BROADBAND AND STUDENT PERFORMANCE GAPS

Lack of broadband and dependence on cell phones for home Internet is leaving rural Michigan students behind

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ABOUT THIS REPORT

Middle and high school students with high-speed Internet access at home have more digital skills, higher grades, and perform better on standardized tests, such as the SAT. Regardless of socioeconomic status, students who cannot access the Internet from home or are dependent on a cell phone for Internet access do worse in school and are less likely to attend college or university. The deficit in digital skills contributes to lower student interest in careers related to science, technology, engineering, and math.

This report is a collaborative effort based on the input and analysis from the following individuals:

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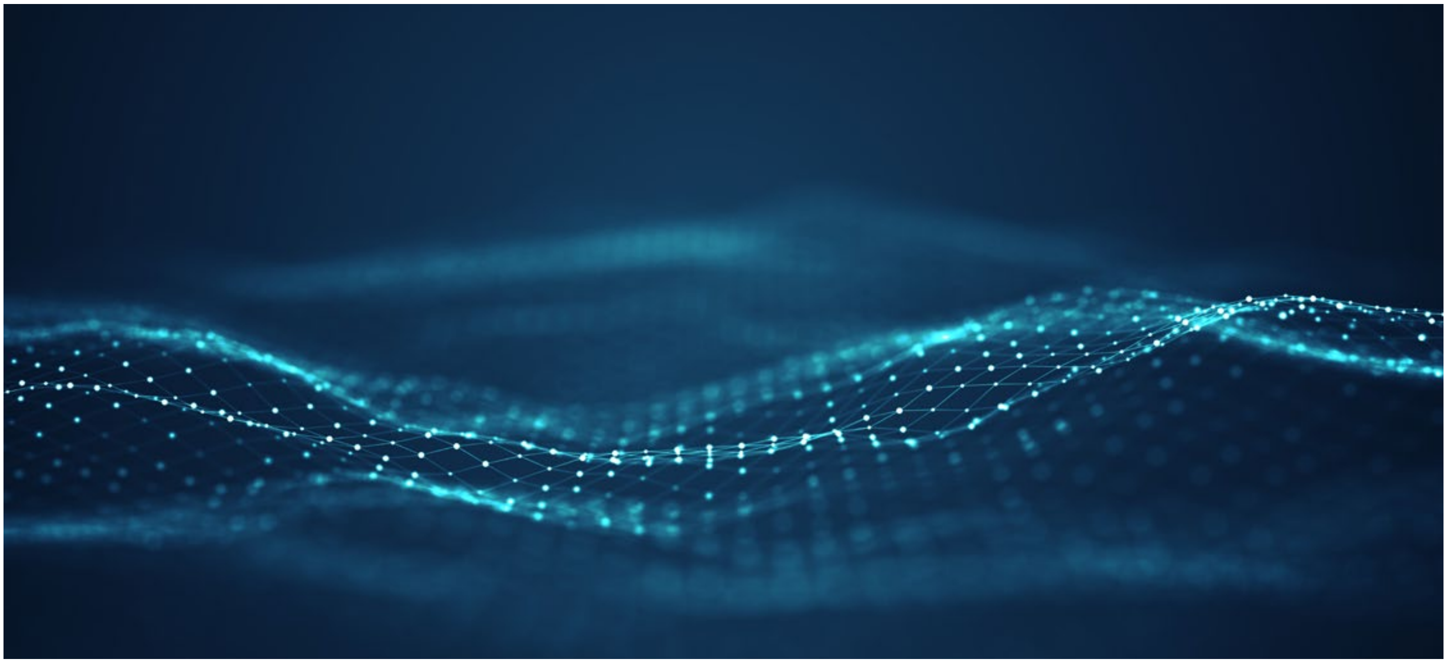

ABOUT THE QUELLO CENTER

The Quello Center is a multi-disciplinary research center within the Department of Media and Information at Michigan State University. The Center seeks to stimulate and inform debate on the economic and social implications of media, communication, and information innovations in the digital age. Its network of researchers includes faculty from across the College of Communication Arts and Sciences, Michigan State University, and associates worldwide. The Center's research is focused on the social and economic implications of developments in communication, media, and information technologies, as well as the policy and management issues raised by these developments. The Center seeks collaborations with other centers of excellence and stakeholders in research on Internet studies and new media.

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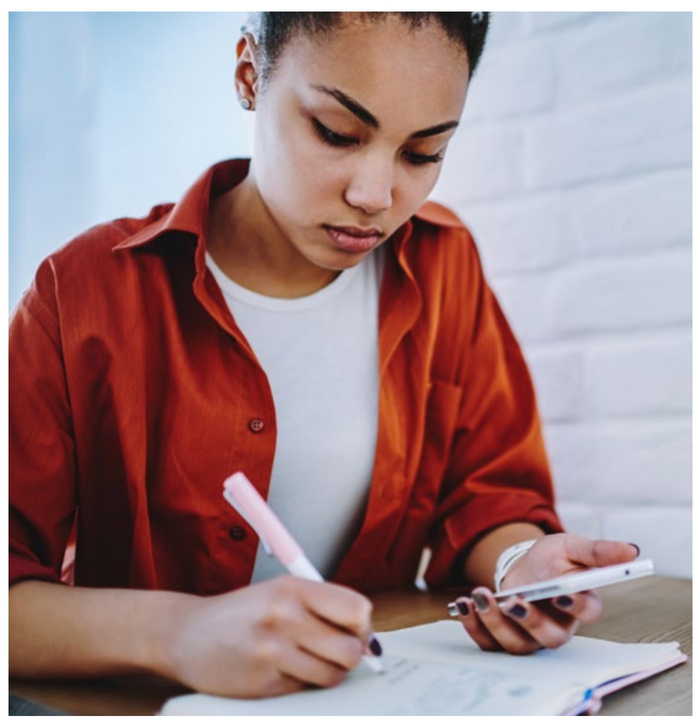
SUMMARY OF FINDINGS

This study was designed to understand the repercussions of absent or poor home Internet connectivity on student performance and the associated costs to society. The focus is on Internet connectivity outside of school among middle and high school students enrolled in rural and small-town schools. This report examines how differences in the type and quality of home connectivity (e.g., broadband vs. cell phone) relate to school performance and other student outcomes in grades 8-11, in fifteen predominantly rural, Michigan, school districts.

Inequalities related to income and race are often used to explain why some people still do not have Internet or broadband access at home. Often overlooked in this discussion is the role of geography. The role of location is not well understood because of difficulties in finding and studying contexts where Internet access is unavailable. In this study, many students do not have Internet access because they live in small towns, rural areas, or on farms that do not have an infrastructure to provide broadband Internet access or any Internet or cell phone service. If Internet access is available, it is often slow, and cell phone data access can be spotty and congested. Although poverty is also prevalent in these areas, many students live in households that would purchase high-speed home Internet access if it were available.

The variety of circumstances in the study for why students have no or poor Internet access makes it possible to differentiate disparities in student performance attributed to home Internet access from those that are related to socioeconomic inequalities (e.g., income, race, etc.). After controlling for socioeconomic factors, quality of home Internet access has an impact on a range of student performance outcomes. Contrary to some expectations that students can get by through the use of a cell phone as a substitute for high-speed home Internet access, those who rely on a cell phone only for Internet access outside of school experience as large, or larger, gaps in performance than those with no home Internet. Unlike their peers, students who are dependent on a cell phone for Internet access outside of school rely on smaller screens with slower devices, have access to content with fewer features, and need to monitor data caps and recharge pre-paid phone plans.

Students who do not have access to the Internet from home or are dependent on a cell phone for access perform lower on a range of metrics, including digital skills, homework completion, and grade point average. They are also less likely to intend on attending college or university. A deficit in digital skills compounds many of the inequalities in access and contributes to students performing lower on standardized tests such as the SAT, and being less interested in careers related to science, technology, engineering, and math.



Rural students and low-income students are less likely to have high-speed Internet access at home.

High-speed home Internet access is less common in rural areas, because rural areas are less likely to have an infrastructure to provide broadband Internet access. Students who lack home Internet access are more likely to be rural, low-income, and children of parents who do not have a university degree.

- 53% of students who live in small-town or rural areas have high-speed Internet access compared to 77% of those who live in suburbs, and 70% of those in cities.
- 9% of students in rural areas, 6% in small towns, 4% in suburbs, and 5% in cities have no Internet access at all.
- Students from families near or below the poverty line (those who are eligible for free or reduced-cost meals) were 25% less likely to have fast Internet access from home and twice as likely not to have Internet access at all or to depend on a cell phone for Internet access from home.

Students without Internet at home are less likely to have alternative sources of online access, such as through neighbors, friends, family, and libraries. Of students who do not have home Internet access:

- 35% live in a home with no computer.
- 34% have no access to the Internet for homework when not at school (i.e., they have no access to a library, church, community center, or home of a friend, neighbor, or relative with Internet access).

Many students without Internet access at home depend on a cell phone to access the Internet when away from school.

- 14% of students do not have dedicated home Internet service or a home computer, laptop, or tablet, but are able to go online through a cell phone.

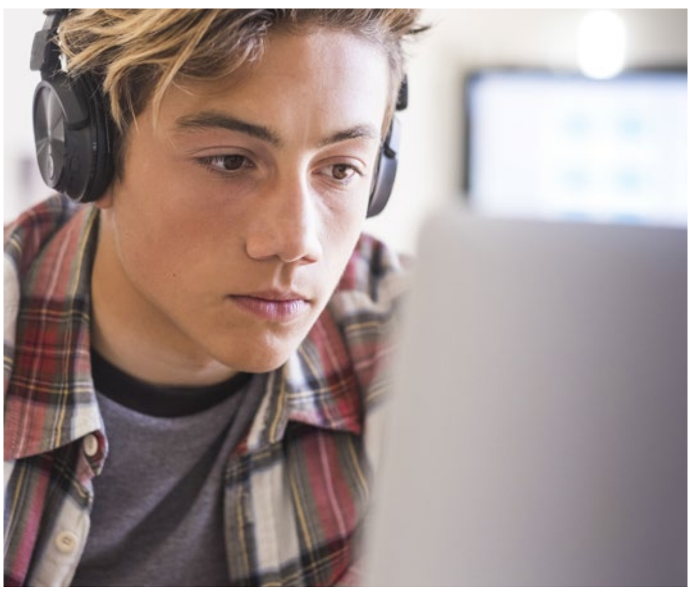
The "homework gap" is only one small indicator of the differences in student performance related to inequalities in home Internet access.

At the level of secondary education, disparities in home access to the Internet are often referred to as the "homework gap."

- 82% percent of students in grades 8-11 report that they sometimes or often receive homework that requires Internet access.
- Homework takes longer for students to complete if they don't have home Internet access. Those who have no Internet access from home spend an average of thirty additional minutes on homework per night, compared to their peers who have high-speed Internet access.

- 64% of students with no home Internet access often or sometimes leave homework unfinished because they lack Internet access or a computer. This compares to 49% of those who rely on cell phones, 39% with slow home access, and only 17% of students with high-speed home Internet access.
- After controlling for ability to access the Internet from home, there is no difference between boys and girls, between students who are racial or ethnic minorities and white students, between those who have an Individualized Education Program (IEP) and those who do not, or between low-income and wealthier students, when it comes to the likelihood that a student will report that he/she often comes to class without having completed his/her homework.

Disparities related to home Internet access go well beyond student experiences with their homework.



Students with high-speed home Internet access do more educational activities online when away from school.

Away from school, the majority of students with high-speed Internet connections continue many of the online activities that they do at school: check their grades (82%), do research (82%), turn in homework (66%), look up class information (62%), and work with their peers on projects (52%). In addition, fast Internet access from home provides unique opportunities for students to collaborate and seek support from peers and teachers. Although these activities are not commonly pursued while at school, students with fast home Internet use their connectivity from home to:

- message classmates for help with coursework (83%)
- video chat with classmates about schoolwork (66%)
- email teachers (54%)

Students without home Internet access and those who depend on a cell phones to access the Internet when away from school are less likely to participate in all online, educational activities outside of school. For example:

- Only 22% of students who are dependent on a cell phone for Internet access create documents online, compared to 47% of those with high-speed home connections.
- Whereas 45% of those with fast Internet connections at home read books and articles online, this is true for only 29% of those who rely on a cell phone.
- 66% of students with fast home Internet access submit homework assignments online while not at school, whereas only 34% of students with cell phone access are able to submit their homework.

Students with slower Internet connections lag behind in their ability to participate in online activities that require higher bandwidth, such as video chatting with peers about schoolwork, doing research, and looking up classroom information. Although many students without a home Internet connection still manage to get online to do some education activities when not at school, they participate in all activities at significantly lower rates.

The gap in digital skills between students with no home access or cell phone only and those with fast or slow home Internet access is equivalent to the gap in digital skills between 8th and 11th grade students.

Digital skills are related to competence with technology, but extend to broader abilities related to working efficiency, effective communication, and managing and evaluating information. Some skills are likely to come from formal education in schools, but others are related to frequency of use and online activities that are more likely to take place outside of school.

Differences in students' access to the Internet outside of school account for differences in their digital skills.

- Students with fast home Internet access have substantially higher digital skills than those without home access or those who have only cell phone access to the Internet.
- After controlling for variation in home Internet access, there is no difference in the level of digital skills reported by low income, minority students, or students from single parent households (although girls and students with IEPs still reported lower digital skills).

This finding, that digital skill is related to home access, is particularly important, because lack of access and having lower digital skills are independently related to many student outcomes.

Students with high-speed, home Internet access have higher overall grade point averages (half a letter grade higher, the difference between a B and a B- average).

Demographic factors explain some differences in GPA. For example, girls and students whose parents have more years of formal education tend to receive higher grades. Low-income, minority students and those from single parent households tend to receive lower grades. However, regardless of these factors, students with fast home Internet access obtain higher grades.

- On average, students with fast home Internet access report an overall grade point average (GPA) of 3.18. This is significantly higher than the average 2.81 GPA for students with no access and the 2.75 average for students who have only cell phone Internet access.
- The absence of fast Internet access at home has a significant negative relationship to overall GPA and grades in English/language arts and social studies, but not in math and science.

Digital skills predict higher scores on pen-and-paper versions of standardized tests, such as the SAT and PSAT.

Although digital skills are acquired through experience with different technologies, these skills are related to higher proficiency in a range of domains pertaining to language, computation, and information management. The College Board's SAT Suite of Assessments tests many of these domains, including evidence-based reading and writing and math. All Michigan students in grades 8-11 are administered pencil-and-paper standardized tests that are part of the SAT Suite of Assessments: the SAT (grade 11), PSAT 10 (grade 10), and PSAT 8/9 (students in grades 8 and 9). The preliminary SAT (PSAT) is used as a benchmark of student growth and performance, whereas the SAT is required in Michigan for high school graduation. Most colleges and universities use it as part of admission decisions and to award merit-based scholarships.

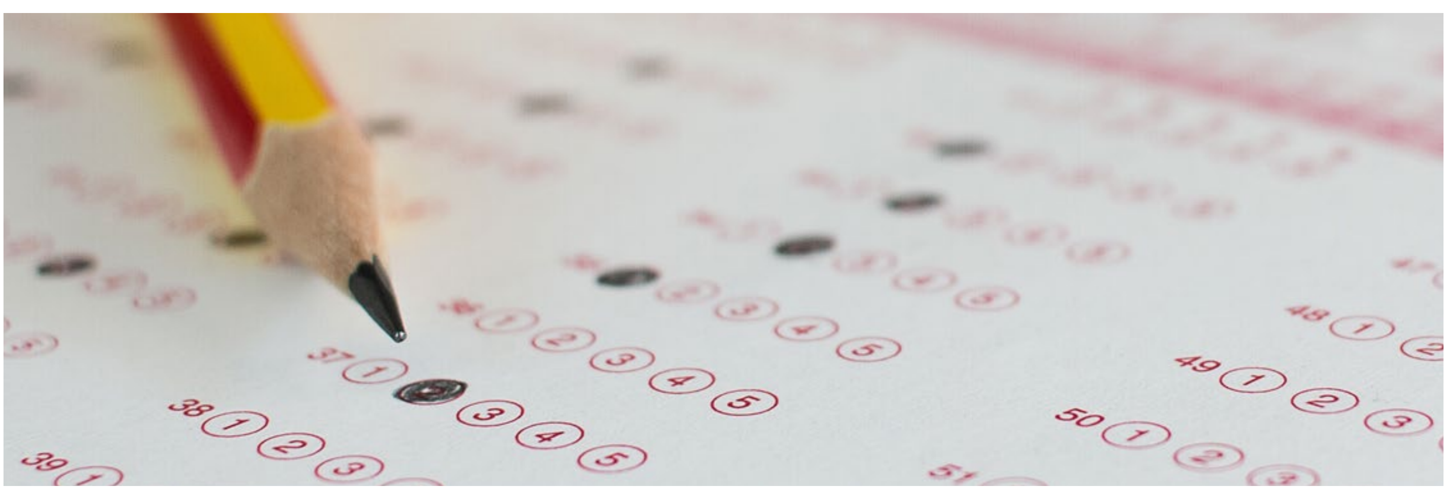
Prior research has found that low income and minority students tend to do worse on the SAT/PSAT. Regardless of income and race, findings show that students who have lower digital skills and those who depend on a cell phone for access to the Internet outside of school do considerably worse.

- A student who is even modestly below average in digital skills (one standard deviation below the mean) tends to rank nearly 7 percentiles lower on their total SAT/PSAT score, 5 percentiles lower in math, and 8 percentiles lower in evidence-based reading and writing.
- Regardless of digital skills, students who are dependent on a cell phone for their home Internet access averaged 5 percentiles lower in their national rank on the SAT and PSAT for evidence-based reading and writing, 6 percentiles lower in math, and 5 percentiles lower overall.

