Broadband and Student Performance Gaps After the COVID-19 Pandemic

Internet Connectivity, Educational Outcomes, and the Well-Being of Michigan's Rural Students

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About the Quello Center

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

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Summary of Findings

The COVID-19 pandemic rapidly changed how Americans viewed the importance of broadband Internet connectivity. In a short period of time, a national emergency shifted how and where people accessed work and education, how they interacted with friends and family, and how they spent their time. An inadequate infrastructure for broadband access left rural Americans and particularly rural youth at higher risk. This study was designed to assess the impact of the COVID-19 pandemic on home Internet connectivity, student achievement, and adolescent well-being. The focus is on middle and high school students enrolled in rural and small-town schools.

This report builds on the findings of a study on *Broadband and Student Performance Gaps* released in the weeks before the start of the COVID-19 pandemic (Hampton et al., 2020). That report highlighted the low levels of broadband access by rural Michigan students and the detrimental impact from a lack of access on their academic performance, educational aspirations, career choices, and general well-being. In 2022, we returned to the same schools that we first surveyed in 2019. We asked students about their experience with Internet technologies and with learning from home during the pandemic.

Our findings paint a picture of how rural school districts and other stakeholders rapidly mobilized to address a national crisis. In a remarkably short period of time, schools accessed state and federal resources to close gaps in rural Internet access and computing devices.

At the height of the COVID-19 pandemic, during the 2020-21 school year, the vast majority of rural Michigan students spent considerable time learning from home like many students across the country. Our findings show that students with better home Internet access experienced fewer problems learning from home. We found evidence that learning from home boosted students' competencies with digital technologies. It also helped insulate some students from a broad pandemic decline in career interests related to science, technology, math, and engineering (STEM). During the COVID-19 pandemic, learning from home did not, however, protect students from a large drop in intention to pursue post-secondary education at a college or university. Although students reported exceptionally high feelings of isolation during the pandemic, these feelings have rapidly diminished. We found no substantive difference in young people's self-esteem in comparison to before the pandemic. Young people are now spending more time in person with their friends than they did in the years before the pandemic. As youth leisure activities shifted, we also found that those young people, who spend more time using a variety of media, especially social media, are spending the most time with friends.

There are early indications that rural communities are at risk of losing the gains in Internet connectivity rapidly achieved over the COVID-19 pandemic. There is a needed shift from a focus on filling the gaps in the infrastructure for home Internet access to ensuring that households are able to maintain access over time. Rates of student home Internet connectivity have already started to decline. We sound an early warning that gains made during the COVID-19 pandemic to address rural, digital inequality are beginning to fade.

Broadband access has increased, and there has been a sharp drop in households without Internet, yet one in three rural students still has inadequate Internet access at home.

The COVID-19 pandemic increased awareness of the importance of home Internet connectivity. Over the course of the pandemic, the number of rural Michigan students who did not have home Internet access declined by 65%, whereas the number with broadband access increased by 20%.

In 2022, 93.2% of students in the schools we surveyed had some form of home Internet access. Of those students, 67.6% describe their Internet access as "fast" or equivalent to broadband speeds. This is an increase from 2019 when only 80.3% of students had some form of home Internet access, and 56.5% had broadband. In 2022, only 2.6% of rural students could not access the Internet at all when at home, whereas an additional 4.2% could do so only on their mobile phones. More than one-quarter of students (25.7%) continue to rely on home Internet access that is below broadband speeds.

Despite the progress achieved during the COVID-19 pandemic, nearly one in three rural students still lack adequate, fast, broadband home Internet (32.5%). Students who have no access, those who are dependent on a mobile phone to go online, and those with slower home connections struggle to complete homework and stay connected. They are more likely to experience deficits in academic performance and well-being (Hampton et al., 2020; Hampton & Shin, 2022).

Schools closed the gap in home Internet access during the pandemic, but student access is on the decline post-pandemic.

The number of students who have Internet access from home is lower than it was at the height of the pandemic. In the 2020-21 school year, 95.6% of students reported that they had Internet access at home compared to 93.3% of students in 2022.

Improvements in rates of student home Internet access were driven largely by the efforts of school districts. During the pandemic, schools provided students without home Internet access with Wi-Fi hotspots. Hotspots are internet access points that students take home to connect to a wireless, cellular, Internet network. Federal and state pandemic relief funding, temporary relaxation of federal regulations, equipment donations, and temporary changes to pricing plans by network operators facilitated these measures.

In the 2020-21 school year, schools provided 17.7% of rural students with Wi-Fi hotspots. In the following school year (2021-22), the proportion of students who were receiving a Wi-Fi hotspot through their school declined to 12.3%. Absent school-provided hotspots, the proportion of rural students with home Internet access in 2022 would have been 83.1%, only marginally higher than the 80.3% of students who had home Internet access before the COVID-19 pandemic.

School-provided hotspots may drive home Internet adoption, but some households are struggling with technology maintenance.

Providing hotspots to students helped drive parents/guardians to adopt home Internet. Less than half of students who received a hotspot in 2020-21 needed a school provided hotspot the following year. Many students who initially received a hotspot (43.9%) lived in households that subsequently replaced the hotspot with another source of home Internet access.

Only 12% of students who were provided a hotspot in the 2020-21 school year but were without home Internet in 2022 lost access because their school no longer provided them with a hotspot. The majority of students who lost home Internet access did so because their household once had Internet access (not a school-provided hotspot), but they could not afford it by the following year, or their parents/guardians lost access for another reason.

The problems associated with household-maintained access will increasingly represent the largest source of student disconnection. Parents and guardians may be unable to pay for access consistently, computing devices can break, and some students, especially those who live with parents/guardians in multiple households can experience access insecurities. Schools often lack resources and systems to identify students who have such access insecurity and are unable to intervene in a short period of time to provide a student with one of a declining number of school-provided hotspots.

Ownership of computing devices skyrocketed during the COVID-19 pandemic.

Not having access to a computer at home greatly impacts the ability of students to complete homework and develop digital skills outside of school. Access to computing devices sharply increased during the pandemic.

Initiatives by school districts to distribute laptops and Chromebooks to students increased during the COVID-19 pandemic. A combination of state and federal pandemic relief funding, collaboration with device manufacturers, and, in some cases, equipment donations, made these programs possible.

In the 2020-21 school year, 55.7% of all students received a laptop/ Chromebook from their school. However, by the 2021-22 school year, this number had declined to 40.3% of students. Yet, despite a reduction in the number of computers sent home by schools, access to either a laptop or a desktop computer at home continued to increase.

In 2019, 75.6% of rural students had access to either a laptop/ Chromebook or a desktop computer. In the 2020-21 school year this had increased to 89.1% of students and, by the end of the 2021-22 school year, 91.2% of students had access to one of these devices.

During the COVID-19 pandemic, Broadband access meant fewer problems with technology when learning from home.

Because of the COVID-19 pandemic, all schools in the State of Michigan closed on March 12, 2020 for the remainder of the academic year and did not reopen until the start of the following school year. During the 2020-21 school year students experienced a mix of learning modalities. Some students attended a full year of school in-person, but most did learning online from home occasionally
or often.

Of rural students in the 2020-21 school year, 73.5% did online learning from home at least occasionally. As a result of the lingering effects of the pandemic, 10.8% of students continued to do online learning from home at least occasionally in the 2021-22 school year.

In the 2020-21 school year, when most students did some school from home, nearly one-third (32.7%) reported that they occasionally or often had "problems at home with technology that made it hard to complete schoolwork." Of those students who had these problems, most did not have fast broadband Internet at home (51.5%). The odds were 200% higher that students who did not have broadband at home would experience problems with technology that made it hard to complete school work.

Learning from home boosted students' digital skills.

Digital skills are a measure of digital competence. Students who spent more time learning from home in the 2020-21 school year tended to report higher digital skills the following year.

Compared to their peers who spent more time in school at the height of the pandemic (2020-21), students who spent more time learning from home reported high digital skills the following year. Compared to a student who rarely did learning from home, a student who often did school at home scored on average 10.7% higher in Internet skills and 8.4% higher in social media skills, and their digital skills were 9.1% higher overall. This difference is roughly equivalent to the difference in digital skills found between a student in the 9th and one in the 11th grade.

Interest in attending college or university dramatically declined but remains higher for students with more digital skills.

There has been a dramatic decline in student interest in pursuing higher education. The proportion of students who have no educational aspirations beyond high school increased from 38% in 2019 to 48% in 2022. The number of students who intend to complete a university degree dropped from 53.5% to 45.9%.

Students who spent more time doing schoolwork from home during the pandemic were no more or less likely to say that they intended to continue with their education. The decline in educational aspirations was consistent across gender, race, grade, digital skills, and the type of Internet connection students had at home. However, students with more digital skills were more likely to say they will obtain at least an undergraduate degree. A student who has even modestly more Internet and social media skills than average (one standard deviation [s.d.] higher) is 36% more likely to intend to complete a university degree. Boys are less likely than girls to want to continue with their education beyond high school, which is consistent with prior trends. Girls are 141% more likely than boys to intend to complete a university degree.

Various factors likely contributed to the decline in educational aspirations. This includes the pull of a tight labor market and narratives around the cost of college and student debt. The overall trend is concerning, given the strong, positive relationship between higher education, individual income, and local economic growth.

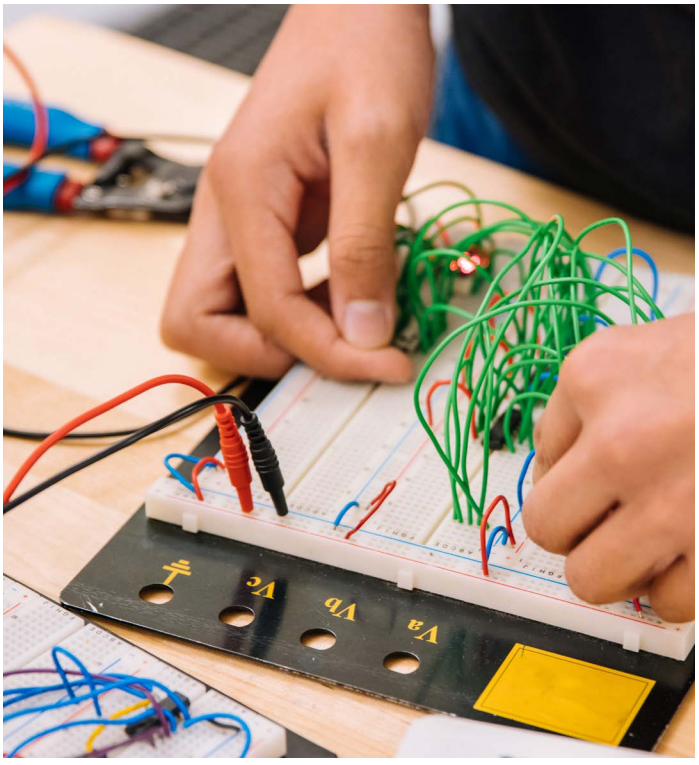
Fewer students expressed an interest in a STEM-related career, but the decline was lower for students who did more learning from home and those with more digital skills.

There has been a dramatic decline in the number of students who are interested in a career related to science, technology, engineering, or math (STEM). In 2019, nearly half (46.3%) of students expressed an interest in a STEM-related career; by 2022 that number had declined to 35.9%.

The decline in STEM interest was found across genders and grade levels, although it was more pronounced among students in earlier grades. However, students who spent more time learning online from home during the COVID-19 pandemic were more likely to have an interest in a STEM career. Compared to a student who rarely did school from home during the pandemic, a student who often did schoolwork from home was 37% more likely to be interested in STEM. Similarly, a student who had even modestly more digital skills (one s.d. above average) was 38% more likely to be interested in a STEM career.

The decline in STEM interest is especially concerning given declining job opportunities in many rural areas, the growth of jobs in STEM fields, the higher income associated with STEM careers, and the potential benefit of STEM-related industry for the economic development in rural areas. This decline is consistent with evidence of a downward trend in STEM enrollment during the COVID-19 pandemic (Greenfield, 2021), and may be related to lower levels of STEM support provided by schools during the pandemic, including missed career counseling or lost STEM-related curricula or experiences. However, the decline in STEM is likely deeper than what is apparent through student career interest alone.

Students increasingly expect to have a career in fields such as engineering and computer science without obtaining a post-secondary degree. Only 62% of students who want a career in engineering or architecture said that they were planning on at least some college or university (a decline from 72% in 2019). Similarly, only 49% of those who said they want to be a computer scientist plan to attend any college or university (down from 63% in 2019). The decline in intent to pursue college-level accreditation was not limited to STEM fields but extended to many careers that generally require a university degree, including social worker, journalist, and advertising professional.



Learning from home did not affect classroom grades, but girls may now be struggling more in the classroom than boys.

Students who spent more time learning from home during the pandemic did not experience lower classroom grades after their return to the classroom. However, the gap between girls and boys in the classroom grades has diminished.

Students who spent more time learning from home during the COVID-19 pandemic (in the 2020-21 school year) tended to have average classroom grades in 2022 that were no higher or lower than their peers who spent more time learning in school. Unlike reports of declines in standardized test scores (Kuhfeld et al., 2022), average classroom grades have remained relatively constant. On a standard 4.0 scale, the average across students in 2022 was almost identical to student averages in 2019: a 3.1 overall, a 3.2 in English/social studies, and a 3.1 in math/science, or a little more than a B average.

Girls tend to receive higher classroom grades than boys. This is something that we observed in 2019 and has been observed elsewhere (Voyer & Voyer, 2014). In 2022, girls tended to score .19 higher than boys in their overall GPA (on a 4.0 scale), .15 higher in math/science, and .24 higher in English/social studies. Although the overall average student grade has not changed, we found that the gap between boys' and girls' grades has shrunk in comparison to before the pandemic. Compared to students from the 2018-19 school year, the gap between boys' and girls' grades has decreased by .11 in English/social studies and by .12 in math/science: an overall decrease of .11. This trend is the result of a small increase in average grades for boys and a small decline in average grades for girls.

The lack of variability in classroom grades over time is likely due to teachers and schools who have made necessary adjustments to their curricula to accommodate individual and grade-level loss in learning due to the COVID-19 pandemic. There may also be grade inflation to maintain the expectation of teachers, parents, and students. The shrinking difference between boys' and girls' grades may represent increased equity in how boys and girls are graded, a small boost in grades related to digital skills that is not experienced by girls, or it may signal that girls are struggling more than their male counterparts to recover in the classroom as a result of the COVID-19 pandemic.

Those students without home Internet continue to experience a grade deficit.

As we observed before the pandemic, students who have no home Internet access receive lower classroom grades. Compared with a student with no home Internet, a student with broadband Internet access has, on average, a GPA that is 0.7 higher in English/Social Studies, 0.4 higher in math/science, and 0.6 higher overall (on a 4.0 scale). For many students, this could be the difference between a B- and a B+ grade.

Social isolation was very high during the COVID-19 pandemic and was worse for students in more rural areas, but it has rapidly declined.

As students pivoted to learning from home during the COVID-19 pandemic, there was concern that this shift could have a lasting negative impact on students' mental health. Most students (58.6%) reported that they often or occasionally felt isolated at the height of the pandemic during the 2020-21 school year. However, these feelings had sharply declined by the end of the 2021-22 school year; 26% of students often or occasionally felt isolated from friends.

In the 2020-21 school year, feelings of isolation from peers were much higher among girls and the most rural students. Seventy percent of girls, but only 50% of boys felt socially isolated. Sixty percent of students who said they lived on a farm or in a heavily rural area felt isolated compared to 48% of those who lived in small, urban areas.

Students who had spent more time learning from home during the pandemic were no more likely to express continued feelings of isolation. However, those who could only access the Internet from home only by using their mobile phone, and those who watch more television continue to feel more isolated from friends. There was no relationship between feelings of isolation and any other media use, including social media.

By the end of 2021-22 school year, feelings of social isolation had declined across all demographics. However, rates of social isolation remained higher among girls and those in the most rural areas.

Adolescent self-esteem has returned to the same level that it was before the COVID-19 pandemic.

By the end of the 2021-22 school year, adolescent self-esteem was largely unchanged in comparison to before the pandemic. Students in our sample of schools completed a multidimensional measure of adolescent self-esteem in 2019 and in 2022. This measure ranges from 0-3, where higher values equate to higher well-being. It has been validated as an assessment of global feelings of self-worth that includes dimensions of body image, peer relations, family, school, and sports/athletics self-esteem.

Self-esteem averaged 1.83 in 2019 and 1.80 in 2022. Students who spent more time learning from home during the pandemic in the 2020-21 school year reported only slightly lower self-esteem in 2022 (0.04 lower out of 3). Although statistically significant, this change is substantively so small that it is unlikely to be consequential.

Post-pandemic, young people are spending more time with their friends in person.

Adolescents are spending more time with friends and less time with family than they did before the COVID-19 pandemic. Young people who have more digital skills and those who spend more time on social media are spending even more time with friends.

In 2022, as we did in 2019, we asked students to report the amount of time spent in person with family and with friends. In 2019, the average student reported spending 2.54 hours per day with family and 2.50 hours with friends. In 2022 young people were spending about 14 minutes more time per day with friends, but about 38 minutes less with family.

A variety of reasons could explain this trend. Young people may be combatting feelings of isolation that were experienced during the COVID-19 pandemic with additional in person time with friends. Or it may be that shifts in how young people spend their leisure time related to media use have resulted in increased time spent with friends. In particular, we found that most media use, including social media, is related to spending more time with friends. For example, those who spent above average time on social media (one s.d. above average) tended to spend roughly 32 more minutes hanging out with friends. Even spending a modestly above average time watching mobile videos/movies and watching television (one s.d. above the average) was related to roughly 12 and 17 more minutes respectively hanging out in person with family and 10 and 15 more minutes respectively with friends.

We also found that young people who had slower home Internet spent less daily in person time with family (about 11 minutes) but not with friends. Adolescents who had even modestly fewer Internet skills (one s.d. below average) also spent less time with family (about five minutes) and friends (about 15 minutes). Young people with even modestly more social media skills (one s.d. above average) reported spending about five extra minutes per day in person with their friends.

How We Did This Study

The aim of this study was to explore how the COVID-19 pandemic changed the experiences of Michigan students from rural and small-town areas, focusing on Internet connectivity, device access, digital skills, academic achievement, and well-being. This work involved a partnership among the Quello Center at Michigan State University, Merit Network, and a dedicated set of stakeholders from two Intermediate School Districts (ISD): the Eastern Upper Peninsula ISD and the St. Clair County Regional Educational Service Agency. The thirteen collaborating local school districts within these ISDs collectively represent some of the most rural schools in Michigan (see Appendix A for the complete list of local districts).

This study is based on data collected in 2019 and 2022. In April and May 2022, our local district partners administered a twenty-minute, pen-and-paper survey to 2,949 students in eighteen schools - a total of 190 classrooms in grades 8-11.[1] This procedure mirrored our collective efforts in the spring of 2019, when we surveyed 2,876 students in these same schools. Our pre-pandemic report, released in March 2020 – weeks into the start of the COVID-19 pandemic – highlighted the cost of a lack of broadband connectivity to the well-being and academic achievement of middle and high school students (Hampton et al., 2020). Three years later we returned to the same schools and compared student experiences from before the COVID-19 pandemic to their experiences in 2022, near the end of the pandemic. In 2022, 72.3 percent of students enrolled in grades 8-11 completed our survey; in 2019, 70.6% of students participated.

