Overcoming Michigan’s Homework Gap:

The Role of Broadband Internet Connectivity for Student Success and Career Outlooks

INFORMING THE DEBATE

Michigan Applied Public Policy Research Brief

Institute for Public Policy and Social Research
MICHIGAN STATE UNIVERSITY

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MAPPR Policy Research Brief

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About the Michigan Applied Policy Research Briefs

INFORMING THE DEBATE

The paper series, **Informing the Debate**, is generated from an internal grant-funded initiative sponsored by the Institute for Public Policy and Social Research (IPPSR) at Michigan State University. The initiative is the Michigan Applied Public Policy Research (MAPPR) Grant Program.

The MAPPR Program supports university faculty-led research projects that are focused on current issues being discussed in communities across Michigan, and often across the nation. A paper briefing of the research follows completion of the project wherein related policy implications are presented.

The MAPPR Program came about in 1992 following a two-day meeting with leaders from the business sector, nonprofit agencies, and university faculty and staff. The group recognized the pressure on urban core leaders to critical choices having long-term impact on communities with little access to research-based information to generate a bank of research as a reference was set in the framework of the MAPPR Program.

Since, the MAPPR Program has bridged the statehouse and the university while cultivating multidimensional connections among community decision-makers. The projects as well as the briefings serve as a central point of discussion and brainstorming. The briefings are reviewed by not only Michigan stakeholders but also by other states' frontrunners who share the need for evidence-based research.

Additional information about IPPSR and the Michigan Applied Public Policy Research (MAPPR) Program is available at IPPSR or by contacting Arnold Weinfeld, associate IPPSR director, at weinfel8@msu.edu.

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Executive Summary

Disparities in home Internet access affect the ability of K-12 students to complete homework. This “homework gap” and its consequences for student success have received increasing attention in debates about digital inequalities and education policy. However, lack of broadband connectivity has additional repercussions for student educational outcomes (which we label “performance gaps”) that have received less attention. Most important, variations in broadband access are associated with different levels of digital skills, career orientation, and student interest in post-secondary education. Digital skills and post-secondary education are increasingly important for success in existing and emerging occupations. The mitigation of the disadvantages associated with insufficient and lack of broadband access is an urgent and important investment in the future of the State of Michigan.

These disparities in Internet access diminish the potential of students to succeed in the future digital economy and potentially put them at a disadvantage early in life. COVID-19 forced schools to adopt continuing education plans within these broadband infrastructure constraints. Based on a sample of schools that received E-Rate funding, Education Superhighway (2019) reported that in 2019, 98% of school districts in Michigan could provide minimum connectivity of 100 kbps per student and 99% were connected to fiber. Nonetheless, these numbers put Michigan in the bottom half of states. A much larger number of K-12 students lacked access to broadband Internet in their homes. With an estimated number of more than 300,000 unconnected, rural homes in Michigan, the figures are even more dramatic in rural and economically distressed areas of the state. Improving Internet access is an important component of safeguarding equitable access to education.

With an emphasis on rural, and small-town, Michigan schools, this study was designed to contribute to a better understanding of the effects of broadband connectivity on educational outcomes. A first goal was to measure how different types of home connectivity (e.g., broadband vs. cell phone) are related to variations in student educational outcomes. A second 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. Third, the project sought to generate insights into the private and social costs of a lack of broadband connectivity. Because of a commitment to work with fully de-identified data and the resulting complicated project logistics, the project needed to focus on a limited number of school districts. We believe that the main insights hold more broadly beyond the areas studied.

In May and June 2019, students aged 13 and older, from grades 8-11, in fifteen school districts located within the Eastern Upper Peninsula Intermediate School District (ISD) ISD, Mecosta Osceola ISD, and St. Clair County Regional Educational Service Agency (SCCRESA) participated in this project. The researchers collected fully de-identified survey, speed-test, and standardized test data. A total of 3,258 students completed surveys, which represented coverage of 70.6% of the eligible students. Eight of the school districts provided de-identified, standardized, student test scores that were matched with student responses to the project survey. In addition, Merit Networks developed and supported an optional speed test of the connection and devices used by students for their homework. These data were used to check the accuracy of the Internet access information provided in the surveys.

Broadband is one among several factors that may be associated with educational outcomes. Other factors include socioeconomic status, such as income and education level of the caretaker, and school-related factors that affect all students in a school similarly. We used a statistical technique, hierarchical linear modeling (HLM), to control for these factors and to isolate the effects of variations in broadband connectivity. The main findings are:

- Fifty-six percent of the students in the sample reported having fast broadband access at home, 23% slow Internet, 14% only cellphone access, and 7% had no Internet access. Forty-seven percent of students living in rural areas and 59.9% of students living in small towns reported fast Internet access. In comparison, 70.3% of students living in cities and 76.7% of students living in suburbs reported fast Internet access.
- Students used the Internet for a wide range of education-related activities, including to access course-related content, do research, and collaborate. Students without home Internet access and those who depend on a cell phone to access the Internet when away from school were less likely to participate in all online, educational activities outside of school.
- Students with no Internet access at home and those who depend solely on a cell phone for Internet access when away from school were more likely to report that they were unable to complete their homework assignments. Sixty-four percent of students with no home Internet access often or sometimes left homework unfinished because they lacked Internet access or a computer. This compared to 49% of those who relied on cell phones, 39% with slow home connections, and 17% of students with high-speed home Internet access. Only 14% of disconnected students never left homework unfinished, compared to 46% of all other students.
- Students who did not have Internet access at home had significantly lower digital skills. Students with no home Internet scored approximately three points lower on the digital skills scale. Those who had only a cell phone to access the Internet scored four points lower than those with fast or slow Internet at home. The finding that digital skill is related to home access is particularly important because our data also show that lack of access and having lower digital skills are independently related to lower scores on standardized tests.
- Students with fast, home Internet connections had higher overall GPAs than students with no home access, slower home access, or cell only access. The difference in overall GPA between those students with home Internet access and those without access or who are dependent on cell phone access was roughly equivalent to the difference between a half letter grade in each class - the difference between a B and a B- average.
- 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). However, other factors affect a student’s standardized test scores. Students from low-income families, minority students, students from single-parent families, and students with Individualized Education Programs (IEPs) tended to score lower on the PSAT/SAT. Students whose parents had a higher level of education performed better.

- 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. Forty percent of students said that they did not plan to ever complete accreditation at a college or university. Fifty-three percent of students who had no home Internet access or had only cell phone access to the Internet did not plan to complete a post-secondary program. This compared with 40% of those with slower home Internet access and 35% of those with fast home Internet.
- Students with less developed digital skills were less likely to want a career related to science, technology, engineering, and math (STEM). The same was true of careers classified under the broader category of science, technology, engineering, the arts, and math (STEAM).

Federal, state, and local policies influence broadband investment in the United States. Ideally, efforts at each level would be coordinated into a synergistic program to close the homework gap. Some of these measures will take time and sustained, innovative efforts. The Coronavirus pandemic required short-term responses that were constrained by the existing inequalities, even though concerted efforts by many stakeholders helped mitigate some of them. To address the homework gap permanently, measures to improve broadband connectivity need to be combined with longer-term measures to improve the resilience of the educational system.

Measures to close the broadband gap include the following.

- At the federal level, broadband, universal service initiatives, such as the E-Rate program and the Lifeline program, will need to be updated. New funding programs will also be needed in addition to the Rural Digital Opportunity Fund (RDOF), as many urban and even rural areas with poor service do not qualify under the current RDOF program.
- Michigan would benefit from better coordination of broadband policy at the state level and from state-level, funding programs. Empirical research shows that state, universal service programs increase adoption by two percentage points. In 2016, key elements of a state-wide plan were developed but never implemented. A forward-looking plan could build on these pillars and provide a common framework and support for local stakeholders.
- The most flexible and scalable, but currently also the most expensive, broadband technology is fiber optical networking. Because civil engineering costs constitute up to 75% of the total costs, careful planning and coordination of infrastructure projects and orchestration of policies to grant access to rights of way could save a significant share of deployment costs. “Dig Once” models deploy conduits and ducts in parallel with road or other infrastructure projects and greatly reduce the cost of fiber rollout. In contrast, in the “Dig Smart” approach, municipalities invest in the conduit to be leased to Internet service providers (ISPs).
- The broader range of connectivity options opened by technological advances allows each community to develop a least-cost, connectivity plan by putting together the most efficient combination of networking technologies. This is often a hybrid solution, using a mix of fixed and wireless technology.
- Existing local, state, and federal laws need to be reviewed to remove obstacles to entrepreneurship, public-private partnerships, and public solutions. In addition, service

providers need to review operating procedures for provisions that are barriers to connectivity.

- In some locations, investment in a public access, broadband network or a public-private partnership may be the most appropriate option. Several, successful models demonstrate the effectiveness of this approach, although not all experiments did well. Section 484.2252 of the Michigan Telecommunications Act of 1991 as amended, which imposes limitations on the ability of public entities to offer telecommunication services, should be reviewed. At the same time, it will be important to create conditions that do not provide artificial, economic advantages for public entities, such as tax breaks.
- Because access inequalities interact with income inequalities, complementary measures to increase affordability, such subsidies to individuals, will be needed. Much will depend on the business model and technology deployment and the resulting price points. Stimulating retail and wholesale competition will also help reduce prices per unit of information.
- Several initiatives have sought to work with communities to develop a deeper appreciation of the importance of broadband and digital connectivity. Schools and other community institutions will need to develop programs to work with parents, grandparents, and other caregivers to broaden digital literacy and skills among these populations.

In addition to these measures, forward-looking, education policy should adopt measures to increase the resilience of the K-12 system. Resilience is the capacity of a system to recover quickly from difficulties and unexpected events and the ability of a system to deliver despite continuing, adverse events. Measures to be considered include:

- Structuring and preparing the K-12 educational system so that it can effectively deliver education online and in other (technology-mediated) modes, should one mode of education become disrupted.
- In addition to addressing the existing digital inequalities, such a model will require systematic teacher, parent, and caretaker training as well as adaptations to the curriculum and pedagogy.
- Increasing the level of resilience will also require including in the curriculum material about potential sources of risks, effects of unanticipated developments, systems thinking, and possible responses.
- Finally, increasing the ability to mobilize spare resources quickly will be critical. This includes emergency funding facilities and individuals who are trained to assist in the provision of educational support in emergency situations.