Students who do not have high-speed Internet access at home are less likely to plan to attend college or university.

Having a post-secondary education leads to higher earnings over a lifetime. The number of college- and university-educated students in a region can attract industry from advanced-skill fields. As the U.S. economy continues to migrate toward technology-intensive jobs across all sectors, individuals with post-secondary degrees have a better chance to work in high-skilled, high-paying occupations. Regions where educational attainment remains low are less likely to attract new technology-intensive industries.

- 47% of students who have no home Internet access or have cell phone only access to the Internet plan to complete a post-secondary program. This compares with 60% of those with slower home Internet access and 65% of those with fast home Internet.
- A student who has digital skills that are even modestly lower than average (i.e., one standard deviation below average) is 29% less likely to plan to complete a college or university program.



Students with higher digital skills are more likely to plan to enter a career in a STEM- or STEAM-related profession.

The demand for science, technology, engineering, and math (STEM) professionals is growing and outpacing the supply of STEM college graduates. More jobs are available in STEM fields than in non-STEM fields, and the average, entry-level salary in a STEM career is higher than in other career options.

- Demographic factors, such as gender and parental education level, were better predictors of interest in STEM careers than variation in home Internet access. However, digital skills predict interest in STEM careers.
- Students who are moderately lower in digital skills, e.g., one standard deviation below average, are 19% less likely to be interested in a STEM-related career.

Poor broadband connectivity impedes the ability of individuals and communities to thrive in the digital economy.

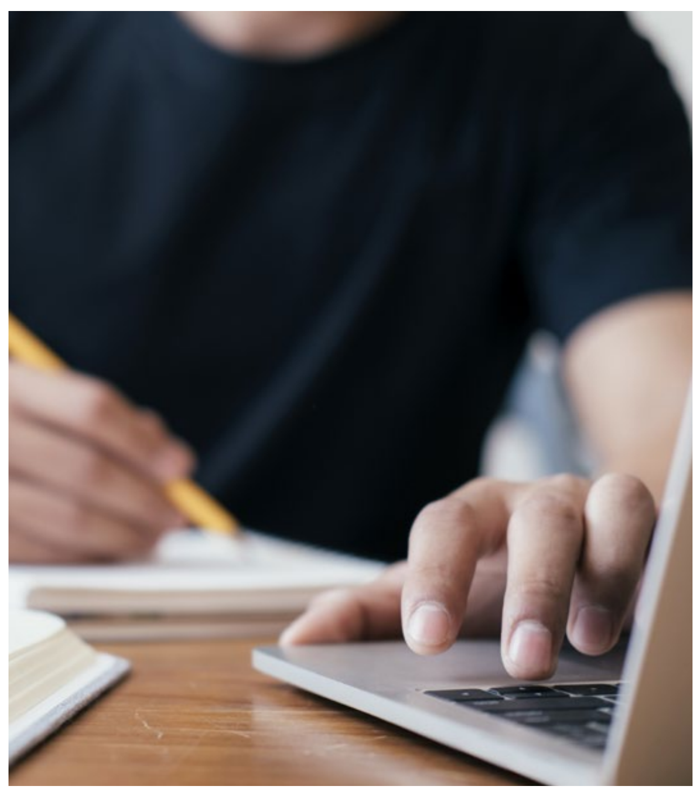
In addition to the effects on educational outcomes, lack of fast Internet access and cell phone only access are associated with disadvantages that have lifelong consequences.

- Lower grades and weaker standardized test scores associated with poor Internet connectivity reduce the chances of students to qualify for scholarships.
- The lower interest in post-secondary education or STEM careers decreases lifelong income opportunities and the ability to find jobs in occupations where future demand is high.
- Compared to communities with fast Internet access, those with poor broadband connectivity will experience fewer benefits from the digital transformation.

Data Collection

Data for this project are based on a study of students in grades 8-11 from fifteen predominately rural Michigan school districts. De-identified student data were collected through: (1) a paper survey completed in class by students aged 13 and older in partner school districts, (2) standardized test scores (i.e., PSAT 8/9, PSAT 10, and SAT) provided by school districts, and (3) home Internet speed tests.

Between May and June 2019, 3,258 students from fifteen school districts in twenty-one schools across 173 classrooms completed the project survey; they represented 70.6% of students aged 13 and older in grades 8-11 in the participating districts. Following the survey, classroom teachers assigned students an optional homework assignment that consisted of an online speed test. Eight of the school districts that participated in this project also provided de-identified standardized student test scores that were matched with students' responses to the project survey.



WHY BROADBAND CONNECTIVITY MATTERS NOW

Surprisingly little attention has been paid to the repercussions of absent or poor home Internet connectivity for high school and middle school students in rural America. This report documents an extensive investigation into the extent to which the students in some of the most rural school districts in Michigan can access the Internet when not at school. There are extreme differences in student performance related to their home connectivity.

Scholars have referred to disparities in home Internet access as the "homework gap" (Reisdorf, Yankelevich, Shapiro, & Dutton, 2019). However, the simple distinction between the ability or lack of ability to complete homework online ignores how variation in the quality of home Internet access affects performance. It does not reflect that home connectivity is tied to broader educational outcomes. The findings outlined in this report highlight how lack of home access negatively affects homework completion, grades, digital skills, standardized test scores (such as the SAT and PSAT), interest in post-secondary education, and even the choice of careers.

There is growing recognition that many rural areas lack broadband service. However, shortfalls in the quality of the data available to identify holes in broadband coverage have left hidden the extent of the gap in broadband coverage. When gaps in land-based, broadband Internet access are recognized, concerns are often minimized through arguments that wireless, cell phone access can provide a stop gap. Yet, students who rely exclusively on cell phones and cell data plans to access the Internet experience many of the same deficits in performance and outcomes, and, at times, to a greater extent.

Despite universal Internet access in schools, and a growing curricular focus on the skills needed to participate competently in the digital economy, schools lack the tools necessary to close the gap in student performance that is tied to student disparities in home Internet access. Consequently, entire regions that lack Internet access may be permanently disadvantaged as a result of unaffordability, not knowing the benefits of connectivity, or missing infrastructure.

[Mis]Mapping Broadband in America

Deficits in the data available to map broadband access have obscured the extent of the connectivity gap in rural America. The National Telecommunications and Information Administration (NTIA) produced the first U.S. Broadband Map in 2009. The Federal Communications Commission (FCC) continued this effort. Broadband service providers must report data to the agency twice a year using Form 477. On this form, they submit information on the geographic areas in which broadband subscribers are located or for which deployment is planned.

Broadband maps are generated from these data. This approach has a number of known weaknesses, which include insufficient granularity, over-estimation of coverage, and weak methods to corroborate the accuracy of provider-reported information (Ford, 2019; Grubesic, 2012; Mack, Dutton, Rikard, & Yankelevich, 2019). This has led to the systematic underestimation of the availability and quality of broadband connectivity in America. For example, Microsoft recently found that 162.8 million people, rather than the 24.7 million as per FCC data, did not have Internet at broadband speeds.[1] Other empirical studies, such as the M-Lab mapping project, have reached similar conclusions. Not only has coverage been broadly underestimated, but the lack of granularity has led to the widespread misclassification of underserved or unserved areas as served. Consequently, programs to support infrastructure development do not reach many of the areas in need.

Several projects are underway to improve the reliability of future data and maps of broadband coverage. This includes efforts from within the government to improve the quality of data reported by broadband service providers,[2] and independent initiatives experimenting with alternative methods to generate reliable broadband data. Most efforts by non-governmental organizations rely on data crowdsourced from Internet users (e.g., Deng et al., 2019; Meinrath et al., 2019). Although crowdsourcing projects can improve the granularity and accuracy of the available information on broadband speeds, they capture only already connected households and do not locate the unconnected.

Evidence from Rural School Districts

The aim of this project was to identify the prevalence of Internet (dis)connectivity in Michigan school districts where students are predominately from rural and small-town areas. One goal was to measure the cost of a lack of connectivity on middle and high school student performance and to explore how different types of home connectivity (e.g., broadband vs. cell phone) are related to variations in student outcomes. A secondary goal was to develop a data collection and analysis framework to serve as a blueprint for future studies to measure the extent of student connectivity and the consequences of unequal and insufficient broadband across America's cities, suburbs, and rural areas.

To discuss initiatives to increase student connectivity at home, Merit Network and the Quello Center at Michigan State University (MSU) brought together in December 2018 the K12 Citizen Science Working Group, a small group of stakeholders from Michigan school districts. From this group, three Intermediate School Districts (ISDs) volunteered to work with the Quello Center and Merit Network to develop and pilot an approach to measure rates of home connectivity among their students and explore the relationship between connectivity and student performance. The three ISDs agreed to work with their school districts to 1) administer an in-class survey to students, 2) have students complete an optional homework assignment consisting of an online speed test, and 3) share de-identified standardized test scores.

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[1] See, for example, https://blogs.microsoft.com/on-the-issues/2019/04/08/its-time-for-a-new-approach-for-mapping-broadband-data-to-better-serve-americans/. In January 2015, the FCC increased the threshold for broadband speed from 4 mbps download/1 mbps upload to 25 mbps download/3 mbps upload. (See https://www.fcc.gov/document/fcc-finds-us-broadband-deployment-not-keeping-pace-0).

[2] In August 2019, the FCC adopted a Report and Order, titled Establishing the Digital Opportunity Data Collection: Modernizing the FCC Form 477 Data Program, with the goal to improve broadband mapping (FCC, 2019b). Using improved methodology, on October 2, 2019, NTIA released data from a pilot project with eight U.S. states (see https://www.ntia.doc.gov/blog/2019/ntia-releases-new-broadband-availability-map-pilot-policymakers).

In compliance with the MSU Institutional Review Board, the Family Educational Rights and Privacy Act (FERPA), and related regulations, the Quello Center collected de-identified survey, speed-test, and standardized test data. In May and June 2019, students, aged 13 and older, from grades 8-11, in fifteen school districts located within the Eastern Upper Peninsula ISD, Mecosta Osceola ISD, and St. Clair County Regional Educational Service Agency participated in this project (see Appendix B for the complete list of districts).[3] The survey was administered to students in 173 classrooms in twenty-one schools. Within these schools, 4,617 students were enrolled in grades 8-11 (Michigan Department of Education & Center for Educational Performance and Information, 2018). The survey took students approximately twenty minutes to complete. A total of 3,258 students completed surveys, representing coverage of 70.6% of eligible students.[4] The survey was coded using a unique participant ID and was accompanied by a separate key sheet that linked the participant ID to the student's school ID. The key, retained by the Intermediate School Districts, was used to pair student surveys with standardized test scores held by the school districts. Eight of the school districts provided de-identified standardized student test scores that were matched with students' responses to the project survey (N=2,001). The ISDs ensured that the student information was fully de-identified before it was made available to researchers at the Quello Center.

Using the M-Lab measurement platform, Merit Networks developed and operated the optional homework assignment. It asked students with Internet access outside of school to visit a website and complete an Internet speed test on any device they used for homework. The speed test recorded information on the quality and speed of their Internet connection. Speed test data were also keyed to the project survey using the unique survey ID.
Like standardized test scores, speed test data were stripped of personally identifiable information (e.g., location, IP address) before they were shared with the Quello Center.

Performance Gaps: Internet Access or Socioeconomic Status?

When studying student performance as it is related to Internet use, it was important to recognize that some demographic characteristics are also related to students' performance gaps. For example, previous research has found that racial and ethnic minorities and students in special education programs tend to receive lower grades, whereas students from families with higher incomes, students with parents who have higher levels of education, and girls tend to receive higher grades (Fortin, Oreopoulos and Phipps, 2015; The College Board, 2013, 2019a). Many of these same demographic factors are also related to whether students have home Internet access. In fact, much of the existing research on inequalities in digital access focuses almost exclusively on how existing inequalities, primarily those related to income and race, are likely to predict lack of access (Campos-Castillo, 2015).

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[3] Initially, this project hoped to survey students in grades 7-12 in fifteen districts. However, the approved IRB procedure for informed consent was limited to students aged 13 and older; as a result many students in grade 7 were not eligible. In addition, the timing of the project survey toward the end of the school year fell after many students in grade 12 had completed their graduation ceremony, which resulted in a precipitous decline in attendance. This report is limited to those students in grades 8-11.

[4] Where noted in the analysis, missing data on some questions may result in fewer cases being reported.

The difficulty involved in finding and studying contexts in which Internet access is unavailable has been an obstacle in identifying differences in student outcomes and performances related to Internet access. In many studies, lack of access is synonymous with poverty and racial inequality. In a study that randomly selects participants from the general American population, few who have the socioeconomic means to purchase broadband home Internet access choose not to. However, this is not always the case in rural America. In this study, many students do not have Internet access because they live in small towns, rural areas, and on farms that do not have an infrastructure to provide broadband or any Internet or cell phone access. If Internet access is available, it is often slow, and cell phone data access can be spotty and congested. Although poverty is also prevalent in these areas, many students live in households that would purchase high-speed home Internet access if it were available. Given the variety of circumstances in this study for why students have no or poor access (socioeconomic factors and geographic factors), we are better able to identify differences in student performance that can be attributed to socioeconomic inequalities (e.g., income, race, etc.) from those that are related to differences in home Internet access.

Although the variation in this sample makes it possible to identify when student performance gaps exist in relation to variation in home Internet access, differences in student performance might still be related to demographic factors and be unrelated to Internet use. To isolate these relationships, we present the results of statistical analyses that control for the influence of sociodemographic factors. Specifically, we use a form of regression analysis called hierarchical linear modeling (HLM) to examine the relationship between student home Internet access and different performance measures. We hold constant gender, grade level, whether a student has an IEP, highest level of parental education, low-income status (is eligible for free or reduced-cost meals at school), whether a student lives primarily with only one parent, and whether a student is a racial or ethnic minority.[5] Findings based on these regression analyses compare the behaviors or outcomes of people with different types of Internet access with demographically similar people. This approach differentiates outcomes that can be attributed to differences in Internet access and those that are related to differences in other demographic factors

Michigan's Rural Districts in Context

Michigan has a population of close to 10 million residents, 75% of whom live in the state's urban land area, consisting of 3,623 square miles (6.4 % of the state's landmass). The remaining 25% of the population (2.5 million people) occupy 93.6% of the state (52,916 square miles) that is rural land (Citizens Research Council of Michigan, 2018). Twenty-one percent of Michigan students are enrolled in schools classified by the National Center for Education Statistics (NCES) as rural, and an additional 12% attend small town schools. Compared to other states, Michigan ranks 31st in the nation for the proportion of students enrolled in either rural or small-town schools (see Appendix A). States with the highest proportion of rural students include Vermont, Maine, Mississippi, and West Virginia. Compared to other Midwest states, only Illinois has a smaller proportion of its students enrolled in rural schools; Michigan has a smaller proportion of rural students than North Dakota, South Dakota, Nebraska, Minnesota, Iowa, Missouri, Wisconsin, Kansas, Indiana, and Ohio.[6]

Sample Characteristics

The fifteen school districts that participated in this project are located in areas that are predominately rural; population densities range from 1.52 people per square mile to 222.81 people per square mile (see Appendix B). Townships in rural Michigan average 102 people per square mile compared to 1,609 people per square mile for urban areas (Citizens Research Council of Michigan, 2018). Eight percent of students in this sample reported living on a farm, 39.1% in a rural area but not a farm, 38.3% in a small town, 6.8% in a suburban area, and 7.7% in a city.

District median household incomes range from $34,205 to $67,371 (the median for all of Michigan is $52,668; the median is $57,652 nationally).[7] The proportion of district families that fall below the federal poverty level is, on average, 9% and ranges from 3.4% to 17.4% (it is 10.9% for all of Michigan and 10.5% nationally). In this sample, 35% of the participating students qualified for free meals or the reduced-cost meal program. Children are eligible for free or reduced-price meals if their household is receiving benefits from the Food Assistance Program (FAP), Family Independence Program (FIP), or Food Distribution Program on Indian Reservations (FDPIR), if they participate in the school's Head Start program, or if they meet Federal Income Eligibility Guidelines (e.g., living in a household with four people and an annual income at or below $47,638).[8]

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[5] HLM also addresses an issue in regression analysis that is related to analyzing nested data. In our analysis, we nested data 2-levels: students who are nested in school districts. HLM accounts for the additional statistical complexity related to studying students across different districts, when students from the same district may have more in common with each other than students at selected at random.

