary, teacher retention, and administrator tenure were all collected. For simplicities sake, these are defined as a matrix of.

Each of these variables has been shown to be associated with variation in performance, although some such as teacher salary are functions of broader economic conditions (Meier & O'Toole 2003; Grissom & Strunk 2012; Wei et al 2018). Specifically, since South Carolina's Education Finance Act does not limit the amount of funding a district can raise more than state funding, teacher salaries are generally higher in districts with higher property tax bases. These variables are used to estimate the initial effects of subgroup scores on overall scores while controlling for socioeconomic conditions that also affect performance.

South Carolina's school districts have inconsistent geographic boundaries, e.g. some map to the county boundary while some cross multiple counties. This provides an important grouping mechanism since the property tax base of the county is not evenly distributed across counties. Therefore, there is variation of per pupil expenditures and median home value within the counties. These data were collected from the SC Department of Education and Zillow. The median home value was collected from Zillow from July 1, 2017 to June 30, 2017, e.g. the year from which the funding budgets for 2018-19 would have collected. Finally, the percent of students in the school who have access to 1:1 computing was also collected, 85.92% (23.876%).

Broadband data were collected from the FCC by neighborhood in each county. These are reported as the proportion of the population who have internet that meets the 100Mbps standard for broadband. These were then mapped to the school district which serve these neighborhoods by GIS overlay, e.g. latitude and longitude matching. The specific measure is the percent of the district that has broadband access and ranges from 0% to 100%, with an average of 95.36% (19.531%). Table 1 provides descriptive statistics of the variables described above. Note that there is wide variation in N test takers which in indicative of the wide range in school size.

Table 1. Descriptive Statistics of Variables, $\mu(\sigma)$

N Math Test Takers	79.333	(66.410)
Math Score (across all grades)	501.388	(65.454)
N ELA Test Takers	79.296	(66.374)
ELA Scores (across all grades)	506.519	(76.417)
% One-to-One Computing	85.917%	
% Broadband Coverage (100Mbps)	98.777%	
% White Students	18.015%	
% Students with Disabilities	8.232%	
% African American Students	16.402%	
% Hispanic/Latinx Students	5.365%	
% Other Race/Ethnicity Students	0.912%	
% English Language Learners	4.734%	
% Students in Poverty	22.626%	
School Poverty Index	67.449	(19.506)
Median Home Price (District)	$174,705.79	($92,487.370)
Per Pupil Expenditure (District)	$10,303.440	($1,963.391)
Principal Tenure	4.923	(4.717)
Teacher Salary	$50,240.96	(3194.237)
Teacher Tenure	7.952	(6.555)

All data points are at the school level unless otherwise indicated. broadband coverage is the average % of coverage in the neighborhoods feeding into a school. One-o-One is the average percent of a given school that has 1:1 computing.

Table 2 provides the distribution of the dependent variables, performance in Math and ELA. Note that across all grade levels minority student perform below white students, and African American students and students in poverty perform below all other groups save for students with Disabilities.

Table 2. Distribution of Performance by Grade and Race/Ethnicity, μ(σ)

	ELA Performance											
	Grade 3		Grade 4		Grade 5		Grade 6		Grade 7		Grade 8	
Total	439.396	(48.366)	498.970	(51.321)	522.970	(44.617)	538.850	(46.232)	589.040	(48.247)	615.573	(43.920)
African American	395.702	(33.004)	450.277	(35.524)	482.173	(28.313)	496.800	(31.200)	544.973	(29.962)	572.753	(29.492)
Disability	349.633	(49.467)	397.916	(48.229)	429.863	(32.895)	426.454	(27.918)	477.877	(26.671)	501.228	(21.756)
English Learner	406.222	(46.001)	467.697	(48.103)	497.426	(39.579)	524.760	(41.724)	566.935	(38.818)	593.319	(37.626)
Hispanic/Latinx	405.071	(37.826)	463.898	(43.659)	499.061	(35.904)	525.192	(36.284)	573.137	(35.402)	595.677	(32.865)
Other	410.400	(37.903)	507.933	(31.354)	528.057	(22.560)	540.720	(36.601)	603.492	(37.085)	631.310	(27.772)
Poverty	416.259	(35.409)	474.247	(37.620)	500.716	(30.663)	514.418	(32.360)	561.597	(32.640)	589.185	(30.076)
White	480.440	(42.879)	540.456	(45.761)	559.922	(41.347)	574.564	(44.239)	625.297	(45.611)	649.483	(40.000)
	Math Performance											
	Grade 3		Grade 4		Grade 5		Grade 6		Grade 7		Grade 8	
Total	458.947	(48.366)	485.313	(51.321)	527.803	(44.617)	529.980	(46.232)	544.906	(48.247)	585.237	(43.920)
African American	409.215	(33.004)	441.203	(35.524)	485.675	(28.313)	487.722	(31.200)	503.637	(29.962)	545.266	(29.492)
Disability	389.781	(49.467)	416.787	(48.229)	445.755	(32.895)	436.296	(27.918)	463.537	(26.671)	496.905	(21.756)
English Learner	447.070	(46.001)	473.620	(48.103)	518.839	(39.579)	531.617	(41.724)	540.856	(38.818)	578.451	(37.626)
Hispanic/Latinx	439.854	(37.826)	465.884	(43.659)	514.823	(35.904)	522.128	(36.284)	536.562	(35.402)	572.254	(32.865)
Other	448.300	(37.903)	472.333	(31.354)	528.900	(22.560)	530.456	(36.601)	555.380	(37.085)	600.900	(27.772)
Poverty	435.666	(35.409)	464.114	(37.620)	505.466	(30.663)	505.777	(32.360)	519.801	(32.640)	560.089	(30.076)
White	501.535	(42.879)	521.910	(45.761)	564.367	(41.347)	564.710	(44.239)	577.593	(45.611)	616.864	(40.000)