The findings of our report provide evidence of the individual, community, and societal costs of lacking digital connectivity. Broadband is one among several factors that are associated with student, educational performance. We therefore recommend pursuit of a multi-pronged strategy that addresses the gaps in connectivity, the socioeconomic environment of the students, and the approaches to using technology in schools. The Coronavirus pandemic has lent a new urgency to the development of educational models that use digital learning in ways that increase the resilience of the system overall. Overcoming inequalities in broadband access, device availability, and skills is an important precondition for the success of all these initiatives.

1. Overview of the Issues

Digital technology is increasingly embedded in the American economic and social fabric. Existing industries, such as manufacturing, transportation, and agriculture, will become more dependent on digital technology and connectivity to improve their efficiency and the quality of their services. More important, emerging applications and services, including additive manufacturing and robotics, the Internet of Things (IoT), and fifth generation (5G) wireless services, offer tremendous innovation opportunities that will transform the national and state economy. Realizing this potential will depend on high-quality, Internet connectivity across the state and on a workforce with appropriate knowledge and skills. Like other U.S. states, Michigan faces significant challenges in achieving these goals. Although progress has been made since broadband was first deployed two decades ago, advanced connectivity continues to be insufficient in many areas of the state. The Coronavirus pandemic has drastically exposed the individual and social costs of lacking or poor connectivity, depriving numerous individual and households from K-12 and higher education, health care, and government services.

During the past decade, awareness about a range of negative effects of inequalities in Internet access and use has been growing. The "homework gap"[1] and disparities in home Internet access and their consequences for school performance are the focal points of recent policy discussions. In 2015, according to data published by the Pew Research Center, approximately five million households with school-aged children did not have broadband Internet connectivity at home (Horrigan, 2015). In 2018, 17% of all teenagers responded that they often or sometimes cannot complete their homework because of a lack of a computer or Internet at home. Socioeconomic factors strongly influence access to broadband. Only 62% of households with an annual income below $20,000 had broadband at home compared to 95% of households with an income of $75,000 or more. Black and Hispanic households were less likely than White households to have broadband at home. Consequently, socioeconomic factors also influence the handicap faced by different groups of students, with Black students and students from low-income families reporting the highest rates of incomplete homework (Anderson & Perrin, 2018).

National data show that technology is increasingly embedded in teaching and learning. Seventy percent of teachers assign homework that requires access to broadband. Thirty percent of school districts in the United States include technology in their curricula. There is growing evidence that these developments disadvantage students who have no or only inadequate Internet access at home. For example, previous research has found that high school students with broadband Internet at home have 6-8 percentage points higher graduation rates than students without broadband access (Fairlie, Beltran, & Das, 2010). National-level research also indicates that students with home Internet access score higher in reading, math, and science (KewalRamani et al., 2017). Research on digital inequalities has revealed a broad range of potential effects that go beyond the ability to complete homework (Hargittai & Hinnant, 2008; Robinson et al., 2015; van Laar, van Deursen, van Dijk, & de Haan, 2017). Students lacking Internet access at home may have lower grades, enjoy school less, experience lower self-esteem, have lower digital skills, lower interest in STEM-related careers, and be disadvantaged

[1] The term is attributed to an editorial by Federal Communications Commissioner, Jessica Rosenworcel, in the *Miami Herald*, titled "How to close the 'Homework Gap'", December 5, 2014.

in pursuing post-secondary education opportunities (Hampton, Fernandez, Robertson, & Bauer, 2020).

Existing challenges were amplified by the COVID-19 pandemic and the subsequent closure of schools and universities. The outbreak revealed the limited capacity of the American educational system to continue to deliver its services under difficult and adverse conditions. Few school districts were prepared to switch quickly to alternative modes of education. After initial closures in support of social distancing, by the end of April 2020, only 44% of K-12 schools offered online instruction that included student monitoring and feedback (Hill, 2020). Others could offer only partial support for learners at home. Most states eased or waived rules for completing the school year to allow students to graduate and advance to the next grade in the fall (see IPPSR, 2020). Short-term, response options were greatly constrained by the inequalities in access to broadband and the lack of devices needed for effective, online teaching and learning. Over the summer, schools and local initiatives developed a plethora of innovative and entrepreneurial solutions to reduce the access gap and adapt teaching to the continuing pandemic. However, to address the problems permanently will require extended, concerted efforts and the development of cost-effective responses.

Problems of lacking, or poor, home broadband connectivity are particularly pressing in rural America and in poorly connected, urban areas (Siefer & Callahan, 2020). According to Federal Communications Commission (FCC) reports, by the end of 2018, 94.4% of the overall population had coverage with broadband Internet access services, defined as 25 mbps download and 3 mbps upload speed (FCC, 2020, p. 18). However, 22.3% of the population in rural areas and 27.7% of Americans on tribal lands did not have fixed, terrestrial, broadband connectivity.[2] Areas that do not have fixed, broadband access may be served by terrestrial wireless and/or satellite, broadband Internet access. These plans are likely not full substitutes for fixed broadband. Terrestrial, mobile data plans typically do not meet the FCC’s threshold for broadband service. Even “unlimited” plans have monthly data caps, above which download speeds are throttled significantly, or they may default to lower speeds if the network is congested. Satellite, Internet access is afflicted with levels of latency (signal delays) that limit certain types of real-time uses, such as videoconferencing. In addition, such access is sensitive to foliage and heavy weather conditions that may deteriorate or completely obstruct the signal.

Differences in Internet access and use have been known and documented for more than two decades, when the U.S. National Telecommunications and Information Administration (NTIA) introduced the term *digital divide* (NTIA, 1995, 1998, 1999, 2000). Several factors contribute to the present, uneven deployment and adoption of broadband across the nation. One set of factors is related to the economic characteristics of broadband. The cost of extending broadband to remote, sparsely populated, and low-income areas is high relative to their revenue potential. Therefore, the incentives for commercial, Internet service providers to extend the network to such areas are very limited. Although policies have changed several times in the past two decades, the FCC decided against applying historical, common carrier obligations to broadband, which would have included a duty to serve all who have a reasonable demand.

[2] For reasons that will be discussed in more detail below, these data are based on statistical conventions that likely overestimate actual availability.

Appropriate universal service policy measures could have overcome the resulting supply gaps, but programmatic and institutional policy failures prevented the adoption of a consistent approach. A combination of legislative inertia, frequent policy changes at the FCC after changes in administrations, and lobbying of local, state, and national governments created a patchwork of programs and regulations rather than an effective set of policies. The gaps in supply were further handicapped by systematic biases in the official broadband data upon which public programs were based. During the past decade, many communities and local advocates have started decentralized, local initiatives, but these projects are often hampered by similar obstacles.

Even if broadband infrastructure is available in a location, other factors are in play that influence whether individuals and households choose to subscribe to it. Users evaluate whether the benefits from subscribing to broadband, which determine their willingness to pay, outweigh the price for broadband service plus the cost of obtaining equipment necessary to use it effectively. If the price is above the willingness to pay, an individual or household will not subscribe. Because prices for broadband and income vary widely by location, it is also possible that broadband service is not affordable for some users in a specific area. One of the benefits of using broadband is to experience goods that require using broadband. Other benefits, such as increased safety or workforce qualifications, may materialized for the community at large (i.e., they are public goods). Consequently, the individual willingness to pay may not reflect the true societal value of being connected. Often smartphones are erroneously regarded as a full substitute (e.g., Horrigan & Duggan, 2015). COVID-19 has likely heightened the awareness of the benefits of fixed broadband but at a time of serious income constraints for many individuals and households. Increasing adoption therefore remains a challenge.

In 2017, Michigan was about average among other states and territories for broadband availability (Michigan Infrastructure Commission, 2018). Based on a sample of schools that received E-Rate funding, Education Superhighway (2019) reported that in 2019, 98% of school districts in Michigan could provide minimum connectivity of 100 kbps per student and 99% were connected to fiber. Nonetheless, these numbers put Michigan in the bottom half of states. A much larger number of K-12 students lacked access to broadband Internet in their homes. With an estimated number of more than 300,000 unconnected, rural homes in Michigan, the figures are even more dramatic in rural and economically distressed areas of the state. As Michigan grapples with issues of educational inequities, it is imperative to address Internet access as part of this fundamental right to learn and be educated. Access to high quality and Internet in and outside of school must be considered in the mix of solutions to address these troubling statistics.

These disparities in Internet access diminish the potential of many students to succeed in the future digital economy and put them at a disadvantage early in life. COVID-19 forced schools to adopt continuing education plans within these broadband infrastructure constraints (Cummings, Kilbride, Turner, Zhu, & Strunk, 2020; Lovitz, Kilbride, Turner, & Strunk, 2020). The provision of additional broadband connectivity is a necessary condition for many forms of online learning, but it is likely not sufficient to achieve the envisioned, educational outcomes. Other factors need to complement Internet connectivity, such as student skills on how to learn with digital and online tools, appropriate parental support, and a curriculum and pedagogy that take advantage of the possibilities of digital learning. To help disentangle these issues, the project team set out to collect data that allow nuanced insights into these relationships. The focus was on how broadband connectivity in predominantly rural and small-town Michigan relates to educational outcomes and aspirations.

This report documents a detailed investigation of the extent to which the students in three rural school districts in Michigan are able to access the Internet when not at school. Shortfalls in the quality of the data available to identify gaps in broadband coverage and related economic constraints to adopt broadband have hidden the extent of the gap in broadband coverage. Our data collection method was designed to overcome these shortcomings. We found significant differences in student performance that were related to their home connectivity. 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 PSAT and SAT), interest in post-secondary education, and even the choice of careers. Internet access using a cell phone is often considered a stop gap for the lack of fixed broadband. Yet, we found that students who rely exclusively on cell phones and mobile data plans without complementary devices, such as wireless hotpots, experience disadvantages that are comparable to having no broadband at home.