[6] Based on the 2017-18 U.S. Department of Education Common Core of Data, available from https://nces.ed.gov/ccd/

[7] Based on NCES and ACS 2013-2017, available at https://nces.ed.gov/ccd/schoolsearch/

[8] See Michigan Department of Education, School Nutrition Programs, Eligibility Certification and Verification https://www.michigan.gov/mde/0,4615,7-140-66254_50144-194552--,00.html

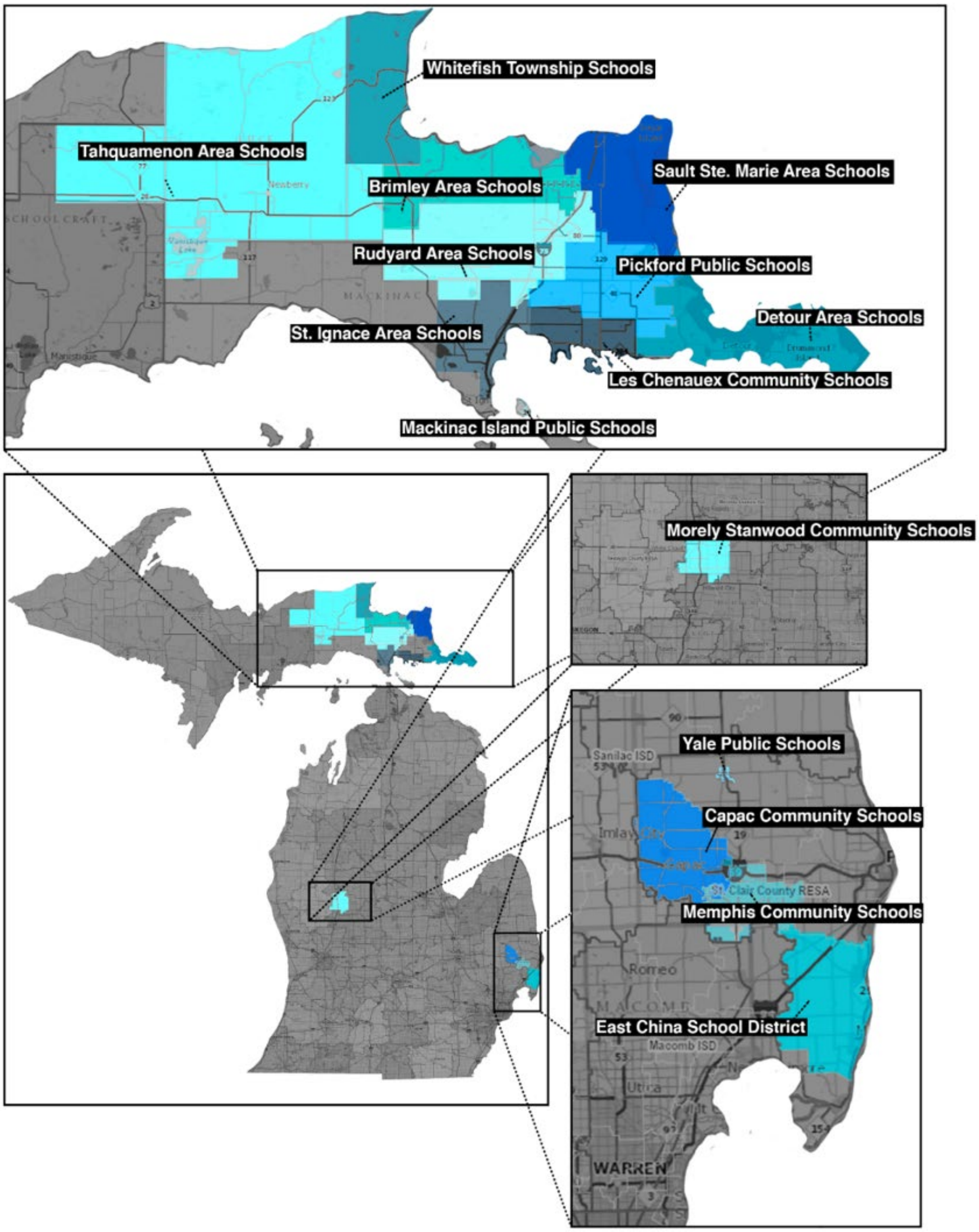
The population of all districts is relatively homogeneous. In this sample, 80.4% of students identified as white, 9.5% as Native American or American Indian, 1.0% as Asian or Pacific Islander, 0.5% as Black or African American, 7.1% as of mixed race, and 1.4% as other.

Students reported their parents' highest education levels as: 32.5% high school or less, 16.6% some college or university, 28.1% an undergraduate degree, and 22.8% a graduate degree or some postgraduate training.

Students were nearly evenly distributed across grades 8-11. There were slightly more girls than boys: 47.7% of the students were male and 52.3% were female. Ages 14, 15, and 16 years were relatively evenly represented (24.2%, 26.2%, and 24.6%, respectively), with smaller shares of students aged 13 (8.6%), 17 (14.9%), and 18 (1.5%) years.

Approximately one-third of the students reported that they were living with only one parent or not living with any parent.

Participating Michigan School Districts



Source: Quello Center. Broadband and Student Performance Gaps

Student Characteristics Based on Project Survey Results

	Students	%
Grade		
8th grade	828	25.4
9th grade	890	27.3
10th grade	847	26.0
11th grade	693	21.3
Total	3,258	100.0
Gender		
Male	1,544	47.7
Female	1,694	52.3
Total	3,238	100.0
Age		
13 years	278	8.6
14 years	782	24.2
15 years	847	26.2
16 years	795	24.6
17 years	483	14.9
18 years	49	1.5
Total	3,234	100.0
Race		
White	2,593	80.4
Black or African American	16	0.5
Asian or Pacific Islander	31	1.0
Native American or American Indian	311	9.5
Mixed Race	228	7.1
Other	46	1.4
Total	3,225	100.0
Receives free or reduced-price lunch		
No	2,114	64.9
Yes	1,144	35.1
Total	3,258	100.0
Highest parental education		
High school or less	966	32.5
Some college or university	494	16.6
Undergraduate degree	834	28.1
Some post grad or graduate degree	679	22.8
Total	2,973	100.0
Location		
Farm	260	8.0
Rural area but not on a farm	1,264	39.1
Small Town	1,238	38.3
Suburb	219	6.8
City	249	7.7
Total	3,230	100.0
Living situation		
Lives with parents	2,156	66.2
Lives with one or no parent	1,079	33.1
Total	3,235	99.3

Note: The totals for each characteristic vary slightly depending on missing data or lack of student response.

Source: Quello Center. Broadband and Student Performance Gaps

GETTING ONLINE

Michigan students lack Internet access at home for a variety of reasons, including the cost of access, the cost of devices, lack of parental interest, and living in areas that are not serviced by an Internet service provider (Michigan Consortium of Advanced Networks, 2018; Fernandez, Reisdorf, & Dutton, 2019). Fewer students in rural areas have Internet access at home. High-speed home Internet access is less common in rural areas, as a result of socioeconomic factors related to income and because rural areas are less likely to have an infrastructure to provide broadband Internet access. Students who lack home Internet access are more likely to be rural, low-income, to identify as a racial or ethnic minority, to receive a free or reduced-cost lunch, and to come from a single-parent family.

Access to the Internet from Home

Students reported whether they had Internet access at home, and whether it was fast or not. They also reported whether they had a cell phone with a data plan and what devices they had at home (e.g., a tablet or computer). In this report a distinction is made between 1) students who report having "fast" or high-speed Internet access that is likely to come into the home from a broadband connection, 2) students who have a slower home connection that might include a digital subscriber line (DSL) or a satellite connection, 3) students who have cell phone only access using a paid data plan and a mobile phone, and 4) students who have no home access but may still get online at places outside their home, such as libraries and free Wi-Fi hotspots.[9]

When pre-testing the survey, we found that students could not reliably self-report the speed of their home Internet connection. Those without Internet access could generally not report why they didn't have access: whether it was related to cost, their parent's lack of interest, or the lack of a broadband service provider in their area. As a result, if they had service, we relied on students' experiences and opinions about whether their Internet access was "fast," which meant that it was of sufficiently high-speed. We then triangulated the results of the survey with data from an optional speed-test homework assignment that provided actual measures of Internet speeds at places and on devices used for homework.

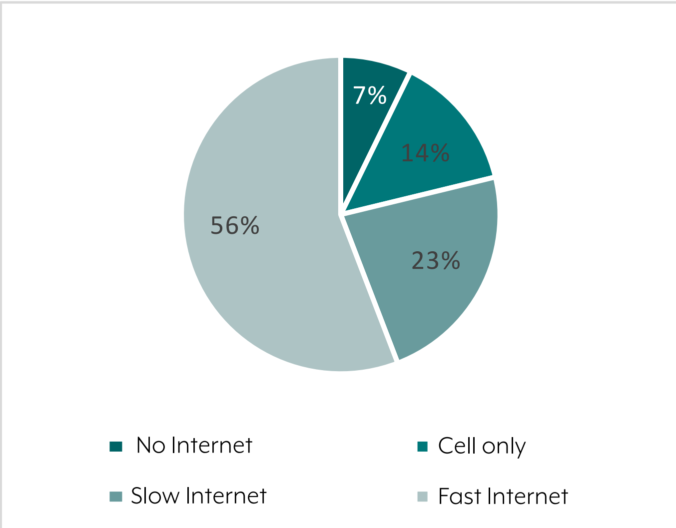
Fifty-six percent of students said that they had fast Internet access at home. An additional 23% reported that they had slower Internet access. Seven percent of students reported that they had no home Internet access at all, whereas 14% reported that, although they did not have dedicated home Internet service, they owned a cell phone with a data plan.

When survey data were compared to the speed-test, we found a pattern that was consistent with student reports; this increased confidence in the survey data. The average download speed for students who said they had fast home Internet was 31.54 mbps (SD = 38.54), whereas the average for students who said they had slow home Internet was 7.97 mbps (SD = 11.89). The average download speed was 27.8 mbps (SD = 38.45) for students who said they had only a cell phone to access the Internet. A similar pattern held for average upload speeds, which were 7.16 mbps (SD = 5.76) for students who said they had fast home Internet, 3.43 mbps (SD = 10.18) for students who said they had slow home Internet, and 6.52 mbps (SD = 4.91) for students who said they had only cell phone access to the Internet (N=264) (see Appendix C for additional details).

[9] In this study, students who relied on a cell phone and a data plan for Internet access did not own a home computer or a tablet.

56% of students have high-speed Internet access at home.

% of students by type of Internet access at home



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

Why No Internet Access?

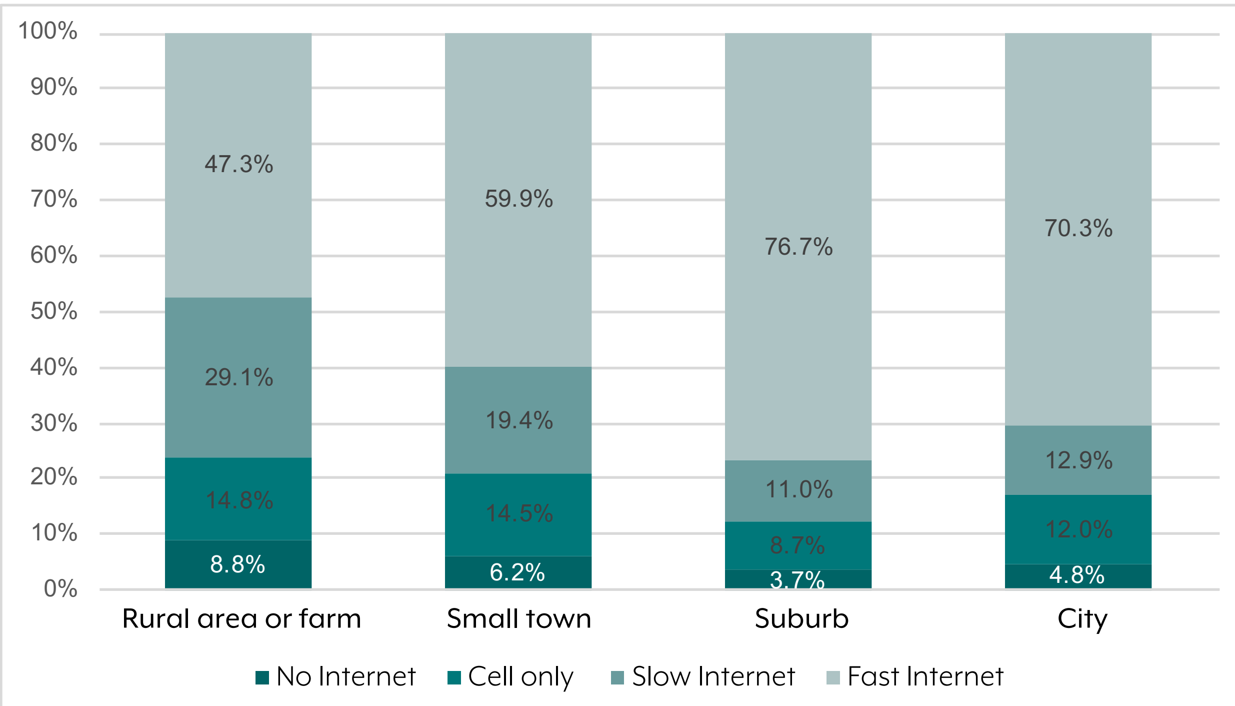
A lack of broadband Internet connectivity is a function of the absence of infrastructure – no broadband service providers or limited competition – and socioeconomic factors, such as income.

In the fifteen predominantly rural school districts included in this study, those students who lived in more isolated areas were less likely to have Internet at home. When they did have Internet access, students in small towns and rural areas were more likely to depend on slow access or access through a cell phone.

- 53% of students who live in small town or rural areas had fast Internet access, compared to 77% of those who live in suburbs, and 70% of those in cities.
- An additional 25% of small-town and rural students had slower home access, compared to 11% in suburbs, and 13% in cities.
- Students who relied only on their cell phones for Internet access include 15% of small-town and rural students, 9% of suburban students, and 12% of students in cities.
- 8% of students in rural and small towns, 4% in suburbs, and 5% in cities have no Internet access at all.

Students who live in more isolated areas are less likely to have high-speed Internet access at home.

Internet connectivity by location (%)



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

In addition to the role of location, students from families with lower income, those in single-parent households, and those who did not have a parent who had completed a university degree were all less likely to have home Internet access. They were also less likely to have high-speed home Internet access and more likely to depend on a cell phone for access to the Internet from home.

- Students from families near or below the poverty line (those who were eligible for free or reduced-cost meals) were 25% less likely to have fast Internet access from home, and twice as likely not to have Internet access at all, or to depend on a cell phone for Internet access from home.
- Students who lived primarily with only one parent (single-parent households), were 18% less likely to have high-speed Internet, 50% more likely not to have Internet access at all, and nearly twice as likely to be cell-phone dependent.
- Those who have at least one parent with a university degree were 23% more likely to have fast home Internet access, 30% less likely to have no home Internet, and half as likely to depend on a cell phone for access to the Internet form home.
- There was no statistically significant difference between the likelihood of having Internet access at home and students who were or were not racial or ethnic minorities, and between students with or without an IEP.

Type of Internet access by demographics (%)

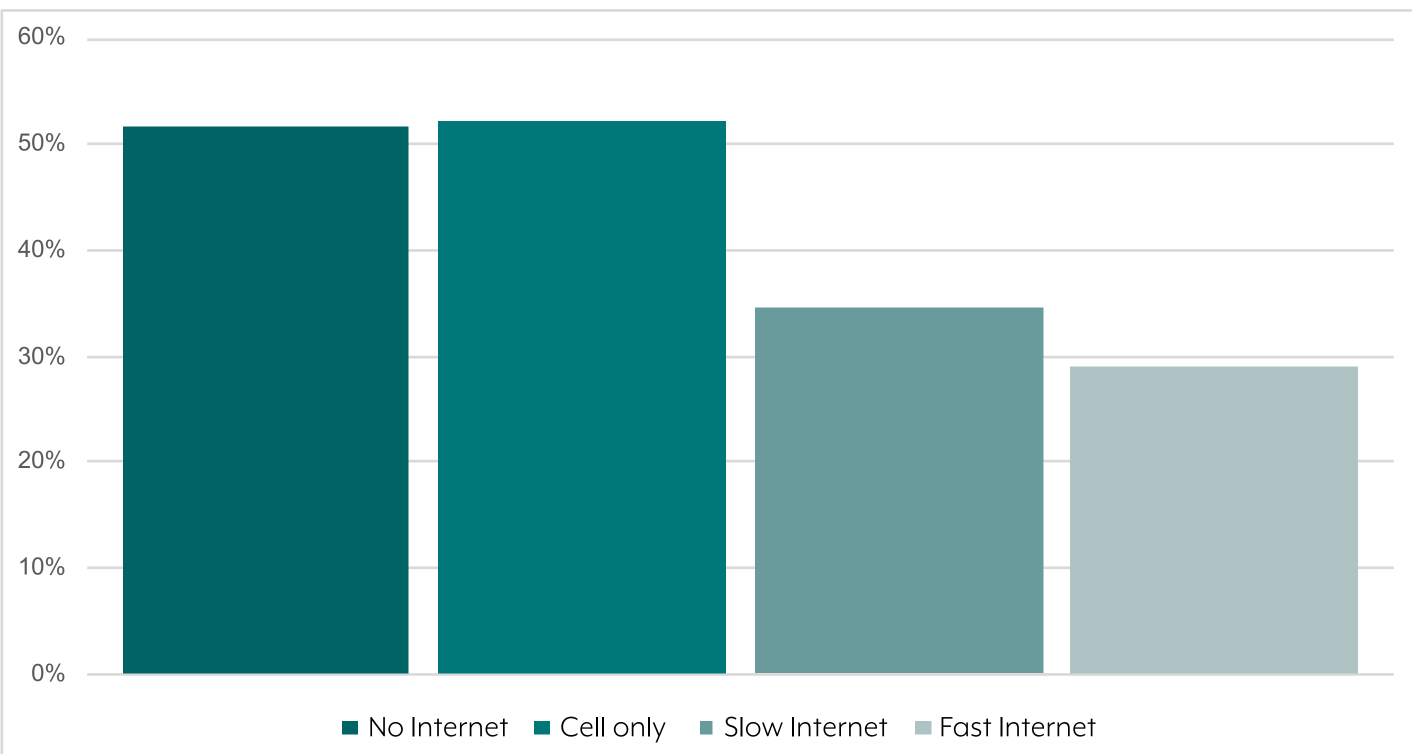
		No Home Access	Cell Only at Home	Slow Home Internet	Fast Home Internet
Low income (free or reduced-cost lunch)	Yes	10.7***	20.7***	22.6	46.1***
	No	5.4	10.3	23.2	61.1
Single-parent family	Yes	9.5***	20.4***	21.3	48.7***
	No	6.1	10.7	23.8	59.4
Racial or ethnic minority	Yes	8.5	15.3	20.2	56.1
	No	6.9	13.6	23.7	55.8
Individualized education plan (IEP)	Yes	8.2	14.0	20.6	57.1
	No	7.1	14.0	23.4	55.6
Parent has a university degree	Yes	5.8**	9.9***	22.9	61.3***
	No	8.4	18.0	23.6	49.9

Note: Students in the "yes" group are statistically different from those who are "no", *p<.05, **p<.01, ***p<.001

Source: Quello Center. Broadband and Student Performance Gaps

Students from low-income families are less likely to have home Internet access.