We see that African American students and Students in poverty perform significantly worse than other minority groups save for those with a Disability. We also see that all minority groups perform worse than White students.

Table 3 provides correlations between the dependent variables and independent variables. Note that no other correlation stronger that ± 0.399 per pupil expenditure and teacher tenure = 0.381, e.g. teachers in better paying districts tend to stay longer; and -0.399 for school poverty and teacher tenure, e.g. teachers leave higher poverty districts at a higher rate.

Table 3. Correlation between DVs and IVs

	Math Score	Math N	ELA Score	ELA N
Disability	-0.263	-0.215	-0.281	-0.216
African American	-0.211	-0.147	-0.163	-0.147
Hispanic/Latinx	0.044	-0.146	0.035	-0.146
Other Race/Ethnicity	0.113	-0.076	0.111	-0.076
Poverty	-0.111	0.031	-0.094	0.031
English Language Learner	0.055	-0.137	0.022	-0.137
Grade Level	**0.562**	0.276	**0.687**	0.276
School Poverty Index	**-0.514**	-0.135	**-0.481**	-0.136
Administrator Tenure	0.022	-0.046	0.006	-0.045
Teacher Salary	0.245	0.049	0.213	0.049
Teacher Tenure	0.108	-0.005	0.083	-0.005
% One to One	0.033	0.110	0.078	0.109
% Broadband	0.057	0.010	0.056	0.010
Per Pupil Expenditure	-0.203	-0.152	-0.167	-0.152
Home Price	0.090	0.005	0.087	0.005

Note, no correlation between one-to-one and performance but strong correlation between Grade Level, N Test Takers, and Performance. No other correlation stronger that ± 0.39 (per pupil expenditure and teacher tenure, e.g. teachers in better paying districts tend to stay longer) and -0.399 school poverty and teacher tenure, e.g. teachers leave higher poverty districts at a higher rate.

Modelling Strategy

To test the hypotheses that (1) 1:1 computing has a moderating effect on student achievement given broadband access, and (2) that positive effects from broadband access and experience and experience with 1:1 computing are distributed to those most likely to have computers in their homes and broadband access (White and not in poverty), this analysis begins by modelling ELA scores for grades 3 – 8 as a hierarchical linear function with districts grouped within counties. This approach is used because districts vary significantly on value of the tax base used to fund schools, as well as the per pupil allotment used to fund schools within the district. Since 10 of the 46 counties in SC have multiple districts within the county (80 districts total) and the outcome data are measured at the school level, this method seems appropriate.

It is well established that areas with higher median home values tend to have better schools (Hanushek, Kain & Rivkin, 2007). Additionally, districts may increase their local effort towards school funding meaning that two districts within the same county may have similar home values, but one district may contribute more in local dollars to education than another. In this way, we can estimate the variance explained by county level variation and the corresponding variance explained by median home price and per pupil expenditures.

MODEL 1 examines the total effects (full data set) to determine if there are direct effects from broadband and 1:1 computing (both as individual and interaction terms) on state math scores (Model 5 does the same for ELA scores). For hypothesis 1 to hold there must be, at minimum, significant effects from 1:1 computing and broadband access. If there is not, then 1:1 access cannot possibly be moderated by broadband access.

Next, MODEL 2 examines the effects on students in districts with less than 100% broadband access, e.g. subset the data to only those with less than 100% broadband access, note Model 6 does the same for ELA). This has an N of 879, too small to model in a hierarchical fashion. As a robustness check though, this was also modeled in the HLM fashion described above. Although the LR test was significant, the model produced non-sensical results, e.g. district scores varying by as much as 1,400 point and almost 1,200 points variation in the county, when the scores only range from 100 to 850. Because of the ubiquity of broadband across the state (98.77% coverage) any effects from broadband in in MODEL 1 are likely to be diluted, with traditional effects such as school poverty and teacher tenure affecting results more. If we wish to examine the effects of broadband on performance, then we should look to the areas that do not have 100% coverage to examine its effects.

If effects from MODEL 2/MODEL 6 are significant for broadband, then we subset the models by race/ethnicity to determine if effects are constant across all racial/ethnic groups, e.g. evidence for absolute effects, or whether there are differences between racial/ethnic groups which would provide evidence for relative effects.