In compliance with the MSU Institutional Review Board(IRB), the Family Educational Rights and Privacy Act (FERPA), and related regulations, the survey data that we collected has been de-identified. Neither school administrators nor the research team at the Quello Center can identify student participants.

Sample Characteristics

Roughly 1.8 million of Michigan's 10 million residents live in rural areas.[2] Michigan ranks 7th among states with the largest rural populations, and 27th regarding the percentage of rural residents.[3]

In the 2021-22 school year, 21 percent of Michigan students attended a rural school, whereas an additional 12 percent attended school in a town outside of a city or suburb.[4] The thirteen local districts that participated in this project typically had housing unit densities that ranged from 4.4 to 99.6 units per square mile (see Appendix A). These densities are well below the 425 units per square mile used by the U.S. Census Bureau to identify an urban core and below the threshold of 200 units per square mile used to classify the remainder of an urban area.[5] A small percentage of students in our sample indicated that they lived in a city (11%); however, the largest urban areas in our study contain fewer than 14,000 residents.

The median household income within the local school districts ranged from $49,688 to $82,946 (the median for all of Michigan is $63,498; the national median is $69,717). The proportion of district families that falls below the federal poverty level ranges from 3.6% to 19.4% (13.1% for Michigan, 12.8% nationally).

In our 2022 survey, students were nearly evenly distributed across grades 8 through 11. Slightly more students identified as male (50.8%) than female (49.2%). 83.7 percent of students in our sample identified as white, and 16.3% as people of color (predominately Native American - 13.6%). 35.4% of the students reported the highest education of a parent/guardian was high school or less; 14.1% some college or university; 25.3% an undergraduate degree; and 25.3% a graduate degree or some postgraduate training. Just under one-third of students were living in a single-parent household (30.1%). Seventeen percent of students had an Individualized Education Plan (IEP) or a 504 plan that outlined a specific disability or learning accommodation. Although we did not ask students to report their family income, the socioeconomic status of students tends to be lower if they are people of color, are from a single-parent household, or are from a household with a lower aggregate level of parental education.

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[1] In 2019, an additional ISD, representing two schools, administered our survey to its students. This ISD did not participate in 2022. The findings reported here are limited to a comparison of only those schools and grades that participated in both 2019 and 2022.

[2] State Fact Sheets: Michigan. U.S. Department of Agriculture, Economic Research Service. 2023. https://data.ers.usda.gov/reports.aspx?StateFIPS=26&StateName=Michigan&ID=17854

[3] United States Census Bureau. State-level Urban and Rural Information for the 2020 Census and 2010 Census. 2023. https://www.census.gov/programs-surveys/geography/guidance/geo-areas/urban-rural.html

[4] National Center for Education Statistics. 2023. https://nces.ed.gov/ccd/schoolsearch/

[5] United States Census Bureau. Redefining Urban Areas following the 2020 Census. 2022. https://www.census.gov/newsroom/blogs/random-samplings/2022/12/redefining-urban-areas-following-2020-census.html

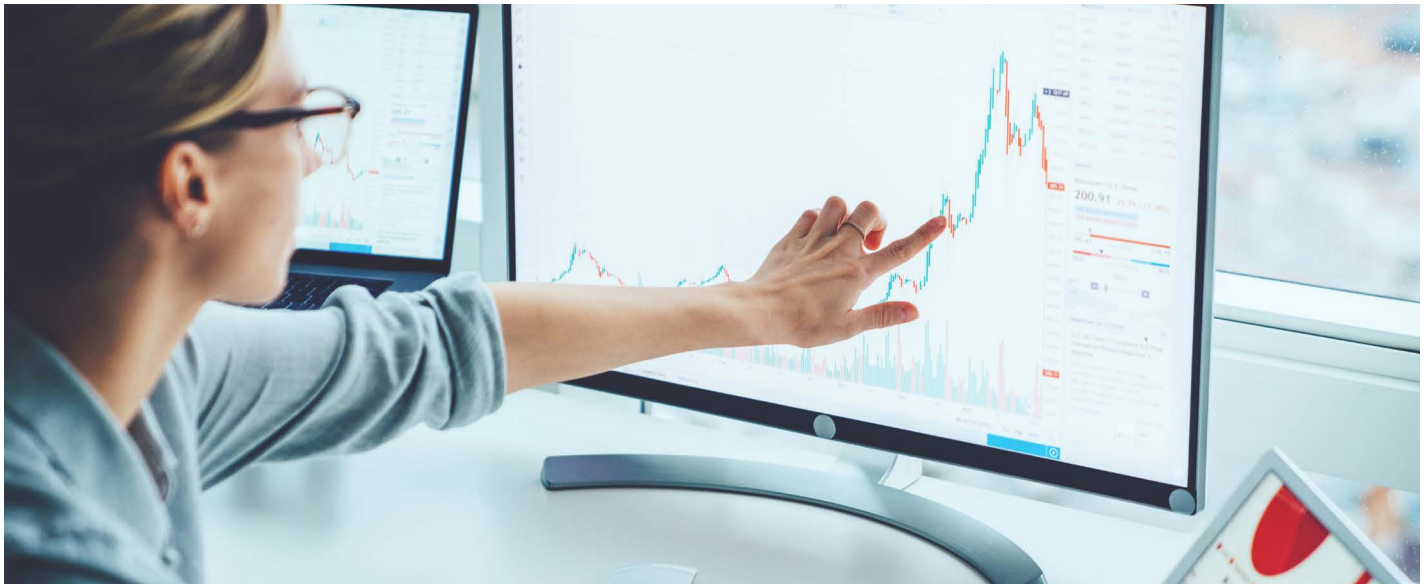
Sample demographics in 2019 and 2022

	2019		2022	
	N	%	N	%
School Grade Level				
Grade 8	718	25.0%	677	23.6%
Grade 9	777	27.0%	784	27.3%
Grade 10	765	26.6%	747	26.0%
Grade 11	615	21.4%	663	23.1%
Gender				
Male	1363	47.7%	1437	50.8%
Female	1493	52.3%	1394	49.2%
Age (Years)	2855	15.1 (1.2)	2859	15.1 (1.2)
Race/Ethnicity				
White	2522	87.7%	2467	83.7%
Black	36	1.3%	57	1.9%
Asian	59	2.1%	49	1.7%
Native American	316	11.0%	401	13.6%
Multiracial	95	3.3%	169	5.7%
Other Race	99	3.4%	107	3.6%
All People of Color	564	19.6%	482	16.3%
Hispanic	192	6.8%	228	7.7%
Parent Highest Education (Years)	2634	14.9 (2.9)	2126	14.7 (3.1)
Location				
Small Urban Area	246	8.6%	326	11.1%
Rural	2607	91.4%	2623	88.9%
Single Parent Household	821	28.7%	887	30.1%
Individualized Education Plan (IEP)	415	14.4%	501	17.0%

Note: N (2019) = 2876, N (2022) = 2949.

Students could select more than one race. Means are reported with the standard deviation (s.d.) in parentheses.

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*



Analysis

This report presents survey data from two groups of student participants from an eighteen-school sample: those who completed a survey in 2022 and those who completed a survey in 2019. In our 2022 interviews, we included some questions that asked students to think back to "last year" (to the 2020-21 school year). The 2020-21 school year was the height of the COVID-19 pandemic, and the questions we asked focused on students' day-to-day experiences while learning from home. When relevant, we present these questions as a third temporal point alongside our two survey groups. Thus, throughout the report we refer to student experiences in the 2018-19, 2020-21, and 2021-22 school years.

We report the percentage or average responses from students in different years to compare the typical student in 2019 (pre-pandemic) with the typical student in 2022 (post-pandemic). However, in identifying gaps in student performance or outcomes, we also recognize that differences may be related to demographic factors that are unrelated to Internet access or use. For example, students of lower socioeconomic status (e.g., lower parental education, living in a single-parent household) are more likely to experience gaps in academic performance.[6] To isolate these relationships, we use a form of statistical regression analyses called hierarchical or multilevel modeling (MLM). Our MLM models incorporate data nested at two levels, with students nested within schools. Like other forms of regression analysis, this two-level approach controls for sociodemographic factors while also considering differences and similarities between and within schools. That is, our MLM models compare students with different types of Internet access and use with demographically similar students. This approach enables us to distinguish outcomes that can be attributed to differences in Internet access or use from those that may be related to variations in other demographic factors.

We employ two types of MLM models to report different types of findings. The first type of model focuses on outcomes from either the 2022 or 2019 survey (see Appendix B). This first MLM regression analysis informs us about the relationship between Internet access and use in each survey year. The second type is an exploratory "moderation analysis" that combines all participants from both the 2022 and the 2019 survey in a single model (see Appendix C). We use this moderation analysis to attempt to identify what has changed between 2019 to 2022. For example, we know that there are slight differences in the demographic makeup of students who completed the survey in 2022 and those who did so in 2019. We are interested in determining whether these demographic variances or the differences in Internet access or use account for our findings. In the exploratory analysis, we assess the potential for moderation using blocks of variables for Internet access, digital skills, and demographics. We report findings from a final model that includes all statistically significant moderations.

[6] American Psychological Association. *Education and Socioeconomic Status*. 2017. https://www.apa.org/pi/ses/resources/publications/education

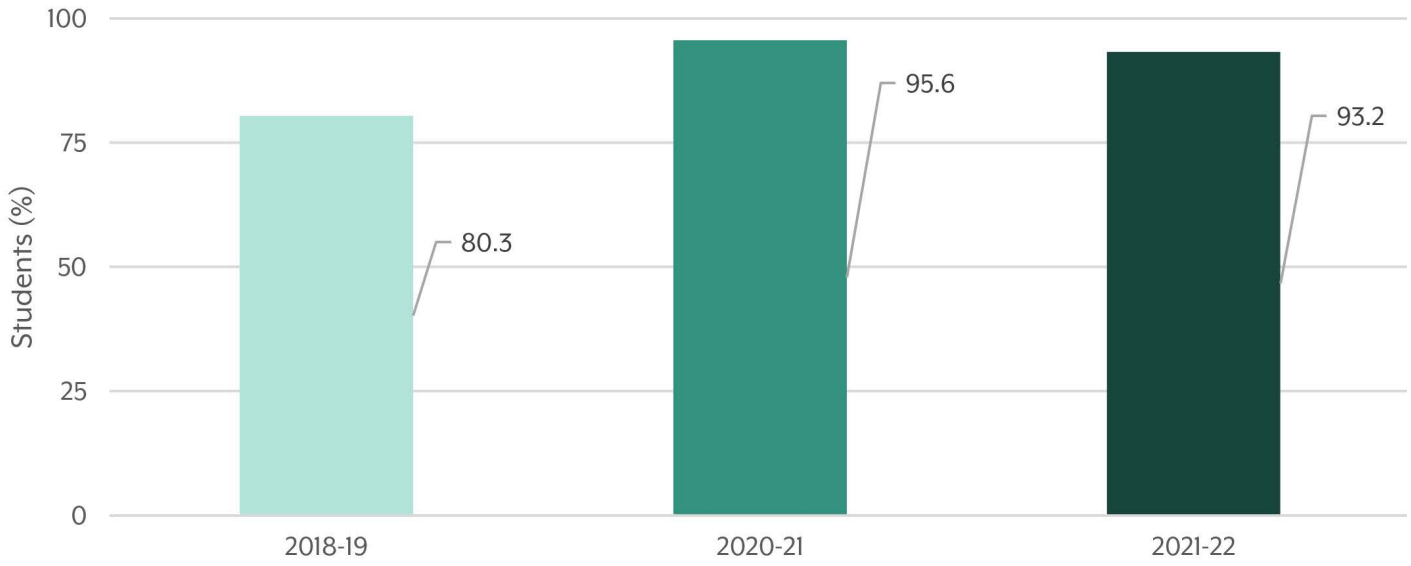
Broadband Access Improved But is Now Declining.

Many more rural students have broadband access at home, and far fewer students remain without fixed home Internet. Since 2019, the number of rural Michigan students who do not have home Internet access dropped by 65%, whereas the number with broadband access increased by 20%.[7] However, the increase in student connectivity has been due largely to the efforts of local school districts that have been providing students with Wi-Fi hotspots. These school-provided hotspots give students a physical access point to connect devices to the Internet at home. In the 2021-22 school year, connectivity receded from a pandemic high that was achieved in the 2020-21 school year.

In 2019 we measured the rural student broadband access gap. At that time, 19.7% of rural Michigan students in grades 8-11 had no home Internet access or depended exclusively on a cell phone to go online. A slim majority of students had high-speed broadband Internet access from home (56.5%), but many more relied on slower home access (23.8%).

Three years later, in 2022, 93.3% of rural students had home Internet access. Only 6.8% had no home Internet or could go online only on a smartphone. There was a marked increase in the number of students with broadband access, rising to 67.6% of students. One-quarter of students (25.7%) continue to rely on home access, which they report as "slow."

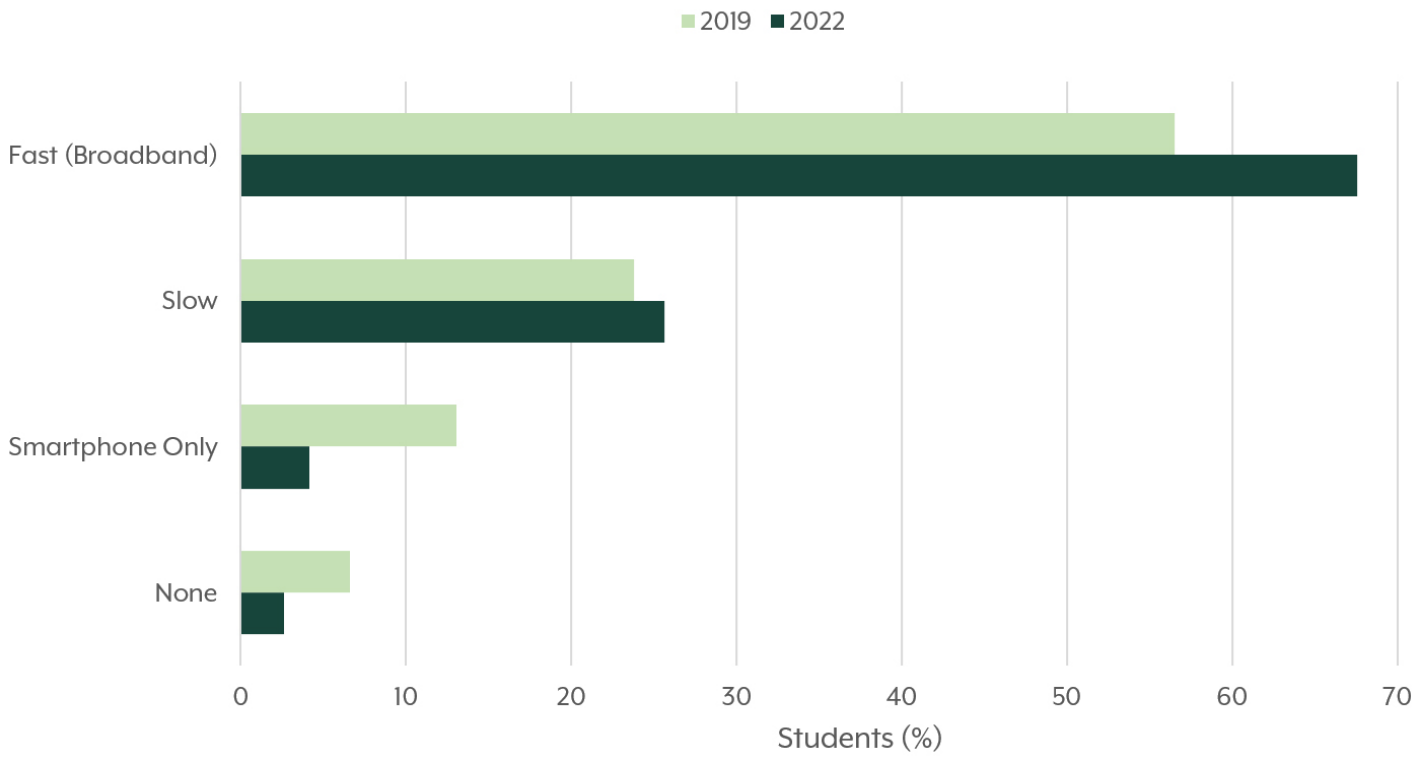
Students with fixed Internet access at home



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

[7] We define disconnected as having no access or being able to go online only by using a smartphone through a data plan. During survey pre-testing, we found that students could not reliably self-report the type (e.g., cable, satellite, etc.) or speed of their home Internet connection or why they did not have home access (e.g., cost, no Internet service provider). Instead, students reported whether they had "fast" home Internet access, slower access, or no home access. In 2019, many students who completed our survey also completed an at-home speed test that allowed us to verify that our survey measure of home Internet connectivity was consistent with real-world speeds. We verified that the average download and upload speeds for students who reported that they had "fast" home Internet access exceeded the minimum requirements set by the Federal Communications Commission for "broadband" speeds (25 mbps download, 3 mbps upload). The speeds were also significantly higher than those speeds reported as "slow."

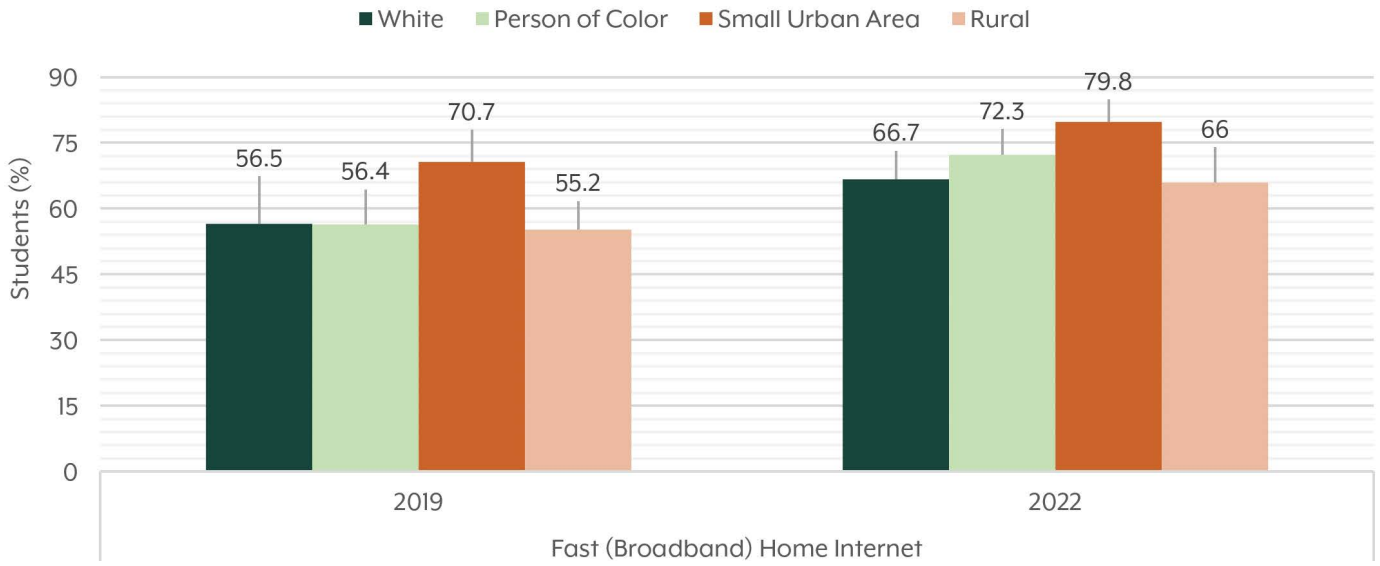
Home Internet access in 2019 and 2022



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Improvements to home connectivity have been uneven. Although our sample is predominantly rural, students living in areas that are even moderately more urban were more likely to have broadband access. In 2019, 70.7% of students in small, urban areas (in our study, generally 14,000 residents or fewer) had fast broadband access at home, compared with 55.2% of students in more rural areas, a gap of 15.5%. In 2022, although both groups of students were increasingly likely to have broadband, the urban-rural gap had shrunk only marginally; 79.8% of urban and 66.0% of rural students had broadband access (a gap of 13.8%). As it was before the pandemic, people of color remained more likely to have no home access or to depend on a cell phone for access (8.4% compared to 6.5% for white students). However, since the pandemic, students of color are now more likely than their white counterparts to have broadband access at home (72.3% vs. 66.7%).