% students who receive a free or reduced-cost school lunch by home Internet access



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

If Not at Home, Where?

Sixty-six percent of those students who do not have Internet access at home travel at least occasionally to another place to use the Internet for homework. This means that 34% of those without home Internet access never have access to the Internet for homework outside of school.

The houses of friends (37%) and family (36%) are the most likely locations for those without Internet access at home to go online, followed by libraries (31%) and restaurants/coffee shops (25%). However, those who have no home Internet access, slower access, or only access over a cell phone, are less likely to use friends, family, and other places to access the Internet when compared to students with fast home Internet. For example, whereas 27% of those with fast home Internet access sometimes use their neighbor's Internet when doing homework, this is true for only 15% of those with no Internet access at home.

If students have lower access as a result of income disparities, or as a result of living somewhere where broadband Internet service is not available, then friends, family, neighbors, and the local community are also less likely to have Internet access. In many situations, students without Internet access at home have no alternative place to go online outside of school.

Where students use the Internet for homework outside of home and school (%)

	No Home Access	Cell Only at Home	Slow Home Internet	Fast Home Internet
Friend's house	37.3	44.6	46.5	53.4
Neighbor's house	15.3	18.2	19.5	26.6
Other family's house	36.4	39.8	44.0	50.2
Coffee shop or restaurant	25.4	24.4	29.4	33.2
Library	30.5	30.8	36.2	36.6
Community center	10.6	13.4	15.5	18.7
Church or place of worship	7.6	10.8	13.4	16.4
N	236	455	748	1819

Source: Quello Center. Broadband and Student Performance Gaps

PERFORMANCE GAPS

Students who do not have home Internet access perform lower on a range of metrics. These differences exist regardless of gender, race, and Ethnicity; parental income and education; and whether the student has an individualized education plan (IEP). For many outcomes, students who access the Internet only through their phones perform similarly to those who cannot access the Internet from home at all. For many students, deficits in outcomes and student performance are amplified by a lack of digital skills, which are closely related to having Internet access from home. Examples of this deficit can be found in students' grades, standardized test scores, homework completion, intention to attend post-secondary education, and career choices.

Educational Activities Online

Students use the Internet for a wide range of education-related activities, including accessing course-related content, doing research, and collaborating. Having Internet access at home allows students to carry activities from the classroom over to the home. In addition, some online activities, especially those related to seeking help from peers and teachers, are more common when outside of school. However, although some students without home Internet do find alternative places to get online, their online activities outside of school are far less diverse than those with a dedicated home Internet connection. Compared to those who rely on a cell phone for access to the Internet, students with faster Internet access at home are better able to complete education-related tasks online. There are also some activities, mainly those that require higher bandwidth, where students with slower home connections also lag.

A majority of students use the Internet at school for the following educational activities:

- Checking grades (90%)
- Creating online documents (87%)
- Doing research (85%)
- Turning in homework (83%)
- Working on projects with peers (82%)
- Looking up class information (74%)
- Watching educational videos (70%)
- Reading books and online articles (58%)
- Using online textbooks (53%)

Away from school, the majority of students with high-speed Internet connections continue to check their grades (82%), do research (82%), turn in homework (66%), lookup class information (62%), and work with their peers on projects (52%). Unlike school-based activities, the majority of students with high-speed connections also use their connectivity from home to:

- Message classmates for help with coursework (83%)
- Video chat with classmates about schoolwork (66%)
- Email teachers (54%)

Having fast Internet access from home provides unique opportunities for students to collaborate and seek support from peers and teachers.

School related activities that students do online from home and school (%)

Online activity	At School	Outside of School			
		No Home Access	Cell Only at Home	Slow Home Internet	Fast Home Internet
Check grades	90.2	56.8***	65.7***	79.0	82.1
Create online documents	87.0	33.9***	21.8***	44.9	47.4
Research	84.8	56.4***	62.6***	77.7*	81.8
Turn in homework	82.9	42.4***	33.8***	62.0	65.6
Work with peers on a project	81.6	31.8***	32.3***	47.9	51.2
Look up class information	73.7	44.1***	40.9***	57.5*	62.1
Watch educational videos	70.2	20.3***	16.3***	31.3	30.8
Read books/online articles	57.5	31.4***	29.0***	44.4	45.3
Use online textbooks	52.5	25.4***	22.6***	36.8	40.4
Email teachers	43.8	39.4***	33.2***	50.1	53.7
Message classmates for help	36.2	68.6***	74.1***	80.3	82.6
Text/message teachers' questions	23.8	33.1***	29.0***	43.0	45.4
Video chat w/ classmates about schoolwork	13.7	51.3***	53.6***	53.6***	65.5
N	3,258	236	455	748	1,819

Note: Statistically lower from students with fast home Internet, *p<.05, **p<.01, ***p<.001

Source: Quello Center. Broadband and Student Performance Gaps.

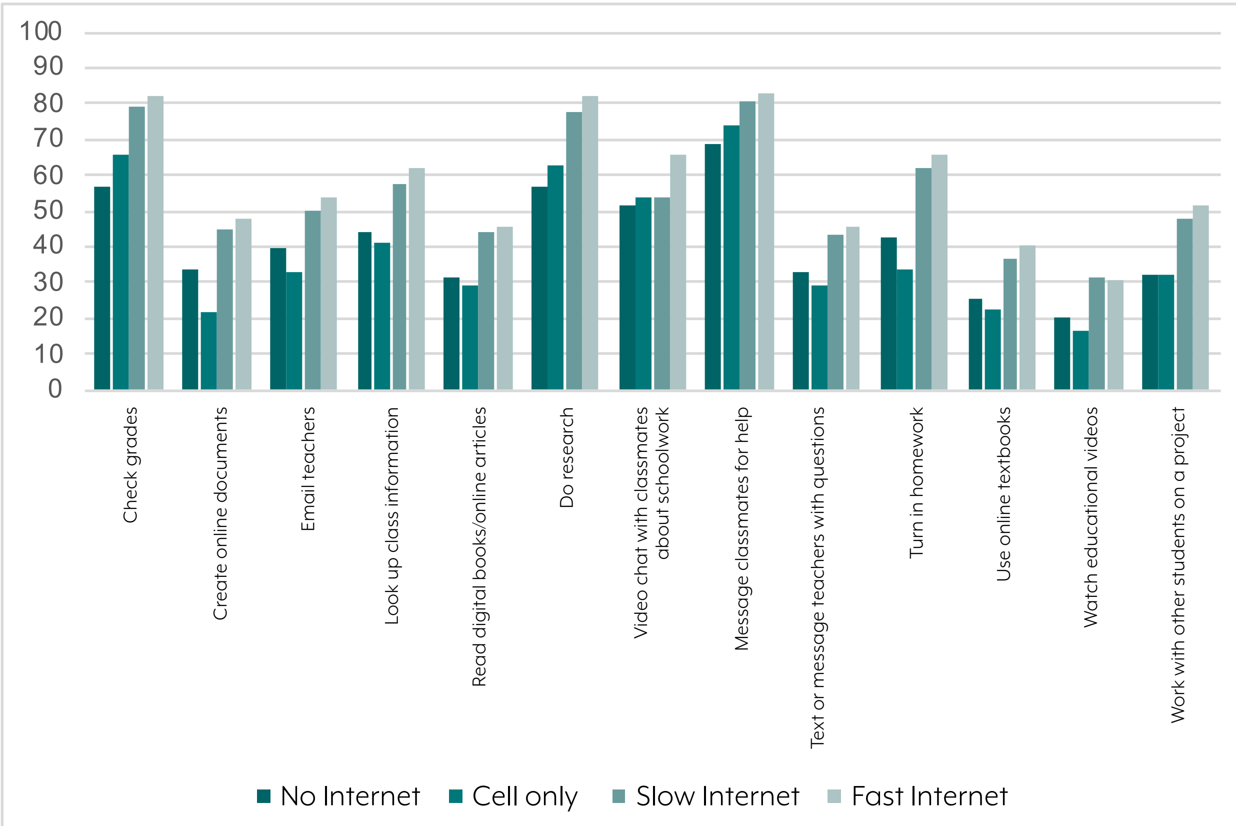
Students without home Internet access, and those who depend on a cell phone to access the Internet when away from school are less likely to participate in all online educational activities outside of school. For example:

- Only 22% of students who are dependent on a cell phone for Internet access create documents online, compared to 47% of those with high-speed home connections.
- Whereas 45% of those with fast Internet connections at home read books and articles online, this is true for only 29% of those who rely on a cell phone.
- 16% of students who can go online only through their cell phones watch educational videos online, compared to 31% of those with fast home connections.
- 66% of students with fast home Internet access submit homework assignments online while not at school, whereas only 34% of students with cell phone access are able to submit their homework.

Slower data speeds, data caps, and the size of devices are all barriers to the engagement of cell phone users with online educational activities. Other research suggests that lower-income groups that rely on cell phones also experience intermittent periods of disconnection because of usage caps and lapses in pre-paid plans (Gonzales, Ems, and Suri, 2016). Students with slower Internet connections lag in their ability to participate in online activities that generally require higher bandwidth, such as video chatting with peers about schoolwork, doing research, and looking up classroom information. Although many students without a home Internet connection still manage to get online when not at school to engage in some online education activities, they participate in all activities at significantly lower rates.

Students with high-speed Internet access at home are more likely to seek help from their teachers and peers.

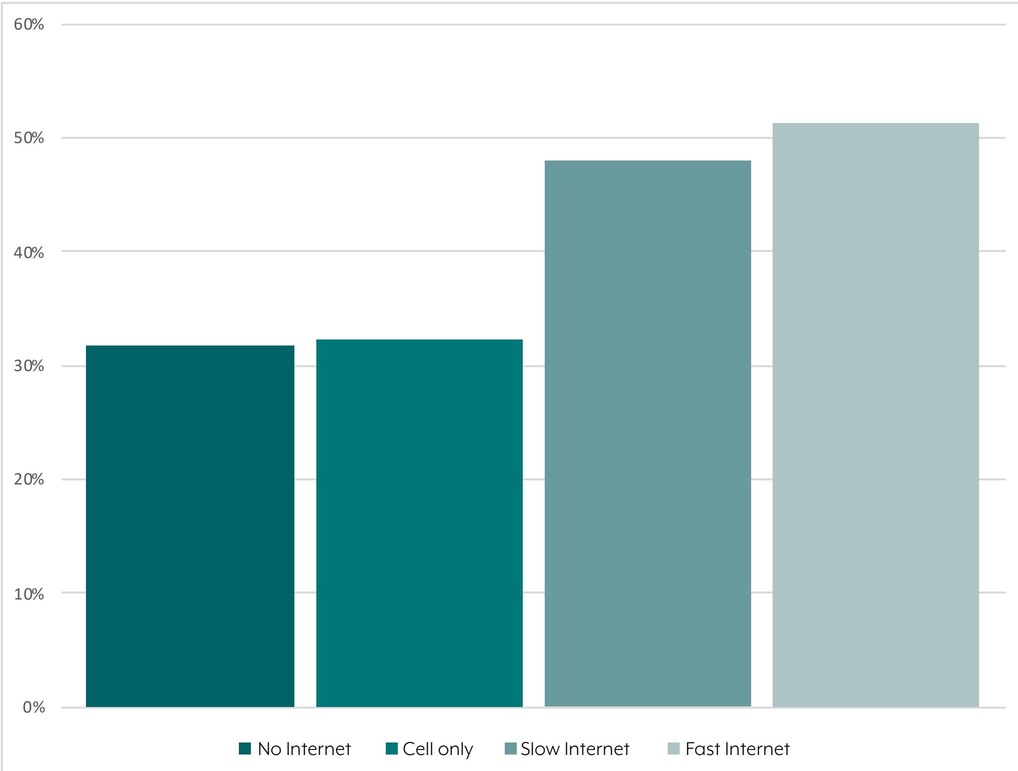
% students who use the Internet for educational activities when away from school by type of home Internet access



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

Students without home Internet access have less opportunity to collaborate with peers on projects.

% students who work with peers on a project online when away from school by type of home Internet access



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

Homework

To understand how access to the Internet from home is related to homework activities, students were asked how often they "receive homework assignments that require Internet access," "go to class without your homework done," "leave homework assignments unfinished because [they] did not have access to the Internet or a computer,"[10] and "how many hours they spent doing homework or studying for math, science, and the rest of their classes on a typical weekday."[11]

Students without Internet access at home were most likely to say that they "often" receive homework that requires them to be online.[12]

- 82% of all students reported that they sometimes or often receive homework that requires Internet access.
- 87% of students with no home access report that they sometimes or often receive homework that requires them to be online, compared to 80% of students that have high-speed access at home.

[10] Response options were "never," "rarely," "sometimes," or "often."

[11] Students could answer in one-hour increments from "none" to "5 or more hours" for each of math, science, and all other classes.

[12] This might suggest that those with home access are so used to their connectivity that they underreport the use of the Internet for homework.

Most students do less than one hour of homework per night in each of three subject areas: math, science, and other classes. Few students do no homework at all.

Average number of hours spent per weekday on homework (%)

Time spent on each subject		Students overall	Home Internet Access			
			No Home Access	Cell Only at Home	Slow Home Internet	Fast Home Internet
Math	None	14.5	15.7	18.9	13.1	13.7
	< 1 hr.	48.2	43.6	47.6	45.8	49.6
	1-2 hrs.	27.2	22.5	24.4	29.3	27.6
	> 2 hrs.	10.1	18.2	9.1	11.8	9.1
Sciences	None	20.5	22.5	24.9	23.4	17.9
	< 1 hr.	47.3	39.4	49.9	42.4	49.6
	1-2 hrs.	23.2	22.1	20.1	24.4	23.6
	> 2 hrs.	9.0	16.0	5.1	9.8	8.9
Other classes	None	11.2	12.3	16.4	10.2	10.1
	< 1 hr.	33.9	33.5	39.3	32.2	33.2
	1-2 hrs.	31.2	22.9	26.7	31.0	33.5
	> 2 hrs.	23.7	31.3	17.6	26.6	23.2
Average hours spent (SD)		3.22 (2.68)	3.68 (3.51)	2.73 (2.49)	3.40 (2.78)	3.20 (2.53)
N		3,225	232	452	737	1,805

Source: Quello Center. Broadband and Student Performance Gaps

The amount of homework completed varied by subject area as well as type of home Internet access. For example, students in science classes who had fast home Internet access were more likely to do homework than other science students.

- 82% of students with high-speed Internet at home did science homework on a typical school night, compared with 76% of students with no, slower, or cell phone-based home Internet access.
- Students who relied on a cell phone for Internet access from home were the least likely to do homework in any subject, possibly because the lack of a computer significantly hinders their ability to complete homework. Compared to those who have fast Internet access at home, those who have only a cell phone also spend less time on homework.
- Access to other devices and the Internet not only facilitates getting homework done, but it makes completing homework more efficient. Students with no home Internet access spend the most time on homework.
- Compared to those with high-speed Internet access, students who rely on their cell phones for Internet access spend about 30 minutes fewer on homework each school night.
- On average, those who have no Internet access at all spend 30 minutes more on homework than their peers who have high-speed Internet access.

How often students leave homework unfinished because of Internet and computer access (%)

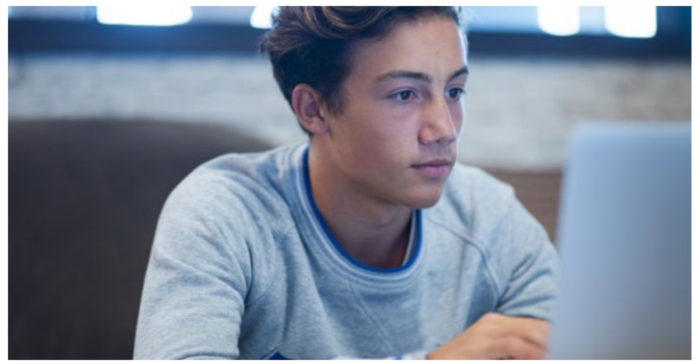
In the past year, how often, if ever, did you leave homework assignments unfinished because you did not have access to the Internet or a computer?	Average	Home Internet Access			
		No Home Access	Cell Only at Home	Slow Home Internet	Fast Home Internet
Never	41.3	13.9	26.2	29.6	53.4
Rarely	28.6	21.7	24.9	31.1	29.3
Sometimes	20.8	27.8	29.6	28.4	14.6
Often	9.3	36.5	19.3	10.8	2.7
N	3,201	230	446	732	1,793

Source: Quello Center. Broadband and Student Performance Gaps

Students with no Internet access at home and those who depend on a cell phone for Internet access when away from school share similar experiences. When asked if lack of Internet access or a computer impacts their ability to complete homework, both groups were more likely to report that they were unable to complete their homework assignments.

- The odds that a student will say that they leave homework unfinished because of a lack of access to a computer or the Internet decrease with better home Internet access.
- 64% of students with no home Internet access often or sometimes leave homework unfinished because they lack Internet access or a computer. This compares to 49% of those who rely on cell phones, 39% with slow home connections, and 17% of students with high-speed home Internet access.
- Only 14% of disconnected students never leave homework unfinished; this compares to 46% of all other students.

Regression analysis was used to statistically control for other factors that are likely to influence the tendency for students to go to class without having done homework (see Appendix D, Table D1). After controlling for home Internet access, this analysis found no difference between boys and girls, between students who are racial or ethnic minorities and white students, between those who have an IEP and those who do not, or between those who receive



free/reduced-cost lunch and those who don't, and the likelihood that a student will report that they often come to class without having completed their homework.