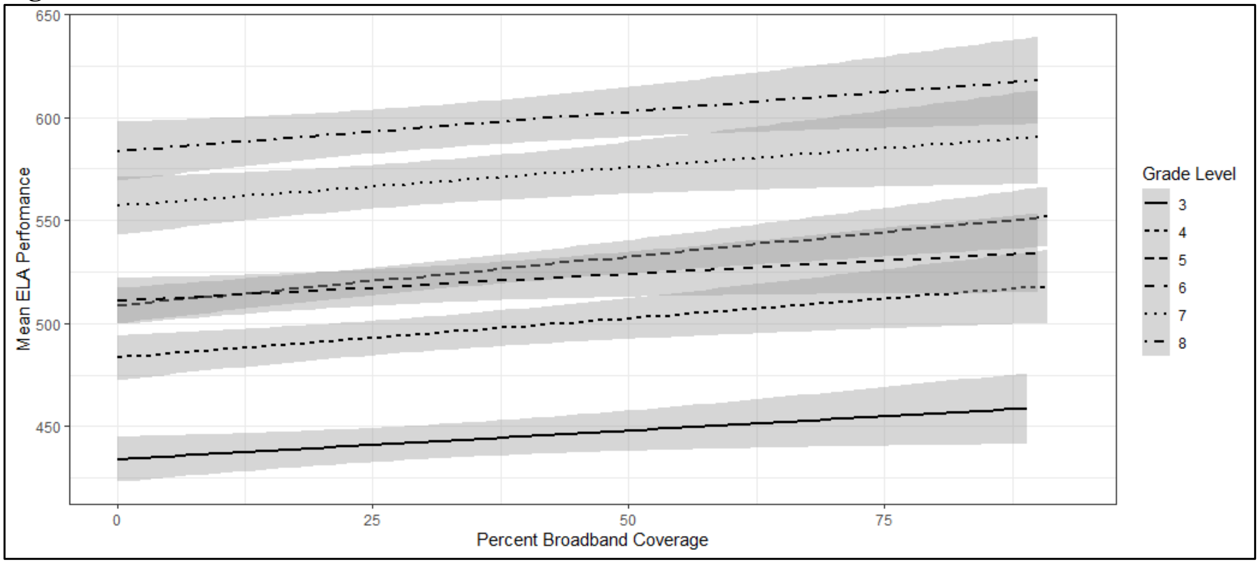
Having examined the effects of broadband, we now turn to the effects from 1:1 computing based on student poverty status, e.g. does 1:1 computing aid students of means more than those without mean? MODEL 3 (MODEL 7 for ELA) then examines the effects for students in poverty, e.g. subset to only students in poverty (N=2,581). Given the larger N, this is modeled as the HLM above. The LR test indicates the more complex model explains more variation.

MODEL 4 (MODEL 8 for ELA) then examines the effects on just students not in poverty. If the effects of 1:1 are significant in MODEL 4 but not MODEL 3 then it indicates that the effects of broadband are confined explicitly to students not in poverty regardless of the poverty index of the school. We can provide good evidence for this given that so many school districts have 100% broadband coverage.

After examining the effects for broadband coverage of any kind, we then repeat this analysis for whether that broadband coverage if of 100Mbps or higher and examine any changes in the coefficients, specifically changes to the effects from 1:1 computing, and effects on student demographics. We do this to determine whether the quality of broadband and not just coverage itself affects test scores, and whether those effects alters the demographic and SES effects for students.

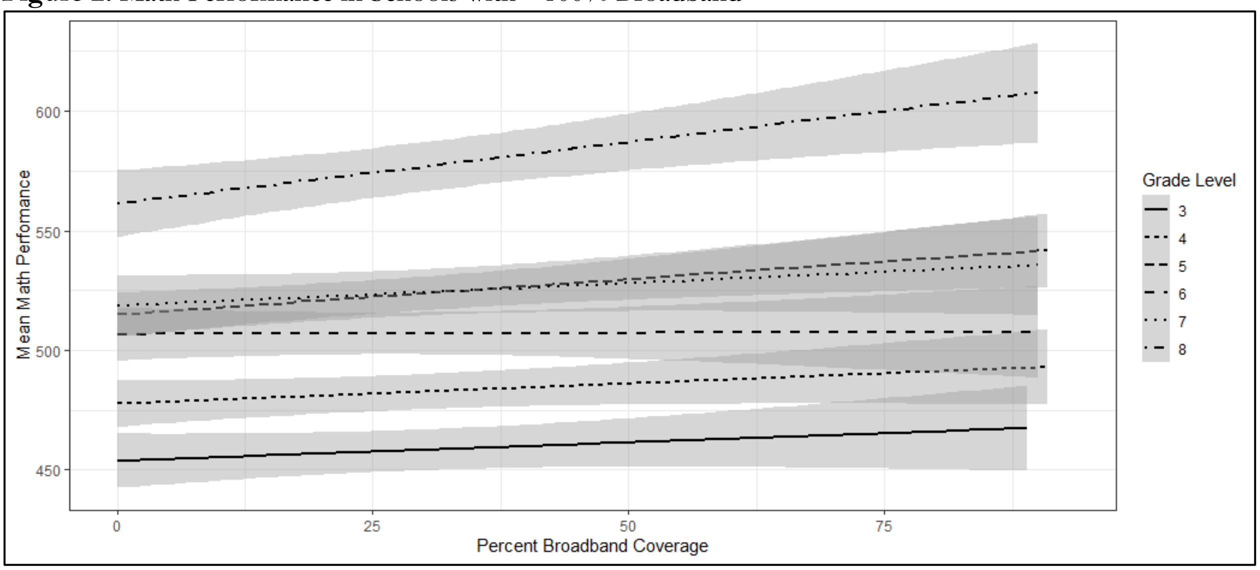
Results

Figure 1. ELA Performance in Schools with <100% Broadband



In schools where neighborhoods lack 100% broadband coverage, increased broadband is associated with increased ELA performance.