Variation in broadband home Internet access by race and location from 2019 to 2022



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Home Internet access in 2022 and 2019 by gender, race, and location (%)

	No Home Access		Cell Only at Home		Slow Home Internet		Fast Home Internet	
	2019	2022	2019	2022	2019	2022	2019	2022
Overall	**6.6**	**2.6**	**13.1**	**4.2**	**23.8**	**25.7**	**56.5**	**67.6**
Gender								
Male	6.5	3.0	13.4	4.0	24.4	26.2	55.7	66.7
Female	6.4	2.0	12.8	4.2	23.4	25.2	57.3	68.6
Race								
White	6.2	2.3	12.8	4.2	24.4	26.9	56.5	66.7
Person of Color	8.3	4.4	14.0	4.0	21.3	19.2	56.4	72.3
Location								
Small Urban Area	4.5	2.5	11.8	2.5	13.0	15.2	70.7	79.8
Rural	6.7	2.6	13.3	4.4	24.8	27.0	55.2	66.0

Note: N (2019) = 2876, N (2022) = 2911.

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Strides toward reducing student disconnection are due primarily to the efforts of school districts. These efforts were enabled by a combination of direct support measures and programs that helped families get connected. During the first year of the COVID-19 pandemic, federal and state pandemic relief funding, the temporary relaxation of federal regulations, equipment donations, and temporary changes to pricing plans by network operators helped expand the resource bases of local school districts. As the pandemic unfolded, the U.S. Congress adopted additional measures to make broadband service more affordable. The Emergency Broadband Benefit (EBB) program and later the Affordable Connectivity Program (ACP) generated demand-side subsidies that reduced the costs of service and equipment purchases.

In the 2020-21 school year, at the height of the pandemic, schools provided nearly one-fifth (17.7%) of rural students with Wi-Fi hotspots. At that time, 95.6% of rural students reported having fixed home Internet access. One year later, in the 2021-22 school year, the proportion of students who were receiving a Wi-Fi hotspot through their school declined to 12.3%. This decline to 93.2% coincided with a drop in the number of students who could access the Internet at home.

The drop in home Internet access coincided with a decline in the number of hotspots provided by local school districts. However, few students became disconnected because they lost access to a hotspot. In fact, by the 2021-22 school year, many students who initially received a hotspot had replaced the hotspot with another source of home Internet access (43.9%). Only 12% of those students who lost Internet access at home did so because their school no longer provided them with a hotspot. The remaining students lost access because their households once had Internet access (not a school provided hotspot) but, we assume, could no longer afford it, or parents/guardians lost access at home for another reason.

Our observation that students are now experiencing periods of disconnection after a period of having home Internet access is consistent with the expectation that as access inequalities decrease, issues of technology maintenance will increasingly represent the largest digital divides (Gonzales, 2016; Gonzales et al., 2020). These periods of disconnection are likely to fall disproportionately on students of the lowest socioeconomic status. Schools struggle to identify students who have access insecurity and to intervene to provide recently disconnected students with school provided hotspots.

Absent school provided hotspots, home connectivity in 2022 would have been 83.1%, only marginally higher than the 80.3% of students who had home Internet access before the pandemic. Although there has been an increase in the number of students with broadband access, if it were not for school- provided hotspots, there would have been little change in the number of students who have home Internet access, and schools are now providing fewer hotspots.

Student home Internet access before, during and after the pandemic (%)

	Had Home Internet			Hotspot Provided by School	
	2019	2021	2022	2021	2022
No	19.7	4.4	6.8	82.3	87.7
Yes	80.3	95.6	93.2	17.7	12.3

Note: *Home Internet* N (2019) = 2876, N (2021) = 2945, N (2022) = 2911

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Device Access Improves

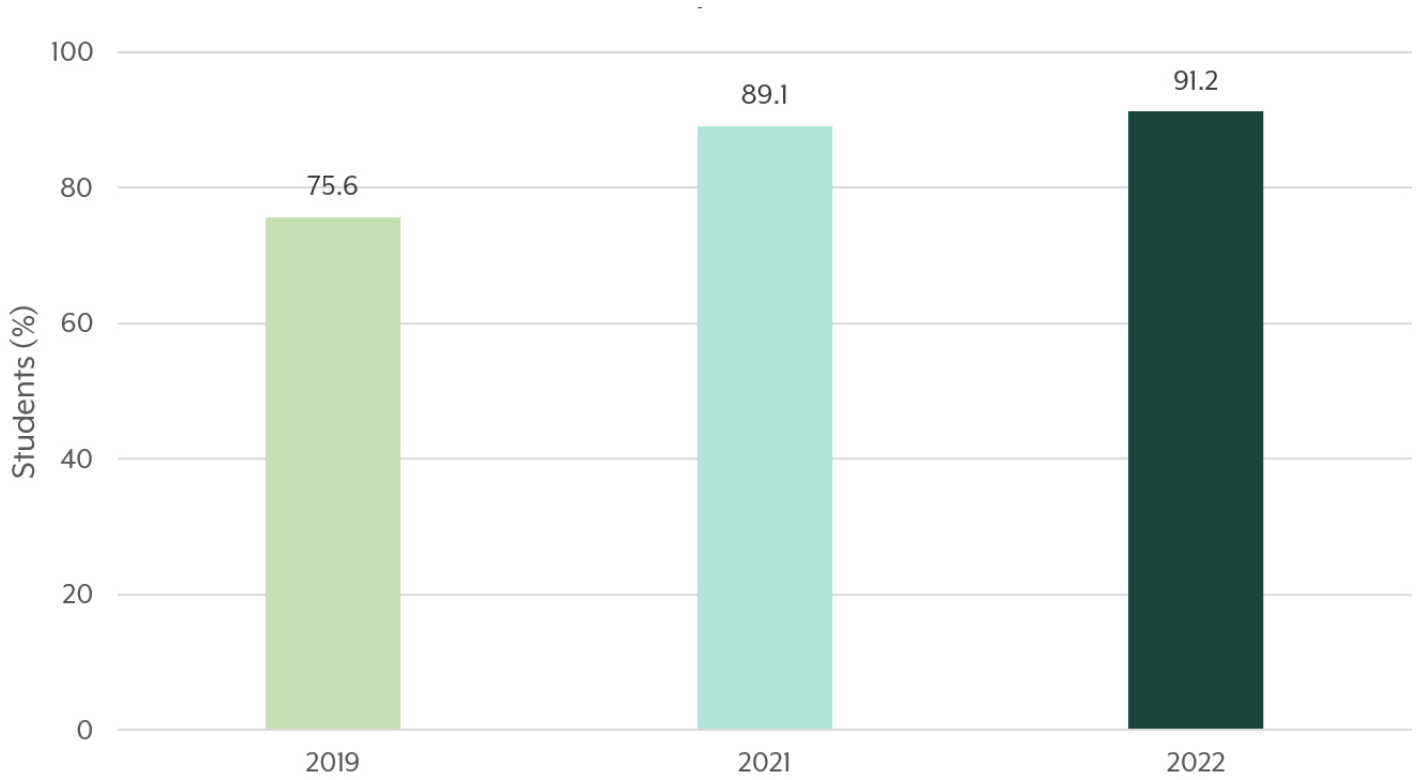
In 2019, only 59.7% of rural students had access to a laptop, and 38.1% had access to a desktop computer at home. (75.6% had access to one device or the other.)

By 2022, 85% of students had a laptop, and 59.6% had a desktop computer (91.2% had one or the other). Tablet ownership increased at a slower rate, from 41.2% to 54.0% of students. Cell phone ownership, which in 2019 was already nearly universal, increased from 93.8% to 96.8% of students. Ownership of video game consoles increased from 65.4% to 85.6% of students.

Gender and racial inequalities persist but the gap has narrowed. Boys remain less likely to have access to a laptop than girls, but girls remain less likely to have access to a desktop computer or video game console. Compared to white students, students of color remain less likely to have access to a laptop or desktop computer, but the gap has narrowed. In 2019, 76.6% of white students had either a laptop or desktop, compared to 71.3% for students of color, a gap of 5.3%. By 2022, that racial gap in computer ownership had dropped to 2.9%.

Although some school districts had initiatives in place prior to the COVID-19 pandemic to provide students with computers, which they could take home each day, these programs increased during the pandemic. Schools benefitted temporarily from additional funding through several COVID-19 relief packages, such as federal CARES funding and additional resources from the State of Michigan. However, the number of devices provided through these programs now appears to be declining.

Desktop or laptop computer access before, during and after the pandemic

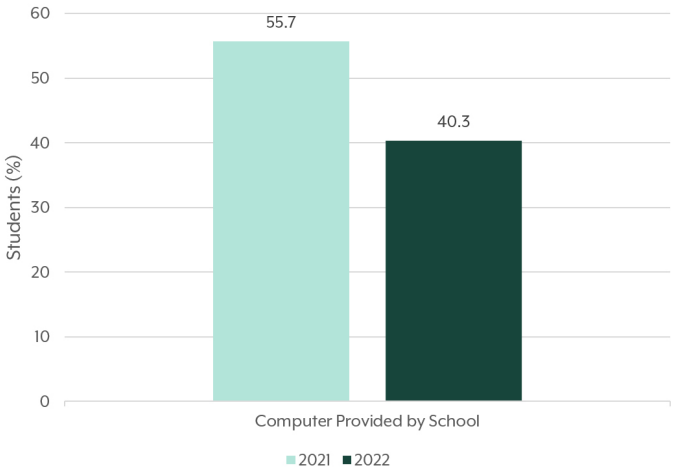


Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

In the 2020-21 academic year, 55.7% of all students received a laptop/Chromebook from their school. In the 2021-22 school year, the number of students who had a school-provided computer declined to 40.3%. Yet, despite a reduction in the number of computers sent home by schools, access to a computer at home, either a laptop or a desktop, continued to increase, from 89.1% in 2021 to 91.2% in 2022.

Of those students who had computer access provided by their school in 2021, 10.2% had no access at all to a desktop or laptop in 2022. This group of students represented the majority of students (65%) who had no access to a computer at home in 2022. Again, this defect represents a needed shift in focus from overcoming divides in access to maintaining access over time.

Students with school provided computer in 2021 and 2022



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Access to a computer and other devices before and after the COVID-19 pandemic (%)

	Cell Phone		Cell Data		Desktop		Laptop		Tablet		Game Console	
	2019	2022	2019	2022	2019	2022	2019	2022	2019	2022	2019	2022
Overall	**93.8**	**96.8**	**83.8**	**90.2**	**38.1**	**59.6**	**59.7**	**85.0**	**41.2**	**54.0**	**65.4**	**85.8**
Gender												
Male	92.7	96.2	82.1	88.2	43.4	63.2	53.2	82.1	39.0	51.1	79.2	92.5
Female	95.1	97.8	85.7	92.7	33.0	56.7	65.8	88.8	43.3	57.0	52.8	79.3
Race												
White	94.2	97.0	85.8	91.4	39.1	60.2	60.1	85.7	41.0	54.4	64.9	86.3
Person of Color	92.0	96.1	75.9	83.8	34.0	56.4	58.3	82.0	42.4	51.5	67.4	83.2

N (2019) = 2876, N (2022) = 2949.
Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Access to a computer or laptop/Chromebook before and after the COVID-19 pandemic (%)

	Desktop or Laptop			Provided by School	
	2019	2021	2022	2021	2022
Overall	**75.6**	**89.1**	**91.2**	**55.7**	**40.3**
Gender					
Male	74.5	88.4	90.0	58.2	42.3
Female	76.6	91.0	93.0	55.3	39.5
Race					
White	76.6	90.2	91.7	55.6	39.7
Person of Color	71.3	83.6	88.8	56.6	43.6

Note: N (2019) = 2876, N (2021/2022) = 2949.
Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

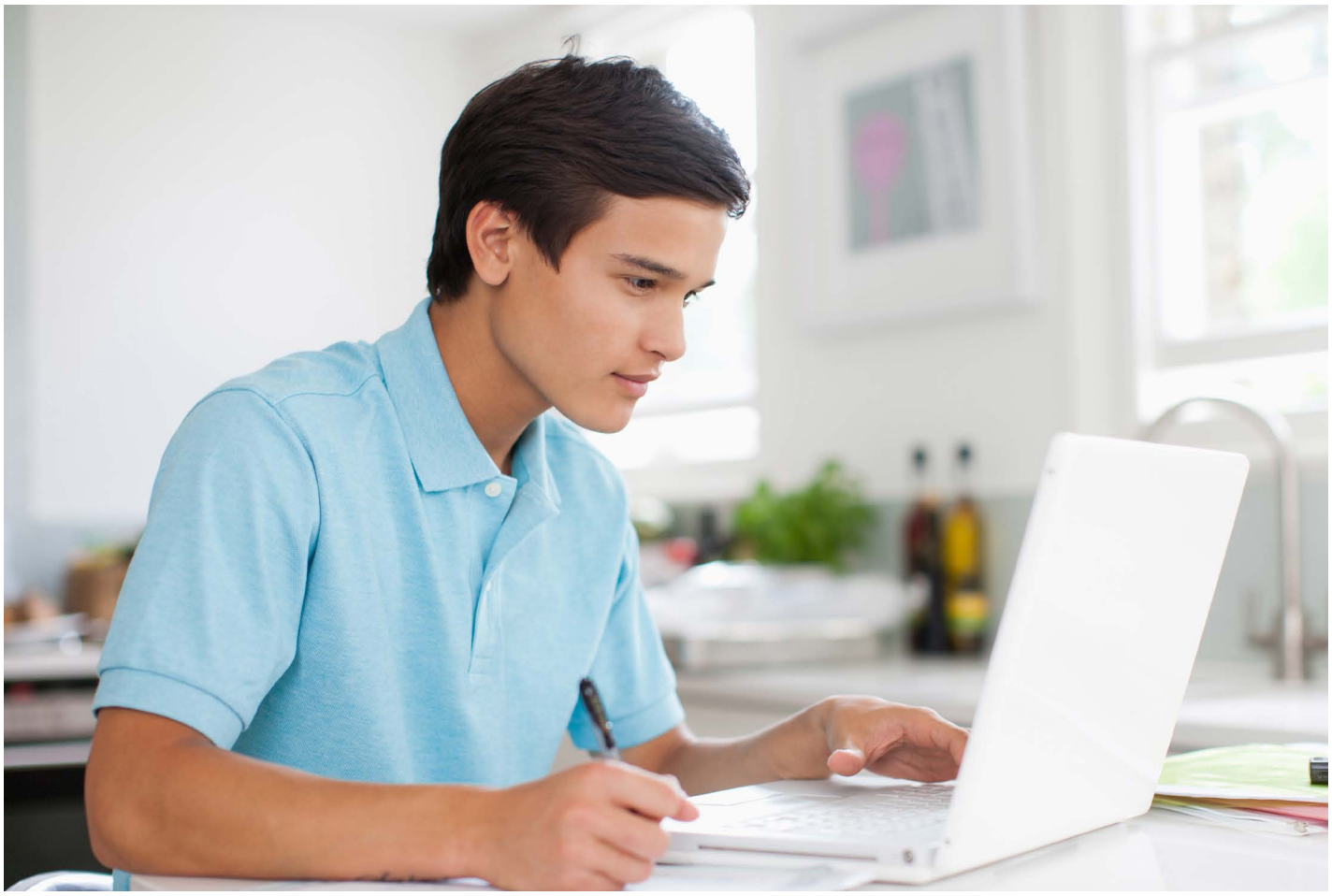
Learning from Home During the Pandemic

At the height of the pandemic, the majority of Michigan students spent time learning from home. In the 2020-21 school year, 73.5% of rural students at least occasionally did online learning from home. As a result of the lingering effects of the pandemic, 10.8% of students continued to do online learning from home at least occasionally in the 2021-22 school year.

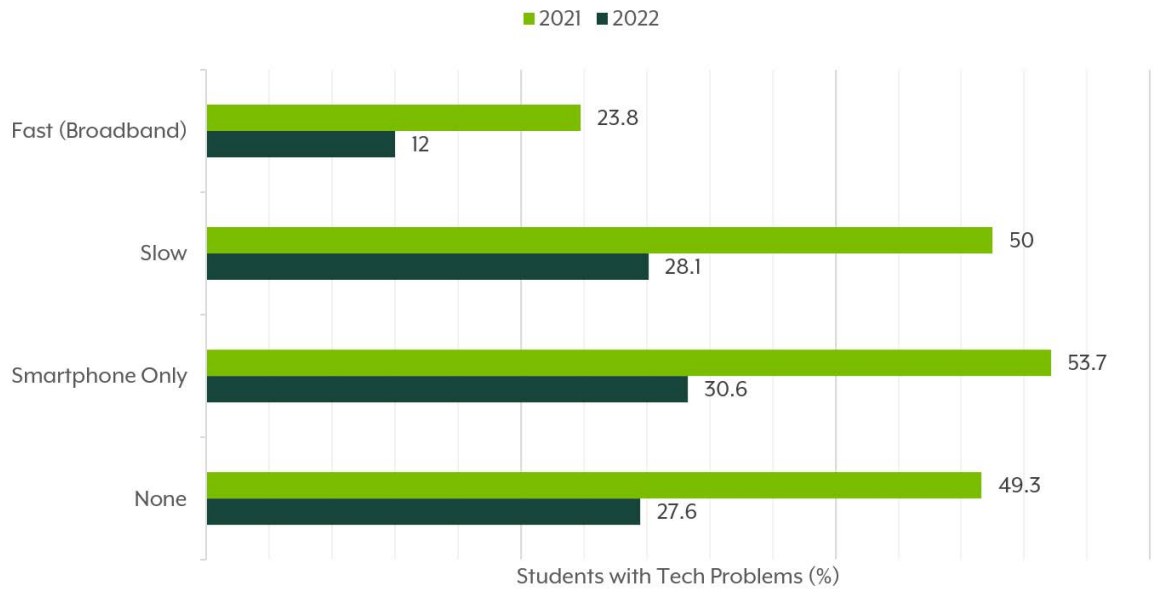
Faster Access, Fewer Problems

Learning online was more challenging for some students than for others. Students who did not have fast, broadband Internet during the pandemic were more likely to experience problems completing homework.

In the 2020-21 school year, when most students frequently did school from home, nearly one-third (32.7%) reported that they occasionally or often had "problems at home with technology that made it hard to complete schoolwork." Of those students who had problems with technology, more than one- half did not have fast broadband Internet at home (51.5%). Only 23.8% of those students with broadband access occasionally or often had technology problems.