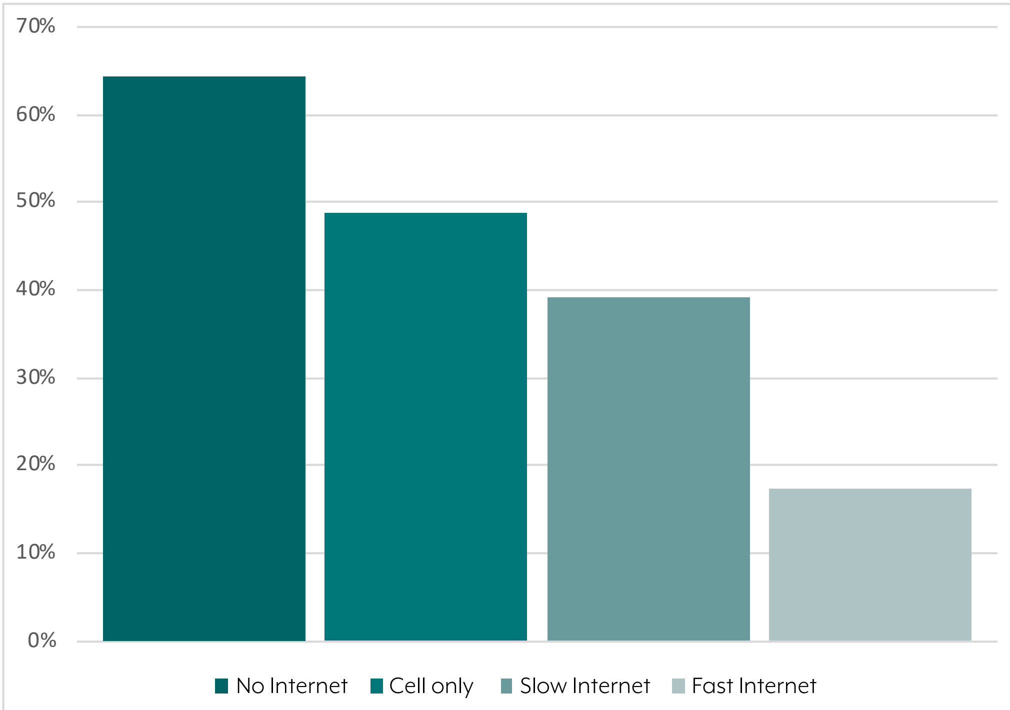
Controlling for demographic factors, those who relied on their cell phones for Internet access at home and those with no home access to the Internet were more likely to say that they often leave homework incomplete.

A comparison of those with high-speed or even slower home Internet access shows:

- Students who have no Internet access at home are 62% more likely to say that they often leave homework unfinished than those with high-speed home Internet access.
- Compared to students with fast home Internet, those students who rely on a cell phone for home Internet access are 47% more likely to often leave their homework unfinished.

64% of students who do not have Internet access at home sometimes or often leave homework unfinished.

% students who sometimes or often leave homework unfinished because of no Internet or computer



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

Digital Skills

Digital skills are a measure of digital competence and are related to a range of technical and social abilities. Although digital skills refer to expertise with the Internet, social media, and related technologies, the skills gained in those areas can have implications beyond students' digital lives. For example, higher levels of digital skills are related to work efficiency, effective communication, and skills in managing and evaluating information (Hargittai & Micheli, 2019).

It is often argued that today's youth are experts in the use of these technologies as a result of being brought up with the Internet and social media. Nevertheless, considerable variation exists in student's digital skills. Students can obtain digital skills through formal education at school, from online educational activities done at home, and through frequently using diverse media and media that are less likely to be used in the classroom (e.g., social media) (Scheerder, van Deursen, & van Dijk, 2017; van Deursen, van Dijk, & Peters, 2011).

This study assessed students' digital skills using scale that asked students to rate their familiarity with sixteen computer-and Internet-related items, providing answers from "no understanding" to "full understanding." (Hargittai & Hsieh, 2012).[13] A student with full understanding on these items would achieve a perfect score of 64, whereas a student with no understand would score a zero. The average student scored 29.9 (SD=13.1) on this measure of digital skill.

[13] Items included: advanced search, PDF, spyware, wiki, JPG, cache, malware, phishing, preference settings, meme, tagging, privacy settings, viral, followers, and hashtag.

Average digital skills by grade and gender (range form 0-64)

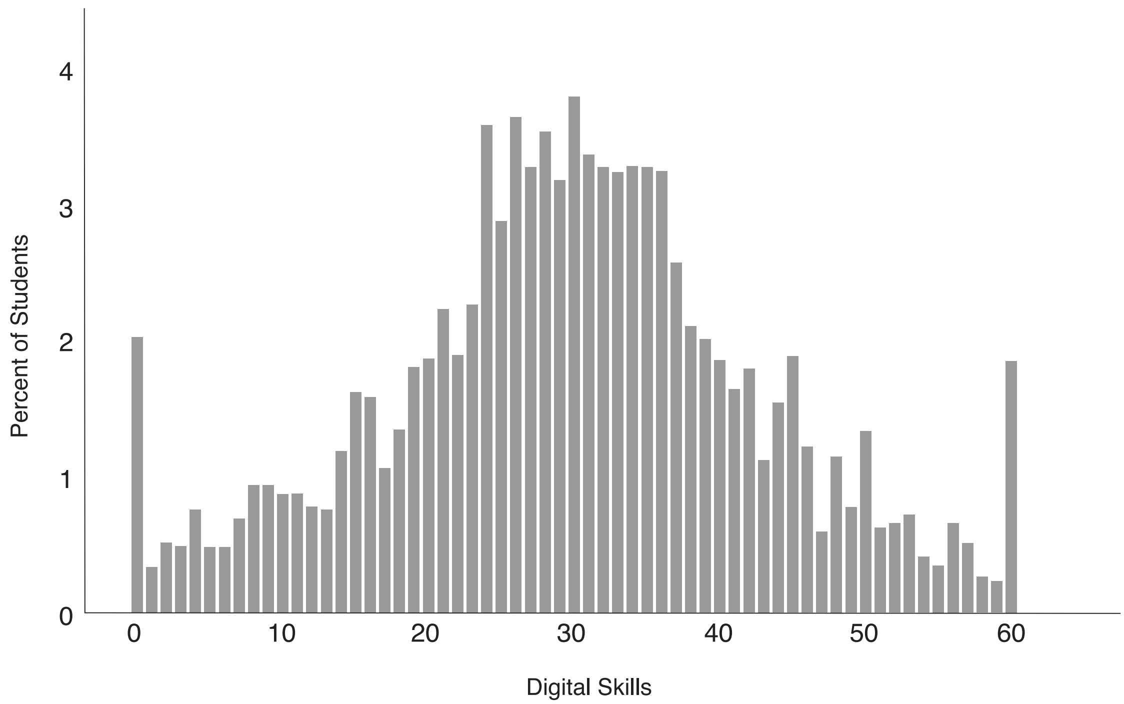
Digital Skills (0-64)	Overall	Grade 8	Grade 9	Grade 10	Grade 11
Girls	29.1 (10.8)	27.8 (10.4)	28.5 (10.5)	29.9 (10.9)	30.4 (11.3)
Boys	30.7 (15.2)	28.4 (14.2)	29.7 (15.4)	31.9 (15.1)	33.3 (15.5)
N	3,238	823	880	842	693

Note: Numbers in parentheses are standard deviations

Source: Quello Center. Broadband and Student Performance Gaps

Many students are not experts with digital technologies. There is a wide distribution in students' digital skills.

Distribution of students' digital skills



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

Statistical analyses reveal (see Appendix D, Table D2) that once variation in Internet access from home has been controlled, there is no difference between the level of digital skill reported by low income students, minority students, or students from single-parent households. However, girls and students with an IEP tend to have fewer digital skills, whereas students with parents who have more years of formal education have more skills. Regardless of the role of these demographic variables, students who do not have Internet access at home have significantly lower digital skills. Students with no home Internet score approximately 3 points lower on the digital skills scale; those who have only a cell phone to access the Internet score 4 points lower than those with fast or slow Internet at home. The magnitude of the relationship between home access and digital skill is larger than the skill gap between girls and boys (2 points) and is comparable to the average difference in digital skill between students in 8th and 11th grade (3 points).

The finding, that digital skill is related to home access, is particularly important because many of the subsequent findings show that lack of access and having lower digital skills are independently related to lower student outcomes.

Grades and Test Scores

Students with fast home Internet connections have higher overall GPAs than students with no home access, slower home access, or cell only access. Similarly, students who have more digital skills tend to score considerably higher on standardized tests, such as the SAT and PSAT 8/9 and PSAT 10.

Grades in STEM and Other Classes

Students were asked to report their most recent final course grades in English/language arts, history/social studies, math, and science. The difference in overall GPA between those with home internet access and those students without access, or who are dependent on cell phone access, is roughly equivalent to the difference between a half a letter grade in each class, i.e., the difference between a B and a B- average.

On average, students with fast home access report an overall GPA of 3.18 (SD=0.86) on a standard 4.0 scale, which is slightly higher than the average 3.10 (SD=0.88) reported by students with slow access. This is significantly higher than the 2.81 GPA (SD=1.01) for students with no access and the 2.75 GPA (SD=0.97) for cell phone only students.

In math and science classes, on average, students with home access have a GPA that is 0.38 higher. In English and social studies classes, their GPA tends to be 0.40 higher than those with no home Internet and those who have only a cell phone.

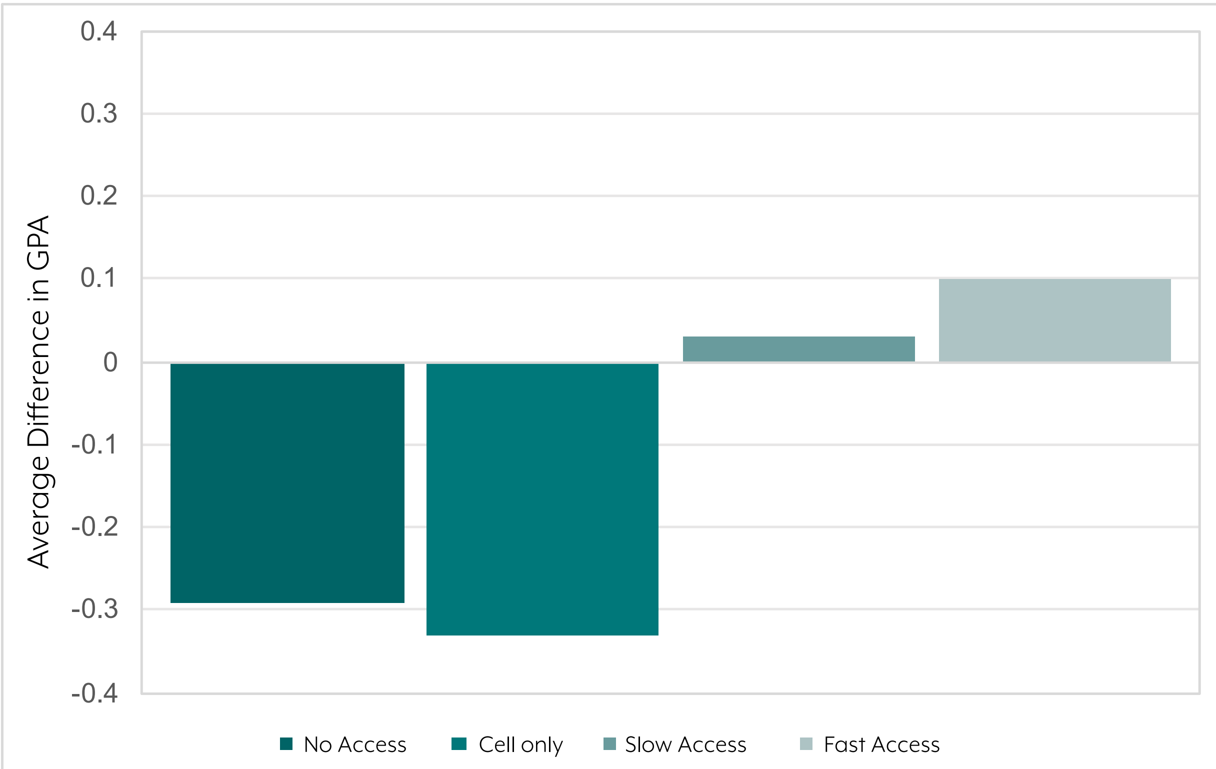
Average GPA for STEM and other subject areas by type of home Internet access

Online activity	Average	Home Internet Access			
		No Home Access	Cell Only at Home	Slow Home Internet	Fast Home Internet
English and Social Studies	3.11 (0.99)	2.82 (1.08)	2.79 (1.09)	3.14 (0.98)	3.21 (0.93)
Math and Science	3.04 (0.97)	2.81 (1.08)	2.71 (1.04)	3.07 (0.95)	3.14 (0.92)
N	3,225	232	452	737	1,805

Note: Numbers in parentheses are standard deviations
Source: Quello Center. Broadband and Student Performance Gaps

On average, the GPA of students with home Internet access is a half letter grade higher, the difference between a B and a B- average.

Variation in overall GPA (on a 4.0 scale) by type of home Internet



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

The results of a regression analysis to examine students with similar demographic profiles confirms that girls and students who have parents with more years of formal education tend to receive higher grades overall (including in STEM and other classes). Low-income and minority students and students with an IEP tend to receive lower grades (see Appendix D, Table D3). However, these factors do not fully account for differences in student grades.

Even when demographic factors are controlled for, students who do not have high-speed Internet access from home tend to have lower grades overall and especially in courses related to English/language arts and social studies/history.

- Students who have no home access, slow access, or cell phone only access to the Internet have significantly lower overall GPAs.
- Across all subjects, students who rely on a cell phone only for Internet access from home tend to receive lower grades than students who have high-speed access, and even lower than students with no access at all.
- Contrary to the expectation that math and science grades are most likely to be related to the presence or absence of home access, having no access is unrelated to math/science GPAs, but does negatively affect overall GPAs and grades in English/language arts and social studies.

- The magnitude of the deficit in grades experienced by students with no Internet access from home is similar to the difference in grades between white students and those who are racial or ethnic minorities.

SAT and PSAT Standardized Test Scores

Students who had only cell phone access to the Internet from home performed lower on standardized tests. Students who had higher digital skills performed significantly better on the SAT and the grades 8/9 and 10 versions of the preliminary SAT (PSAT).

In the 2018-19 school year, all Michigan students in grades 8-11 were administered pencil-and-paper standardized tests from the SAT Suite of Assessments. Students in grades 8 and 9 were administered the PSAT 8/9, students in grade 10 were administered the PSAT 10, and all students in grade 11 were given the SAT. The SAT Suite, developed by the College Board, provides grade-level testing. In grades 8 and 9, the PSAT is used as a benchmark of student performance to identify areas where students excel and those areas where teachers and schools need to focus. The PSAT 10 is used to monitor student growth and performance and as practice for the SAT. The SAT is used by most colleges and universities as part of admissions decisions and to award merit-based scholarships. The Every Students Succeeds Act (ESSA), the 2015 federal law that governs K–12 public education policy, provided new flexibility in the standardized tests that states can administer for high school graduation. In addition to Michigan, the SAT is a high school graduation requirement in Colorado, Connecticut, Delaware, Illinois, Maine, New Hampshire, Ohio, Rhode Island, and West Virginia, and can be used as a testing option in Alaska, Arkansas, Arizona, Florida, Idaho, Maryland, Minnesota, Mississippi, New Mexico, New York, Oklahoma, Oregon, South Carolina, Tennessee, Texas, Washington, and Washington, D.C. (Heimbach, 2019; Gewertz, 2019).

The SAT, PSAT 10, and PSAT 8/9 are divided into sections for evidence-based reading and writing (EBRW) and math. Each exam also produces a total score. Scores are nationally benchmarked with a percentile rank that shows how students performed relative to typical U.S. students for each grade (percentiles range from 1 to 99). For example, a student who performs in the 75th percentile on the SAT scored higher than or equal to 75 percent of all SAT test takers. Eight of the school districts that participated in this project provided de-identified student percentile scores that were matched with each student's responses to the project survey.