Figure 2. Math Performance in Schools with <100% Broadband



In schools where neighborhoods lack 100% broadband coverage, increased broadband is associated with increased Math performance.

Table 4. Predicting Math Performance

Random Effects, $\sigma^2(\sigma)$	MODEL 1		MODEL 2		MODEL 3		MODEL 4	
District (80 groups)	178.036	(13.343)			205.206	(14.325)	160.428	(12.666)
County (45 groups)	69.422	(8.332)			99.441	(9.972)	65.740	(8.108)
Residual	1014.486	(31.851)			726.680	(26.957)	1385.477	(37.222)
Interclass Correlation	19.609%				29.539%		14.033%	

Fitted Effects $b(\sigma)$	MODEL 1		MODEL 2		MODEL 3		MODEL 4	
% One-to-One	-0.134***	(0.018)	0.211*	(0.102)	-0.103**	(0.032)	-0.135***	(0.021)
% Broadband			0.275***	(0.079)				
log N Test Takers	-16.926***	(1.404)	-32.716**	(10.447)	-26.498***	(2.929)	-18.641***	(1.605)
Students with Disabilities	-109.122***	(1.435)	-119.126***	(9.576)			-109.837***	(1.519)
African American Students	-50.794***	(1.008)	-55.995***	(6.528)			-50.698***	(1.052)
Hispanic/Latinx Students	-36.840***	(1.618)	-44.801***	(11.675)			-37.152***	(1.697)
Other Race/Ethnicity Students	-9.375*	(3.690)					-11.098**	(3.833)
Students in Poverty	-33.923***	(0.842)	-36.475***	(5.706)				
English Language Learners	-31.548***	(1.685)	-41.247***	(12.063)			-31.858***	(1.765)
Grade Level	23.582***	(0.225)	22.527***	(1.762)	24.856***	(0.430)	23.463***	(0.259)
School Poverty Index	-1.266***	(0.021)	-0.974***	(0.199)	-0.758***	(0.040)	-1.399***	(0.025)
Administrator Tenure	0.516***	(0.074)	-0.322	(1.067)	0.500***	(0.127)	0.518***	(0.087)
Teacher Salary	0.001***	(0.000)	0.002*	(0.001)	0.001**	(0.000)	0.001***	(0.000)
Teacher Tenure	0.085**	(0.027)	0.304*	(0.140)	0.151**	(0.048)	0.070*	(0.031)
Per Pupil Allotment			-0.007***	(0.002)				
Median Home Price			0.0002*	(0.000)				
Intercept (White, Non-Poverty, Gr 3)	481.523***	(9.324)	660.201***	(57.493)	414.297***	(16.144)	493.595***	(10.781)
N	10051		258		2272		7783	
AIC	98371.180				76582.980		76582.981	
R2 (Adj R2)			0.715 (0.697)					
LR v No Broadband	3.647*		12.709**		2.434		3.611	
LR v No One-to-One	13,328.143***		5,833.622***		2.433		10,327.321***	
Durbin-Watson			2.032					
Breusch-Pagan			24.318					

*p<0.05; **p<0.01; ***p<0.001

For Math performance, One-to-One computing is generally of benefit in schools with less than 100% broadband coverage. Additionally, in schools with less than 100% broadband coverage increases in coverage correspond to increasing test scores. Segmenting out students by poverty class though, we see that broadband has no effects, perhaps due to the ubiquity within schools traditional elements such as poverty affect performance more, e.g. broadband is subsumed by school poverty and teacher/principal characteristics. When models 1, 3, and 4 included broadband, all effects were below 0.258 and not statistically significant due to the lack of variation given the ubiquity of coverage.

Table 5. Predicting ELA Performance

Random Effects, $\sigma^2(\sigma)$	MODEL 5				MODEL 7		MODEL 8	
District (80 groups)	95.551	(9.775)			99.860	(9.993)	90.535	(9.515)
County (45 groups)	49.028	(7.002)			76.230	(8.731)	41.809	(6.466)
Residual	855.680	(29.252)			558.377	(23.630)	913.611	(30.226)
Interclass Correlation	14.454%				23.975%		12.653%	