Given the desire to work with highly granular data, it was necessary to focus on a few, selected, school districts. A primary goal was to measure how different types of home connectivity (e.g., fast broadband, slow Internet, cellphone, no Internet) are related to variations in student outcomes. A precondition to designing remedial measures was a better understanding of these relations and especially the costs of not being connected. A secondary goal was to develop a framework for data collection and analysis that could serve as a blueprint for future assessments of the consequences of unequal and insufficient broadband connectivity across America's cities, suburbs, and rural areas. Broadband connectivity and digital learning technology are not static but evolve rapidly. Connectivity that is sufficient today may not be able to support the next generations of learning tools, such as learning in virtual environments and in interactive online worlds. A measurement and monitoring framework can facilitate learning from experience and using the insights to continuously improve connectivity, access devices, teach, and learn in these changing conditions. Moreover, such a framework can also help in the design of a resilient education system that can deliver under conditions of distress.

2. The Homework Gap in Michigan

In July 2019, 9,987,000 people resided in Michigan.[3] Approximately 74.6% of the population (about 7.4 million people) lived in the state's urban land area, which consists of 3,623 square miles (6.4 % of the state's landmass). The remaining 25.4% of the population (about 2.5 million people) inhabited 93.6% of the state (52,916 square miles) that is considered rural land (Citizens Research Council of Michigan, 2018). Twenty-one percent of Michigan students were enrolled in schools classified by the National Center for Education Statistics (NCES) as rural, and an additional 12% attended small-town schools. According to data from the National Center

[3] U.S. Census Bureau, State Population Totals and Components of Change: 2010-2019, available at https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-total.html#par_textimage_1574439295 (retrieved September 4, 2020).

for Education Statistics, Michigan ranked 31st in the nation for the proportion of students enrolled in either rural or small-town schools. Among Midwestern states, only Illinois had a smaller proportion of students enrolled in rural schools. In North Dakota, South Dakota, Nebraska, Minnesota, Iowa, Missouri, Wisconsin, Kansas, Indiana, and Ohio, a larger share of students attended rural schools.[4]

Several factors complicated the reliable assessment of disparities in home broadband access. Technical characteristics of a network connection and several other factors influence user experience with broadband Internet access. For example, download and upload speeds are typically affected by the type and capabilities of the devices used to access the Internet, whether a Wi-Fi hotspot provides connectivity in the home, as well as the number of simultaneous users and their online activities (e.g., streaming, browsing, and email). Most providers offer several tiers of service that are differentiated by quality of service and price. Mobile data plans typically have data caps, beyond which the data rate of the connection is throttled to below broadband speed, unless a user purchases an additional data allowance. Slow Internet access can also be an affordability issue rather than a network availability issue. Budget constraints may force a household to subscribe to a lower quality of service or to rely on a mobile data plan with a low data cap.

A reliable assessment of access is also complicated by deficits in the data that are available to map broadband access, which 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. They must submit information on the geographic areas (typically census blocks) in which broadband subscribers are located or for which deployment is planned. Broadband maps generated from these data consider the entirety of each census block in which at least one customer is or will be served at broadband speed as a location with broadband. This may be a reasonable approximation of locations with service in small, densely populated city blocks where the incremental costs of adding a customer are small. It grossly overestimates the availability of broadband in large, sparsely populated census blocks, where the incremental costs of adding subscribers is high. NTIA and the FCC are aware of these shortcomings and have recently initiated steps to improve the quality of data in the future, but regrettably only after a decade during which broadband programs were based on erroneous information.[5]

Frustrated by this lack of coherent data, many independent initiatives are experimenting with alternative methods to generate reliable broadband data. These studies have corroborated the errors in the FCC data in general and for Michigan. A 2019 Microsoft study, based on user browser data, found that 162.8 million people across the United States, rather than the 24.7

[4] Based on the 2017-18 U.S. Department of Education Common Core of Data, available at https://nces.ed.gov/ccd/.
[5] In August 2019, the FCC adopted a Report and Order, titled Establishing the Digital Opportunity Data Collection: Modernizing the FCC Form 477 Data Program (FCC, 2019) with the goal to improve broadband mapping. 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).

million as per FCC data, did not use the Internet at broadband speeds. According to the same study, 5.7 million people in Michigan, rather than the 969,000 reported by the FCC, did not use the Internet at broadband speed.[6] A detailed examination of Internet access speeds for Washtenaw County similarly found that the official data grossly overestimated actual availability (Washtenaw County Broadband Task Force & Merit Network, 2020). Other empirical studies, such as the M-Lab mapping project (e.g., Deng, Feng, Gharakheili, & Sivaraman, 2019), and initiatives in several states have reached similar conclusions. For instance, the Georgia Broadband Deployment Initiative (GBDI)[7] and a mapping project in the State of Pennsylvania (Meinrath et al., 2019) found similar discrepancies. Some of these projects rely on crowd-sourced measurement data from Internet users. Although this can improve the granularity and accuracy of the available information on broadband speeds, it captures data only on connected, but not on unconnected households. Recent projects, including our own work, have therefore added instruments, such as pen-and-paper surveys or phone surveys, to also collect information on unconnected households (e.g., Hampton et al., 2020; Washtenaw County Broadband Task Force & Merit Network, 2020).

Table 1: Broadband connectivity in Michigan

Source	Status	Base	Connectivity	Served	Unserved
U.S. Census (ACS)[a]	July 2018	Households	Broadband Internet	79.0%	21.0%
FCC, 2020 Broadband Report[b]	December 2018	Population	Fixed terrestrial broadband (25/3 mbps)	94.7%	5.3%
FCC, 2020 Broadband Report[c]	December 2018	Population	LTE wireless (10/3 mbps)	93.1%	6.9%
Connect Michigan[c]	July 2018	Households	Fixed broadband (25/3 mbps)	92.3%	7.7%

Notes: [a] ACS … American Community Survey, conducted on an ongoing basis using a sample of 3.5 million households, https://www.census.gov/quickfacts/MI. [b] FCC (2020), based on FCC Form 477 data, self-reported by Internet Service Providers (ISPs). [c] Connect Michigan, https://connectednation.hatfield.marketing/michigan/planning/. Based on FCC Form 477 data, subject to same simplifying assumptions.

Given these concerns, it is important to keep the strengths, limitations, and biases of data on broadband connectivity in Michigan in mind. Table 1 provides an overview of the range of official statistics. Information from the American Community Survey (ACS) is collected from a representative sample of households. In contrast, the data published by the FCC and Connect Michigan are based on Form 477 data, self-reported by Internet Service Providers (ISPs). As

[6] 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.
[7] See Georgia Department of Community Affairs, FCC vs. GBDI Broadband Comparison, available at https://broadband.georgia.gov/fcc-vs-gbdi-broadband-comparison (visited on September 4, 2020).

discussed above, a census block is treated as served in its entirety, if one customer subscribes to broadband or will be served in the future. These simplifying assumptions exaggerate the share of individuals or households considered as served, which is clearly obvious in Table 1 in the discrepancy of 14.1 percentage points between the number of households with broadband according to the ACS data and the Connect Michigan number. Given the more reliable method employed by the ACS, it is likely that the ACS number is a better reflection of the actual connectivity situation. Our own survey data, reported in more detail in section 4.1 below, are much closer to the ACS than the Connect Michigan numbers.

In 2020, 832 Local Education Agency (LEA) and Public School Academy (PSA) districts served the more than 1.5 million K-12 students in the State of Michigan (EPIC, 2020; MDE, 2020). A sample of Michigan schools participate in the National Assessment of Educational Progress (NAEP). In the latest round of assessments in 2019, Michigan schools scored on the national average in Grade 8 Mathematics and in Grades 4 and 8 Reading. Only in Grade 4 Mathematics, were scores below the national average. Scores in Grade 4 Reading and Grade 8 Mathematics improved, compared to 2015, when Michigan had been below the national average. The latest science scores are from 2015, when Michigan scored at the national average in both Grade 4 and 8. However, data show great variation by social factors, such as income, race/ethnicity, and location.[8] In 2016, Michigan adopted the Top 10 in 10 Years Strategic Education Plan,[9] updated in 2020. The plan includes a detailed set of aspirational metrics for student proficiency, access to learning, and other important dimensions of the education process.

COVID-19 forced Michigan schools, like schools across the nation, to adapt quickly under tremendous, resource constraints and concerns about health and safety of students, teachers and staff (Cummings et al., 2020; Lovitz et al., 2020). Broadband connectivity and availability of appropriate devices were two of several obstacles that many schools needed to overcome. The very short response horizon forced schools nationwide to adopt available and, in many cases, likely only temporary fixes. Regulatory measures in the wake of the lockdown in March 2020, such as temporary modifications to the E-Rate program by the FCC, allowed the extension of the signal footprint of school Wi-Fi networks to beyond buildings. Private sector providers helped by expanding their low-income programs, waiving data caps on mobile data plans, and offering discounted services and devices. Some schools equipped school buses with Wi-Fi hotspots and placed them at strategic locations across their district. Funding by the federal Coronavirus Aid, Relief, and Economic Security Act (CARES) Act allowed many schools to purchase tablets, notebooks, and hotspots. Some schools and cities used CARES funding and/or private donations to negotiate one- or two-year, discounted, single-payer contracts with Internet Service Providers (Davis, 2020).

As of August 2020, 16% of Michigan school districts planned to operate fully in-person only; 43% planned to offer fully in-person as an option; 10% planned to operate hybrid only; 17% to offer hybrid as an option; and 12% to operate in remote mode only (EPIC, 2020). Thus, approximately 40% will need to rely strongly on remote learning methods and an additional 43% will have to use them for part of their students. During the final weeks of the spring semester

[8] See https://www.nationsreportcard.gov/, visited September 8, 2020.
[9] See https://www.michigan.gov/mde/0,4615,7-140-80635---,00.html, visited September 8, 2020.