Student technology problems by home Internet access in 2021 and 2022



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

We used regression analysis to statistically control other factors that might have been related to students having problems with technology, such as grade level and parents' education (see Appendix B, Table B1). This analysis verified that for students, who did not have broadband Internet at home, the odds were at least 200% higher that they would experience problems with technology that made it harder to complete schoolwork.[8]

Building Digital Skills

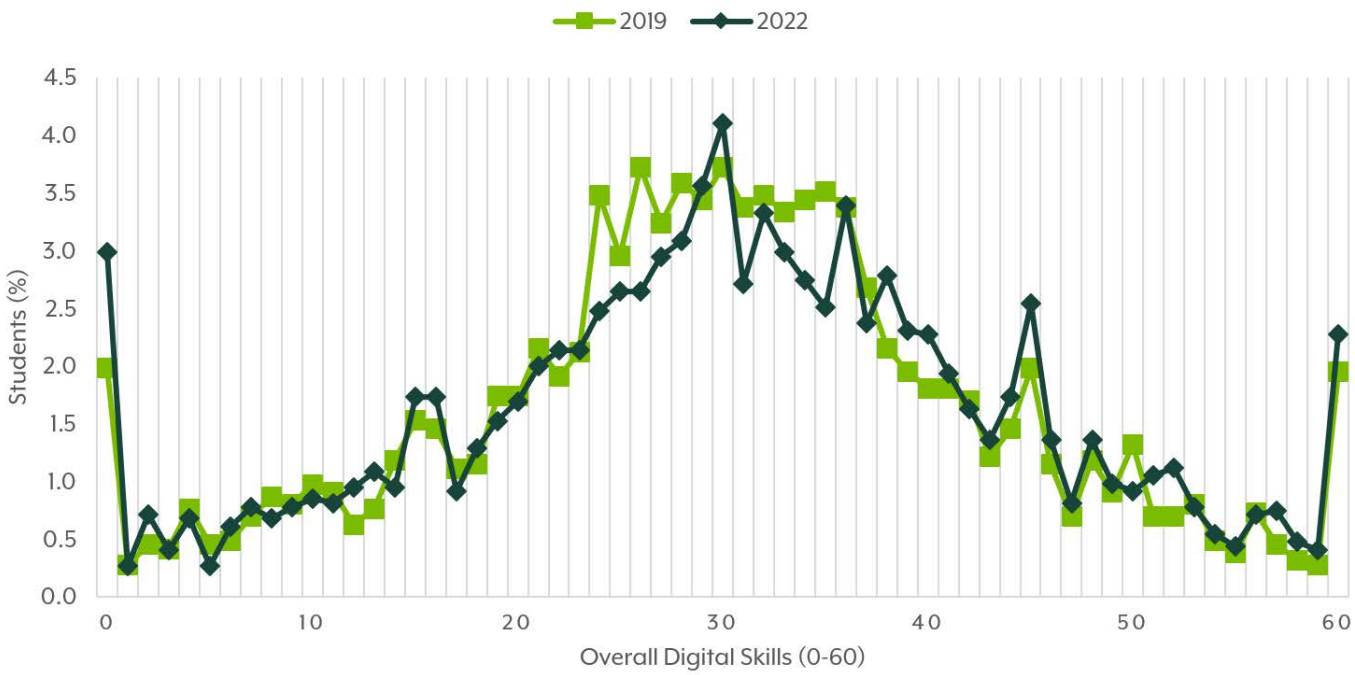
Digital skills are a measure of digital competence. Students who spent more time learning from home in the 2020-21 school year tended to report higher digital skills the following year.

In our report from before the pandemic, we described how rural students, who had no Internet access at home or could go online using only their cell phones, had much lower digital skills than their better connected peers (Hampton et al., 2020). We found that when young people have better home Internet access, they do more things online (e.g., surfing the Web, using social media, etc.), and the time they spend on these activities is associated with higher digital skills (Hampton et al., 2021). We also found that students who had more digital skills had higher academic performances, in particular, standardized test scores.

We assessed students' digital skills using a scale that asked students to rate their familiarity with sixteen computer-and Internet-related items. There answers could vary from "no understanding" to "full understanding." This measure was developed by Hargittai and Hsieh (2012) based on observations of people's actual use of these technologies (Hargittai, 2005). This measure includes an overall score (out of 64), and sub-scores for dimensions of Internet (out of 32) and social media skills (out of 28).

[8] We express caution when interpreting findings from our 2022 survey related to students who have no Internet access or can only access the Internet from a smartphone. The number of students who have no home Internet is relatively small. In a regression model, variables with a small number of cases are less reliable.

Distribution of students' overall digital skills before and after the COVID-19 pandemic



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

In 2022, the average student scored 30.6 out of 64 in overall digital skills, 10.3 out of 32 in internet skills, and 20.3 out of 28 in social media skills. There is considerable variation in the digital skills of young people. However, average scores on our measures of digital skills in 2022 were very similar to the scores from students in the same schools in 2019. The average score was 30.7 (s.d. = 14.0) in overall digital skills, 10.3 (s.d. = 8.33) in Internet skills, and 20.3 (s.d. = 7.8) in social media skills.

Digital skills differed based on how much time students had spent learning from home during the pandemic. Compared to their peers who spent more time in school, students who spent more time learning from home reported higher digital skills in the 2021-22 school year.[9] Using regression analysis to statistically control for other factors that might account for these differences, we found that compared to a student who rarely did learning from home during the pandemic, a student who often did school at home tended to score 1.1 points higher in Internet skills (10.7% higher than average), 1.7 higher in social media skills (8.4% higher than average), and 2.8 points higher in overall skills (9.1% higher than average) (See Appendix B, Table B2). This difference is roughly equivalent to the difference in digital skills between students in grades 9 and 11.

When we used regression analysis to compare students in 2019 with those in 2022, one additional major difference emerged (See Appendix C, Table C1). In 2018-19 we found no difference in digital skills based on students' race. In 2021-22, students of color tended to score lower in Internet skills (-1.2 points, or 11.7% less than average) but not in social media skills.

[9] We operationalized the extent to which students were learning from home by asking students to think back to "last year" (i.e., the 2020-2021 school year) and respond to the question, "because of COVID-19 I did school from home," on a 4-point Likert scale ranging from never to often.

Average digital skills by demographics in 2019 and 2022

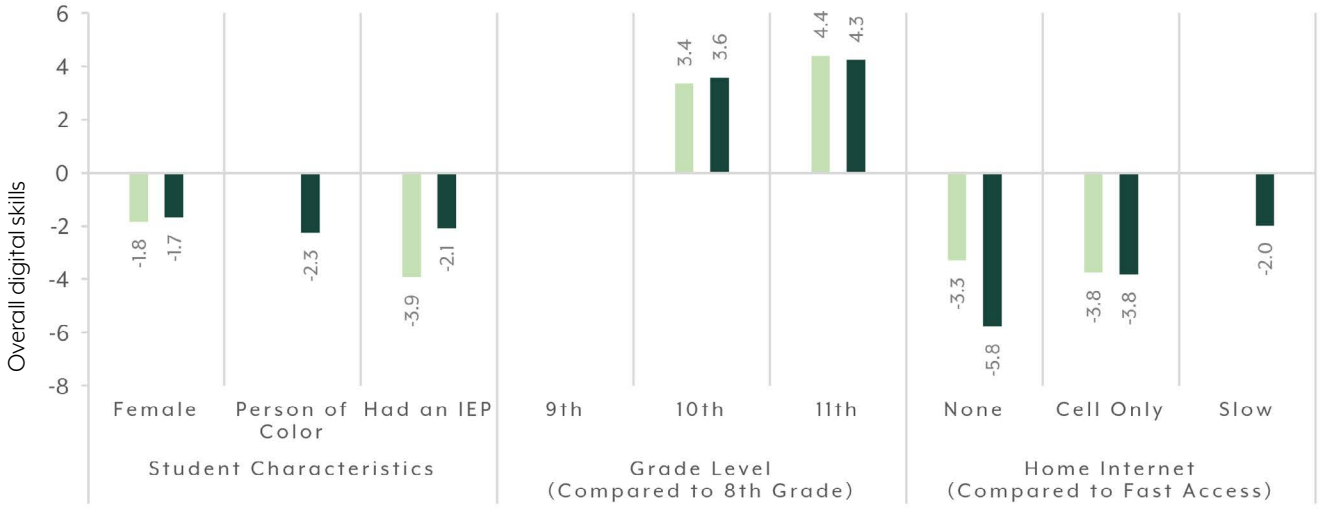
	Overall Digital Skills		Internet Skills		Social Media Skills	
	2019	2022	2019	2022	2019	2022
Overall	**30.3 (13.1)**	**30.7 (14.0)**	**9.8 (7.9)**	**10.3 (8.3)**	**20.4 (7.5)**	**20.3 (7.8)**
Gender						
Male	31.1 (15.2)	31.0 (15.7)	11.8 (9.0)	11.9 (9.1)	19.3 (8.2)	19.2 (8.4)
Female	29.4 (10.7)	30.5 (11.7)	8.0 (6.3)	8.7 (7.0)	21.5 (6.6)	21.8 (6.8)
Race						
White	30.3 (13.0)	31.1 (13.8)	9.8 (7.9)	10.5 (8.4)	20.5 (7.4)	20.6 (7.7)
Person of Color	30.0 (13.5)	28.1 (14.5)	9.8 (8.2)	9.3 (8.1)	20.2 (7.7)	18.8 (8.5)
Location						
Small Urban Area	28.0 (13.7)	29.3 (14.8)	9.1 (8.0)	9.7 (8.3)	18.9 (8.2)	19.6 (8.7)
Rural	30.5 (13.0)	30.8 (13.8)	9.9 (7.9)	10.4 (8.3)	20.6 (7.4)	20.4 (7.7)
School Grade						
Grade 8	28.0 (12.4)	28.0 (14.2)	8.1 (7.2)	8.8 (8.0)	19.9 (7.7)	19.2 (8.4)
Grade 9	29.7 (13.1)	29.7 (13.7)	9.6 (7.9)	9.7 (8.1)	20.0 (7.5)	20.0 (7.9)
Grade 10	31.3 (13.2)	32.4 (13.7)	10.3 (8.1)	11.3 (8.5)	21.0 (7.3)	21.1 (7.4)
Grade 11	32.4 (13.3)	33.0 (13.4)	11.4 (8.3)	11.6 (8.3)	21.0 (7.4)	21.4 (7.2)

Note: N (2019) = 2876, N (2022) = 2949.

Standard deviation (s.d.) in parentheses.

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Variation in overall digital skills based on student characteristics in 2019 and 2022



Note: Values are based on regression analysis coefficients in Table B2.

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Declining and Changing Aspirations and Achievement

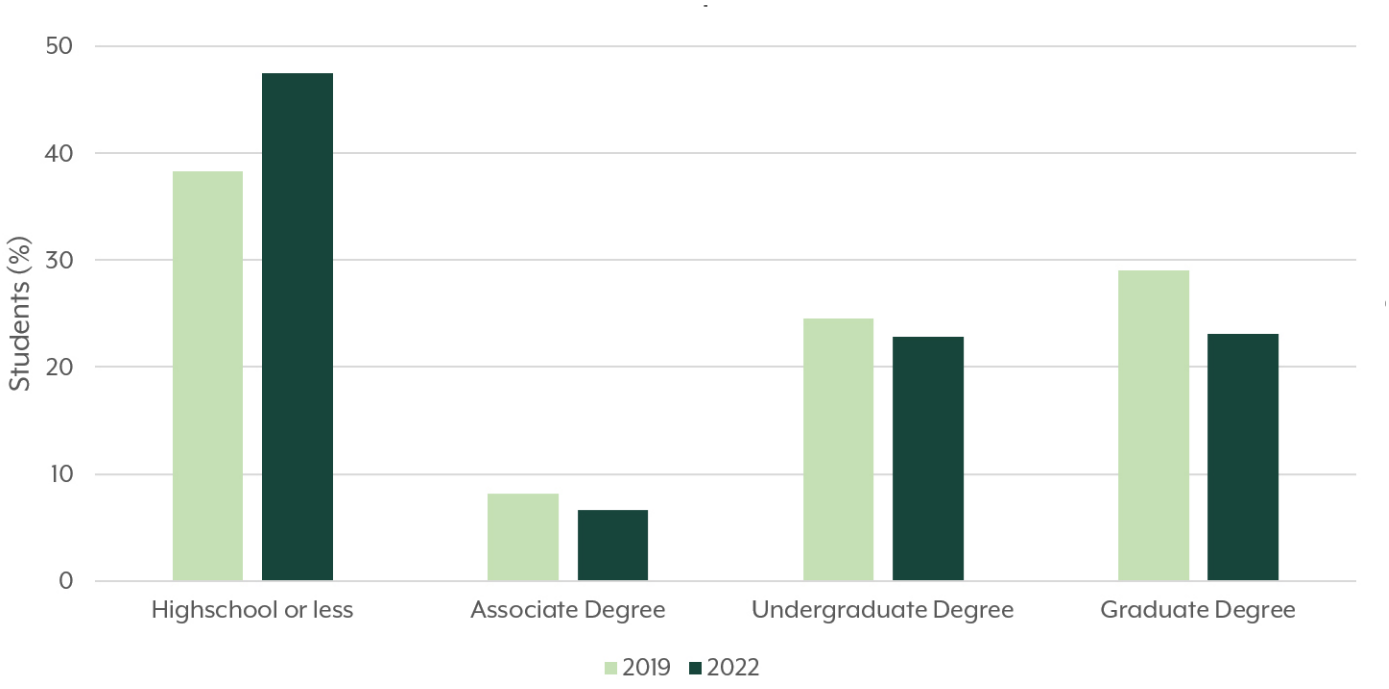
There have been declines in educational aspirations and interest in STEM careers, but not in classroom grades.

Education Goals

During the pandemic, students' educational aspirations declined. The number of students who intend to complete a university degree dropped from 53.5% to 45.9%. Similarly, the proportion of students who had no educational aspirations beyond high school increased from 38% in 2019 to 48% in 2022.

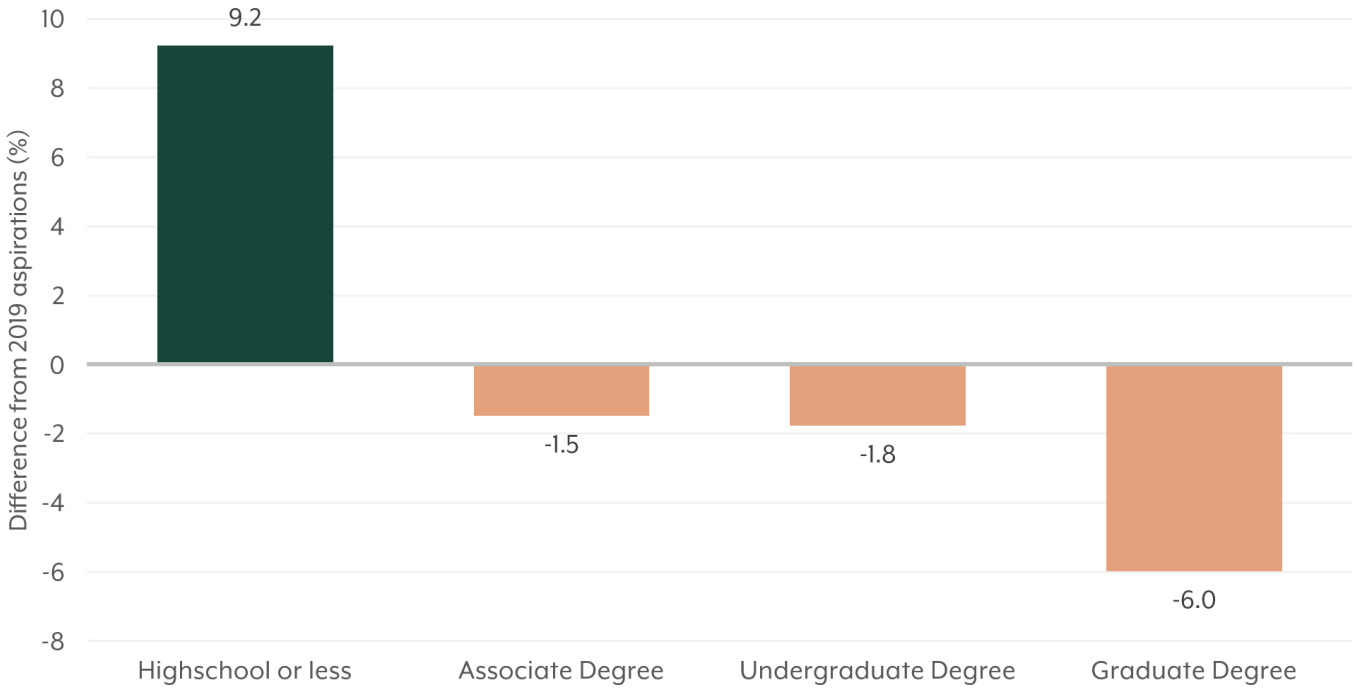
Boys are much less likely than girls to want to continue with their education beyond high school. The same is true for students with an Individualized Education Program (IEP) and students from single-parent households. Girls are 141% more likely than boys to intend to complete a university degree. Whereas students from single-parent households are 21% less likely to consider attending university, students with an IEP are 30% less likely. Regression analysis also confirmed that students who spent more or less time doing school from home during the pandemic were no more or less likely to say that they intended to continue with their education (Appendix B, Table B4). However, students with more digital skills were more likely to say they will enroll in and obtain some college or university-level degree after high school. A student who has even modestly more Internet and social media skills than average (one s.d. higher) is 36% more likely to intend to complete some level of college or university.

Students' educational aspirations before and after the COVID-19 pandemic



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Change in students' educational aspirations 2019 to 2022

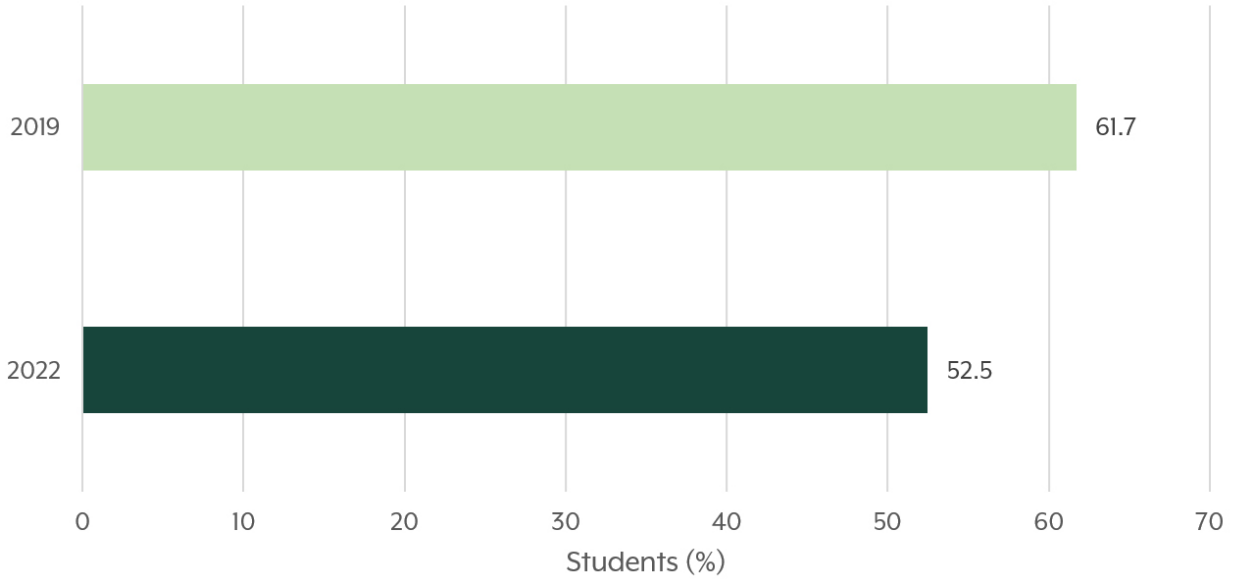


Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

When we used regression analysis to look for differences between students in 2019 and those in 2022, we confirmed a general decline in educational aspirations. We did not identify changes in any specific student characteristic that contributed to being more or less likely to express lower educational aspirations (Appendix C, Table C3). That is, the decline appears relatively consistent across gender, race, grade, digital skills, and the type of Internet connection students had at home.