Fitted Effects $\beta(\sigma)$	MODEL 5		MODEL 6		MODEL 7		MODEL 8	
% One-to-One	-0.129***	(0.017)	0.091	(0.091)	-0.095***	(0.028)	-0.132***	(0.020)
% Broadband			0.353***	(0.070)				
log N Test Takers	-22.130***	(1.287)	-37.213***	(9.271)	-27.688***	(2.552)	-24.478***	(1.479)
Students with Disabilities	-134.743***	(1.316)	-145.127***	(8.517)			-135.816***	(1.400)
African American Students	-53.726***	(0.925)	-60.202***	(5.804)			-53.751***	(0.971)
Hispanic/Latinx Students	-48.691***	(1.484)	-58.461***	(10.385)			-49.412***	(1.565)
Other Race/Ethnicity Students	-20.528***	(3.388)					-22.646***	(3.539)
Students in Poverty	-36.158***	(0.773)	-38.842***	(5.075)				
English Language Learners	-51.161***	(1.546)	-57.523***	(10.724)			-51.823***	(1.628)
Grade Level	33.818***	(0.206)	33.515***	(1.566)	34.715***	(0.376)	33.756***	(0.239)
School Poverty Index	-1.392***	(0.020)	-0.759***	(0.177)	-0.894***	(0.034)	-1.524***	(0.023)
Administrator Tenure	0.492***	(0.068)	-1.085	(0.948)	0.517***	(0.111)	0.492***	(0.080)
Teacher Salary	0.001***	(0.000)	-0.002	(0.001)	0.001**	(0.000)	0.001***	(0.000)
Teacher Tenure	0.122***	(0.024)	0.237	(0.124)	0.150***	(0.042)	0.115***	(0.029)
Per Pupil Allotment			-0.004**	(0.001)				
Median Home Price			0.0003***	(0.000)				
Intercept (White, Non-Poverty, Gr 3)	465.717***	(8.475)	550.683***	(51.135)	388.311***	(14.041)	479.985***	(9.862)
N	10055		258		2272		7783	
AIC	96673.990				21009.890		75363.440	
R2 (Adj R2)			0.837 (0.816)					
LR v No Broadband	4.244*		25.863**		3.406		3.917*	
LR v No One-to-One	13,055.444***		5,662.146***		2,871.151***		10,123.231***	
Durbin-Watson			2.034					
Breusch-Pagan			24.614					

*p<0.05; **p<0.01; ***p<0.001

For ELA performance, One-to-One computing generally corresponds to decreases in performance, and unlike Math performance, does not result in positive performance in schools with less than 100% broadband coverage. As with Math, when schools lack 100% broadband coverage, increased coverage corresponds to increased performance. Note, when the data are subset to address only schools without 100% one-to-one the effects become non-significant for both Math and ELA, and obviously if one focuses only on 100% then there is no variation and therefore no effects can be estimated. When models 5, 7, and 8 included broadband, all effects were below 0.178 and not statistically significant due to the lack of variation given the ubiquity of coverage.

Table 6. Subsets of Models 2 and 6 to examine effects of Race, β(σ) (boot σ)

	Minority ELA			White ELA			Minority Math			White Math		
log ELA Test Takers	-9.342	(10.989)	(9.927)	25.17	(29.581)	(37.039)						
log Math Test Takers							-13.888	(12.922)	(11.477)	61.177	(30.242)	(37.237)
Student with Disability	-114.767***	(9.652)	(9.856)				-95.543***	(11.319)	(10.433)			
African American Student	-38.685***	(6.650)	(6.224)				-38.753***	(7.803)	(8.035)			
Hispanic/Latinx Student	-27.292*	(11.128)	(11.812)				-20.59	(13.047)	(12.939)			
Student in Poverty	-22.357***	(5.463)	(5.067)				-22.611***	(6.405)	(6.250)			
English Learner	-27.290*	(11.402)	(11.933)				-18.019	(13.379)	(14.432)			
Grade Level	31.520***	(1.616)	(1.475)	36.267***	(5.051)	(5.116)	20.909***	(1.897)	(1.864)	27.911***	(5.196)	(5.298)
School Poverty Index	-0.517**	(0.178)	(0.212)	0.130	(0.696)	(1.308)	-0.794***	(0.208)	(0.222)	0.366	(0.713)	(1.264)
Administrator Tenure	0.259	(0.967)	(1.076)	9.619*	(4.033)	(8.657)	0.614	(1.136)	(1.045)	7.225	(4.133)	(8.721)
Teacher Salary	-0.002	(0.001)	(0.001)	0.001	(0.003)	(0.004)	-0.002	(0.001)	(0.001)	0.000	(0.003)	(0.004)
Teacher Tenure	0.158	(0.128)	(0.110)	0.027	(0.319)	(1.904)	0.245	(0.150)	(0.137)	0.125	(0.328)	(1.844)
% One-to-One	0.078	(0.092)	(0.083)	-0.196	(0.283)	(0.568)	0.168	(0.108)	(0.103)	0.152	(0.291)	(0.565)
% Broadband	0.319***	(0.071)	(0.072)	0.790**	(0.225)	(0.408)	0.235**	(0.083)	(0.078)	0.751**	(0.231)	(0.442)
Per Pupil Expenditure	-0.004**	(0.001)	(0.001)	0.000	(0.006)	(0.013)	-0.007***	(0.002)	(0.002)	-0.006	(0.006)	(0.013)
Median Home Price	0.000***	(0.000)	(0.000)	0.000	(0.000)	(0.000)	0.000*	(0.000)	(0.000)	0.000	(0.000)	(0.000)
Intercept	463.194***	(52.899)	(47.776)	262.683	(196.203)	(414.823)	590.502***	(62.015)	(68.751)	261.352	(201.666)	(401.179)
N	213			45			213			45		
R2	0.835 (0.823)			0.838 (0.791)			0.687 (0.663)			0.775 (0.705)		
F Statistic	66.567***			17.617***			28.811***			11.706***		

*p<0.05; **p<0.01; ***p<0.001

Given the small N resulting from the sub-setting broadband <100% into White and Minority, bootstrapped standard errors are also presented. These standard errors do not change the significance for the Minority models but make most variables insignificant for the White models, save for Grade Level and % Broadband coverage. We see that the effects of broadband coverage are greater for White students than for Minority students, although the intercept is not significant meaning any effect from omitted variables is insignificant.