2020, schools chose a range of approaches to online learning in response to barriers to broadband Internet access encountered by their students. Initiatives included the distribution of hardcopies of assignments or of assignments on flash memory to students without stable Internet access (Lovitz et al., 2020). Although these are workable patches in the short run, it would be desirable to develop a state-wide, longer-term strategy to overcome the existing Internet access barriers and expand the digital skills of students, parents, and teachers. Such an approach would allow building a resilient K-12 education system that could continue to deliver its services under adverse conditions or recover quickly after a serious disruption. To facilitate rational decisions for such programs, the Quello Center embarked on a detailed study of the effects of broadband access and use on student performance and the individual and social costs of lack of broadband.

3. Examining Broadband and Educational Outcomes in Rural Michigan

3.1 Research Approach and Study Design

Our study was designed to contribute to a better understanding of the relationship between broadband and educational outcomes. It also needed to overcome the shortcomings of existing broadband data. The research project sought to identify the prevalence of Internet (dis)connectivity in selected Michigan school districts where students are predominately from rural and small-town areas. A first goal was to measure how different types of home connectivity (e.g., broadband vs. cell phone) are related to variations in student educational outcomes. A second 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. Third, the project sought to generate insights into the private and social costs of a lack of broadband connectivity.

Because of a need to collect fully de-identified, yet highly granular data, the project was logistically complicated. To keep it manageable, it was necessary to focus on a limited number of school districts. 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 emerged from the K-12 Citizen Science Working Group, a small group of stakeholders from Michigan school districts brought together for a discussion of initiatives to increase student connectivity at home, organized by Merit Network and the Quello Center at Michigan State University (MSU) in December 2018. 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.

In compliance with the research ethics guidelines of the MSU Institutional Review Board (IRB), the Family Educational Rights and Privacy Act (FERPA), and related regulations, the Quello Center collected de-identified surveys, speed-tests, 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 Table 2 for a list of participating districts).[10] 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). A total of 3,258 students completed surveys, representing coverage of 70.6% of eligible students.[11] Most students completed the survey in approximately twenty minutes. The survey was coded using a unique participant ID and was accompanied by a separate key sheet that linked the survey 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 student responses to the project survey. The ISDs ensured that the student information was fully de-identified before it was made available to researchers at the Quello Center. The information was combined with the survey data, using the unique participant IDs.

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. The network-based speed test data were used to verify the accuracy of the self-reported Internet access information provided on the paper surveys.

3.2 Sample Characteristics

The fifteen school districts that participated in this project are from predominately rural areas with population densities ranging from 1.52 people per square mile to 222.81 people per square mile (see Table 2). 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). In our sample, 8% of students reported living on a farm, 39.1% in a rural area but not on a farm, 38.3% in a small town, 6.8% in a suburban area, and 7.7% in a city.

District median household incomes ranged from $34,205 to $67,371 (the median for all of Michigan is $52,668; it is $57,652 nationally).[12] The proportion of district families that were below the federal poverty level was, on average, 9% and ranged from 3.4% to 17.4% (it is 10.9% for all of Michigan and 10.5% nationally). In our sample, 35.1% of the participating students qualified for free meals or the reduced-cost meal program. Children were eligible for free or reduced-price meals if their household received benefits from the Food Assistance Program (FAP), Family Independence Program (FIP), or Food Distribution Program on Indian Reservations (FDPIR), if they participated in the school's Head Start program, or met Federal

[10] 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.
[11] Where noted in the analysis, missing data on some questions may result in fewer cases being reported.
[12] Based on NCES and ACS 2013-2017, available at https://nces.ed.gov/ccd/schoolsearch/.

Income Eligibility Guidelines (e.g., lived in a household with four people and an annual income at or below $47,638).[13]

The population of all districts was relatively homogeneous. In our 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 level as: high school or less – 32.5%, some college or university –16.6%, an undergraduate degree – 28.1%, and a graduate degree or some postgraduate training – 22.8%.

Table 2: School district demographic data (as of the 2018-2019 school year)

School District	Total Population	Population density (people per square mile)[a]	Students 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%

[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.
Sources: American Community Survey (ACS), 2013-2017; Hampton et al. (2020).

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 years (8.6%), 17 years (14.9%), and 18 years (1.5%). Approximately one-third of the students reported that they were living with only one parent or not living with any parent.

[13] See https://www.michigan.gov/mde/0,4615,7-140-5373_6526_6551-472670--,00.html. Last visited September 22, 2020.

3.3 Examining the Contribution of Broadband to Educational Outcomes

The homework gap discussion explores the association between home Internet access and homework completion at an aggregated level. Schools, educators, and communities recognize and struggle with the potential impact of insufficient broadband connectivity on educational outcomes at the local level. Arguments for the provision of expanding broadband service are often linked to equity concerns, such as the desire to facilitate digital learning of all students (e.g., Fox & Jones, 2019). A desire for digital equity and inclusion is a powerful reason to overcome the broadband gap. Policy proposals are often also more narrowly linked to evidence of higher performance scores in reading, mathematics, and science for students with home Internet access (e.g., KewalRamani et al., 2017). However, broadband is only one of several factors, including socio-economic status, location, and pedagogy, that influence educational outcomes. The importance of broadband relative to these factors and their interactions with broadband have not been explored in detail. Although a strong argument for broadband connectivity could be made on digital inclusion grounds alone, a detailed understanding of how broadband affects educational outcomes will help to develop better solutions.

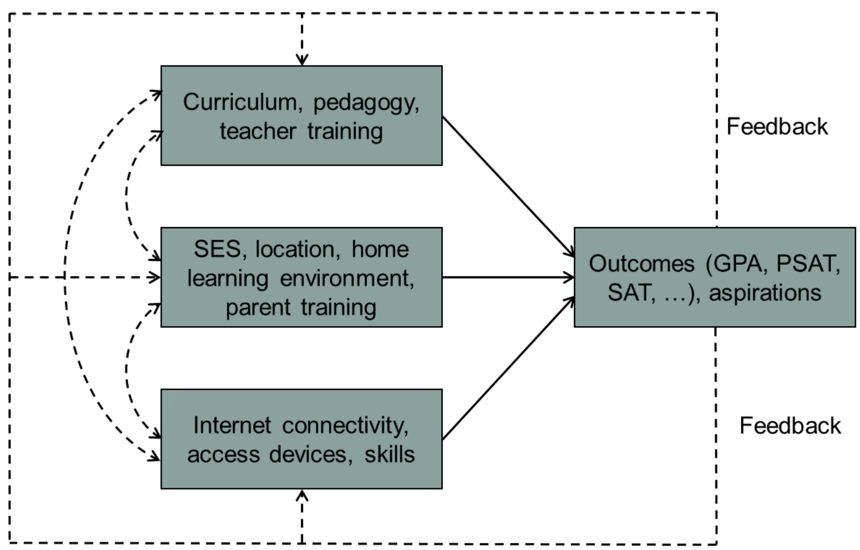

Figure 1: Groups of factors that influence student educational outcomes. Internet connectivity is one among several interrelated factors that influence educational outcomes directly and indirectly. School-related factors, such as pedagogy, and household-related factors, such as socio-economic status and location, interact with broadband and affect educational outcomes directly and indirectly. Over time, observed learning outcomes may affect these factors (feedback) with the goal to improve overall performance.

Three broad groups of factors influence educational outcomes, typically measured with metrics such as grade point average (GPA), standardized test scores (SAT, PSAT), and possibly career and post-secondary educational aspirations. School-related factors include, but are not limited to, the curriculum, pedagogy, and the training of teachers to utilize digital learning effectively. Location, the socio-economic status (SES) of a household, the home learning environment, and parental attitudes and training to support digital learning will also influence educational outcomes. Internet connectivity, including the type of network connection, the kind of devices used to access the Internet, and the skills of utilizing Internet access constitute a third group of factors. They are typically related to socioeconomic factors and possibly to school-related factors. It is not clear whether broadband access has a direct effect on educational outcomes or whether it affects these outcomes indirectly through other factors, such the ability to interact with peers and digital skills.

A multitude of relevant factors complicates empirical research on the relationships between Internet access and educational outcomes. Furthermore, because technology and its uses change rapidly, findings also evolved. Studies have used a variety of methods, including cross sectional designs, panel data, and interventions, to disentangle the relative influence of these factors. Data and resource constraints often force researchers to examine a subset of all the relationships, for example, to focus on the link between computers and educational outcomes without considering connectivity issues or digital skills. Our study was not completely free of these constraints, because we could not examine how classroom pedagogy might have interacted with Internet connectivity and other factors. Although the complexity of the issues has generated a range of outcomes and variability with the findings of prior studies, relatively consistent patterns emerge overall.

Cross-sectional studies have produced a range of results. Several studies have found negative or non-significant relationships between computer use and educational outcomes (Fairlie & Robinson, 2013; Fuchs & Woessmann, 2004; Hunley et al., 2005; Vigdor, Ladd, & Martinez, 2014). Austin and Totaro (2011) detected that moderate Internet use for high school students was associated with higher grades, but excessive or low use was associated with lower grades. Dettling, Goodman, and Smith (2018) found positive effects of broadband on SAT test scores and on college applications. Using highly aggregated data, KewalRamani et al. (2017) also found associations between school broadband availability and educational outcomes. Several studies outside of the United States have found a positive relationship (Erdogdu & Erdogdu, 2015 for Turkey; Meggiolaro, 2018 for Italy; Wainer et al., 2008 for Brazil). Findings regularly show that the benefits of home computer access are concentrated among students from families with higher incomes and non-minority students (Attewell & Battle, 1999; KewalRamani et al., 2017).

Intervention studies and those with longitudinal survey designs have generally resulted in findings of a positive relationship (Fairlie, 2012; Fairlie & Robinson, 2013; Jackson et al., 2006). A panel study found a large association between home computer and Internet access, higher GPAs, and a higher likelihood of high school graduation. This was possibly because computers made school assignments easier to complete and stimulated interest in schoolwork (Fairlie, Beltran, & Das, 2009). One study did, however, find a negative relationship between computer ownership and student test scores over time (Vigdor & Ladd, 2010; Vigdor et al., 2014). However, the preponderance of the evidence indicates that Internet access is beneficial for students' educational outcomes, including test scores, grades, and graduation rates, especially when complemented by appropriate teaching and learning environments and skills.

