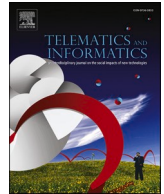




ELSEVIER

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Telematics and Informatics

journal homepage: www.elsevier.com/locate/tele

How variation in internet access, digital skills, and media use are related to rural student outcomes: GPA, SAT, and educational aspirations

Keith N. Hampton^{a,d,*}, Craig T. Robertson^{a,d}, Laleah Fernandez^{b,d}, Inyoung Shin^c, Johannes M. Bauer^{a,d}

^a Department of Media and Information, Michigan State University, United States

^b College of Education, Michigan State University, United States

^c Department of Communication, University of Wisconsin-Milwaukee, United States

^d Quello Center, Michigan State University, United States

ARTICLE INFO

Keywords:

School interest
Broadband
Mobile
Homework
Sports
Digital inequality
COVID-19
Excessive use

ABSTRACT

Some have pointed to divides in the availability of fixed home broadband Internet access as a contributor to rural students' lower levels of educational attainment. Based on standardized exams (SAT Suite) and a survey of rural Michigan students in grades 8–11, we find that rural students with broadband home Internet access are more interested in school and leave homework incomplete less often. However, the relationship to classroom grades (GPA) is relatively trivial. Yet, we find that students who are not dependent on a cell phone for Internet access and those with higher digital skills, especially social media skills, rank considerably higher on the SAT. Rural students with broadband Internet access are able to participate in a more diverse array of online media activities, which supports building digital skills. Any negative relationship between time spent on social media, video games, other digital media and educational outcomes is outweighed by the benefit to digital skills. However, aspects of rural culture; including the emphasis on activities such as sports, as a path to postsecondary schooling and upward, social mobility; may be stunting the positive relationship between access, digital skills, and educational aspirations. Whereas extra-curricular sports have no direct relationship to SAT performance, students who spend more time on sports receive higher grades and have higher educational aspirations than those with more digital skills. We discuss the implications for rural students' access to human capital and how the unequal relationship between digital skills and performance in the classroom and on the SAT may perpetuate inequalities.

1. Introduction

Compared with their urban and suburban peers, rural students in the United States and other OECD countries are less likely to complete higher education (Echazarra and Radinger, 2019). Thus they forego one of the main paths to the development of human capital and its associated individual and community benefits, including health and economic well-being (Faggian et al., 2017). Some

* Corresponding author at: Department of Media and Information, Michigan State University, 404 Wilson Road, Room 409, East Lansing, MI 48824, United States.

E-mail address: khampton@msu.edu (K.N. Hampton).

<https://doi.org/10.1016/j.tele.2021.101666>

Received 15 March 2021; Received in revised form 7 June 2021; Accepted 13 June 2021

Available online 16 June 2021

0736-5853/© 2021 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license

(<http://creativecommons.org/licenses/by/4.0/>).

have pointed to divides in Internet access due to gaps in the infrastructure for fixed home broadband as a contributor to rural students' reduced ability to acquire human capital; divides that became especially clear in face of the COVID-19 pandemic and the sudden need to provide remote schooling. Overcoming the "homework gap" between students who can and cannot use the Internet from home has been suggested as one solution to bridge human capital divides (Reisdorf et al., 2019). However, there is mixed evidence that home Internet use plays a supportive role in student outcomes related to grade point average (GPA), performance on standardized exams, and their educational aspirations. Not all measures of student outcomes may benefit from digital media. Some argue that media use occupies the time and minds of young people, distracts from human capital-building activities, and thus diminishes educational opportunities. These relationships are overlaid into the unique culture and sociality of rural areas (Hardy et al., 2019), which may limit the value of digital media to support the educational aspirations of students by emphasizing more traditional activities seen as a path to postsecondary schooling and upward, social mobility.