Findings & Discussion

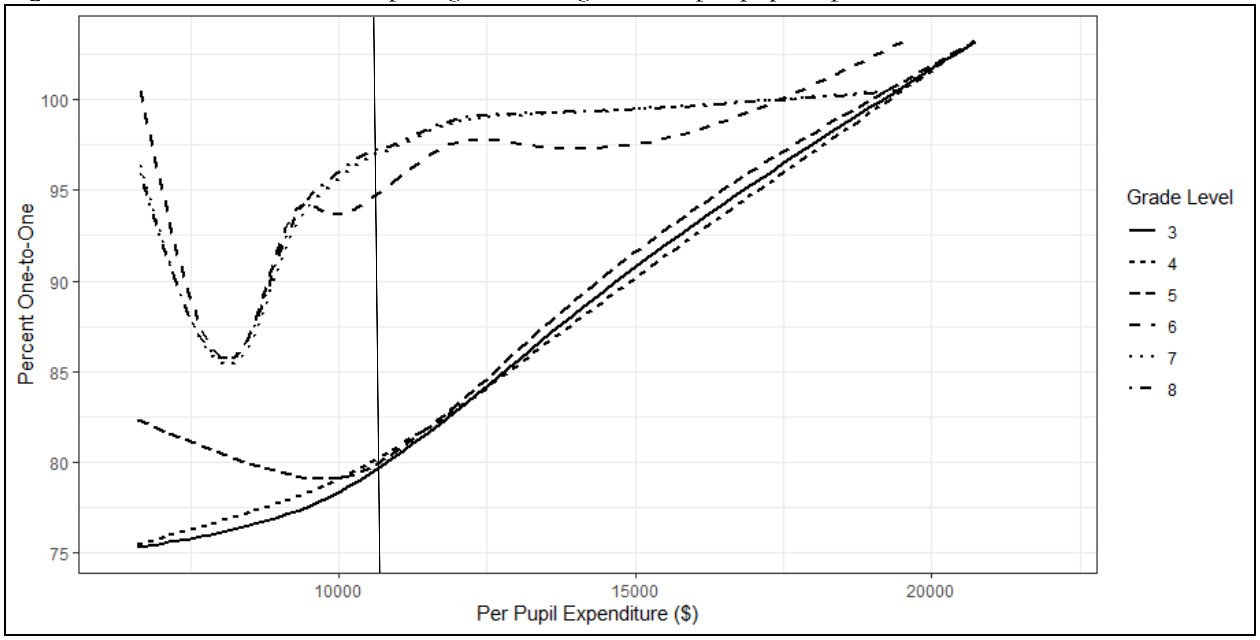
In Models 1,3 and 4 for Math performance, we see that as levels as 1:1 computing in a school increase, performance of students decreases. Upon finding this, we examined whether the 1:1 was polarized based on per pupil funding, or whether it was used more in one grade than another. We do not see strong correlations between grade level and 1:1 or economic indicators and 1:1, e.g. it may be that 1:1 serves as a distraction to instruction, or that the distribution of 1:1 is polarized. Examining this further, we see that higher grades are more likely to have 1:1 even with lower per pupil expenditures, and beyond average per pupil expenditures of $10,303.441 – see figure 3, all grade levels see an increase. After sub-setting the data to only focus on grades 5-8, the effect of one-to-one remains negative, b = -0.116 (0.022) for Math and b = -0.109 (0.019) for ELA. Therefore, we do not find evidence to support hypothesis 2, that the benefits of 1:1 are distributed to upper income areas. While it is clear from figure 3 that upper income areas enjoy more 1:1 computing, it is not the case though that it yields benefits.

The one area where we do see a benefit of 1:1 is in Math performance in areas where there is not 100% broadband coverage (Model 2). For every one percent increase in 1:1 computing in a school where the surrounding areas do not have 100% broadband, we see a corresponding increase in math performance of 0.211 points. In areas that lack 100% coverage of any kind, the average area covered is 89.88%; this represents a positive average effect of 18.964 points, or 2/5 of one standard deviation, e.g. a significant and meaningful effect from broadband. This finding adds nuance to prior results from Bebell and Kay (2010) and Tay, Nair, and Lim (2017).