Previous studies have also uncovered evidence of the relationships between socioeconomic factors and educational outcomes. Researchers 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, & Phipps, 2015; The College Board, 2013, 2019b). Many of these same demographic factors are also related to whether students have home Internet access. In fact, much of the existing research on digital inequalities focuses almost exclusively on how existing social inequalities, primarily those related to income and race, are likely to predict lack of access (Campos-Castillo, 2015).

It is difficult to find and study contexts in which Internet access is unavailable, which, in turn, complicates isolating differences in student outcomes and performances that are related to Internet access. In many studies, lack of access is synonymous with poverty and racial inequality. Research that randomly selects participants from the general, American population, faces the challenge that 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 Internet access 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 our 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.) than those that are related to differences in home Internet access.

Although the variation in our 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 also used statistical analyses that control for the influence of sociodemographic factors, when appropriate. Specifically, we used 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.[14] 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 those behaviors or outcomes that can be attributed to differences in Internet access and those that are related to differences in other demographic factors.

[14] HLM also addresses an issue in regression analysis that is related to analyzing nested data. In our analysis, we nested data at 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 that have more in common with each other than students selected at random.

4. Main Findings of the Study[15]

4.1 Internet Access from Home

The quality and type of Internet access in our sample varied by location and socioeconomic characteristics. We asked students whether they had Internet access at home and whether it was fast. We asked specifically 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 policy brief, we distinguish 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 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 still may get online at locations outside their home, such as libraries and free Wi-Fi hotspots.[16]

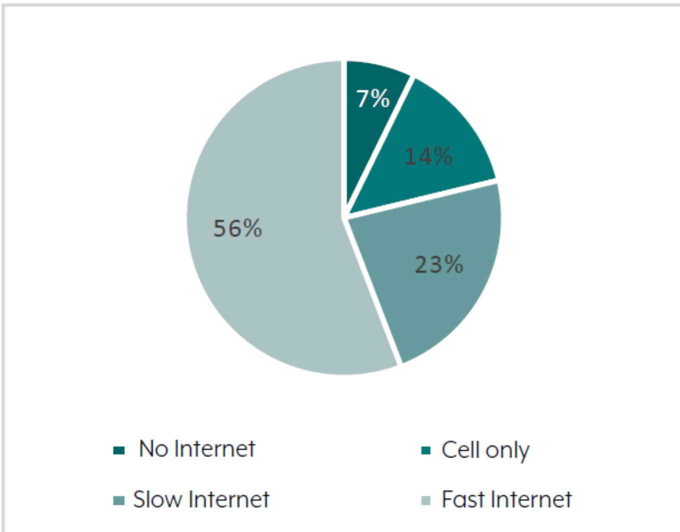

Figure 2: Percent of students by type of Internet access at home (N=3,258). Fifty-six percent of the students in our sample reported having fast broadband access at home, 23% had slow Internet, 14% had cellphone access only, and 7% did not have Internet access. Source: Hampton et al. (2020).

When pre-testing our survey, we found that students could not reliably self-report the speed of their home Internet connection. Those without Internet access generally could not report whether this was related to the cost of a broadband subscription, their parent's lack of interest, or the lack of a broadband service provider in their area. As a result, for those students who did have access, we relied on self-assessments of their Internet experience. Having "fast" Internet access meant that it was of sufficiently high-speed to accomplish their tasks. We validated the

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[15] This section draws heavily on Hampton, K. N., Fernandez, L., Robertson, C., & Bauer, J. M. (2020). Broadband and student performance gaps. Quello Center Report. Available at https://quello.msu.edu/broadbandgap and SSRN: http://dx.doi.org/10.2139/ssrn.3614074.

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

results of our survey with speed test measurement data from an optional homework assignment that provided actual measures of Internet speeds at locations 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. Seven percent reported that they did not have Internet access. These numbers are largely in line with data from the American Community Survey reported above. They provide further evidence that the FCC and Connect Michigan numbers overestimate the broadband availability on the ground because of the simplifying, statistical assumptions used in generating them.

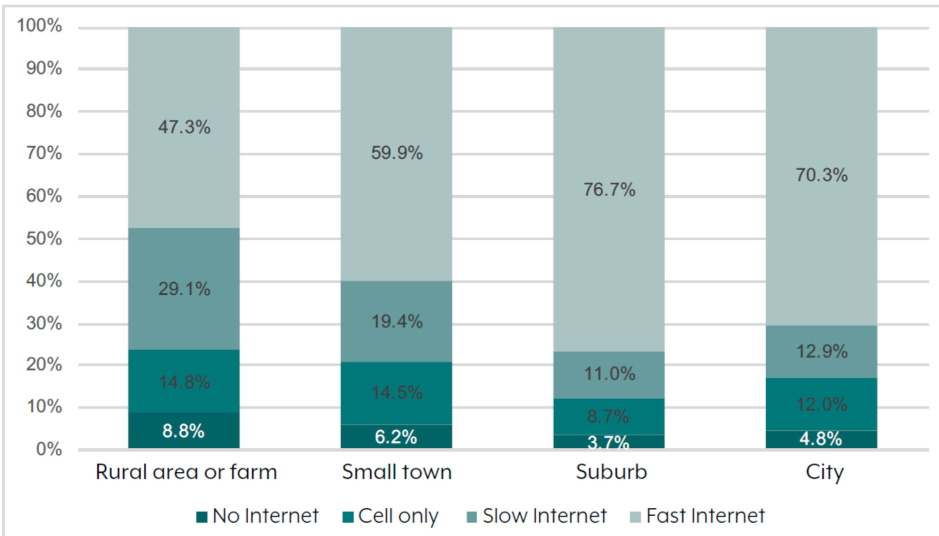

Figure 3. Internet connectivity by location. 47.3% of students living in rural areas and 59.9% of students living in small towns reported fast Internet access. In comparison, 70.3% of students living in cities and 76.7% of students living in suburbs reported fast Internet access. Source: Hampton et al. (2020).

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. Taken together, 53% of students who live in a small town or rural area have 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, whereas 11% of those living in suburbs and 13% of those in cities had slower home access. 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. Eight percent of students in rural and small towns, 4% in suburbs, and 5% in cities have no Internet access at all.

In addition to the role of location, students from families of lower income, those in single-parent households, and those who do not have a parent who 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 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 from home. In our sample, there was no statistically significant difference between students who were or were not racial or ethnic minorities or between students with or without an IEP and the likelihood of having Internet access at home.

4.2 Internet Use and Homework

Students used the Internet for a wide range of education-related activities, including accessing course-related content, doing research, and collaborating. Having Internet access at home allowed students to carry activities over from the classroom to the home. In addition, some online activities, especially those related to seeking help from peers and teachers, were more common when outside of school. However, although some students without home Internet did find alternative places to get online, unsurprisingly, their online activities outside of school were far less diverse than those with a dedicated, home Internet connection (see Table 3). Compared

Table 3: 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	1819

Note: Statistically lower from students with fast home Internet, *p<.05, **p<.01, ***p<.001. Source: Hampton et al. (2020).

to those who relied on a cell phone for access to the Internet, students with faster Internet access at home were better able to complete education-related tasks online. Students with slower home connections also lagged in some activities, mainly those that require higher bandwidth.

Students without home Internet access and those who depend on a cell phones to access the Internet when away from school were less likely to participate in all, online, educational activities outside of school. For example, only 22% of students who were dependent on a cell phone for Internet access created documents online, compared to 47% of those with high-speed home connections. Forty-five percent of those with fast Internet connections at home read books and articles online, but this was true for only 29% of those who relied on a cell phone. Sixteen percent of students who could went online only through their cell phones watched educational videos online compared to 31% of those with fast home connections. Sixty-six percent of students with fast home Internet access submitted homework assignments online while not at school, whereas only 34% of students with cell phone access were able to submit their homework.

Table 4: Students leaving 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: Hampton et al. (2020).

Students with no Internet access at home and those who depended on a cell phone for Internet access when away from school shared similar experiences. When asked if lack of Internet access or a computer affected their ability to complete homework, both groups were more likely to report that they were unable to complete their homework assignments (see Table 4).

The odds that a student said that he/she left homework unfinished because he/she did not have access to a computer or the Internet decreased with better, home Internet access. Sixty-four percent of students with no home Internet access often or sometimes left homework unfinished because they lacked Internet access or a computer. This compared to 49% of those who relied on cell phones, 39% with slow home connections, and 17% of students with high-speed, home Internet access. Only 14% of disconnected students never left homework unfinished compared to 46% of all other students.

Regression analysis was used to control statistically for other factors that are likely to influence the tendency for students to go to class without having completed their homework (see Hampton et al., 2020, Appendix D, Table D1). After controlling for home Internet access, this analysis found no difference between boys and girls, between students who were from racial or ethnic minorities and white students, between those who had an IEP and those who did not, or between those who received free/reduced-cost lunch and those who did not, and the likelihood that a student would report that he/she often came to class without having completed homework.

4.3 Digital Skills

Digital skills are a measure of digital competence and are related to a range of technical and social abilities. Because of the increasingly pervasive role of computers and information technology in our lives, digital skills can be considered as part of human capital. Although digital skills refer to expertise with the Internet, social media, and related technologies, the skills gained in that area 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).

Although it is often argued that today's youth, who are being raised with the Internet and social media, are experts in the use of these technologies, we found considerable variation in students' digital skills. Students can obtain some digital skills through formal education at school; however, many types of digital skills come from online, educational activities done at home, the frequency of using diverse media, and by using 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 a well-known, validated scale that asked students to rate their familiarity with sixteen computer and Internet-related items, from "no understanding" to "full understanding" (Hargittai & Hsieh, 2012).[17] A student with full understanding would achieve a perfect score of 64 on these items, whereas a student with no understanding would score a zero. In our sample, on this measure of digital skill, the average student scored 29.9 (SD=13.1); girls scored 29.1 (SD=10.8) and boys scored 30.7 (SD=15.2) (see Table 5).

Table 5: Average digital skills by grade and sex (range from 0 to 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: Hampton et al. (2020).