Various factors have likely contributed to the decline in educational aspirations beyond the COVID-19 pandemic. These factors include the pull of a tight labor market where unemployment is low and workers are in high demand, increases in the minimum wage, narratives about the cost of college and student debt, and the challenges of accessing post-secondary education in rural areas (Arsen et al., 2022; Bauer et al., 2019). In addition are narratives about the decreasing importance of university degrees (Kaplan, 2023). The overall trend is concerning given the strong relationship between higher educational attainment and individual income and local economic growth (Lund et al., 2019).

Students' aspirations to complete some college, before and after the COVID-19 pandemic



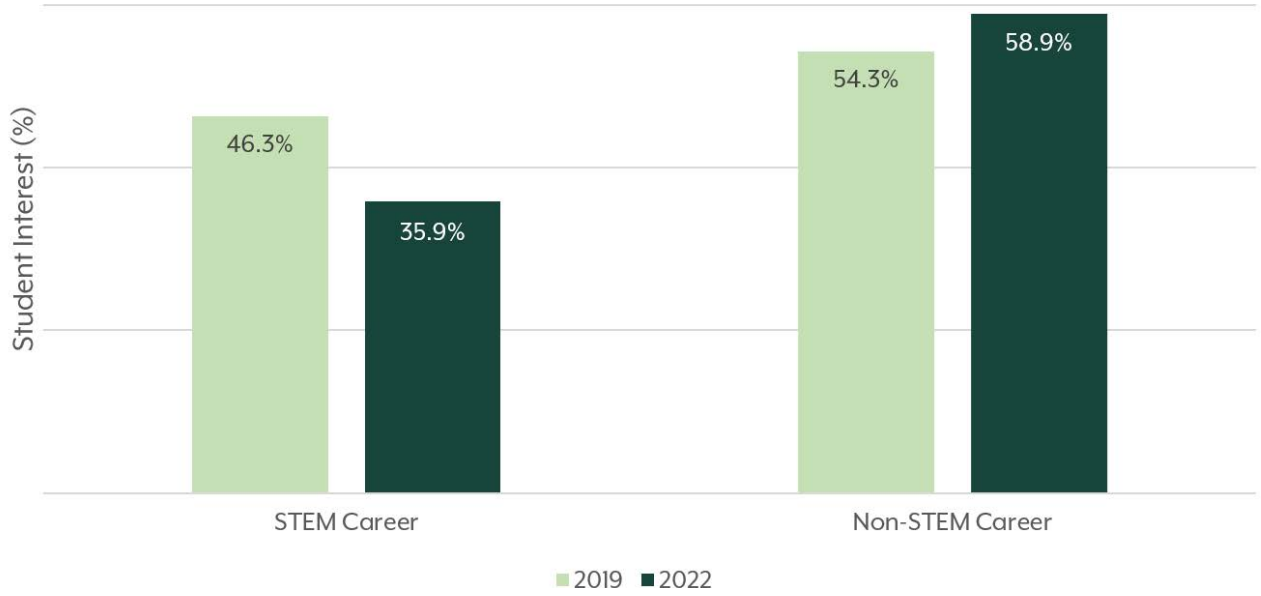
Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Educational aspirations in 2019 and 2022 (%)

	Highschool or less		Associate Degree		Undergrad Degree		Graduate Degree	
	2019	2022	2019	2022	2019	2022	2019	2022
Overall	**38.3**	**47.5**	**8.1**	**6.6**	**24.5**	**22.8**	**29.0**	**23.1**
Gender								
Male	45.6	56.4	9.3	6.6	24.0	20.8	21.1	16.2
Female	31.2	37.3	7.2	6.5	25.1	25.6	36.5	30.6
Race								
White	36.5	45.2	8.4	6.9	25.9	23.8	29.2	24.1
Person of Color	45.7	59.1	7.1	5.6	19.0	17.4	28.2	17.8
School Grade								
Grade 8	42.9	52.4	5.6	5.3	19.1	18.8	32.5	23.5
Grade 9	42.3	52.4	6.0	4.7	22.0	19.0	29.6	23.9
Grade 10	36.7	45.5	9.5	7.4	25.2	23.7	28.5	23.4
Grade 11	29.6	37.1	12.0	9.2	33.3	31.5	25.0	22.2

Note: N (2019) = 2876, N (2022) = 2949.
Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Students' career interests before and after the COVID-19 pandemic



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

The Decline of STEM and Accreditation

There has been a dramatic decline in the number of students interested in a career related to science, technology, engineering, or math (STEM). In 2019, nearly half (46.3%) of all students expressed an interest in a STEM-related career; by 2022 that number had declined to 35.9% of students. Learning from home during the pandemic appears to have offered some protection from a loss in STEM interest. Similarly, students who have more digital skills remain more likely to have interest in STEM careers. However, there is a growing tendency for those who have an interest in STEM careers, particularly in engineering and computer science, to believe that they can enter these fields without post-secondary education.

Students were presented with a list of twenty-six different careers and were asked to select those that best described what they want to be. The list of possible careers included a range of occupations that could broadly be classified as STEM and a selection of careers that are generally not STEM-related. Examples of STEM careers included health professional, engineering, and math or science teacher. Non-STEM careers included professions such as police officer, mechanic, counselor, musician, plumber, and retail or restaurant worker.

The decline in STEM interest was found across genders and grade levels. Although all examples of STEM careers decreased in popularity, working as a "health professional" remained the most popular career choice (but still declined from 23.1% to 16.0% of all students). Engineer/Architect dropped in rank from second to third (from 10.5% to 8.6%), replaced by "Mechanic/Electrician/Plumber" (from 7.9% to 9.7%), which increased in rank from fourth place. Computer scientist dropped from third to sixth place (from 6.3% to 5.2%), behind Police Officer/Detective/Firefighter (from 9.7% to 6.9%) and Businessperson (from 5.3% to 5.9%).

The decline in STEM interest may be even deeper than what is apparent from student interest alone. Although careers such as engineer and computer scientist remain popular career choices, students increasingly expect to have a career in these fields without a post-secondary degree. Only 62% of students who want a career in engineering or architecture said that they were planning on at least some college or university (a decline from 72% in 2019). Similarly, only 49% of those who say they want to be a computer scientist plan to attend any college or university (down from 63% in 2019). In fact, one group that has expressed increased interest in STEM careers since the pandemic consists of those with the lowest aspirations to attend post-secondary institutions.

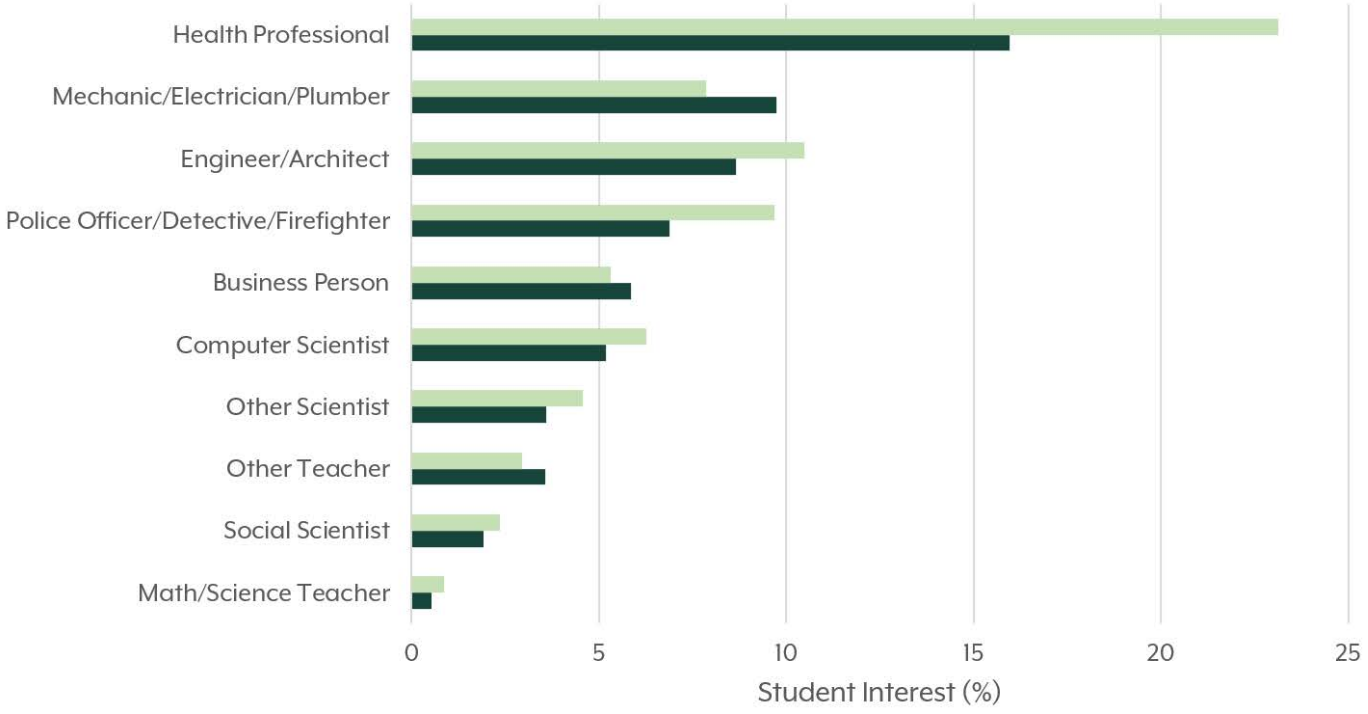
The decline in intent to pursue college-level accreditation was not limited to STEM fields but extends to many careers that generally require a university degree, including social worker, journalist, and advertising professional. Whereas a career in a trade, such as mechanic, electrician, or plumber, can be obtained through on-the-job training and apprenticeships, careers in these fields also often require at least some college-level courses. The number of students who expect to have a career in the trades without attending any college has increased from 64% in 2019 to 72% in 2022.

Regression analysis confirmed that students who have more Internet and social media skills, as well as those who spent more time doing learning from home during the pandemic, are more likely to be interested in a STEM career (Appendix B, Table B5). A student who is even modestly higher in both Internet and social media skills (one s.d. above average) is about 38% more likely to be interested in a STEM career. Compared to a student who rarely did school from home during the pandemic, a student who often did school from home is 37% more likely to be interested in STEM.

When we used regression analysis to identify differences between students in 2019 and 2022 that explain change in STEM interest, we found that the decline was greatest among students in earlier grades (Appendix C, Table C4). In 2022, students from Grades 8 and 9 were 47% less likely, students in Grade 10 were 30% less likely, and students in Grade 11 were 25% less likely to have an interest in STEM, compared to students in the same grades in 2019. Given that learning from home during the pandemic was generally protective of interest in STEM careers, older students who did more learning from home during the pandemic may not have experienced a loss in STEM interest during that time.

The decline in STEM interest among rural students is especially concerning given declining job opportunities in many rural areas, the current and expected growth of jobs in STEM fields, the higher income associated with STEM careers, and the potential benefit of STEM-related industry for the economic development in rural areas and the State of Michigan (Lund et al., 2019). Some school districts are pioneering youth apprenticeship programs in STEM fields, such as cybersecurity, for students who may not intend to attend college or university (TV6, 2023). However, currently, STEM workers are roughly twice as likely as other workers to have earned at least one university degree (Fry et al., 2021). Although there is a trend in some industries to reduce degree requirements, such positions often still require skills that are obtained through at least some post-secondary education. Because the availability of skilled workers was below demand during the pandemic, employers may have only temporarily been willing to accept employees into positions that once had degree requirements (Fuller et al., 2022).

Interest in most popular career choices in 2019 and 2022



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Interest in STEM careers in 2019 and 2022 (%)

	Interest in a STEM Career	
	2019	2022
Overall	**46.3**	**35.9**
Gender		
Male	42.5	32.3
Female	50.0	39.3
Race		
White	47.0	37.0
Person of Color	43.3	30.3
School Grade		
Grade 8	45.5	32.5
Grade 9	46.1	33.4
Grade 10	46.4	38.3
Grade 11	47.2	39.7

Note: N (2019) = 2853, N (2022) = 2831.

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

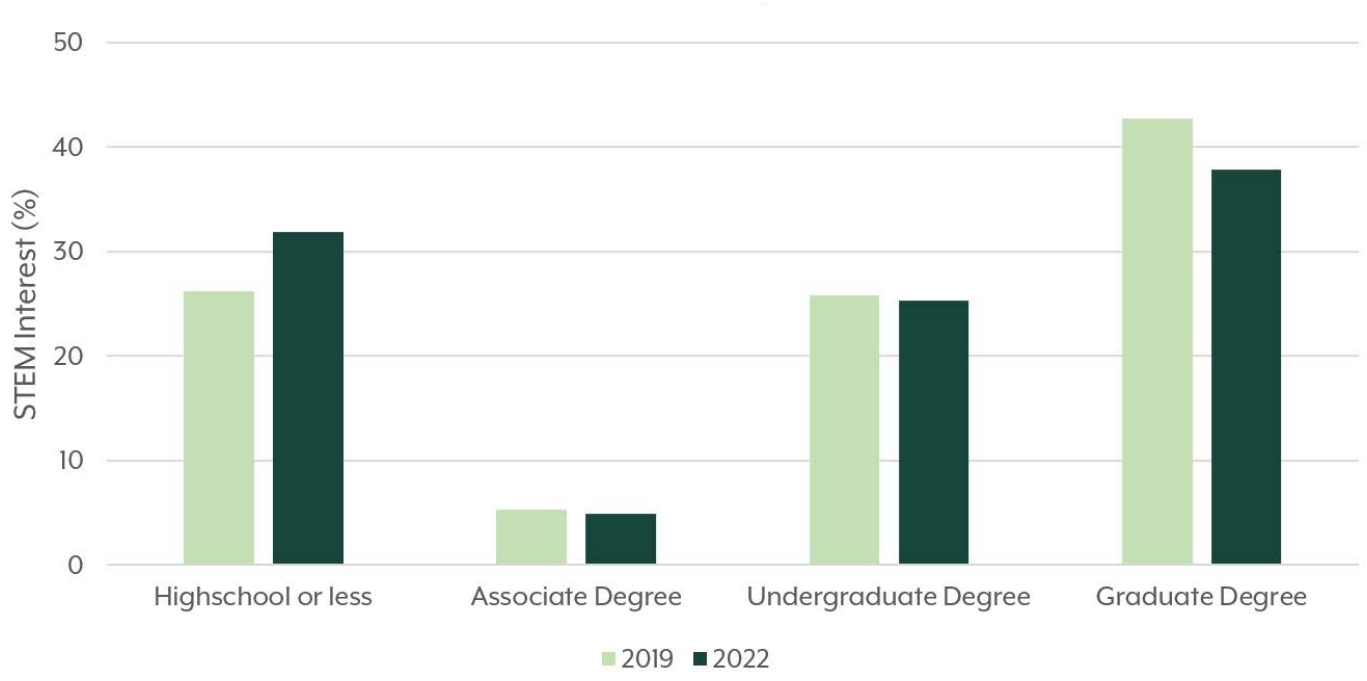
Relationship between educational aspirations and STEM career interest (%)

	Interest in a STEM Career	
	2019	2022
Highschool or less	26.2	31.9
Associate Degree	5.3	4.9
Undergraduate Degree	25.8	25.3
Graduate Degree	42.7	37.8

Note: N (2019) = 2876, N (2022) = 2949.

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Educational aspirations by STEM career interest before and after the COVID-19 pandemic



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Career interests by educational aspirations in 2019 and 2022 (%)

	Career Interest		Educational Aspirations			
			Highschool or less		Some college or above	
	2019	2022	2019	2022	2019	2022
Overall Categories						
Interested in a STEM career	46.3	35.9	26.2	31.9	73.8	68.1
Interested in a NON-STEM career	54.3	58.9	48.6	55.8	51.4	44.2
Specific Careers						
Health Professional	23.1	16.0	24.1	25.7	75.9	74.3
Engineer/Architect	10.5	8.6	28.2	38.4	71.8	61.6
Computer Scientist	6.3	5.2	36.7	51.0	63.3	49.0
Social Scientist	2.4	1.9	17.6	21.1	82.4	78.9
Other Scientist	4.6	3.6	26.7	24.5	73.3	75.5
Math/Science Teacher	0.9	0.5	24.0	18.8	76.0	81.2
Other Teacher	3.0	3.6	28.2	34.3	71.8	65.7
Actor/Dancer/Musician	5.6	4.1	60.5	52.9	39.5	47.1
Other Artist	3.9	3.9	54.0	68.7	46.0	31.3
Police Officer/Detective/Firefighter	9.7	6.9	47.5	52.7	52.5	47.3
Lawyer/Judge	3.3	2.7	22.9	24.1	77.1	75.9
Childcare Worker	1.4	1.1	50.0	59.4	50.0	40.6
Counselor/Social Worker	4.0	2.7	28.4	43.2	71.6	56.8
Journalist/Writer	2.3	2.3	41.5	55.2	58.5	44.8
Marketing/Advertising Professional	1.3	0.9	22.2	32.1	77.8	67.9
Mechanic/Electrician/Plumber	7.9	9.7	63.7	72.1	36.3	27.9
Carpenter/Construction Worker	3.3	3.6	76.6	76.6	23.4	23.4
Farmer/Farm Manager	1.7	2.5	78.0	69.9	22.0	30.1
Factory/Warehouse Worker	0.6	0.4	81.3	69.2	18.7	30.8
Accountant/Insurance Agent/Banker	1.7	1.4	26.0	22.0	74.0	78.0
Realtor	0.6	1.1	23.5	53.1	76.5	46.9
Manicurist/Makeup Artist/Hairstylist	2.1	2.4	73.8	62.5	26.2	37.5
Retail Sales/Hotel Staff	0.1	0.1	75.0	100	25.0	0.0
Cook/Restaurant Staff	2.0	2.8	70.7	64.6	29.3	35.4
Other Customer Service	0.9	0.8	81.5	65.2	18.5	34.8
Businessperson	5.3	5.9	34.6	42.8	65.4	57.2

Note: N (2019) = 2876, N (2022) = 2949. Categories and careers may not sum up to 100%. Some students selected more than one possible career.
Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Classroom Grades

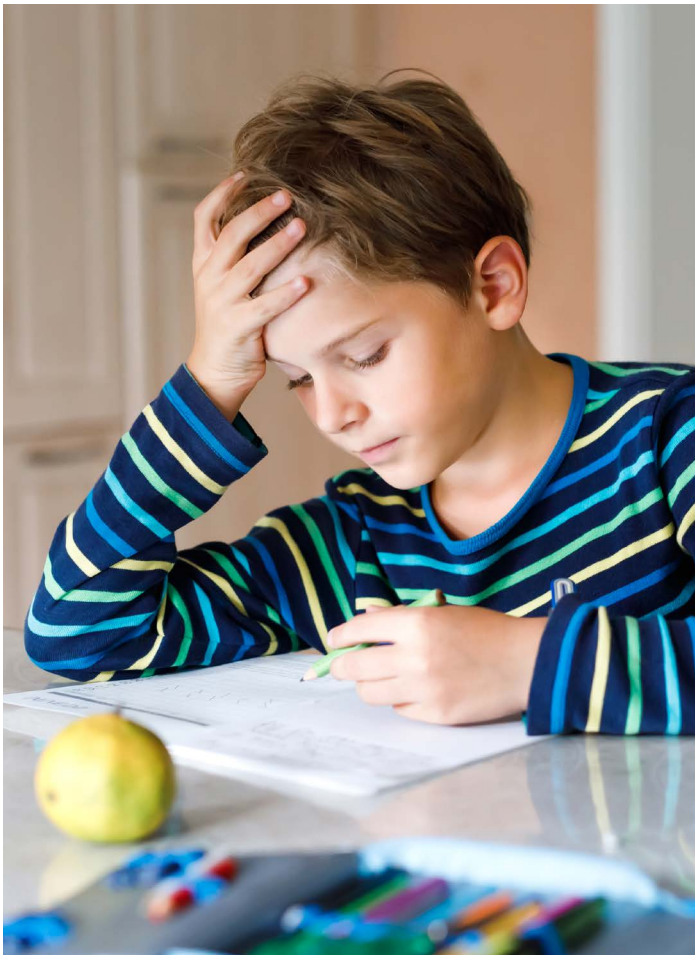
Students who spent more time learning from home during the pandemic did not experience lower classroom grades after their return to the classroom. On average, there has been little change in classroom grades since before the pandemic. This contrasts with reports that there has been a drop in academic achievement on standardized exams (Kuhfeld et al., 2022). The lack of variability in grades likely represents the combined influence of schools and teachers, who have made necessary adjustments to their curricula to account for any individual or grade-level gaps in learning that may have been the result of the pandemic, and preexisting expectations of schools, parents, and students about grade distributions. Whereas average classroom grades have remained relatively constant, there are some important differences related to gender, IEPs, and digital skills.