While we see positive effects from 1:1 computing in math, we see negative effects in ELA. This suggests that content or curriculum may play a role in the differences between 1:1 effect. Additionally, we do not find moderating effects for 1:1 computing as did Tay, Nair, and Lim (2017). We find that the positive effects are confined to areas that lack 100% broadband coverage but become negative when broadband is ubiquitous. It may therefore be that specific students are being benefitted by 1:1 since the traditional effects on education do not necessarily subsume the effects of broadband access when it is not 100%. In other words, when broadband is at 100% coverage, it becomes an individual rather than a systematic issue and so the effects of poverty, minority status, etc. again increase their leverage, whereas when an area does not have 100% broadband coverage, then the most beneficial effects, for math in this case, may be confined to students with greater access to broadband. The findings in table 6 seem to reinforce this, e.g. increased benefits from 1:1 computing for White students.

Still, we cannot ignore than in general, the effects of 1:1 computing are negative as broadband coverage of any kind goes to 100%. This suggests that just as the effects are broadband disappear as it becomes ubiquitous, so to the effects of 1:1 computing may have a general negative effect in areas that have 100% broadband and increased 1:1 computing since the same socioeconomic priors that predict educational performance, also predict the comfort with 1:1 computing and virtual education in general, e.g. Rauh (2011), Scherer and Siddiq (2019), and Handel et al (2020). Overall, the mixed results herein add to the incongruence in the literature around 1:1 computing and should be a call for additional research into the causes of success of failure in 1:1 computing.

Figure 3. Distribution of 1:1 computing based on grade and per pupil expenditure.



Beyond the average per pupil expenditure, one-to-one computing generally increases as student spending increases.

The higher initial values for White students and student who are not in poverty implies that any benefit received from broadband will result in higher test scores for White students and thus absolute scores that are higher than minority students. One must allow that benefits can be relative though, e.g. the absolute scores may still be lower because of lower initial values, but the benefit received from broadband may nonetheless be higher for one cohort of students than another. To examine if this was the case, we subset Model 2 into White and Minority cohorts (table 6). Examining the coefficients as well as the standard errors and bootstrapped standard errors given the small sample size, we see that he overall benefit received by White students from broadband is higher than that for minorities. Therefore, we fail to reject hypothesis 2 that the effects of broadband are distributed to white students more than to minority students. Given the higher scores for White students in Model 2 and the higher benefits for White students in the subsets of Model 2, we can say that Whites are benefitted by broadband in both absolute and relative terms.

Given that we see negative effects from 1:1 computing in all areas but Math when there is not 100% broadband coverage, it cannot be the case that Whites or minorities are benefitted more from 1:1 computing in a general sense. To examine whether this may be true in the instances where there was not 100% broadband coverage, we subset the data to examine only schools without 100% 1:1 computing. When we did this, the effects became non-significant. We can say, therefore, that negative effects occur as 1:1 computing approaches 100%. While this analysis offers no reasons for this, a reasonable hypothesis may be that students become more reliant on computers to do their work, or focus less on the learning process since they can use the computer to quickly find an answer without engaging in more critical thought. In any case, the negative effect is sufficient to reject hypothesis 1 – that 1:1 computing has a moderating effect, as well as 2b – that 1:1 computing confers more benefits to White students, and 2c – that greater benefits are enjoyed by White students from both broadband and 1:1 computing.

In considering other effects, we see that as per pupil spending increases scores tend to decrease. This is not surprising since we tend to see diminishing returns to performance beyond median spending. As the school poverty index increases, students tend to perform worse. This reinforces the known relationship between poverty and performance, e.g. Hanushek and Rivkin (2009). In keeping with results from Adnot et al (2017) and Grissom and Bartanen (2017), we see minimal though significant effects from teacher tenure. With an average of 7 years and an average effect across all subjects of 0.212, this yields approximately 1.5 points. In keeping with Branch, Hanushek and Rivkin (2012) and Azaiez & Slate (2017) we see similar small but significant effects from principal tenure, 1.2 points on average.

These results hold when we examine only areas that have broadband speeds of 100Mbps (Table 1A in the Appendix) in a hierarchical fashion, or in a linear fashion (Table 2A). The intercept values increase relative to MODELS 1 and 5 for the multilevel models of 100Mbps from ~482 for

Math to ~515, and from ~466 to ~480 for ELA. Additionally, in examining the changes in the linear models for areas that do not have 100 broadband coverage of any kind (Models 2 and 4) to those that have broadband but lack 100Mbps speeds (Models 12 and 13 in Table 2A in the appendix) we see that the intercepts decline significantly and remain significant. This in conjunction with the changes seen in the nested models indicate that the differences between schools is as are the differences between districts and counties. Examining the effects of one-to-one computing for ELA for example, in areas that lack 100Mbps speeds, the effects of 1:1 remain significant for math but the sign flips to negative and the other coefficients approach the values of Models 1 and 5 respectively. This tells us two things explicitly, first it reinforces the idea that as broadband becomes ubiquitous, the effects of socioeconomics and other traditional predictors of performance still take precedence. Second, the effects of one-to-one computing, negatively correlate to broadband coverage not because of coverage speeds but because the ubiquity of service means that one-to-one even with full broadband coverage with either high speed or any speed for that matter, is not enough to out-leverage socioeconomic effects on student performance.