Average student percentile rank on SAT, PSAT 8/9, PSAT 10 by type of home Internet access

Nationally representative percentile rank on SAT/PSAT	Average	Home Internet Access			
		No Home Access	Cell Only at Home	Slow Home Internet	Fast Home Internet
Evidence-Based Reading/Writing	55 (27)	49 (28)	47 (27)	56 (28)	57 (27)
Math	54 (26)	49 (25)	46 (26)	54 (27)	56 (26)
Total	56 (26)	50 (26)	48 (26)	56 (27)	58 (26)
N	2,001	114	249	479	1,159

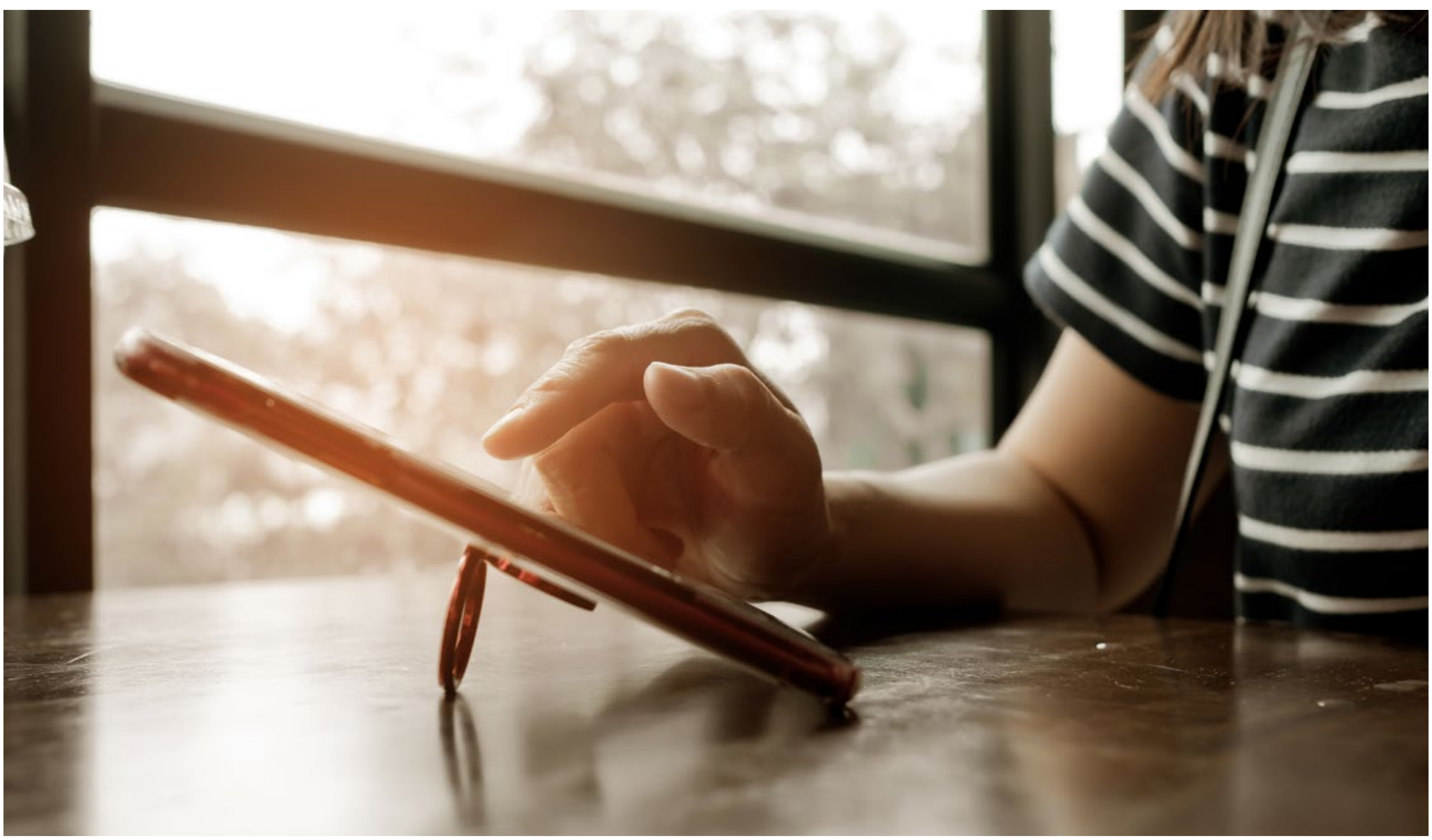
Note: Numbers in parentheses are standard deviations

Source: Quello Center. Broadband and Student Performance Gaps

On average, students who had no Internet access at home and those who relied on a cell phone scored lower on the SAT/PSAT in each of EBRW, math, and total scores. However, there are many factors that can affect a student's standardized test scores (The College Board, 2013; The College Board, 2019a, b). Statistical procedures used to identify those factors corroborated much of what is known from prior research (see Appendix D, Table D4). Low-income, minority students, students from single-parent families, and students with IEPs tend to score lower on the SAT/PSAT. Those students whose parents have a higher education perform better. Girls tend to score higher on the EBRW. Controlling for demographic factors – that is, comparing students who are similar on those conditions that influence standardized test scores – there remains a difference between students who had high-speed Internet access at home and students who have only cell phone access to the Internet from home.

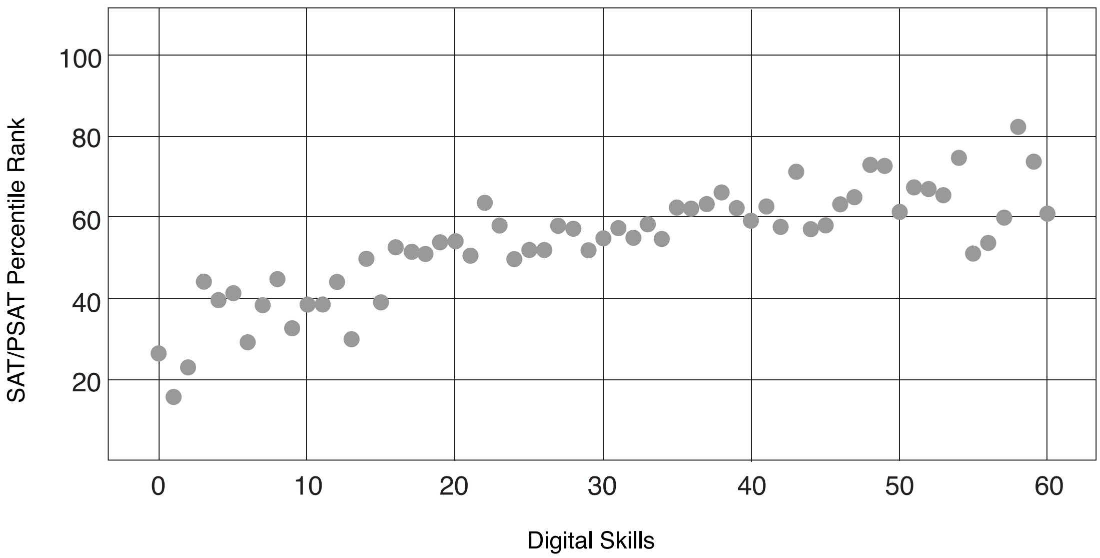
- Regardless of other demographic factors, students who had only a cell phone for home Internet access tended nationally to rank 5 percentiles lower in evidence-based reading and writing, 6 percentiles lower in math, and 5 percentiles lower overall.

The negative relationship between having to use a cell phone for home Internet access and SAT/PSAT performance was larger than the deficit in percentile rank experienced by students from low-income families relative to higher-income families or that experienced by racial and ethnic minorities relative to white students, both of which, independently, tend to rank 3-4 percentiles lower than their peers.



Students with higher digital skills perform significantly higher on pencil-and-paper versions of the SAT and PSAT.

Summary point plot of percentile rank on SAT Suite of Assessments by digital skills.



Source: Quello Center. Broadband and Student Performance Gaps

Although those without Internet access at home did not do worse on standardized tests than those who had high-speed access, findings point to a relationship between type of access and digital skills. Regardless of demographic factors, digital skills were one of the strongest predictors of how students performed on standardized tests. The relationship is particularly large relative to other factors that predict student performance on the SAT/PSAT.

- A student who scored even modestly lower in digital skills (13 points lower than average, or 1 standard deviation) tended to rank nationally nearly 7 percentiles lower on their total SAT/PSAT score, 5 percentiles lower in math, and 8 percentiles lower in evidence-based reading and writing.
- This compares to the 3-4 percentile difference in SAT/PSAT national rank between white students and those who are racial or ethnic minorities, or the 3-4 percentile difference between low-income students and those who do not receive a free or reduced-cost lunch.
- Digital skills account for 8.7% of the variance explained in total SAT/PSAT percentile rank within districts.

Post-Secondary Goals

Students who do not have high-speed Internet access at home and those with fewer digital skills are less likely to have an interest in attending college or university.

Achieving a post-secondary education leads to higher earnings over a lifetime and can help boost segments of the Michigan economy most in need of a high-skilled work force. Only 28% of Michigan adults hold a bachelor's degree or higher, and the state ranks 36th nationally for post-secondary attainment (Bridge, 2018). Although all Michigan counties have seen unemployment rates decline over the past ten years, nine of the ten counties with the highest jobless rates are among the most rural (VanHulle & Wilkinson, 2019). The U.S. economy continues to migrate toward technology-intensive jobs, for example in precision agriculture, advanced logistics, industry 4.0, and artificial intelligence-enhanced health care. Consequently, it is likely that both the number of low-skilled and high-skilled jobs will increase, whereas the number of mid-skill jobs will stagnate or even shrink. Individuals with post-secondary degrees have a better chance to work in high-skilled, high-paying, high-opportunity occupations.

Year after High School

Compared to peers who enroll immediately after high school graduation, previous research has shown that students who delay starting post-secondary education for even as little as one year have a considerable risk of not completing a post-secondary credential (Bozick & DeLuca, 2005; Roksa & Velez, 2012). To assess post-secondary goals, students were asked to state their long-term educational ambitions and what they planned to do in their first year after high school. Overall, 58% of students , in this predominantly rural sample, said that they intended to go to college or university immediately after high school.

Based on type of home Internet access, there is no difference in intent to enroll in a post-secondary program in the year after high school. Gender, parental education, and income explain the differences in plans to go to college or university between students with and without home access. (see Appendix D, Table D5). However, these demographic factors do not account for a relationship between digital skills and the intent to attend a post-secondary program in the year after high school. Students lacking in digital skills are substantially less likely to report that they intend to go on to higher education immediately after high school.

- A student who is moderately lower in digital skills (13 points below average, or one standard deviation) is 26% less likely to intend to attend college or university the year after high school.

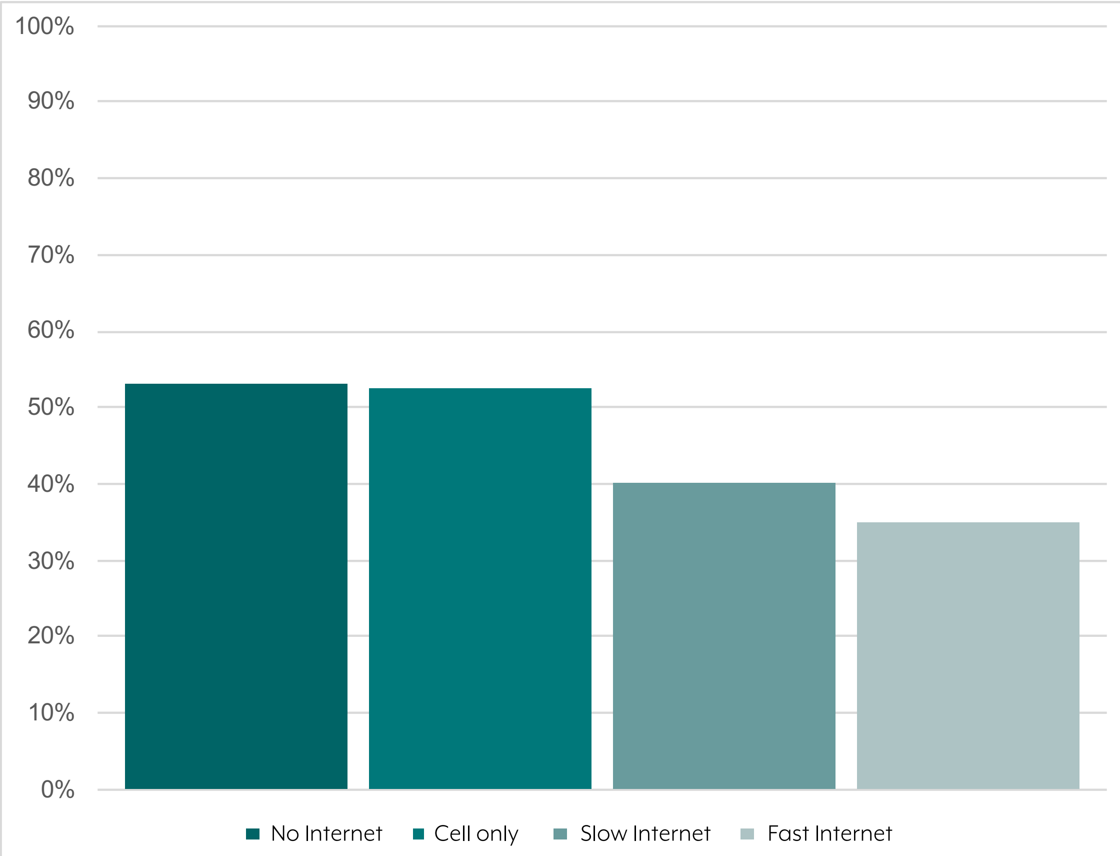
Long-term Educational Goals

Although digital skills and socioeconomic factors are better predictors than type of home Internet access in determining whether a student will plan to attend college or university in the year after high-school, students with cell phone access only, slower access, or no access to the Internet from home are more likely to say that they have no plan to ever complete a post-secondary credential at any time. Forty percent of students said that they have no intention ever to complete accreditation at a college or university.

- 53% of students who have no home Internet access or have cell phone only access to the Internet do not plan to complete a post-secondary program. This compares with only 40% of those with slower home Internet access and 35% of those with fast home Internet.

Most students who do not have home Internet access and those who rely on a cell phone for their home Internet access have no plan to complete a college or university degree.

% students who do not plan to complete any college or university beyond high school



Source: Quello Center. Broadband and Student Performance Gaps, N=3,258

Boys, students with an IEP, and those from low-income families are all less likely to say that they plan to complete a post-secondary education (see Appendix D, Table D5). An analysis used to compare students with similar demographics found that the relationship between intention to complete a college or university program and Internet access exists regardless of socioeconomic status. Students who have slow Internet access, cell phone access only, or no home Internet are all less likely to say that they will complete a post-secondary program (when compared to those with fast home Internet access).

In addition, regardless of access type, those with fewer digital skills are also more likely to say they have no intention ever to attend a college or university. Regardless of other demographic factors, compared to students with high-speed Internet access from home:

- Students with slower home Internet access are 21% less likely to say they plan to complete college or university.
- Students using a cell phone as their only means of access to the Internet from home are 34% less likely to intend to complete college or university.

- Those with no home access are 29% less likely to intend to finish a post-secondary education.
- In addition to deficits in access, having digital skills that are even one standard deviation below average (13 points on the scale of digital skills, mean=30) is associated with a student being 29% less likely to say they never plan to complete a college or university program.

Career Aspirations

Students with less developed digital skills are less likely to want a career related to science, technology, engineering, or math (STEM). The same is true of careers classified under the broader category of science, technology, engineering, math, and the arts (STEAM).

The United States needs more workers interested in STEM occupations. During the decade between 2015 and 2025, the U.S. Bureau of Labor Statistics estimates a shortfall of 1 million STEM workers.[14] The demand for STEM professionals, particularly those in healthcare and information technology, is growing and outpacing the supply of STEM college graduates.[15] More jobs are offered in STEM fields compared to non-STEM fields, and opportunities for individuals with college degrees are more plentiful than for high school graduates. Moreover, estimates suggest that the average salary for entry-level STEM careers is approximately $10,000-$14,000 higher compared to non-STEM careers.[16] The pervasive use of information and communication technologies and the increasingly dynamic adaptations needed from employees have added an emphasis on creative components (hence, STEAM). Many emerging and future occupations will likely require skill sets that benefit from an integration of engineering and technological knowledge with creative problem-solving skills.

Students were presented with a list of 26 different careers and asked to select those that best described what they want to be.[17] The list of possible careers spread across a range of fields that could broadly be classified as STEM, STEAM, and those careers that are generally not STEM- or STEAM-related. Examples of STEM careers included health professional, engineering, and math or science teacher. STEAM careers included those that dealt with science, technology, engineering and math, as well as the arts, such as actor or musician, or another type of artist. Non-STEAM careers include professions such as a police officer, mechanic, counselor, plumber, and retail or restaurant worker.

Forty-six percent of students expressed interest in a STEM-related profession, and 54% in a STEAM-related career. On average, those with home Internet access were more likely to say that they wanted a career in a STEM-related field, and the same was true for STEAM professions.

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14 See https://www.bls.gov/opub/mlr/2015/article/stem-crisis-or-stem-surplus-yes-and-yes.htm
15 See https://www.burning-glass.com/wp-content/uploads/Real-Time-Insight-Into-The-Market-For-Entry-Level-STEM-Jobs.pdf
16 Based on estimates provides by Burning Glass Technologies, a company providing job market analytics. See https://www.burning-glass.com/research-project/stem/
17 The full list of occupations consisted of: *+Health professional (e.g., doctor, nurse, dentist, veterinarian); *+Engineer or Architect; *+Computer scientist (e.g., programmer, video game design); *+Social scientist (e.g., psychologist, sociologist); *+Other scientist (e.g., biologist, chemist, physicist); *+Math or science teacher; Other teacher; +Actor, dancer, or musician; +Other type of artist; Police officer, detective or firefighter; Lawyer or judge; Childcare worker (e.g., day care, nanny); Counselor or social worker; Journalist or writer; Marketing or advertising professional; Mechanic, electrician or plumber; Carpenter or construction worker; Farmer or farm manager; Factory or warehouse worker; Accountant, insurance agent, or banker; Realtor; Manicurist, makeup artist or hair stylist; Retail sales or hotel staff; Cook or restaurant staff; Other customer service; Business person. ("*" indicates STEM, "+" indicates STEAM)

Demographic differences between students who were interested in STEM or STEAM careers and factors such as students' gender and parents' education were betters predictors of STEM and STEAM career choice than home Internet access (see Appendix D, Table D6). However, although Internet access at home is not related to a difference in career interests, digital skills are related to STEM/STEAM career choices, and students without and with poor home Internet access tend to have a significant deficit in digital skills relative to their peers.

- Compared to students in the top 50th percentile for digital skills, students who rank in the bottom 25th percentile for digital skills are 17% more likely to pick a career that is not in a STEM field and 16% more likely not to want a STEAM-related career.

The results of a statistical analysis to control for demographic factors are that students who were moderately lower in digital skills (13 points lower than average in digital skills, 1 SD below the mean) were 19% less likely to be interested in STEM and 24% less likely to be interested in STEAM professions.