Students were asked to report their most recent final course grades in English/language arts, history/social studies, math, and science. We combined their grades into three categories: overall, English/social studies, and math/science.

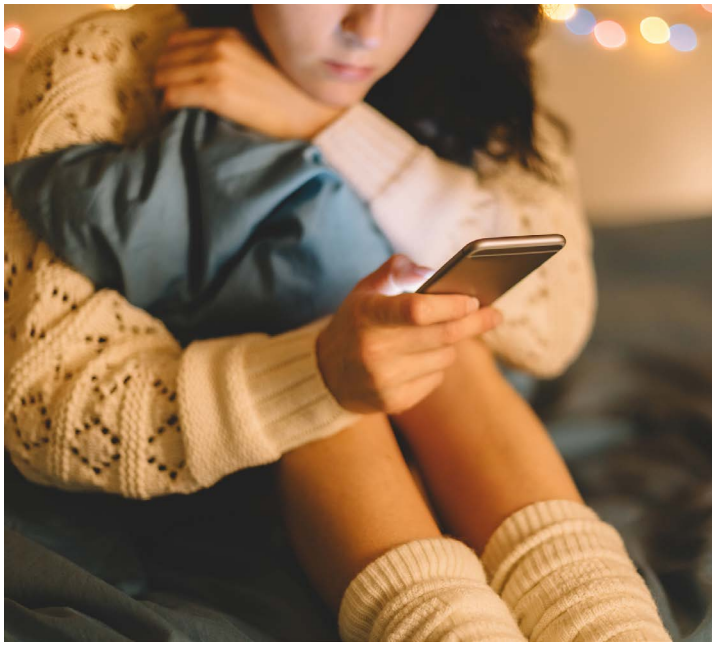
Average classroom grades have not changed since before the pandemic. When we compared average grades from before the pandemic in 2019 to the grades of students in 2022, student grades were nearly identical. On a standard 4.0 scale, students averaged 3.1 (SD=0.9) overall, 3.2 (SD=1.0) in English/social studies, and 3.1 (SD=0.9) in math/science.

Students who spent more time learning from home during the pandemic (in 2020-21) tended to have average classroom grades in 2021-22 that were no higher or lower than their peers who spent more time in school (Appendix B, Table B3). However, as we also observed before the pandemic, students who have no home Internet access received lower classroom grades (Hampton et al., 2020). On average, compared to a student with no home Internet, a student with broadband Internet access had a GPA that was 0.7 higher in English/Social Studies, 0.4 higher in math/science, and 0.6 higher overall. For many students, this could be the difference between a B- and a B+ average. We also found that students with higher digital skills, particularly social media skills, tended to report slightly higher grades in English/social studies. A student with higher social media skills (one s.d. above the mean) tended to have a GPA that was .08 higher (out of 4.0) in English/social studies.

We used regression analysis to explore how different variables were related to differences in student grades since 2019 (Appendix C, Table C2). We found that in 2022, students who had slower than broadband Internet access continued to perform worse in English/social science, but not as poorly as students did in 2019. We also found that girls' classroom grades have declined relative to boys' grades. This trend is likely the combination of a small increase in average grades for boys and a small decline in average grades for girls. Boys also averaged higher digital skills, which then may have a stronger relationship to grades for boys than girls. When compared to the 2018-19 school year, girls scored lower in English/social studies (-.11 GPA) and math/science (-.12) in the 2021-22 school year. Overall, the average GPA for girls was -.11 lower than in 2018-19. However, girls still tended to receive higher grades than boys in all subject areas that we measured. We also found that students who have an IEP received lower grades in math/science (-.18 GPA) compared to before the pandemic.

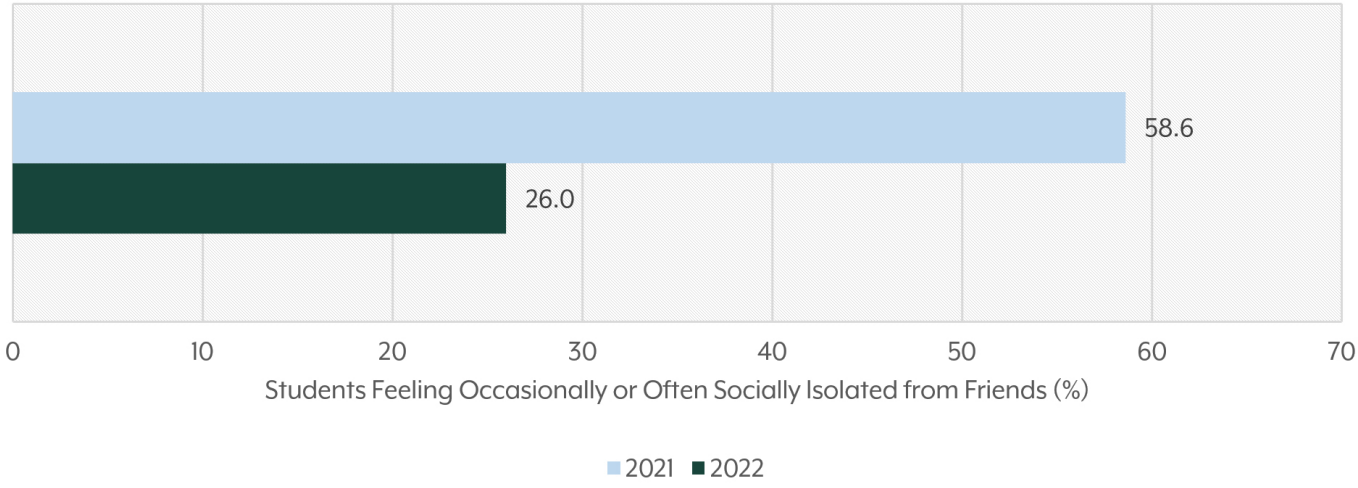


Well-Being During and After the Pandemic



As students pivoted to learning from home during the pandemic, there was concern that this shift could have a lasting, negative impact on students' well-being. We found a statistically significant, but substantively trivial decline in the self-esteem in 2022 in comparison to before the pandemic. Although it was very high in the 2020-21 school year, students' feelings of isolation from friends — particularly among girls — had substantively declined by 2022. In comparison to young people in 2019, youth now reported spending more time in person with friends but less time with family. Young people who have better home Internet connectivity feel less isolated from friends, spend more time in person with friends, and spend more time with family. Those with more digital skills also spend more time with friends and family, and those who spend more time on social media see their friends in person more often.

Feelings of social isolation among rural Michigan students



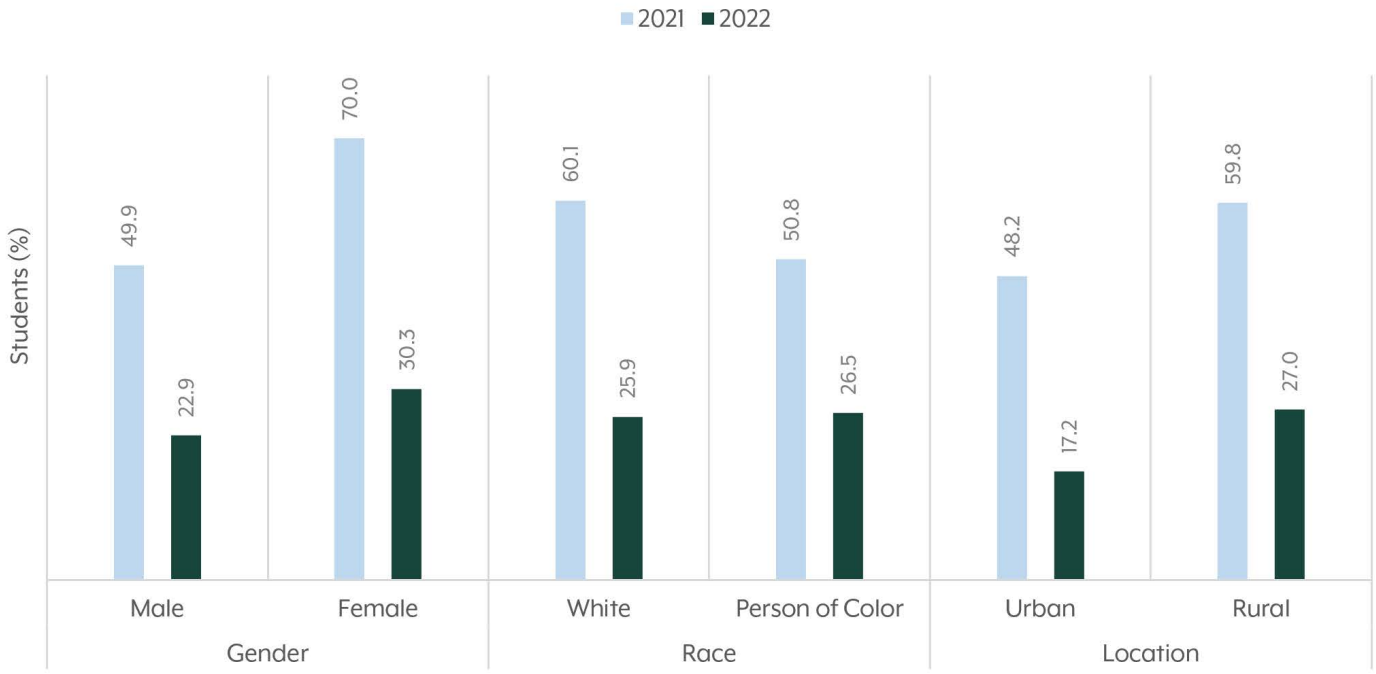
Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Social Isolation

We asked students to think back to the 2020-21 school year and whether they had felt isolated from their friends. Most students (58.6%) reported that they often or occasionally felt isolated. Feelings of isolation from peers were much higher among girls. Seventy percent of girls but only 50% of boys felt socially isolated. Similarly, students in rural areas were more likely to feel isolated (60%) than those in even small urban areas in our sample (48%). By the end of 2021-22 school year, feelings of social isolation had declined across all demographics so that only 26% of students often or occasionally felt isolated from friends.

Regression analysis confirmed that rates of social isolation remained higher among girls and those in the most rural areas in 2022 (Appendix B, Table B6). Feelings of social isolation were 66.5% higher among girls compared to boys, whereas those living in predominantly rural areas were 40.5% more likely than those in small urban areas to feel isolated.

Feeling socially isolated in 2021 and 2022



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Students who spent more time learning from home during the pandemic were no more or less likely to report feelings of isolation in 2022. Those who relied on a cell phone to access the Internet from home and those who watched more television (one s.d. above average or about three hours in total watching TV per day) also reported feeling 58.4% and 13% more isolated from friends, respectively. There was no relationship between feelings of isolation and the use of any other media, including social media.

Our findings are consistent with related research conducted by the U.S. Center for Disease Control and Prevention (CDC) on the impact of the COVID-19 pandemic on high school students in the 2020-21 school year (Center for Disease Control and Prevention, 2022). Like the CDC, we found an alarming rate of a sense of social isolation in 2020-21. However, our more recent data from 2022 suggest that adolescent mental health is improving from pandemic lows. We find that there was no relationship between learning from home during the pandemic and feelings of isolation a year later.

Feeling isolated in 2019 and 2022 (%)

	Felt Isolated from Friends	
	2021	2022
Overall	**58.6**	**26.0**
Gender		
Male	49.9	22.9
Female	70.0	30.3
Race		
White	60.1	25.9
Person of Color	50.8	26.5
Location		
Small Urban Area	48.2	17.2
Rural	59.8	27.0

Note: N (2021) = 2909, N (2022) = 2934.

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Time with Friends and Family

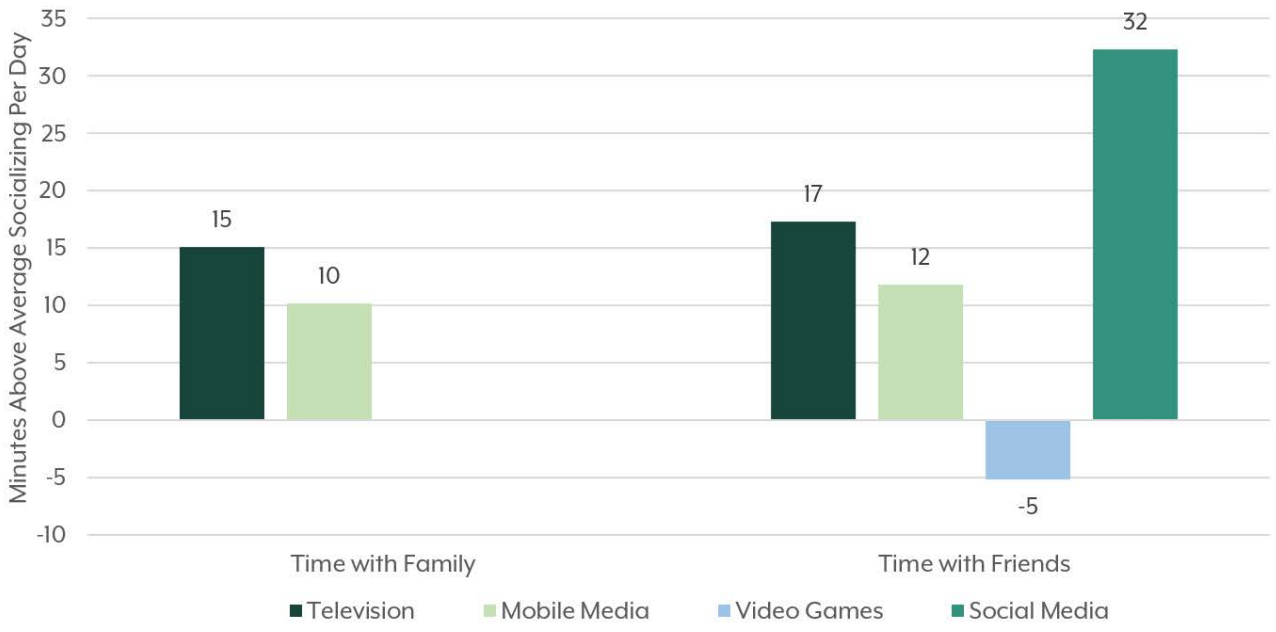
In 2019 and again in 2022, we asked students to report the amount of time spent on a typical weekday in person with family and with friends.

In 2019, the average student reported spending 2.54 (s.d.=1.76) hours with family and 2.50 (s.d.=1.86) hours with friends. In 2022, students reported slightly less time spent with family, 2.66 (s.d.=1.81) hours, and slightly more time spent with friends, 2.75 (s.d.=1.95) hours.

Regression analysis confirmed that in 2022, students who had slower home Internet spent less daily in person time with family (about eleven minutes) but not with friends (Appendix B, Table B7). Adolescents who had even modestly lower Internet skills (one s.d. below average) also spent less time with family (about five minutes) and friends (about fifteen minutes). Young people with even modestly more social media skills (one s.d. above average) reported spending about five extra minutes per day in person with their friends. Similarly, young people who spent more time on social media reported more, not less time with friends. In fact, students who spent above average time on social media (one s.d. above average, or around four and one-half hours per day) spent roughly thirty-two more minutes hanging out in person with friends. Similarly, time spent watching television and watching movies on mobile, streaming devices were associated with more time spent with family and friends. Even spending a modestly above average time watching mobile videos/movies and watching television (one s.d. above the average) relates to roughly twelve and seventeen more minutes respectively hanging out in person with family and ten and fifteen more minutes respectively with friends. In contrast, time spent playing video games was found to have a slight negative relationship to time spent with family. However, a student who played more video games than the average (one s.d. above the mean, or almost four hours a day typically spent roughly five minutes less per day in person with family.

An exploratory regression analysis focused on identifying differences between students in 2019 and 2022 confirmed that young people are now spending more time with friends — an additional fourteen minutes per day — than before the pandemic and less time with family (Appendix C, Table C5). Although the average young person spends about thirty-eight minutes less per day with family than they did in 2019, the loss was marginally lower within families in which parents had higher levels of education. For example, a family in which a parent/guardian had a university degree compared to a high school diploma, tended to spend twelve more minutes together. Similarly, in families where young people watched more streaming services on mobile devices, they tended to spend more time with family (presumably watching together); at one s.d. above average, or one hour and forty-five minutes more time watching movies per day, this equates to eight minutes more with family.

Relationships between heavy media use and socializing with family and friends in 2022



Note: Values are based on regression analysis coefficients in Table B7.

Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

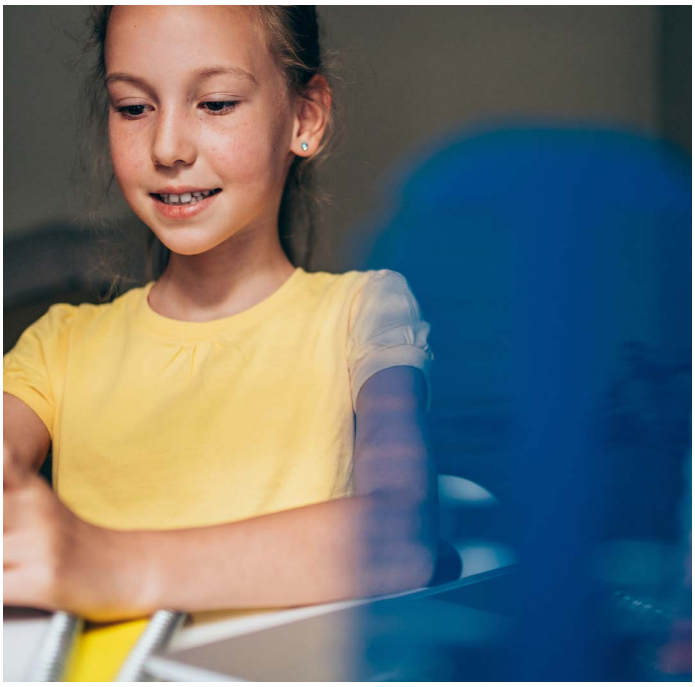
Self-Esteem

As a measure of self-esteem, in 2019 and again in 2022, students completed a multidimensional measure of adolescent self-esteem. The Self-Esteem Questionnaire (SEQ) includes eight questions and has been validated as an assessment of global feelings of self-worth that includes dimensions of body image, peer relations, family, school, and sports/athletics self-esteem (DuBois et al., 1996). This measure positively predicts perceived social support and negatively predicts daily stressors/hassles and negative life events. Higher values correspond to higher self-esteem.

Self-esteem was largely unchanged after the pandemic. In our population, average self-esteem went from a mean of 1.83 (s.d. 0.60) in 2019 to 1.80 (s.d. 0.59) in 2022. A regression analysis comparing students in 2019 and 2022 confirmed that although the observed drop in self-esteem was statistically significant, the decline was likely trivial in magnitude (Appendix C, Table C6).

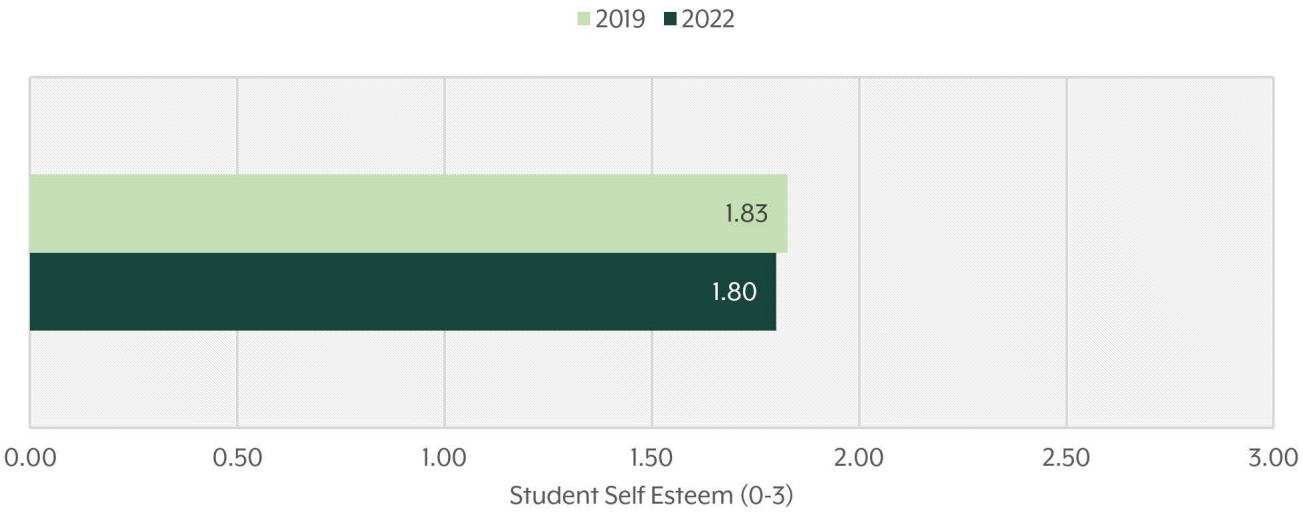
Students who spent more time learning from home during the pandemic in the 2020-21 school year reported slightly lower self-esteem in 2022 (Appendix B, Table B8). The difference between a student who rarely learned from home and one who often did learn from home in the 2020-21 school year was .04 on our four-point scale of self-esteem. Again, although statistically significant, the magnitude of this difference was not substantive.

Students who had slower Internet connections at home had slightly lower self-esteem (-0.08). Students who spent more time surfing the Web and on social media also reported slightly lower self-esteem. A student who spent modestly more time on the Web (one s.d. above



average or 2.4 total hours per day) tended to score .04 lower on our measure of self-esteem. Similarly, spending roughly two hours above average on social media (one s.d. above the mean, or 4.7 total hours per day) is associated with scoring .03 lower in self-esteem. Again, the magnitude of these relationships was very small to trivial. A detailed analysis of trends in self-esteem from our 2019 survey revealed that these relationships tend to be gender specific and that time on screens has almost no substantive impact on the self-esteem of most adolescents (Hampton & Shin, 2022).

Adolescent self-esteem before and after the COVID-19 pandemic



Source: Quello Center, *Broadband and Student Performance Gaps After the COVID-19 Pandemic*

Broader Implications and the Need for New Action

Our study shows the ability of school districts, government, and private sector players to work together in times of crisis and to mitigate many of its impacts. But it also shows the constraints and limitations of such emergency measures and points to several challenges that must be addressed going forward. Some of these challenges are related to finding sustainable solutions to improving access to reliable broadband. However, our study also hints to other aspects that may need to be addressed to fully harness the potential benefits of broadband in educational settings.

The persistence of discrepancies in access to reliable broadband at home, especially in rural America and among vulnerable populations, was known long before the COVID-19 pandemic forced students to learn from home. Our work with school districts before the pandemic provided detailed evidence of the multifaceted pattern of interactions between broadband connectivity and educational outcomes for K-12 students (Hampton et al. 2020). It showed particularly the relevance of factors in addition to the availability and quality of access to broadband. Even if infrastructure and gaps in device access can be addressed in the coming years, it will be important to develop comprehensive approaches to utilizing the benefits of digital connectivity to improve K-12 education.

During the pandemic, collaboration between school districts, state and federal governments, the private sector, and volunteers alleviated access gaps but it could not eliminate digital access divides. Programs in response to the pandemic provided temporary and partial relief but no long-term, sustainable solutions. In response, additional federal and state initiatives were initiated to expand broadband networks to unserved and underserved locations. Moreover, programs were increased to support the ability of low-income households to buy broadband services. However, several challenges remain. It will take several years to complete infrastructure programs, and the programs that support affordability are currently not funded beyond the spring of 2024.

Our data suggest that between 2019 and 2022, households also adjusted their preferences and spending priorities. In places where school programs to loan tablets and notebooks declined, access to devices and device ownership did not decline equally. During the pandemic, it became abundantly clear that broadband was a necessity and not just a convenience or even luxury. It seems plausible that changes in user behavior reflect the perceived increase of the value of broadband access. One would expect that this is associated with a reallocation of household expenses in favor of broadband, even among low-income populations. Our data seems to indicate such a shift possibly at considerable hardship for resource-constrained households. These changes in user decisions alleviated some of the negative impact of reduced support by schools during the later phases of the pandemic. At the same time, lower income households are more limited in making such adjustments and therefore more likely to experience renewed disadvantages. Thus, additional efforts are needed.

At the federal level, the most important and far-reaching set of measures are the programs authorized in the Infrastructure Investment and Jobs Act (IIJA) 2021. The Broadband Equity, Access, and Deployment program (BEAD) will allocate $42.45 billion to the states to bring high-speed Internet to currently unserved locations and to improve the quality of connectivity in locations that are currently considered "underserved" (that is, they receive broadband access below 100 Mpbs upload and 20 Mbps download). On June 26, the U.S. Department of Commerce announced that Michigan will receive $1.56 billion to connect unconnected locations and use remaining funds to improve the access speeds of those that are currently underserved. In addition, IIJA and earlier programs appropriated funds to support middle mile infrastructure.[10] These programs complement previous initiatives, including Connect America Fund subsidies, Rural Digital Opportunities Fund (RDOF) support, and other initiatives.

Michigan benefited from several grants from these programs. In May 2022, Merit Network received a $5.3 million grant to build seventy miles of fiber optical network infrastructure in the Eastern Upper Peninsula. Later that year, the National Telecommunications and Information Administration (NTIA) awarded $10.5 million from the Broadband Infrastructure Program to Michigan State University and Merit Network to upgrade the existing statewide middle mile network. A recent $61 million NTIA grant to Peninsula Fiber Network (OFN) will facilitate the construction of 535 miles of middle mile fiber in the Upper Peninsula.[11] In February 2023, Alpha Enterprises received a $19.5 million award from the ReConnect program administered by the U.S. Department of Agriculture to connect 1,023 residential locations, nineteen businesses, and ten farms to a fiber network in Chippewa and Mackinac counties in the Upper Peninsula.[12]

Federal funding also benefited regional and local initiatives in the Eastern Upper Peninsula (EUP). The members of the EUPConnect Collaborative[13] pooled nearly $750,000 from American Rescue Plan (ARPA) and Elementary and Secondary School Emergency Relief (ESSER) funds. The collaborative facilitates the provision of high-speed Internet to all households in the tri-county area of Chippewa, Luce, and Mackinac county. Federal funding also benefited the tribal communities in the tri-county region. In September 2022, the Sault Ste. Marie Tribe of Chippewa Indians was awarded a $25 million grant from the Rural Utility Serivces' ReConnect program.[14] In April 2023, the Bay Mills Indian Community received $499,850 from the NTIA Tribal Broadband Connectivity Program to support broadband infrastructure deployment. $500,000 were awarded by the same program to the Sault Ste. Marie Tribe of Chippewa Indians to support broadband use and adoption.[15] In 2022, the State of Michigan received funding from the Capital Projects Fund, administered by the U.S. Department of the Treasury. That allocation supports the $238 million Realizing Opportunity with Broadband Infrastructure Networks (ROBIN) program, a competitive program to extend broadband infrastructure and service to locations currently lacking access to at least 100/20 Mbps.

[10] https://statescoop.com/heres-how-much-every-state-is-getting-from-bead-grant-program/

[11] https://www.michigan.gov/leo/news/2023/06/16/whitmer-announces-michigan-wins-funding-to-build-525-miles-of-high-speed-internet

[12] https://www.rd.usda.gov/newsroom/news-release/biden-harris-administration-invests-195-million-high-speed-internet-rural-michigan

[13] https://www.eupschools.org/eupconnect for a list of the members of the collaborative.

[14] https://www.saulttribe.com/newsroom/7852-sault-tribe-awarded-25-million-in-federal-grant-dollars-to-expand-broadband-access-on-tribal-lands

[15] https://broadbandusa.ntia.doc.gov/funding-programs/tribal-broadband-connectivity

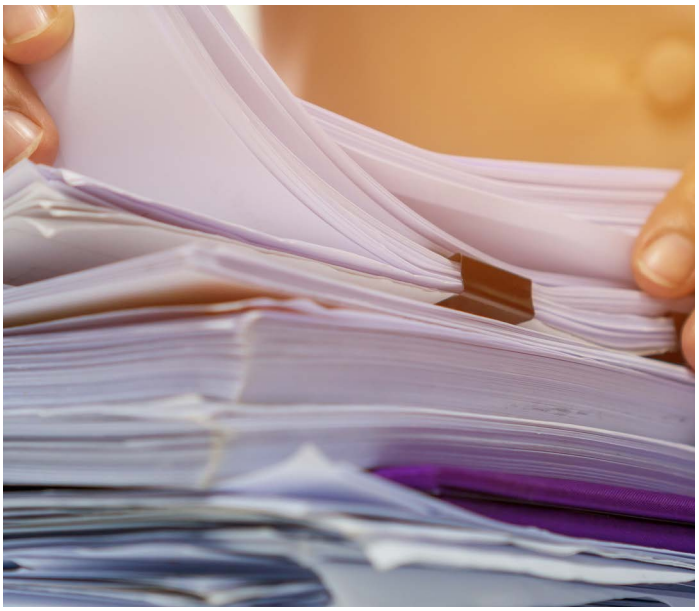
Initial Grant Recommendations (IRGs) were announced on June 20, 2023 and are now subject to a challenge process until August 4, 2023.[16] Finalists are expected to provide 100/100 Mbps service to approximately 100,000 unserved locations throughout the state. Projects are expected to be completed within a three-year timeline, by the end of the 2026 fiscal year.

These programs are complemented by measures aimed at making broadband more affordable. In response to the pandemic, the Federal Communications Commission (FCC) established the Emergency Broadband Benefit (EBB) program to supplement the previously existing Lifeline program. As part of the IIJA, the U.S. Congress appropriated $14.4 billion for the Affordable Connectivity Program (ACP), which provides a $30 per month discount toward internet service for eligible households that are at or below 200% of the federal poverty line and meet other criteria.[17] The program supports up to $75 per month for households on eligible Tribal lands. If they contribute between $10 and $50 themselves, eligible households can also receive a one-time benefit of up to $100 to purchase a laptop, desktop, or tablet from a participating provider.

The programs that subsidize network investment and those that support eligible users mutually reinforce each other. Recipients of investment subsidies typically participate in ACP and Lifeline, because these programs help sustain their revenue stream and render projects commercially viable. Providers receiving funding under the network investment programs therefore participate in demand-side programs designed to make service more affordable for users. All of these measures aim to narrow broadband access and affordability gaps. Nonetheless, there is an abundance of funding programs with a variety of aims, eligibility conditions, timelines, and evaluation conditions. This raises the question of whether the funds are used most effectively and in ways that maximize their impact.

Because infrastructure investment is time-consuming and slow, there will be a multi-year transition period during which rural and marginalized populations will continue to experience gaps in network access. At least during this transition period, additional measures are needed to temporarily close the prevailing gaps. Schools currently have no mechanisms in place to identify students who lack access. Even if classes meet in person, appropriate planning for the next six to ten years is therefore critical to avoid cascading disadvantages for the affected locations and populations as more and more educational functions and school-related services migrate online. For the likely transition period, a continuation of the loaner device and hotspot programs might work. Likewise, schools could work with parents to make sure they are signed up for eligible support programs, such as ACP. As of 2023, only 40.2% of eligible households in Michigan have signed up for ACP.[18]

Our data also suggest that technology support and device maintenance played an increasing role over time. The Digital Equity Act of 2021, passed as part of the IIJA, acknowledges this challenge and appropriates funds to provide technology support. States are required to assess the effectiveness of measures in fulfillment of this goal. Again, the timeline is a challenge, because these programs will be rolled out only gradually beginning in 2024. In the meantime, several communities across the state have experimented with digital navigators - individuals who assist users with obtaining the most affordable broadband connectivity with managing devices and software and device maintenance. Often, schools and libraries serve this function as a default. There is a need to establish a coordinated, effective technology support infrastructure, perhaps in a resource-sharing model across schools and possibly school districts.



Online learning during the pandemic was considered by many as a back-up, second-best alternative to in-class learning. Our pre-pandemic study revealed a positive association between online activities and digital skills, which, in turn, were positively associated with standardized test scores (Hampton et al., 2021). Our work during the pandemic corroborated these findings. Students with more online learning have higher digital skills with their associated benefits. This suggests that there is a need for a reconsideration of the role of digital technology and online learning in K-12 education.

[16] https://www.michigan.gov/leo/news/2023/06/20/unserved-homes-and-businesses-to-connect-to-high-speed-internet-throughinitial-grant-recommendations

[17] https://www.fcc.gov/acp

[18] https://acpdashboard.com/

It seems to be desirable to integrate online modes of learning more proactively into the standard curriculum. We reiterate our call from the first study to develop explicit standards and approaches to support the development of digital skills as part of the K-12 curriculum. We also encourage schools and parents to lessen restrictions on unstructured use of devices and home Internet access. We have found that digital skills benefit from everyday lived experiences using a variety of digital media (Hampton et al., 2021).

Rethinking how in-class and online learning can be integrated is an important component to building education systems that are more resilient in the face of possible future, disruptive emergencies. Although it is most likely not possible to prepare fully for unanticipated events, embracing and integrating online learning will be an important component of any effective approach, in addition to the benefits it creates for digital skills. This requires sustained and concerted efforts to close the remaining gaps in connectivity and access to appropriate devices, to develop complementary digital literacy, and the coordinated development of social and technical support infrastructures. It will also require additional efforts to rebuild interest in STEM careers and in post-secondary education. Several innovative experiments are unfolding across the state. One example is the establishment of a youth-registered apprenticeship program in Dickinson County.[19] The Digital Equity Act also appropriated funding for sustained training and life-long education programs to improve digital literacy and skills which could complement K-12 programs.

Because the pending infrastructure programs will take six to ten years to completion, sustained measures are needed to minimize digital discrepancies during this long transition period. Schools, school districts, government, the private sector, non-profit organizations, educators, and parents are all called to contribute. Ideally all these stakeholders would align their activities, each acting where they can be most effective to achieve the best overall outcomes.

[19] https://wzmq19.com/news/313409/michigan-launches-first-youth-registered-apprenticeship-program-in-cybersecurity-pathway/.