Statistical analyses revealed that once we control for variations in Internet access from home, there is no difference between the digital skill levels reported by low income students, minority

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

students, or students from single-parent households (see Hampton et al., 2020, Appendix D, Table D2). However, girls and students with an IEP tended to have fewer digital skills, whereas students with parents who had more years of formal education had more skills.

Regardless of the role of these demographic variables, students who did not have Internet access at home had significantly lower digital skills. Students with no home Internet scored approximately 3 points lower on the digital skills scale, whereas those who had only a cell phone to access the Internet scored 4 points lower than those with fast or slow Internet at home. The magnitude of the relationship between home access and digital skills was larger than the skill gap between girls and boys (2 points) and was comparable to the average difference in digital skills between students in 8th and 11th grade (3 points).

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

4.4 Grades

Students with fast, home Internet connections had higher overall GPAs than students with no home access, slower home access, or cell only access. 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 GPAs between those with home Internet access and those students without access or those who were dependent on cell phone access was roughly equivalent to the difference between a half letter grade in each class, i.e., the difference between a B and a B- average.

On average, students with fast, home access reported an overall GPA of 3.18 (SD=0.86) on a standard 4.0 scale; this was slightly higher than the average 3.10 (SD=0.88) reported by students with slow access. This was significantly higher than the 2.81 GPA (SD=1.01) reported by students with no access and the 2.75 GPA (SD=0.97) for cell-phone-only students (see Table 6).

Table 6: Average GPA for STEM and other subject areas by type of home Internet access

Online activity	Average	Home Internet Access			
		No Home Access	Cell Phone Only at Home	Slow Home Internet	Fast Home Internet
All	3.10 (0.88)	2.81 (1.01)	2.75 (0.97)		3.18 (0.86)
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	1805

Note: Numbers in parentheses are standard deviations. Source: Hampton et al. (2020).

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

The results of a regression analysis to examine students with similar demographic profiles confirmed that girls and students who had parents with more years of formal education tended to receive higher grades overall (including STEM and other classes). Low income, minority, and students with an IEP tended to receive lower grades (see Hampton et al. 2020, Appendix D, Table D3). However, these factors did not fully account for differences in student grades.

Even when demographic factors were controlled for, students who did not have high-speed Internet access from home tended to have lower grades overall and especially in courses related to English/language arts and social studies/history. Students who had no home Internet access, slow Internet access, or cell phone only access to the Internet had significantly lower overall GPAs. Across all subjects, students who relied on a cell phone for Internet access from home tended to receive lower grades than students who had high-speed Internet access from home. Grades were even lower than for students with no access at all.

Having no home access was not related to the math/science GPA, contrary to the expectation that math and science grades would most likely be related to the presence or absence of home Internet access. However, it did negatively affect the overall GPA and grades in English/language arts and in social studies. The magnitude of the deficit in grades experienced by students with no Internet access from home resembled the difference in grades between white students and those who are racial or ethnic minorities.

4.5 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 to benchmark student performance to identify areas in which students excel and those areas in which teachers and schools need to focus. The PSAT 10 is used to monitor student growth and performance and as practice for the SAT. Most colleges and universities use the SAT as part of admissions decisions and to award merit-based scholarships.

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 75^{th} percentile on the SAT scored higher than or equal to 75 percent of SAT test takers. Eight of the school districts that participated in this project provided de-identified, student percentile scores that were matched with student’s responses to the project survey.

Table 7: Average student percentile rank on SAT, PSAT 8/9, and PSAT 10 by type of home Internet access

Nationally representative percentile rank on SAT/PSAT	Average	Home Internet Access			
		No Home Access	Cell Phone 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: Number in parentheses are standard deviations. Source: Hampton et al. (2020).

On average, students who had no Internet access at home and those who relied on a cell phone scored lower on the PSAT/SAT in each of EBRW, math, and total score. However, there are many other factors that can affect a student's standardized test scores (The College Board, 2013, 2019a, 2019b). Statistical procedures used to identify those factors corroborated much of what is known from prior research (see Hampton et al. 2020, Appendix D, Table D4). Students from low-income families, minority students, students from single-parent families, and students with IEPs tended to score lower on the PSAT/SAT. Those students who had parents with a higher education performed better. Girls tended to score higher on the EBRW.

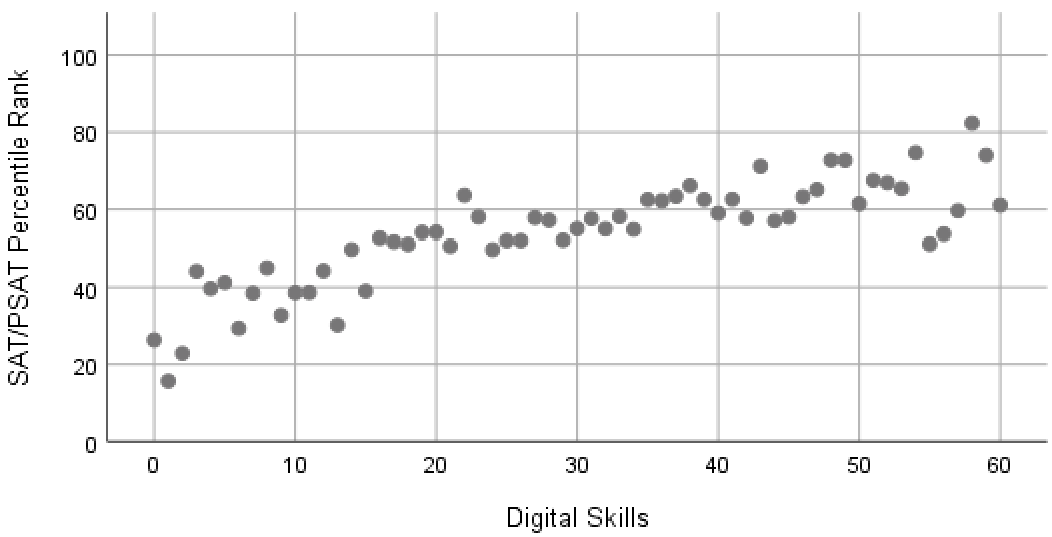

Figure 4: Percentile rank on SAT Suite of Assessments PSAT 8/9, PSAT 10, and SAT, by digital skills. Students with higher digital skills perform significantly higher on pencil-and-paper versions of the PSAT and SAT. Source: Hampton et al. (2020).

Controlling for demographic factors – that is, comparing students who are similar in those conditions that influence standardized test scores –a difference remained between students who had fast Internet access at home and students who had cell phone only access. We found that regardless of other demographic factors, students who had only a cell phone for home Internet access tended to rank 5 percentiles lower nationally 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 PSAT/SAT performance was larger than the deficit in percentile rank experienced by students from low-income families relative to higher-income families. It was also larger than that experienced by racial and ethnic minorities relative to white students, both of which, independently, tended to rank 3-4 percentile lower than their peers.

Although those without Internet access at home did not do worse on standardized tests than those who had fast access, findings pointed 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 was particularly large relative to other factors that predicted student performance on the PSAT/SAT.

A student who scored even modestly lower in digital skills (13 points or 1 standard deviation lower than average) tended to rank nationally nearly 7 percentiles lower on his/her total PSAT/SAT score, 5 percentiles lower in math, and 8 percentiles lower in evidence-based reading and writing. This compared to the 3-4 percentile difference in PSAT/SAT 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 did not receive a free or reduced-cost lunch. Digital skills accounted for 8.7% of the variance explained in total PSAT/SAT percentile rank within districts.

4.6 Post-secondary Education Aspirations

Students who did not have high-speed Internet access at home and those with fewer digital skills were less likely to have an interest in attending college or university. Previous research has shown that students who delay starting post-secondary education for as little as even one year are at a considerable risk of not completing a post-secondary credential in comparison to peers who enroll immediately after high school graduation (Bozick & DeLuca, 2005; Roksa & Velez, 2012). To assess post-secondary goals, students were asked what they planned to do in the first year immediately after high school and their long-term, educational ambitions. Overall, 58% of students said that they intended to attend college or university immediately after high school.

There was no difference in intent to enroll in a post-secondary program in the year after high school based on the type of home Internet access. Gender, parental education, and income explained differences in their plans to attend college or university between students with and without home access (see Hampton et al., 2020, Appendix D, Table D5). However, these demographic factors did not account for a relationship between digital skills and the intent for post-secondary education in the year after high school. Students lacking in digital skills were substantially less likely to report that they intended to go on to higher education immediately after high school. A student who was moderately lower in digital skills (13 points below average, or one standard deviation) was 26% less likely to plan to attend college or university the year after high school.

Digital skills and socioeconomic factors were better predictors than type of home Internet access in determining whether a student planned to attend college or university in the year after high school. Still, students with slower, cell phone only, or no access to the Internet from home were more likely to say that they had no plan to complete a post-secondary credential at any time. Forty percent of students said that they did not plan ever to complete accreditation at a college or university. Fifty-three percent of students who had no home Internet access or had cell phone only access to the Internet did not plan to complete a post-secondary program. This compared with 40% of those with slower home Internet access and 35% of those with fast home Internet.

Boys, students with an IEP, and those from low-income families were less likely to say that they planned to complete a post-secondary education (see Hampton et al., 2020, 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 existed regardless of socioeconomic status. Students who had slow, cell phone only, or no home Internet were less likely to say that they would 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 were also less likely to say they had a plan to ever 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 were 21% less likely to say they ever planned to complete college/university. Students using a cell phone as their only means of accessing the Internet from home were 34% less likely to plan to complete college or university. Those with no home access were 29% less likely to intend to finish a post-secondary education. In addition to deficits in access, having digital skills that were even one standard deviation below average (13 points on our scale of digital skills, mean=30) were associated with a student being 29% less likely to say he/she never planned to complete a college or university program.