% of Students Choosing STEM, STEAM, and non-STEAM careers by digital skill

Career	Overall	Digital Skills			
		Below 25th percentile	25th-49th percentile	50th-75th percentile	Above 75th percentile
STEM	45.5	38.4	44.8	47.7	50.5
STEAM	54.2	46.1	53.1	57.6	59.5
Non-STEM	55.2	60.7	56.2	52.8	51.4
Non-STEAM	46.7	53.4	48.3	43.0	42.7
N	3,225	232	452	737	1,805

Note: Categories of STEM/Non-STEM and STEAM/Non-STEAM may not sum to 100%. Some students selected more than one possible career.
Source: Quello Center. Broadband and Student Performance Gaps

BROADER IMPLICATIONS AND THE NEED FOR CORRECTIVE ACTION

The evidence presented in this report points to individual, community, and societal repercussions of poor broadband connectivity at home. Better connectivity is associated with clear advantages for school performance and broader outcomes, including the development of career interests that may have lifelong consequences. These advantages are not available to those with poor connectivity. These unrealized benefits constitute direct and indirect costs that leave individuals, communities, and society worse off than what would be possible under conditions of better connectivity.

Other socioeconomic factors, such as income and parental education, also affect outcomes. Connectivity interacts with these factors and influences outcomes separately. Regardless of these factors, students in rural and small-town locations in Michigan with access to high-speed Internet at home have more digital skills, higher grades, and perform better on standardized tests, such as the SAT. Better educational outcomes and a stronger interest in pursuing STEM/STEAM careers or post-secondary education translate into better chances for higher, lifelong incomes.

In contrast, students with no Internet access at home and students who can access the Internet only via a cell phone do worse in school and are less likely to pursue post-secondary education. Broadband connectivity does not explain all variation in outcomes, however. Independent of the quality of Internet access, socioeconomic status has a bearing on student performance and life outlooks. Coming from a low-income household, lower parental education, living in a single-parent family, and identifying as a member of a racial or ethnic minority are associated with lower performance. These findings suggest the need for a multi-pronged strategy that addresses both the gaps in connectivity and the socioeconomic environment of students.

The direct and indirect costs of poor Internet connectivity

Lack of fast Internet access or cell phone only access is associated with disadvantages that likely have lifelong consequences. Lower grades and weaker standardized test scores associated with poor Internet connectivity reduce the chances of students to qualify for scholarships, further impeding their ability to pursue postsecondary education programs. Compared to a high school diploma, having a college degree typically increases the earning potential of an individual. Although there are differences between fields of study, occupation, race, and gender, recent data show that the median 2018 earnings of individuals with a bachelor's degree were $24,900 higher than those of high school graduates (Ma, Pender & Welch, 2019). Job market data also show a premium for STEM jobs over non-STEM jobs regardless of educational achievement. In 2015, this premium was highest for workers with high school diplomas, whose average hourly earnings in STEM occupations were 38% higher than in non-STEM occupations (Noonan, 2017, p. 5).[18] Given the anticipated growth in STEM occupations and the continued shortage of qualified workers, these pay premiums will likely persist.

[18] This comparison controls for other factors that might influence hourly pay.

Better broadband connectivity indirectly, through higher digital skills, increases the chances of individuals to pursue such higher paying occupations. Therefore, it would likely increase the income of some individuals and, in the aggregate, of the communities in which they reside. Digital skills improve the ability of individuals to succeed in an increasingly digital economy. If Internet connectivity is not improved, these better income and employment opportunities are unavailable to the affected students and have ripple effects on local communities, such as higher unemployment rates and higher rates of poverty. Everything else being equal, these inaccessible opportunities constitute a hardship or burden due to the lack of high-speed broadband access.[19]

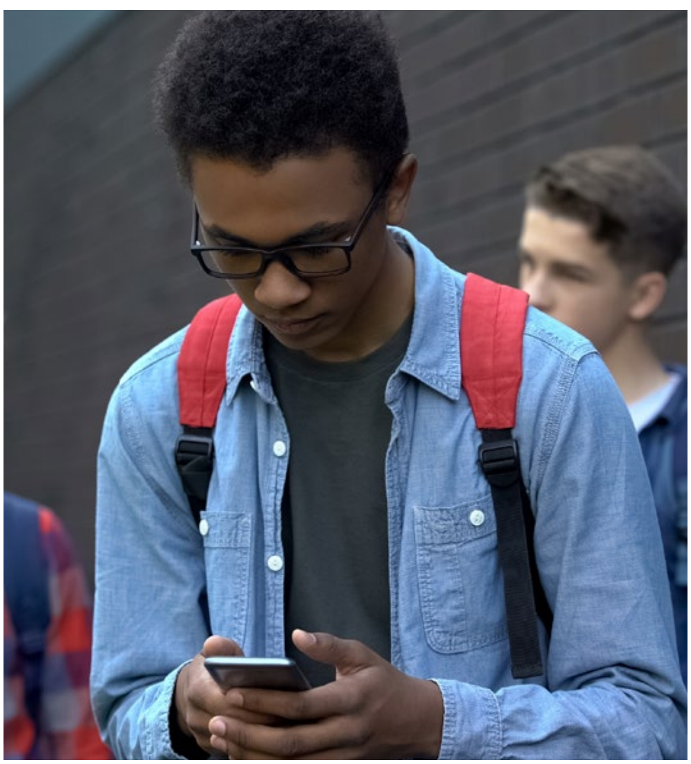
Additional considerations are relevant from the perspectives of schools and the surrounding communities. For example, the funding of schools may, to some extent, be contingent on the outcomes of annual tests. Lack of Internet connectivity may contribute to lower scores and hence reduce the resource base of schools. From a broader perspective, the vibrancy of local communities is related to the qualifications of the local workforce. Digital skills are an important precondition of successful participation in the digital economy. For instance, the ability of a local business to prosper by developing an effective online presence is affected by the knowledge and skills of the local and regional workforce (see the detailed discussion in Sallet, 2019, especially chapters 1 and 4). Likewise, the ability of a community to attract entrepreneurs and new businesses is influenced by the qualifications of the local workforce and by the availability of high-performance broadband.

The effects of broadband are not limited to education but need to be examined in the broader community context. Although this is not the focus of this report, access to high-performance broadband can positively affect the livability of communities beyond education. Access increases the ability to take advantage of services enabled by digital technology. Examples range from e-government applications that improve the quality and efficiency of government-citizen interactions; citizen informatics services that create more livable communities, such as timely and current information about ongoing construction projects or traffic conditions; to improved public safety services that increase the efficiency and effectiveness of emergency responders. All this points to synergies between the positive contributions of high-performance broadband to educational outcomes and its positive effects on the vibrancy of communities.

Compared to communities with high-performance broadband, places with poor connectivity forgo these and related benefits at potentially high cost to citizens and businesses. Most likely, these potential disadvantages will grow over time, because many of the emerging job opportunities will be in occupations that require digital skills and high-quality connectivity. Even service industries with a very high human component, such as medical service and care for the elderly, will increasingly be dependent on high-quality connectivity. Communities without proper connectivity therefore face the risk of seeing the effects of their lack of high-performance broadband amplified in a vicious cycle of compounding disadvantages. The finding that individuals without high-speed broadband at home have fewer digital skills illustrates this risk of falling behind.

[19] The assumption that all other conditions remain equal is a widely used methodological simplification in the social sciences, which allows focusing on the effect of changes in one specific factor. Of course, other relevant factors will likely change over time. Such simultaneous changes in factors affecting outcomes can be incorporated by building different forward-looking scenarios. For example, the income differences between individuals with varying educational achievements may increase or decrease, which would either increase or decrease the implied income disadvantages.

In sum, lack of high-speed broadband connectivity entails both private costs borne by individual households and public costs spread across the community. This observation does not imply that broadband connectivity alone will suffice to avoid undesirable outcomes, but that it is an important precondition. A challenge is that communities are called to support the deployment of digital infrastructures while also facilitating, and possibly providing complementary measures that assist organizations and individuals to harness the benefits of digital connectivity. It will be important to integrate digital skills across subject areas, not only in dedicated classes on technology, but as part of mathematics and science, English, and social studies. It needs to be recognized that some digital skills, such as those that might come from social media and video game use, cannot be taught in the classroom and can come only from independent, student exploration outside of the classroom. In addition to ensuring that the K12 curriculum supports the development of digital skills, this may include programs to help citizens take advantage of digital connectivity. It may also include working in innovative partnerships with service providers, device manufacturers, and users to better meet community needs (see, for example, the discussion in Sallet, 2019).



Toward corrective actions to mitigate performance gaps

The findings of this study offer insights that can inform discussions about specific corrective actions. Because the focus of this work on educational performance gaps, we will focus on implications related to those gaps. However, in line with the findings of other studies, these results also suggest consequences of poor broadband connectivity beyond the immediately affected students and households. These observations beg the question of whether interventions are warranted and feasible, and, if they are, what the appropriate roles of individual households, communities, and state and federal decision makers should be. Doing nothing is often the default option, based on the justification that it may be just a matter of time until reasonably priced high-speed broadband will be available even to the most rural areas, and the most socioeconomically challenged families. Satellite Internet, higher speed wireless connectivity (such as the emerging fifth generation (5G) of services) and technological progress that lowers the costs of providing access all promise market-driven solutions. Local, state, and federal agencies can help expand the footprint of entrepreneurial initiatives and market forces. Measures such as coordination of infrastructure projects (e.g., “dig once” models), facilitation of obtaining rights of way and permits, and sharing of public infrastructure would be positive contributions.

Nonetheless, it is unlikely that market forces alone will close the gap. While market forces may mitigate the problems identified in this report, they also have shortcomings. There is considerable uncertainty about the speed of these developments and whether they can effectively close the broadband access gaps in an acceptable time frame. Moreover, they will do little to address other factors that are in play and may leave certain populations in a connectivity trap. We conclude that a superior approach would be systematically to evaluate alternative courses of action to assess their advantages and disadvantages. Often, rational responses will require a clear understanding of the costs and benefits of different responses to a challenge. Although cost-benefit analysis focuses primarily on economic effects, and has other challenges, if appropriately used, it offers a starting point to consider relevant aspects of a problem. Whereas it may be difficult to place monetary values on intangible benefits or to compare varying benefits across individuals, these shortcomings can be overcome. Once the benefits to a community are better understood, the relevant private and public stakeholders can develop a technical solution and business model that safeguards positive net benefits.

Our findings can be embedded in such a framework to address issues related to the K12 performance gap. This approach would have to be augmented to consider benefits that were not at the core of our investigation. The cost-benefit framework is flexible and can be applied to decision making at different levels, including individual households, communities (e.g., townships, cities), school districts, counties, and the state or federal levels. Performing the analysis at an aggregated level allows one to properly consider the broader public good aspects of poor connectivity that do not influence into the decisions of individual households but are relevant for communities and the state. For that reason, it seems that it would be best used at the community or school level. This raises the challenge that school districts in Michigan do not map directly onto townships and municipalities, so that some collaborative efforts might be desirable to coordinate responses appropriately.

Specifically, the data from this report can help to gauge important components of the benefits of connectivity. They allow calculating the probability of changes in outcomes contingent on the availability of broadband and the specific socioeconomic situation of a student. For example, providing fast broadband access to a socioeconomically disadvantaged household would increase by 2 percentage points for male K12 students and 3 percentage points for female K12 students the probability that they would seek postsecondary education.[20] Although at first glance these numbers may seem small, they represent substantial improvements and translate into considerable cumulative income benefits. For example, although somewhat dependent on the field, gender, and race, the additional net life income associated with a college degree can be in the $600,000 to $900,000 range (Ma et al., 2019). The expected higher income would in many cases more than justify the cost to households, schools, or other levels of government, of subscribing to broadband at going market rates for the years during which the student attends school. If complementary measures are adopted that improve the broader socioeconomic conditions of such a household, the positive effect could be further enhanced. Similar probabilities can be calculated for other scenarios of families in different socioeconomic circumstances.

Cost-benefit analyses at the community level allow consideration of the direct benefits and

[20] Compared to the initial likelihood to attend college, this represents a 22.8% increase in the likelihood to attend college for males and a 26% increase for females.

costs associated with better connectivity and its indirect repercussions. Some of the benefits have the character of private goods that directly benefit individual households. Others are public goods that materialize for the community at large and hence are spread across many individuals. Although such public goods can be considered at the community level, they will typically not be considered by decentralized individual households. Effects such as potential higher income for individuals, improvements for local businesses, and benefits for the economic vitality of communities at large can be measured in monetary terms. Other benefits, such as improved public safety, the creation of more livable communities, or the facilitation of more civic participation do not lend themselves to easy monetary quantification. It might be even more difficult to put numerical estimates on the positive effects of digital connectivity in enhancing individual capabilities to succeed in life. The relative importance of these factors will likely vary from community to community. However, in many cases, the potential magnitude and importance of these effects suggests that the benefits far outweigh the costs (see also the review of existing research in Sallet, 2019, which corroborates this observation).

An important first step in a careful decision process to identify the best options to overcome barriers is an assessment of the local situation. Although some factors hold across all rural and small-town communities, there are also location-specific components. At an aggregate level, our data suggest that three factors are in play and, to a certain degree, compound each other. Each barrier requires a different response. If high-speed broadband is not available, viable ways need to be found to deploy broadband. One effective way to extend the footprint of the existing high-speed broadband network is to facilitate additional competition. There are numerous barriers to competition that could be alleviated by local, state, and federal policymakers.[21] If a household is income constrained, some form of subsidy may be effective to enable it to subscribe to broadband access. Information and education about the individual and community benefits of broadband access may be an appropriate intervention. In many cases, more than one measure may be required.

[21] For example, local decision makers can simplify the process required to obtain rights of way and other permits. “Dig once” policies can help reduce the cost of infrastructure deployment considerably, given that civil engineering costs constitute up to 75 percent of the deployment costs. State laws affect the ability of communities to facilitate competition, and federal laws could do more to improve the ability of competitors to enter local markets.

Cost-benefit analysis can help identify which combination of responses can contribute to more fully realizing the great benefits of digital technology. This may include subsidies to expand fast broadband access, measures to facilitate competition and entrepreneurship, and possibly adaptations in curriculum design and pedagogy. However, this is not to say that all relevant issues can be fully resolved through an economic lens. Not all situations may yield positive net benefits. The question arises about how decision makers shall respond in such cases. A more compelling rationale for action may be rooted in a human rights perspective, which an increasing number of communities across the United States and other nations have adopted. This would entail a strong commitment by communities that vital infrastructures should be available on a ubiquitous basis to preserve equal opportunities for all citizens and especially the next generation of citizens. Communities across the United States are experimenting with innovative approaches to close the connectivity. These include measures to reduce barriers for entrepreneurs to enter the market, public-private partnerships, cooperatives, and, in some cases, municipal projects. In addition, to effectively address the problems, states and federal policymakers have roles to play using instruments available to them that are appropriate to narrowing

the existing gaps. A broad coalition of stakeholders can contribute to shaping a forward-looking vision and workable solutions (see Shapiro, 2019; Merit Network, 2019; Fox and Jones, 2019).

Conclusion

This report provides detailed evidence of the importance of high-speed Internet connectivity for educational and life outcomes. Whereas the negative effect of lacking broadband connectivity for homework completion has been known for some time, the study uses much more granular data and more comprehensive outcome measures. They reveal that poor Internet connectivity has repercussions that go far beyond the ability to complete homework assignments. In many cases, students will possibly be disadvantaged for life. Middle and high school students with high-speed Internet access at home have more digital skills, higher grades, and perform better on standardized tests, such as the SAT. Regardless of socioeconomic status, students who cannot access the Internet from home do worse in school and are less likely to attend college or university. The deficit in digital skills also contributes to lower academic success and to these students being less interested in higher-paying STEM careers. Students who have only cell phone Internet access, but no complementary devices such as a tablet of notebook computer, are as disadvantaged as students with no access at home.

The findings are an urgent call to address the state of affairs. An important first step is an assessment of the local situation. Although some factors hold across all rural and small-town communities, there are also location-specific components. The reasons for (dis)connectivity can be complex and include a mix of factors such as, no service is available, Internet access being too expensive relative to the resources of the family and household decision makers that do

not fully appreciate the benefits from subscribing to home broadband.

Each of these barriers requires different responses that range from measures to extend broadband service, to interventions to make service more affordable, and sharing information about how the benefits of broadband can be harnessed (while mitigating legitimate concerns). Although advances in terrestrial wireless and satellite technology will enable new and innovative solutions to provide high-speed connectivity in rural areas, a wait-and-see strategy may impose high costs on individuals, families, and communities. Communities across the United States are experimenting with innovative models to extend service to areas and locations not served by market-driven commercial service providers. We hope that the findings of this report will contribute to the design of effective interventions and responses that will help overcome the identified challenges and deficits.