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Appendix A: District Demographics

Demographic information on participating school districts

District	Population	Housing density[a]	Students in grades 8-11[b]	Median household income	Families below federal poverty level
Capac Community Schools	8,970	35.08	271	$81,840	4.8%
DeTour Area Schools	1,904	7.41	33	$50,313	9.4%
East China Schools	29,076	99.55	1346	$73,171	5.0%
Les Cheneaux Community Schools	2,167	20.07	65	$57,188	8.9%
Mackinac Island Public Schools	1,025	249.18	25	$60,500	8.7%
Memphis Community Schools	5,630	37.43	251	$82,946	3.6%
Pickford Public Schools	3,210	6.61	163	$62,604	5.4%
Rudyard Area Schools	7,851	7.18	198	$53,327	19.4%
Sault Ste. Marie Area Schools	20,128	35.74	760	$52,659	12.2%
St. Ignace Area Schools	3,548	13.98	190	$49,688	11.4%
Tahquamenon Area Schools	6,584	4.40	172	$50,000	8.5%
Whitefish Township Schools	500	4.93	19	$54,844	6.0%
Yale Public Schools	10,890	29.15	584	$62,932	11.6%

[a] Housing units per square mile. 2021 American Community Survey.
[b] Michigan Department of Education, & Center for Educational Performance and Information. (2021/2022). MI School Data: K-12 School Data Files: https://www.mischooldata.org/

Appendix B: MLM Regression Tables

Table B1: MLM (logistic) regression on student technology problems

	Problems with Tech at Home
	2021
	b
Controls	
Female	0.14
Single Parent Household	0.02
Person of Color	0.03
IEP	0.23
Parent Highest Edu (*Years*)	-0.03 *
Grade 9 [a]	-0.20
Grade 10	0.01
Grade 11	-0.16
Home Internet [b]	
None	1.34 ***
Cell Only	1.34 ***
Slow	1.19 ***
Digital Skills	
Internet Skills (0-32)	0.01
Social Media Skills (0-28)	-0.01
School From Home 2021 (0-3)	0.25 ***
Intercept	-1.31 ***
R-Squared *(%)*	11.40 ***

*p<.05, **p<.01, ***p<.001
Within Level N (2021/2022) = 2684, Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table B2: MLM regression on digital skills

	Overall Digital Skills		Internet Skills		Social Media Skills	
	2022	2019	2022	2019	2022	2019
	b	*b*	*b*	*b*	*b*	*b*
Controls						
Female	0.55	-0.71	-2.06***	-2.62***	2.60***	1.92***
Single Parent Household	1.61***	1.03*	0.97***	0.64*	0.65**	0.38
Person of Color	-0.94	0.40	-0.61	0.43	-0.34	-0.02
IEP	-2.68***	-4.03***	-0.74*	-1.45***	-1.95***	-2.59***
Parent Highest Edu (*Years*)	0.34***	0.49***	0.21***	0.27***	0.13**	0.22***
Grade 9 [a]	1.89**	1.12	0.92*	1.21*	0.98*	-0.09
Grade 10	4.34***	2.62**	2.57***	1.98***	1.78**	0.64
Grade 11	5.02***	3.64***	3.05***	2.97***	1.98***	0.68
Home Internet [b]						
None	-4.11*	-2.34*	-0.65	-0.54	-3.42***	-1.80**
Cell Only	-2.88*	-3.39***	-1.17	-2.31***	-1.66*	-1.07
Slow	-1.45*	0.01	-0.60	0.02	-0.81*	0.00
Time on Media (hrs/day)						
Television (0-5.5)	-1.05***	-1.26***	-0.46***	-0.73***	-0.59***	-0.54***
Mobile Videos/Movies (0-5.5)	0.40**	0.15	0.04	0.04	0.36***	0.11
Video Games (0-5.5)	1.31***	0.99***	0.86***	0.71***	0.46***	0.28***
Web Browsing (0-5.5)	1.44***	1.23***	1.01***	0.83***	0.42***	0.40***
Social Media (0-5.5)	0.22	0.62***	-0.19**	-0.10	0.41***	0.72***
School from Home 2021 (0-3)	1.42***	-	0.55***	-	0.87***	-
Intercept	20.73***	22.32***	5.74***	6.00***	15.08***	16.33***
R-Squared (%)	13.90***	12.80***	15.00***	16.50***	14.20***	11.90***
ICC (%)	0.20	1.10	0.40	1.10	0.30	1.20

*p<.05, **p<.01, ***p<.001
Within Level N (2019) = 2553. Within Level N (2022) = 2684. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table B3: MLM regression on grade point average (GPA)

	Overall GPA		Math/Science GPA		English/Social Studies GPA	
	2022	**2019**	**2022**	**2019**	**2022**	**2019**
	b	***b***	***b***	***b***	***b***	***b***
Controls						
Female	0.19***	0.36***	0.15***	0.32***	0.24***	0.39***
Single Parent Household	-0.27***	-0.34***	-0.24***	-0.31***	-0.30***	-0.38***
Person of Color	-0.17***	-0.22***	-0.17***	-0.24***	-0.17***	-0.21***
IEP	-0.32***	-0.14**	-0.37***	-0.13*	-0.27***	-0.15**
Parent Highest Edu (*Years*)	0.07***	0.06***	0.07***	0.06***	0.07***	0.06***
Grade 9 [a]	0.07	-0.11	0.02	-0.14	0.13	-0.07
Grade 10	-0.01	0.02	-0.06	-0.03	0.06	0.07
Grade 11	0.19*	0.07	0.15*	-0.01	0.23*	0.13
Home Internet [b]						
None	-0.36***	-0.12**	-0.27*	-0.06	-0.46***	-0.18***
Cell Only	-0.12	-0.31***	-0.15	-0.31***	-0.08	-0.31***
Slow	-0.07	-0.06	-0.08	-0.04	-0.06	-0.09*
Digital Skills						
Internet Skills (0-32)	0.00	0.00	0.00	0.00	0.00	0.00
Social Media Skills (0-28)	0.01*	0.01*	0.00	0.01*	0.01***	0.01
School from Home 2021 (0-3)	0.03	-	0.03	-	0.03	-
Intercept	2.14***	2.30***	2.15***	2.31***	2.13***	2.29***
***R-Squared** (%)*	14.8***	18.10***	11.5***	14.20***	14.0***	16.80***
***ICC** (%)*	2.5	3.8	1.8	3.5	3.4	4.4

*p<.05, **p<.01, ***p<.001
Within Level N (2019) = 2553. Within Level N (2022) = 2684. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table B4: MLM (logistic) regression on educational aspirations

	Intention to Attend University or Higher	
	2022	**2019**
	b	***b***
Controls		
Female	0.88 ***	0.81 ***
Single Parent Household	-0.24 *	-0.44 ***
Person of Color	-0.25 *	-0.16
IEP	-0.36 ***	-0.39 ***
Parent Highest Edu (*Years*)	0.16 ***	0.15 ***
Grade 9 [a]	-0.02	-0.20
Grade 10	0.22	0.25
Grade 11	0.60 **	0.62 ***
Home Internet [b]		
None	-0.33	-0.22
Cell Only	-0.43	-0.43 ***
Slow	-0.07	-0.18
Digital Skills		
Internet Skills (0-32)	0.02 ***	0.02 *
Social Media Skills (0-28)	0.02 *	0.03 ***
School from Home 2021 (0-3)	0.07	-
Intercept	-2.76 ***	-1.93 ***
R-Squared *(%)*	17.90 ***	17.30 ***

*p<.05, **p<.01, ***p<.001
Within Level N (2019) = 2529. Within Level N (2022) = 2684. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table B5: MLM (logistic) regression on interest in a STEM career

	STEM Career Interest	
	2022	**2019**
	b	***b***
Controls		
Female	0.28**	0.37***
Single Parent Household	-0.23**	-0.12
Person of Color	-0.07	0.01
IEP	-0.08	-0.16
Parent Highest Edu (*Years*)	0.08***	0.07***
Grade 9 [a]	0.03	-0.13
Grade 10	0.19	0.00
Grade 11	0.22	0.01
Home Internet [b]		
None	0.12	-0.01
Cell Only	-0.27	-0.29*
Slow	-0.01	0.02
Digital Skills		
Internet Skills (0-32)	0.02***	0.01
Social Media Skills (0-28)	0.02*	0.01
School from Home 2021 (0-3)	0.16***	–
Intercept	-2.19***	-1.22***
R-Squared *(%)*	6.30***	3.50***

*p<.05, **p<.01, ***p<.001
Within Level N (2019) = 2529. Within Level N (2022) = 2684. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table B6: MLM (logistic) regression on feeling isolated in 2022

	Felt Isolated from Friends
	b
Controls	
Female	0.51***
Single Parent Household	0.02
Person of Color	0.24
IEP	0.37**
Parent Highest Edu (*Years*)	0.00
Rurality	0.34*
Grade 9[a]	0.00
Grade 10	0.07
Grade 11	0.09
Home Internet[b]	
None	-0.17
Cell Only	0.46*
Slow	0.14
Digital Skills	
Internet Skills (0-32)	0.01
Social Media Skills (0-28)	-0.01
Time on Media (hrs/day)	
Television (0-5.5)	0.08*
Mobile Videos/Movies (0-5.5)	-0.04
Video Games (0-5.5)	0.03
Web Browsing (0-5.5)	0.04
Social Media (0-5.5)	0.02
School from Home 2021 (0-3)	0.00
Intercept	-1.88***
***R-Squared** (%)*	3.80***

*p<.05, **p<.01, ***p<.001
Within Level N = 2684. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table B7: MLM regression on time spent socializing with family and friends (hrs/day)

	Socializing with Family		Socializing with Friends	
	2022	2019	2022	2019
	b	*b*	*b*	*b*
Controls				
Female	0.09	0.10	-0.04	-0.01
Single Parent Household	-0.31 ***	-0.38 ***	-0.03	0.01
Person of Color	-0.04	0.10	-0.08	0.01
IEP	0.05	0.21 **	0.05	0.18 *
Parent Highest Edu (*Years*)	0.03 *	-0.01	0.02	0.01
Grade 9 [a]	-0.12	-0.09	-0.09	-0.08
Grade 10	-0.27 *	-0.04	-0.33 *	-0.25 *
Grade 11	-0.19	-0.34 ***	-0.26	-0.23 **
Home Internet [b]				
None	-0.25	-0.13	-0.02	0.06
Cell Only	-0.03	-0.28	0.12	-0.09
Slow	-0.19 *	-0.16 *	-0.07	-0.24 ***
Digital Skills				
Internet Skills (0-32)	-0.01 *	-0.01	-0.03 **	-0.02 ***
Social Media Skills (0-28)	0.01	0.00	0.01 **	0.02 **
Time on Media (hrs/day)				
Television (0-5.5)	0.19 ***	0.24 ***	0.16 ***	0.13 ***
Mobile Videos/Movies (0-5.5)	0.11 ***	0.06 *	0.10 ***	0.09 ***
Video Games (0-5.5)	-0.05 *	-0.05 **	-0.01	0.01
Web Browsing (0-5.5)	0.06 *	0.02	0.03	-0.01
Social Media (0-5.5)	0.04	0.08 **	0.28 ***	0.31 ***
School from Home 2021 (0-3)	0.01	-	0.04	-
Intercept	2.50 ***	2.89 ***	2.68 ***	2.59 ***
***R-Squared** (%)*	7.90 ***	9.20 ***	16.00 ***	17.50 ***
***ICC** (%)*	0.00	0.50	0.00	0.10

*p<.05, **p<.01, ***p<.001
Within Level N (2019) = 2529. Within Level N (2022) = 2684. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table B8: MLM regression on self-esteem

	Self-Esteem	
	2022	2019
	b	*b*
Controls		
Female	-0.33***	-0.35***
Single Parent Household	-0.07*	-0.08***
Person of Color	0.00	-0.05
IEP	0.06	0.07*
Parent Highest Edu (*Years*)	0.01	0.00
Grade 9 [a]	-0.01	-0.06
Grade 10	-0.04	0.01
Grade 11	0.01	-0.03
Home Internet [b]		
None	-0.07	-0.12
Cell Only	-0.08	-0.15***
Slow	-0.08***	-0.14***
Time on Media (hrs/day)		
Television (0-5.5)	0.02*	0.01
Mobile Videos/Movies (0-5.5)	-0.01	-0.01
Video Games (0-5.5)	-0.02	-0.02
Web Browsing (0-5.5)	-0.03***	-0.03**
Social Media (0-5.5)	-0.01*	0.00
Overall GPA (0-4)	0.13***	0.18***
School from Home 2021 (0-3)	-0.02*	-
Intercept	1.55***	1.59***
***R-Squared** (%)*	15.00***	17.50***
***ICC** (%)*	0.70	0.80

*p<.05, **p<.01, ***p<.001
Within Level N (2019) = 2529. Within Level N (2022) = 2684. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Appendix C: MLM Exploratory Moderation Tables

Table C1: MLM exploratory moderation on digital skills

	Overall Digital Skills	Internet Skills	Social Media Skills
	b	***b***	***b***
Controls			
Female	-0.05	-2.39***	2.34***
Single Parent Household	1.34***	0.82***	0.52**
Person of Color	-0.12	0.12	-0.38
IEP	-2.71***	-0.82**	-1.89***
Parent Highest Edu (*Years*)	0.42***	0.25***	0.17***
Grade 9[a]	1.83*	1.24***	0.55
Grade 10	3.53***	2.24***	1.25***
Grade 11	4.34***	3.03***	1.27***
Home Internet[b]			
None	-2.47**	-0.40	-2.07***
Cell Only	-3.25***	-1.95***	-1.30*
Slow	-0.99**	-0.27	-0.72***
Time on Media (hrs/day)			
Television (0-5.5)	-1.05***	-0.53***	-0.53***
Mobile Videos/Movies (0-5.5)	0.24	0.03	0.22*
Video Games (0-5.5)	1.30***	0.88***	0.43***
Web Browsing (0-5.5)	1.34***	0.93***	0.41***
Social Media (0-5.5)	0.36***	-0.19***	0.55***
Moderation Terms[c]			
Year 2022	0.85	0.65	0.14
Person of Color * Year 2022	-1.56	-1.18*	–
Intercept	22.94***	6.14***	16.84***
***R-Squared** (%)*	12.50***	16.10***	11.50***
***ICC** (%)*	0.90	1.10	0.70

*p<.05, **p<.01, ***p<.001
Within Level N = 4705. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
[c] "Year 2022" is the moderating variable, and is coded as: 0 = 2019, 1 = 2022. A dash ("–") indicates the interaction term was not significant when initially testing for the corresponding dependent variable, and therefore was not included in the final model.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table C2: MLM exploratory moderation on grade point average (GPA)

	Overall GPA	Math/Science GPA	English/Social Studies GPA
	b	***b***	***b***
Controls			
Female	0.36***	0.32***	0.40***
Single Parent Household	-0.32***	-0.30***	-0.34***
Person of Color	-0.21***	-0.23***	-0.19***
IEP	-0.22***	-0.14**	-0.21***
Parent Highest Edu (*Years*)	0.06***	0.06***	0.06***
Grade 9 [a]	0.02	-0.04	0.09
Grade 10	0.01	-0.06	0.09
Grade 11	0.10	0.04	0.16
Home Internet [b]			
None	-0.21***	-0.15***	-0.26***
Cell Only	-0.26***	-0.28***	-0.24***
Slow	-0.06*	-0.04	-0.12***
Digital Skills			
Internet Skills (0-32)	0.00	0.00	0.00
Social Media Skills (0-28)	0.01*	0.01*	0.01*
Moderation Terms [c]			
Year 2022	0.07	0.09	0.06
Sex * Year 2022	-0.11*	-0.12*	-0.11*
IEP * Year 2022	–	-0.18*	–
Slow Internet * Year 2022	–	–	0.09*
Intercept	2.26***	2.27***	2.24***
R-Squared *(%)*	16.20***	13.00***	15.20***
ICC *(%)*	2.7	2.1	3.4

*p<.05, **p<.01, ***p<.001
Within Level N = 4670. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
[c] "Year 2022" is the moderating variable, and is coded as: 0 = 2019, 1 = 2022. A dash ("–") indicates the interaction term was not significant when initially testing for the corresponding dependent variable, and therefore was not included in the final model.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table C3: MLM exploratory moderation on educational aspirations

	Educational Aspirations (Years)
	b
Controls	
Female	1.32 ***
Single Parent Household	-0.51 ***
Person of Color	-0.06
IEP	-0.48 ***
Parent Highest Edu (*Years*)	0.24 ***
Grade 9 [a]	-0.09
Grade 10	-0.03
Grade 11	0.06
Home Internet [b]	
None	-0.16
Cell Only	-0.52 ***
Slow	-0.13
Digital Skills	
Internet Skills (0-32)	0.03 ***
Social Media Skills (0-28)	0.03 **
Moderation Terms [c]	
Year 2022	-0.30 ***
Intercept	11.32 ***
R-Squared *(%)*	15.30 ***
ICC *(%)*	1.2

*p<.05, **p<.01, ***p<.001
Within Level N = 4705. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
[c] "Year 2022" is the moderating variable, and is coded as: 0 = 2019, 1 = 2022. A dash ("–") indicates the interaction term was not significant when initially testing for the corresponding dependent variable, and therefore was not included in the final model.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table C4: MLM (logistic) exploratory moderation on STEM career interest

	STEM Career Interest
	b
Controls	
Female	0.42***
Single Parent Household	-0.18**
Person of Color	-0.03
IEP	-0.15*
Parent Highest Edu (*Years*)	0.08***
Grade 9[a]	-0.05
Grade 10	-0.03
Grade 11	-0.08
Home Internet[b]	
None	0.06
Cell Only	-0.20*
Slow	-0.03
Digital Skills	
Internet Skills (0-32)	0.02**
Social Media Skills (0-28)	0.01**
Moderation Terms[c]	
Year 2022	-0.63***
Grade 9 * Year 2022	0.12
Grade 10 * Year 2022	0.28*
Grade 11 * Year 2022	0.34*
Intercept	-1.33***
R-Squared *(%)*	5.90***

*p<.05, **p<.01, ***p<.001
Within Level N = 4705. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
[c] "Year 2022" is the moderating variable, and is coded as: 0 = 2019, 1 = 2022. A dash ("–") indicates the interaction term was not significant when initially testing for the corresponding dependent variable, and therefore was not included in the final model.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table C5: MLM exploratory moderation on time spent socializing with family and friends (hrs/day)

	Socializing with Family	Socializing with Friends
	b	*b*
Controls		
Female	0.13*	-0.02
Single Parent Household	-0.35***	-0.02
Person of Color	0.03	-0.07
IEP	0.12*	0.08
Parent Highest Edu (*Years*)	-0.01	0.01
Grade 9 [a]	-0.07	-0.08
Grade 10	-0.11	-0.32**
Grade 11	-0.29**	-0.32***
Home Internet [b]		
None	-0.15	0.03
Cell Only	-0.15	-0.04
Slow	-0.16*	-0.19*
Digital Skills		
Internet Skills (0-32)	-0.01**	-0.02***
Social Media Skills (0-28)	0.00	0.01***
Time on Media (hrs/day)		
Television (0-5.5)	0.24***	0.17***
Mobile Videos/Movies (0-5.5)	0.06	0.07***
Video Games (0-5.5)	-0.02	0.01
Web Browsing (0-5.5)	0.04	0.01
Social Media (0-5.5)	0.06***	0.31***
Moderation Terms [c]		
Year 2022	-0.63**	0.23***
Parent Highest Edu * Year 2022	0.05***	–
Mobile Videos/Movies * Year 2022	0.08**	–
Intercept	2.94***	2.60***
R-Squared *(%)*	10.00***	18.40***
ICC *(%)*	0.20	0.20

*p<.05, **p<.01, ***p<.001
Within Level N = 4705. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
[c] "Year 2022" is the moderating variable, and is coded as: 0 = 2019, 1 = 2022. A dash ("–") indicates the interaction term was not significant when initially testing for the corresponding dependent variable, and therefore was not included in the final model.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.

Table C6: MLM exploratory moderation on self-esteem

	Self-Esteem
	b
Controls	
Female	-0.34***
Single Parent Household	-0.08***
Person of Color	-0.01
IEP	0.07**
Parent Highest Edu (*Years*)	0.00
Grade 9 [a]	-0.05*
Grade 10	-0.02
Grade 11	-0.02
Home Internet [b]	
None	-0.15
Cell Only	-0.16***
Slow	-0.13***
Time on Media (hrs/day)	
Television (0-5.5)	0.01**
Mobile Videos/Movies (0-5.5)	-0.01*
Video Games (0-5.5)	-0.02*
Web Browsing (0-5.5)	-0.03***
Social Media (0-5.5)	-0.01*
Overall GPA (0-4)	0.16***
Moderation Terms [c]	
Year 2022	-0.07*
No Home Internet * Year 2022	0.11
Cell Only Home Internet * Year 2022	0.10
Slow Home Internet * Year 2022	0.06
Intercept	1.60***
***R-Squared** (%)*	15.50***
***ICC** (%)*	0.80

*p<.05, **p<.01, ***p<.001
Within Level N = 4279. Between Level N = 18.
[a] Grade 8 is the reference category.
[b] "Fast" broadband is the reference category.
[c] "Year 2022" is the moderating variable, and is coded as: 0 = 2019, 1 = 2022. A dash ("–") indicates the interaction term was not significant when initially testing for the corresponding dependent variable, and therefore was not included in the final model.
Italicized variables are mean centered. We used the MCMC multiple imputation method (10 imputations, 100 iterations) to estimate missing cases.