4.7 Career Aspirations

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

Most analyses of job market developments attest to a shortage of individuals 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.[18] The demand for STEM professionals, particularly those in healthcare and information technology, is growing and outpacing the supply of STEM college graduates.[19] More jobs are available in STEM fields

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[18] See https://www.bls.gov/opub/mlr/2015/article/stem-crisis-or-stem-surplus-yes-and-yes.htm.
[19] See https://www.burning-glass.com/wp-content/uploads/Real-Time-Insight-Into-The-Market-For-Entry-Level-STEM-Jobs.pdf.

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.[20] 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 into creative, problem-solving skills.

Students were presented with a list of twenty-six different careers and asked to select those that best described what they wanted to be.[21] 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, engineer, 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, musician, or another type of artist. Non-STEAM careers included professions, such as a police officer, mechanic, counselor, plumber, and retail or restaurant worker.

Table 8: % of Students Choosing STEM, STEAM, non-STEM, and non-STEAM careers by digital skill

Career	Overall	Digital Skills			
		Bellow 25th pctl	25th-49th pctl	50th-75th pctl	Above 75th pctl
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	1805

Note: Categories of STEM/Non-STEM and STEAM/Non-STEAM may not sum to 100%. Some students selected more than one possible career. Source: Hampton, et al. (2020).

Overall, 45.5% of students expressed interest in a STEM-related profession, and 54.2% 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 (see Table 8).

[20] Based on estimates provides by Burning Glass Technologies, a company that provides job market analytics. See https://www.burning-glass.com/research-project/stem/.

[21] The full list of occupations consisted of (with an asterisk (*) indicating STEM and a (+) STEAM) : *+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; Child-care worker (e.g., day care teacher, 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.

Demographic differences between students who were interested in STEM or STEAM careers and factors, such as student's gender and parent's education were betters predictors of a STEM and STEAM career choice than home Internet access (see Hampton et al., 2020, Appendix D, Table D6). However, although Internet access at home was not related to a difference in career interests, digital skills were related to a STEM/STEAM career choice. Students without home Internet access tended to have a significant deficit in digital skills relative to their peers. Compared to students in the top 50th percentile for digital skill, students who ranked in the bottom 25th percentile for digital skills were 17% more likely to pick a career that was not in a STEM field, and 16% were more likely not to want a STEAM-related career.

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

4.8 Paths between Broadband Access and Educational Outcomes

Our analysis thus far established an association between types of broadband access and educational outcomes, controlling for factors, such as socioeconomic status and school district. We were also interested in whether broadband access affected educational outcomes directly, indirectly via other factors, such as homework completion and the development of digital skills, or perhaps both directly and indirectly. To this end, a second set of analyses was conducted using path analysis, a statistical technique that allows the exploration of the direct and indirect ways in which independent variables affect outcomes. Although this is work in progress, it is possible to share a few initial findings here.

The rich research on digital inequalities has found evidence that Internet access typically affects outcomes directly and indirectly (e.g., van Dijk, 2020). Recent empirical studies in the United States corroborate some of these findings. For example, a detailed study by Gallardo, Whitacre, Kumar, and Upendram (2020) found that broadband availability was only weakly related to job productivity. Rather, job productivity was associated with broader measures of digital inclusion or digital distress, which are more closely related to job productivity than measures of speed and availability. Similarly, research found that higher-level, digital skills are critical to utilize the capabilities of digital connectivity more fully (e.g., van Laar et al., 2017).

Our own analysis shows that many associations between broadband and educational outcomes (GPA, PSAT/SAT, educational ambitions) are indirect. For example, fast broadband access is associated with higher rates of homework completion, which in turn is associated with higher grades (explaining about one-third of the variation in GPAs). Better home Internet access is also associated with higher digital skills, which, in turn, are associated with better performance on standardized tests such as the SAT. In our data, the only direct effect between the type of connectivity and educational outcomes is the negative association between having cellphone access only and student performance. Students who must rely on a cellphone only with no complementary device such as a tablet or notebook connected to a cellphone hotspot, perform weaker on all educational outcomes.

These insights show that it is important to understand broadband as part of a broader ecosystem of teaching and learning that includes other media uses and activities. It also emphasizes that the provision of better broadband access and devices can help overcome some of the disadvantages experienced by students who are fully reliant on cellphones. However, it also suggests that providing broadband access alone will be less effective than an approach that also takes these other factors into consideration.

5. Implications for Policy and Other Decision Makers

The evidence presented in this report has highlighted individual, community, and societal repercussions of poor broadband connectivity at home. Our data show that other socioeconomic factors, such as income and parental education, also affect outcomes. Broadband connectivity interacts with these factors and sometimes influences outcomes separately. Better connectivity is directly and indirectly associated with advantages for school performance and broader outcomes, for example, 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 for individuals, communities, and society. They leave individuals, communities, and society worse off than they would be under conditions of better connectivity.

These findings suggest the need for a multi-pronged strategy that addresses both the gaps in connectivity and the socioeconomic environment of the students. The Coronavirus pandemic has lent a new urgency to the development of educational models that use digital learning in ways that increase the resilience of the system overall. Overcoming inequalities in broadband access, device availability, and skills are important preconditions for all these initiatives. Our work also points to the need to address complementary factors, such as adapting pedagogical approaches and curricula, teacher and learner skills, as well as working with parents and caretakers to develop the support skills needed to take full advantage of digital learning. The recommendations in this section for decision makers will focus on measures to overcome inequalities in broadband access.

Broadband investment in the United States is influenced by federal, state, and local policies. Schools and libraries have benefited from the federal E-Rate program, designed to improve connectivity to anchor institutions. However, they have only limited resources and authority to assure that students have appropriate broadband connectivity at home. CARES Act funding and philanthropy have bought a short reprieve and enabled more schools to provide tablets, notebooks, and hotspots to students in the short run and. However, sustainable solutions will need to be developed. An integrated approach would ideally leverage federal, state, and local programs in a synergistic way. Such an approach would require a shared vision of the problem and its solutions. Given the absence of such an overarching approach, several initiatives involving government, business, and civil society actors will have to work in parallel.

5.1 Market Deficiencies and a Proliferation of Policy Initiatives

The current broadband inequalities are an outcome of both market deficiencies and policy failure. First generation broadband could be configured with incremental, additional investment using existing telephone and cable TV networks. Facing increased competition from satellite TV, starting in the late 1990s, cable companies introduced broadband Internet access to build a new revenue stream. Unlike telephone companies, whose networks provided the infrastructure for dial-up, Internet access, cable companies were not treated as common carriers in U.S. communications law. Rather than reclassify cable broadband as a common carrier, the FCC decided to reclassify all other service platforms (DSL, mobile, powerline) as information service providers, subject to only light-handed regulation and few public interest obligations (e.g., Bauer, 2006). Except for a brief period between 2015 and 2018, when Internet Service Providers were reclassified as common carriers to safeguard network neutrality, broadband evolved largely driven by private investment and market forces, with a smaller fringe of municipal and cooperative broadband.

Free of common carrier obligations, commercial broadband providers deploy networks to areas and customer groups that generate sufficient revenue streams to cover investment costs. Consequently, large service providers that are present across multiple areas will serve sparsely populated areas that are expensive to serve. They serve low-income areas that have low revenue potential very late in the investment cycle or not at all. Even if they are served late, the affected individuals and communities likely experience considerable disadvantages during the wait periods with broad, economic, and social repercussions. Cost-reducing innovations in networking technologies, such as fixed and mobile wireless or satellite Internet connectivity have expanded the boundaries of the areas that are served by market forces. Entrepreneurial initiatives and municipal projects have also contributed to connecting more individuals and households to broadband. Despite these accomplishments, large areas remain where the market model is deficient, leaving large areas and parts of the population without broadband Internet access.

Instruments that would overcome these market deficiencies are well understood, but the consensus needed to deploy them in a concerted way has been difficult to achieve during the past decade. A well-designed, comprehensive, universal, broadband service program, possibly with federal and state components, would go a long way. Components of such a program are in place at the federal level as programs within the Universal Service Fund (USF) and have been modified to support broadband. The USF historically supported universal telephone service. Key USF programs provide support for anchor institutions, such as schools and libraries (E-Rate program), rural health care providers, and low-income households (Lifeline program).[22] However, the reforms of these programs have not gone far enough and therefore have had a lower than needed impact on broadband access. For example, the Lifeline program, intended for low-income households, currently provides only $9.95 per month as a subsidy, which is likely insufficient to help low-income households to obtain broadband. The E-Rate program has helped bring connectivity to many anchor institutions but continues to be criticized as highly bureaucratic. Moreover, the program imposes many constraints on recipients and does not offer the ability to extend service to individual households, as recommended by the General Accounting Office in a Report to Congress (GAO, 2019).

Already in 2010, at the direction of the American Recovery and Reinvestment Act (ARRA) of 2009, the FCC created a National Broadband Plan, titled Connecting America.[23] When aspects

[22] These programs are administered by the Universal Service Administrative Co., see https://www.usac.org/.
[23] Available at https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf, visited September 12, 2020.

of this plan were implemented, the high-cost program within the Universal Service Fund was renamed Connect America Fund (CAF). In January 2020, during Phase I, the FCC adopted a $20.4 billion Rural Digital Opportunity Fund (RDOF) to bring connectivity with 25/3 mbps broadband to six million homes and small businesses in census blocks that were not entirely served. (Phase I was to use up to $16 billion with $4.4 billion reserved for a smaller Phase II designed to bring service to partially served locations and those not served during Phase I.) The plan uses reverse auctions, in which bids will go to the entity bidding the lowest price to serve an area. Although the auction, scheduled to start in October 2020, is an important step toward closing the broadband gap, it fails to fully close the existing broadband gap.