APPENDIX A: RURAL STUDENTS BY STATE

Proportion of students enrolled in school districts by location type

State	City	Suburban	Town	Rural
Alabama	23.74	22.15	14.03	40.07
Alaska	34.26	8.91	25.63	31.20
Arizona	48.09	31.37	10.26	10.29
Arkansas	28.53	13.74	22.25	35.48
California	42.73	45.12	5.76	6.39
Colorado	38.66	38.47	8.95	13.91
Connecticut	30.24	55.36	2.92	11.48
Delaware	12.90	50.99	15.95	20.16
Florida	25.41	58.22	4.30	12.07
Georgia	15.74	46.51	9.92	27.84
Hawaii	23.71	44.79	21.49	10.01
Idaho	23.06	26.79	23.11	27.04
Illinois	29.57	49.41	10.13	10.90
Indiana	31.04	27.16	13.89	27.92
Iowa	27.49	13.34	24.77	34.39
Kansas	27.74	17.52	25.39	29.34
Kentucky	21.61	17.11	23.95	37.32
Louisiana	29.67	29.46	13.23	27.64
Maine	12.78	16.80	16.42	54.00
Maryland	20.89	61.89	3.51	13.71
Massachusetts	17.97	71.60	1.44	8.99
Michigan	23.28	44.02	11.72	20.98
Minnesota	21.46	36.46	20.11	21.97
Mississippi	10.58	14.03	27.53	47.86
Missouri	18.53	34.42	19.79	27.26
Montana	25.08	1.96	36.42	36.54
Nebraska	39.84	13.11	19.26	27.79
Nevada	50.57	35.14	7.27	7.02
New Hampshire	14.62	36.62	14.12	34.64
New Jersey	10.66	79.38	2.01	7.96
New Mexico	34.54	14.03	26.54	24.88
New York	46.47	36.26	6.14	11.14
North Carolina	28.68	24.09	10.43	36.80
North Dakota	26.53	11.81	18.71	42.95
Ohio	19.27	45.30	12.81	22.62
Oklahoma	24.07	22.30	22.66	30.97
Oregon	34.71	26.58	23.63	15.08
Pennsylvania	21.30	51.27	8.99	18.44
Rhode Island	26.13	64.08	0.00	9.79
South Carolina	19.61	35.30	10.66	34.43
South Dakota	26.46	1.64	29.47	42.42
Tennessee	32.60	20.87	16.42	30.11
Texas	40.84	32.11	9.40	17.65
Utah	15.94	62.65	10.88	10.53
Vermont	7.90	9.58	26.88	55.64
Virginia	22.85	45.54	6.79	24.82
Washington	32.91	42.56	12.45	12.08
West Virginia	15.43	20.53	20.99	43.05
Wisconsin	29.06	28.35	19.52	23.07
Wyoming	25.37	1.68	42.24	30.71

Source: Common Core public school data provided by the National Center for Education Statistics. Available from: https://nces.ed.gov/ccd/

APPENDIX B: DISTRICT DEMOGRAPHICS

School district demographic data based on the American Community Survey 2013-17

School District	Total Population	Population density (people per square mile)[a]	Student Grades 8-11[b]	Median household income	Families below federal poverty level
Brimley Area Schools	3,470	11.73	153	$50,281	10.1%
Capac Community School District	9,215	86.33	307	$67,371	7.1%
DeTour Area Schools	2,036	5.54	41	$41,313	5.4%
East China School District	28,919	222.81	1372	$61,200	6.0%
Les Cheneaux Community Schools	2,037	16.67	78	$43,485	7.0%
Mackinac Island Public Schools	676	157.94	30	$47,989	6.9%
Memphis Community Schools	5,601	94.06	299	$61,096	7.8%
Morley Stanwood Community Schools	9,481	58.67	349	$42,442	13.3%
Pickford Public Schools	2,431	10.01	144	$49,857	5.6%
Rudyard Area Schools	6,290	15.67	172	$40,120	17.4%
Sault Ste. Marie Area Schools	19,572	72.20	707	$43,634	11.9%
St. Ignace Area Schools	3,807	22.89	161	$40,368	13.8%
Tahquamenon Area Schools	6,287	4.91	189	$41,211	11.6%
Whitefish Township Schools	374	1.52	13	$34,205	3.4%
Yale Public Schools	10,550	67.54	602	$54,635	7.9%

Notes:

[a] Total population per square mile, based on district square mileage https://www.michigan.gov/documents/squaremiles_11742_7.pdf

[b] Michigan Department of Education, & Center for Educational Performance and Information. (2018/2019). MI School Data: K-12 School Data Files. https://www.mischooldata.org/DistrictSchoolProfiles2/EntitySummary/SchoolDataFile.aspx

APPENDIX C: TRIANGULATING ACCESS SPEEDS

Self-reported home Internet speeds were cross-checked with speed test data. Among the students who conducted a speed test at home (N = 264), the average download speed was 31.54 mbps (SD = 38.54) for students who said they had fast home Internet, 7.97 mbps (SD = 11.89) for students who said they had slow home Internet, and 27.8 mbps (SD = 38.45) for students who said they only had a cell phone to access the Internet. Average download speeds between groups were significantly different ($p < .001$), with post hoc tests showing significant differences between students with fast and slow Internet ($p < .001$), and between students with cell only and slow Internet ($p < .05$). The average upload speed was 7.16 mbps (SD = 5.76) for students who said they had fast home Internet, 3.43 mbps (SD = 10.18) for students who said they had slow home Internet, and 6.52 mbps (SD = 4.91) for students who said they had only cell phone access to the Internet. Average upload speeds between groups were significantly different ($p < .01$), with post hoc tests showing a significant difference between students with fast versus slow Internet ($p < .01$). For reference, the FCC defines broadband as having a minimum download speed of 25 mbps and a minimum upload speed of 3 mbps. The speed test data validate student self-assessments and reports of the speed of their home Internet connections.

APPENDIX D: HLM REGRESSION TABLES

Table D1: HLM (logistic) predicting if students go to class without homework done

	Coef.	SE
Intercept	-1.36	(0.30)***
Female[1]	-0.14	(0.10)
Single parent[2]	0.21	(0.11)*
Minority[3]	0.15	(0.12)
Low income[4]	0.16	(0.11)
IEP[5]	0.23	(0.13)
Parent education (yrs., 6-20)[6]	-0.04	(0.02)*
Grade 9[7]	-0.02	(0.14)
Grade 10	0.28	(0.14)*
Grade 11	0.46	(0.14)***
Home Internet – none[8]	0.48	(0.18)**
Home Internet – cell	0.38	(0.14)**
Home Internet – slow	0.12	(0.12)
Digital skills (centered, 0-64)[9]	0.01	(0.00)
Digital skills squared[10]	0.00	(0.00)
ICC (%)	0.59	**
N level 1 (level 2)	2,915 (15)	

*p<.05, **p<.01, ***p<.001

Notes:

[1] Reference category for female is male.

[2] "Single parent" refers to the student's primary living situation or does not live with a parent.

[3] The reference category for "minority" is white.

[4] Low income is measured as receives a free or reduced-cost lunch.

[5] IEP is an Individualized Education Plan.

[6] Parent education is the highest education of either parent.

[7] Grade 8 is the reference category for grade level.

[8] Fast home Internet is the reference category for home Internet access.

[9] Digital skills is mean centered.

[10] Digital skills squared accounts for a curvilinear relationship between digital skills and the outcomes.

Analysis performed using HLM 8, estimated using penalized quasi-likelihood, Bernoulli distribution, population-average model, individuals nested in school districts.

Table D2: HLM of overall digital skills

	Digital Skills	
	Coef.	SE
Intercept	24.98	(1.60)***
Female[1]	-2.21	(0.46)***
Single parent[2]	0.98	(0.52)
Minority[3]	0.53	(0.59)
Low income[4]	-0.56	(0.55)
IEP[5]	-3.37	(0.66)***
Parent education (yrs., 6-20)[6]	0.37	(0.08)***
Grade 9[7]	1.02	(0.65)
Grade 10	2.67	(0.65)***
Grade 11	3.37	(0.68)***
Home Internet – none[8]	-2.56	(0.93)**
Home Internet – cell	-3.79	(0.71)***
Home Internet – slow	-0.46	(0.58)
ICC (%)	4.22	***
Pseudo R^2 (%)	8.65	
N level 1 (level 2)	2,945 (15)	

*p<.05, **p<.01, ***p<.001

Notes:

[1] Reference category for female is male.

[2] "Single parent" refers to the student's primary living situation or does not live with a parent.

[3] The reference category for "minority" is white.

[4] Low income is measured as receives a free or reduced-cost lunch.

[5] IEP is an Individualized Education Plan.

[6] Parent education is the highest education of either parent.

[7] Grade 8 is the reference category for grade level.

[8] Fast home Internet is the reference category for home Internet access.

Analysis performed using HLM 8, estimated using restricted maximum likelihood, individuals nested in school districts. Pseudo R2 based on Snijders and Bosker (1999).

Table D3: HLM of grade point average

	Overall		STEM		English / Social Studies	
	Coef.	SE	Coef.	SE	Coef.	SE
Intercept	2.55	(0.10)***	2.54	(0.11)***	2.52	(0.11)***
Female[1]	0.34	(0.03)***	0.29	(0.03)***	0.39	(0.03)***
Single parent[2]	-0.31	(0.03)***	-0.29	(0.04)***	-0.32	(0.04)***
Minority[3]	-0.17	(0.04)***	-0.19	(0.04)***	-0.15	(0.04)***
Low income[4]	-0.27	(0.04)***	-0.25	(0.04)***	-0.30	(0.04)***
IEP[5]	-0.11	(0.04)**	-0.10	(0.05)*	-0.13	(0.05)**
Parent education (yrs., 6-20)[6]	0.05	(0.01)***	0.05	(0.01)***	0.05	(0.01)***
Grade 9[7]	-0.10	(0.04)*	-0.15	(0.05)***	-0.07	(0.05)
Grade 10	-0.04	(0.04)	-0.08	(0.05)	-0.01	(0.05)
Grade 11	0.02	(0.04)	-0.05	(0.05)	0.07	(0.05)
Home Internet – none[8]	-0.16	(0.06)**	-0.12	(0.07)	-0.19	(0.06)**
Home Internet – cell	-0.26	(0.04)***	-0.25	(0.05)***	-0.26	(0.05)***
Home Internet – slow	-0.08	(0.04)*	-0.04	(0.04)	-0.11	(0.04)**
Digital skills (centered, 0-64)[9]	0.01	(0.00)***	0.01	(0.00)***	0.00	(0.00)***
Digital skills squared[10]	-0.00	(0.00)	-0.00	(0.00)	-0.00	(0.00)
ICC (%)	4.40	***	4.08	***	4.96	***
Pseudo R^2 (%)	22.95		18.22		22.63	
N level 1 (level 2)	2,931 (15)		2,925 (15)		2,925 (15)	

*p<.05, **p<.01, ***p<.001

Notes:

[1] Reference category for female is male.

[2] "Single parent" refers to the student's primary living situation or does not live with a parent.

[3] The reference category for "minority" is white.

[4] Low income is measured as receives a free or reduced-cost lunch.

[5] IEP is an Individualized Education Plan.

[6] Parent education is the highest education of either parent.

[7] Grade 8 is the reference category for grade level.

[8] Fast home Internet is the reference category for home Internet access.

[9] Digital skills is mean centered.

[10] Digital skills squared accounts for a curvilinear relationship between digital skills and the outcomes.

Analysis performed using HLM 8, estimated using restricted maximum likelihood, individuals nested in school districts. Pseudo R2 based on Snijders and Bosker (1999).

Table D4: HLM of nationally representative percentile rank: PSAT 8/9, PSAT 10, SAT

	Total		Math		EBRW[11]	
	Coef.	SE	Coef.	SE	Coef.	SE
Intercept	50.91	(2.58)***	51.27	(3.71)***	44.82	(3.79)***
Female[1]	3.19	(1.04)**	-0.81	(1.09)	6.94	(1.12)***
Single parent[2]	-5.34	(1.17)***	-6.19	(1.23)***	-4.56	(1.26)***
Minority[3]	-3.52	(1.34)**	-3.60	(1.41)**	-3.23	(1.44)*
Low income[4]	-3.94	(1.26)**	-3.18	(1.32)*	-4.10	(1.35)**
IEP[5]	-13.53	(1.49)***	-11.93	(1.56)***	-14.52	(1.60)***
Parent education (yrs., 6-20)[6]	1.29	(0.19)***	1.24	(0.19)***	1.27	(0.20)***
Grade 9[7]	-3.23	(1.49)*	-2.42	(1.56)	-1.76	(1.60)
Grade 10	-11.08	(1.48)***	-11.62	(1.56)***	-4.97	(1.60)**
Grade 11	-23.49	(1.52)***	-21.52	(1.60)***	-18.46	(1.64)***
Home Internet – none[8]	-0.97	(2.26)	-1.19	(2.37)	-1.13	(2.43)
Home Internet – cell	-5.38	(1.63)***	-5.67	(1.71)***	-4.51	(1.75)**
Home Internet – slow	1.24	(1.25)	0.97	(1.31)	1.57	(1.35)
Digital skills (centered, 0-64)[9]	0.52	(0.04)***	0.40	(0.04)***	0.60	(0.04)***
Digital skills squared[10]	-0.01	(0.00)***	-0.01	(0.00)**	-0.01	(0.00)**
ICC (%)	3.78	***	3.31	***	3.27	***
Pseudo R^2 (%)	30.50		25.51		26.67	
N level 1 (level 2)	1,857 (8)		1,857 (8)		1,857 (8)	

*p<.05, **p<.01, ***p<.001

Notes:

[1] Reference category for female is male.

[2] "Single parent" refers to the student's primary living situation or does not live with a parent.

[3] The reference category for "minority" is white.

[4] Low income is measured as receives a free or reduced-cost lunch.

[5] IEP is an Individualized Education Plan.

[6] Parent education is the highest education of either parent.

[7] Grade 8 is the reference category for grade level.

[8] Fast home Internet is the reference category for home Internet access.

[9] Digital skills is mean centered.

[10] Digital skills squared accounts for a curvilinear relationship between digital skills and the outcomes.

[11] Evidence-Based Reading.

Analysis performed using HLM 8, estimated using restricted maximum likelihood, individuals nested in school districts. Pseudo R2 based on Snijders and Bosker (1999).
A separate HLM model (not shown) was conducted separately for each grade with similar findings.

Table D5: HLM (logistic) predicting intention to attend college or university after high school graduation

	First Year After		Will Ever Attend	
	Coef.	SE	Coef.	SE
Intercept	-1.65	(0.26) ***	-1.70	(0.26)***
Female[1]	1.05	(0.08) ***	0.74	(0.09)***
Single parent[2]	-0.51	(0.09) ***	-0.32	(0.09)***
Minority[3]	-0.29	(0.10) **	-0.19	(0.10)
Low income[4]	-0.21	(0.09) *	-0.41	(0.09)***
IEP[5]	-0.04	(0.12)	-0.30	(0.12)**
Parent education (yrs., 6-20)[6]	0.12	(0.01) ***	0.15	(0.02)***
Grade 9[7]	0.09	(0.11)	-0.06	(0.11)
Grade 10	0.27	(0.11) *	0.16	(0.12)
Grade 11	0.59	(0.12) ***	0.49	(0.12)***
Home Internet – none[8]	-0.23	(0.16)	-0.33	(0.16)*
Home Internet – cell	-0.24	(0.12)	-0.41	(0.12)***
Home Internet – slow	-0.01	(0.10)	-0.23	(0.10)*
Digital skills (centered, 0-64)[9]	0.02	(0.00) ***	0.02	(0.00)***
Digital skills squared[10]	-0.00	(0.00) ***	-0.00	(0.00)
ICC (%)	0.84	***	0.29	***
N level 1 (level 2)	2,945 (15)		2,945 (15)	

*p<.05, **p<.01, ***p<.001

Notes:

[1] Reference category for female is male.

[2] "Single parent" refers to the student's primary living situation or does not live with a parent.

[3] The reference category for "minority" is white.

[4] Low income is measured as receives a free or reduced-cost lunch.

[5] IEP is an Individualized Education Plan.

[6] Parent education is the highest education of either parent.

[7] Grade 8 is the reference category for grade level.

[8] Fast home Internet is the reference category for home Internet access.

[9] Digital skills is mean centered.

[10] Digital skills squared accounts for a curvilinear relationship between digital skills and the outcomes.

Analysis performed using HLM 8, estimated using penalized quasi-likelihood, Bernoulli distribution, population-average model, individuals nested in school districts.

Table D6: HLM (logistic) predicting interest in a STEM- or a STEAM-related career

	STEM		STEAM	
	Coef.	SE	Coef.	SE
Intercept	-1.28	(0.24) ***	-0.72	(0.24)**
Female[1]	0.34	(0.08) ***	0.49	(0.08)***
Single parent[2]	-0.16	(0.09)	-0.14	(0.09)
Minority[3]	0.02	(0.09)	0.14	(0.10)
Low income[4]	-0.14	(0.09)	-0.01	(0.09)
IEP[5]	-0.07	(0.11)	-0.09	(0.11)
Parent education (yrs., 6-20)[6]	0.08	(0.01) ***	0.05	(0.01)***
Grade 9[7]	-0.06	(0.11)	-0.14	(0.11)
Grade 10	0.01	(0.11)	-0.15	(0.11)
Grade 11	-0.04	(0.11)	-0.13	(0.11)
Home Internet – none[8]	-0.04	(0.15)	-0.11	(0.15)
Home Internet – cell	-0.22	(0.12)	-0.10	(0.12)
Home Internet – slow	-0.02	(0.09)	-0.04	(0.09)
Digital skills (centered, 0-64)[9]	0.01	(0.00) ***	0.02	(0.00)***
Digital skills squared[10]	-0.00	(0.00)	-0.00	(0.00)
ICC (%)	0.00	*	0.35	***
N level 1 (level 2)	2,945 (15)		2,945 (15)	

*p<.05, **p<.01, ***p<.001

Notes:

[1] Reference category for female is male.

[2] "Single parent" refers to the student's primary living situation or does not live with a parent.

[3] The reference category for "minority" is white.

[4] Low income is measured as receives a free or reduced-cost lunch.

[5] IEP is an Individualized Education Plan.

[6] Parent education is the highest education of either parent.

[7] Grade 8 is the reference category for grade level.

[8] Fast home Internet is the reference category for home Internet access.

[9] Digital skills is mean centered.

[10] Digital skills squared accounts for a curvilinear relationship between digital skills and the outcomes.

Analysis performed using HLM 8, estimated using penalized quasi-likelihood, Bernoulli distribution, population-average model, individuals nested in school districts.

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ABOUT THE QUELLO CENTER

The Quello Center is a multidisciplinary research center within the Department of Media and Information at Michigan State University. The Center's research is focused on the social and economic implications of developments in communication, media, and information technologies, as well as the policy and management issues raised by these developments.