Conclusion

This analysis sought to explore the effects of broadband access and 1:1 computing on student performance. The impetus for this research was to determine: (1) if students benefit from broadband access; and (2) if students benefit from 1:1 computing? In answering these questions, it was hoped that we could provide some insights on how worried we should be about the lack of broadband and computer access during COVID. On the first question, there are significant and material benefits from having broadband access. Therefore, a lack of broadband access raises serious concerns about student equity, i.e. students in areas that lack broadband – traditionally poor and rural areas – were at a significant disadvantage relative to their peers an this is likely to be exacerbated during COVID. On the question of 1:1 computing the answer is more complex. While it is necessary for students to have a computer to enjoy the benefits of broadband, engaging students using 1:1 has general negative effects. Therefore, we should be worried about all students, on average, if the model of instruction becomes explicitly 1:1 computing.

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Appendices

Table 1A: Effects of 1:1 Computing with 100Mbps (Models 1 & 3) and without 100Mbps (Models 9 & 11), Math (1 & 3) ELA (10 & 12), □ (σ)

Fixed Effects	MODEL 9		MODEL 10		MODEL 11		MODEL 12	
% One-to-One	-0.145***	(0.023)	-0.118***	(0.032)	-0.133***	(0.021)	-0.141***	(0.030)
log N Test Takers	-20.568***	(1.748)	-12.392***	(2.343)	-24.677***	(1.611)	-18.554***	(2.133)
Students with Disability	-113.191***	(1.804)	-104.293***	(2.359)	-137.635***	(1.665)	-131.061***	(2.147)
African American Students	-48.538***	(1.232)	-54.687***	(1.723)	-51.937***	(1.138)	-56.758***	(1.568)
Hispanic/Latinx Students	-38.078***	(2.078)	-36.222***	(2.591)	-48.030***	(1.917)	-49.587***	(2.358)
Other Race/Ethn Students	-19.272***	(4.367)	9.201	(6.721)	-26.483***	(4.036)	-9.197	(6.116)
Limited English Proficiency	-32.087***	(2.153)	-31.811***	(2.721)	-49.363***	(1.988)	-53.369***	(2.477)
Students in Poverty	-32.159***	(1.007)	-37.416***	(1.498)	-34.352***	(0.931)	-39.534***	(1.363)
Grade Level	24.183***	(0.290)	22.917***	(0.362)	34.400***	(0.267)	33.195***	(0.329)
School Poverty	-1.288***	(0.031)	-1.218***	(0.031)	-1.330***	(0.029)	-1.409***	(0.028)
Administrator Tenure	0.378***	(0.095)	0.644***	(0.117)	0.448***	(0.088)	0.491***	(0.107)
Teacher Salary	0.0005**	(0.000)	0.001***	(0.000)	0.0003	(0.000)	0.001***	(0.000)
Teacher Tenure	0.011	(0.035)	0.170***	(0.041)	0.074*	(0.033)	0.179***	(0.037)
Intercept	514.784***	(10.269)	443.143***	(13.246)	480.255***	(9.345)	446.477***	(12.142)
Random Effects								
District	224.670	(14.989)	106.028	(10.297)	59.707	(7.727)	174.663	(13.216)
County	58.156	(7.626)	25.331	(5.033)	91.623	(9.572)	0.487	(0.698)
Residual	949.194	(30.809)	1105.164	(33.244)	812.193	(28.499)	914.337	(30.238)
N Groups								
District	59		21		59		21	
County	34		11		34		11	
Observations	6,308		3,743		6,311		3,744	
log Lik	-30,662.07		-18,445.84		-30,168.30		-18,101.77	
AIC	61,358.14		36,925.69		60,370.60		36,237.54	

*p<0.05; **p<0.01; ***p<0.001

Table 2A: Linear Model of Math (Model 5) and ELA (Model 6), w/o 100Mbps, β(σ)

	MODEL 13		MODEL 14	
% One-to-One	-0.078***	(0.019)	-0.079***	(0.017)
% Broadband Access (Any)	0.080	(0.072)	(-0.050)	(0.064)
log N Test Takers	-16.690***	(1.818)	-19.461***	(1.676)
Students with Disability	-108.807***	(1.951)	-132.789***	(1.739)
African American Students	-50.388***	(1.343)	-51.925***	(1.197)
Hispanic/Latinx Students	-35.593***	(2.256)	-44.801***	(2.009)
Other Race/Ethn Students	-11.258*	(4.786)	-18.433***	(4.266)
Limited English Proficiency	-29.738***	(2.342)	-45.646***	(2.088)
Students in Poverty	-32.398***	(1.117)	-34.072***	(0.996)
Grade Level	23.397***	(0.303)	33.556***	(0.270)
School Poverty	-1.294***	(0.031)	-1.319***	(0.028)
Administrator Tenure	0.699***	(0.098)	0.701***	(0.087)
Teacher Salary	0.001***	(0.000)	0.001***	(0.000)
Teacher Tenure	-0.047	(0.037)	0.025	(0.033)
Per Pupil Expenditure	-0.002***	(0.000)	-0.001***	(0.000)
Median Home Value	0.000**	(0.000)	0.000	(0.000)
Intercept	479.780***	(11.599)	442.721***	(10.338)
Observations	6,308		6,311	
R2	0.714		0.831	
Adjusted R2	0.713		0.83	

*p<0.05; **p<0.01; ***p<0.001