One problem is that it focuses on rural areas and does not provide relief to urban areas with poor connectivity and poor affordability (Siefer & Callahan, 2020). A second problem is that it uses hypothetical cost modeling data rather than actual connectivity information to identify areas that qualify for support. Although the program allows network operators to contest the inclusion of an area in the auction, it does not allow other stakeholders to request that an area be added. This design flaw risks creating a bias in favor of existing network operators. The State of Michigan initiated the Connecting Michigan Communities (CMIS) grant program in 2019, which has similar provisions. The model is perpetuated in Michigan House Bill No, 4288, the Michigan Broadband Expansion Act, introduced in February 2019 by Representative Michele Hoitenga (R) and currently pending. Like CMIS, it would allow the exclusion of areas that have 10 mbps wireless service and introduces a veto opportunity for incumbent network operators.[24]

In response to the Coronavirus pandemic, Congress passed the Coronavirus Aid, Relief, and Economic Security Act (CARES) (P.L. 116-36). The $2.2 trillion stimulus package included several appropriations to improve broadband connectivity and distance education. The Rural Utilities Service (RUS) in the U.S. Department of Agriculture (USDA) received an additional $100 million for the ReConnect Loan and Grant Program and $25 million for its Distance Learning, Telemedicine, and Broadband Program (DLT). Allocations were also made for programs to the U.S. Department of Education ($30.7 million to establish an Education Stabilization Fund) and $50 million to the Institute of Museum and Library Services in support of distance learning. In addition, several bills are pending, including the Digital Equity Act of 2019 (S.1167)[25] that would appropriate additional support for broadband and digital inclusion. In August 2020, Michigan Governor, Gretchen Whitmer, announced that $65 million of CARES funding would go to educational institutions, including disadvantaged school districts, to help mitigate Coronavirus impacts.[26]

Private sector businesses quickly responded to the Coronavirus by adopting measures that facilitated broadband access in the very short term. Many of the measures were subsequently extended through the end of the year and possibly longer. These initiatives have helped reduce the cost of broadband, alleviated device shortages and data usage limitations, and facilitated

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[24] See Michigan Department of Technology, Management and Budget, Connecting Michigan Communities (CMIC) Grant Program, visited on September 14, 2020 at https://www.michigan.gov/dtmb/0,5552,7-358-82547_56345_91154---,00.html.
[25] See https://www.congress.gov/bill/116th-congress/senate-bill/1167.
[26] See https://www.clickondetroit.com/news/michigan/2020/08/19/michigan-announces-65m-in-cares-act-funding-for-schools-amid-coronavirus-pandemic/.

the expansion of broadband to customers who can be connected easily. Among the initiatives are the commitment by nearly 200 service providers not to disconnect any residential or small business customers because of their inability to pay bills; to waive any late fees; and to keep Wi-Fi hotspots open.[27] Mobile network operators have increased data caps for existing customers. Several major fixed network operators, such as Comcast, have volunteered to make their low-cost offerings available to additional low-income customers. An growing number of providers have signed single-payer agreements with schools and other organizations, which allow the extension of access and service to low-income individuals and households (Davis, 2020).

In addition to these government and network operator initiatives, the Coronavirus pandemic and the available funding opportunities have contributed to numerous, entrepreneurial, and community-driven projects to expand connectivity. Some of these initiatives build "gap networks", such as Wi-Fi in school buses or community Wi-Fi 6[28] access points, that allow to buy time until longer-term solutions can be put in place. Previous studies found that partial understanding of the potential benefits of broadband, income constraints, and poor information about available programs compounded barriers to adoption. Non-profit groups, such as the National Digital Inclusion Alliance (NDIA), Common Sense, the National Christina Foundation, PCs for People and many others have intensified their activities. Local organizations, such as Chicago Connected, The Enterprise Center in Chattanooga, TN, Tech Goes Home (Boston, MA), and PHLConnectED (City of Philadelphia, PA) have expanded existing programs to increase access and digital literacy. Often boosted by CARES funding, these non-profit groups have started new projects to address the homework gap and digital inequalities. Digital Navigators, a program initiative by NDIA (Roach, 2020), assist unconnected individuals in an increasing number of communities to find the best plan and program for their needs.

5.2 Sustained Measures to Improve Broadband Access

These measures have provided much-needed, short-term relief, but CARES funding is not recurring, and many business initiatives will be time-limited. Overcoming the existing digital inequalities and their repercussions for learning outcomes will therefore require sustained measures to close the gaps in access to broadband connectivity and devices. Because broadband has many benefits beyond support for learning, solutions that consider the broader community effects are preferable. The FCC currently defines broadband as a connection supporting 25 mbps download speed and 3 mbps upload speed. As digital technology advances, new forms of learning, such as immersion into virtual worlds, will arise that may need higher bandwidth support. Any long-term connectivity policies therefore will have to include provisions for the continuous revision of the programs to avoid new digital inequalities.

Long-term connectivity planning will also require sustained complementary efforts to address gaps in digital skills and the knowledge of parents on how to best use digital technology to

[27] See FCC Keep America Connected Pledge, https://www.fcc.gov/document/more-providers-take-chairman-pais-keep-americans-connected-pledge, last visited September 22, 2020.

[28] Wi-Fi 6 is a next generation of Wi-Fi technology. It offers several feature upgrades, including higher throughput, which allows connecting a larger number of devices without noticeable reductions in download speeds.

support learning. Many of these challenges interact with sociodemographic factors and other types of inequality. Furthermore, schools may need to review and overhaul their use of instructional technology. Technological advances during the past decades have reduced some of the costs of connectivity, and this development is expected to continue. New, low-orbiting satellites, terrestrial 5G wireless in some locations, fixed wireless, and new, wide area Wi-Fi will all contribute to the mitigation of present, broadband access divides. However, it is likely that more will be needed, and these measures require coordination among local, state, and federal government agencies and with stakeholders in the private and non-profit sectors.

- At the federal level, it would be desirable to update broadband, universal service initiatives, such as the E-Rate program and the Lifeline program. New funding programs will be needed in addition to the Rural Digital Opportunity Fund, as many urban and even rural areas with poor service do not qualify under the current RDOF program.
- Michigan would benefit from better coordination of broadband policy at the state level and from state-level funding programs. Empirical research shows that state universal service programs increase adoption by two percentage points (Whitacre & Gallardo, 2020). Already in 2016, key elements of a state-wide plan had been developed in Michigan but were never implemented (21st Century Infrastructure Commission, 2016).
- The most flexible and scalable, but currently also the most expensive, broadband technology is fiber optical networking. Because civil engineering costs constitute up to 75% of the total costs, the careful planning and coordination of infrastructure projects and the orchestration of policies to grant access to rights of way could save a significant share of deployment costs. “Dig Once” models deploy conduits and ducts in parallel to road or other infrastructure projects and greatly reduce the cost of fiber rollout. In contrast, in the “Dig Smart” approach, municipalities invest in the conduit to be leased to ISPs (FTTH Council, n.d.).
- The broader range of connectivity options opened by technological advances allows each community to develop a least-cost, connectivity plan by putting together the most efficient combination of networking technologies. This is often a hybrid solution, using a mix of fixed and wireless technology.
- In some locations, investment in a public access, broadband network or in a public-private partnership may be a viable option. Several successful models have demonstrated the effectiveness of this approach (see the examples in Merit Network, n.d.; Sallet, 2019), although not all experiments did well.
- Existing local, state, and federal laws need to be reviewed to remove obstacles to entrepreneurship, public-private partnerships, and public solutions. Section 484.2252 of the Michigan Telecommunications Act of 1991 as amended, which imposes limitations on the ability of public entities to offer telecommunication services, should be reviewed. At the same time, it will be important to create conditions that do not provide artificial advantages for public entities, such as tax breaks. In addition, service providers need to review operating procedures for provisions that are barriers to connectivity.
- Because access inequalities interact with income inequalities, complementary measures to increase affordability, such subsidies to individuals, will be needed. Much will depend on the

business model and technology deployment and the resulting price points. Stimulating retail and wholesale competition will also help to reduce prices per unit of information.

- Several initiatives have sought to work with communities to develop a deeper appreciation of the importance of broadband and digital connectivity. Schools and other community institutions will need to develop programs to work with parents, grandparents, and other caregivers to broaden digital literacy and skills among these populations.

5.3 Strategies to Increase the Resilience of K-12 Education

The COVID-19 pandemic and the challenges of shaping appropriate responses to it have brought the vulnerabilities of the K-12 education system into sharp focus. Resilience is the capacity of a system to recover quickly from difficulties and unexpected events and the ability of a system to deliver despite continuing, adverse events. Organizations, technologies, and social systems can be designed with resilience in mind. Thus far, resilient approaches to education have been implemented in crisis regions, mostly in low-income countries, but they offer lessons for high-income countries also. Forward-looking education policy will be well advised to consider resilient design. Measures to be considered include:

- Structuring and preparing the K-12 educational system so that it can deliver education effectively online and in other (technology-mediated) modes, should one mode of education become disrupted.
- In addition to addressing the existing digital inequalities, such a model will require systematic teacher, parent, and caretaker training as well as adaptations to the curriculum and pedagogy.
- Increasing the level of resilience will also require the inclusion of material about potential sources of risks, the effects of unanticipated developments, systems thinking, and possible responses in the curriculum.
- Finally, increasing the ability to mobilize spare resources quickly will be critical. These include emergency funding facilities and individuals who are trained to assist in providing educational support in emergency situations.

6. Conclusion

This report provides detailed evidence of the importance of high-speed Internet connectivity for educational and life outcomes. Although the negative effect of lacking broadband connectivity for homework completion has been recognized for some time, our study uses much more granular data and more comprehensive outcome measures than earlier work. They reveal that poor Internet connectivity affects the ability to complete homework assignments and has further-reaching repercussions. In some cases, students may experience disadvantages that may affect their life course. 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 also contributes to these students being less interested in higher-paying STEM careers. We also found that students who have only cellphone broadband access and no complementary devices, such as a tablet or notebook computer, are as disadvantaged as students with no access at home (and sometimes are even more disadvantaged).

The findings are an urgent call to address the situation. A plethora of programs exists at the federal level, not least in response to the Coronavirus pandemic. It would be desirable to develop a coordinated approach at the state level to complement and facilitate community-level efforts. 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. Because our data is de-identified, we do not have information on the specific households that do not have Internet access. Therefore, we cannot distinguish whether they do not have service because no service is available, because is it too expensive relative to the resources of the family, or whether decision makers do not fully appreciate the benefits from subscribing to broadband. At the aggregate level, our data show that it is most likely that all three factors are in play.

Each barrier requires different responses that range from measures to extend broadband service to measures 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.

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