Rural areas experience some of the largest inequalities in broadband Internet access (Kahan, 2019). The predominant perspective in the study of digital inequality is that the most pronounced divides are not a result of how people access the Internet, but how they utilize the information at their disposal. As such, policies to cure the digital inequalities experienced by rural students have increasingly focused on "leapfrogging" fixed-line, broadband infrastructure, by providing wireless, broadband phone networks (Nandi et al., 2016). However, a growing body of evidence suggests that wireless Internet access may not be associated with the same levels of engagement, content production or information seeking (Napoli and Obar, 2014). Thus, while some research supports a positive relationship between Internet access and outcomes related to homework completion and interest in school, different types of access may be related to different outcomes. Perhaps more importantly, it is not clear that Internet access as a means to facilitate homework completion is a substantive contributor to overall educational performance or aspirations. The path between access and student performance may be more complex, with quality of access influencing what students do online, which affects their digital skills, which shapes academic achievement. Thus, efforts during the COVID-19 pandemic to mend gaps in digital access may do little to rectify substantive disparities in media use and digital skills that underlie the relationship to academic performance.

Competing narratives about how to improve the infrastructure for rural broadband access, the value of digital skills, and the detrimental effects of excessive media use (e.g., activities such as social media and video games) cloud the perceived importance of digital media use for parents, rural schools, and other institutions that can play a role in reducing rural inequalities. This paper addresses incomplete and sometimes conflicting arguments about the role for educational outcomes of access to and use of digital media in a rural context. Survey data and standardized test scores from students enrolled in grades eight to eleven in rural Michigan schools are used to explore how student GPA and performance on the Scholastic Aptitude Test Suite of Assessments (SAT) are related to the quality of home Internet access. This includes fast broadband, slower access, no access, or dependence on a mobile phone for home Internet. We examine the effect of this access on homework completion, interest in school, and digital skills. We explore the relative contribution of Internet access and social media skills to academic performance and whether time spent on digital media is detrimental. Finally, we explore how variation in Internet access and digital skills relates to the educational aspirations of students relative to traditional measures of academic potential. We also examine how such variation relates to the emphasis placed on other activities considered in rural communities as pathways to economic and educational mobility, such as participation in extracurricular sports. We discuss the implications of our findings for rural students' access to human capital and the roles that home Internet access and digital skill may play in relation to secondary and higher educational institutions in overcoming rural inequalities. We conclude with a discussion of how decisions related to how students access information, how students use information, and the value that parents and teachers place on certain information, influence student outcomes and ultimately how these factors may shape the equity of admissions policies used by postsecondary institutions.

2. Literature review

2.1. Human capital

Human capital consists of the "skills and knowledge acquired by an individual" (Coleman, 1988, p. S100).¹ Rural students attend postsecondary institutions at lower rates because of a combination of factors that constrain human capital, including distance to postsecondary institutions; lower, aggregate education levels in the community; and lower proportions of technical and scientific occupations (Abel et al., 2014; Roscigno and Crowle, 2009). Students from families of lower socioeconomic status (SES) and those who are racial or ethnic minorities are even less likely to attend college or university. They receive less academic encouragement from parents and are more likely to be disinterested in school and to leave homework incomplete (Green et al., 2012). Systemic inequalities related to how human capital is assessed, including biases in how teachers recognize academic achievement, can further disadvantage minority students and those of low SES.

Human capital is commonly measured in the middle and high school years in terms of classroom grades and standardized test scores. GPA partially reflects student performance through assessments of classroom achievements and subject-based knowledge (Brookhart et al., 2016). It also reflects broader cognitive and non-cognitive skills. GPA is the product of cumulative school experience

¹ Some have suggested that this definition should be expanded to include factors such as health (Bleakley, 2010). However, at the individual level, physical and mental health are more appropriately conceptualized as antecedents (Danziger et al., 2000) and outcomes of educational attainment (Masters et al., 2015) or the outcome of a more limited set of cognitive and non-cognitive skills that are expressed early in life (Duke & Macmillan, 2016). Thus, we focus on the narrower definition of human capital that is related to measures of knowledge and skill.

measured from teacher perceptions of classroom behavior and beliefs about a student's academic propensity (Entwisle and Hayduk, 1988). Although GPA may include the cumulative gain of demonstrated early cognitive ability, it may also be the outcome of implicit and explicit biases about suitability and propensity for achievement, based on a student's race, ethnicity, and gender. Such factors often disproportionately affect students of lower SES, who tend to be judged by teachers as less academically competent than their actual abilities (Alvidrez and Weinstein, 1999). Students with higher family incomes are more likely to participate in activities, such as extracurricular sports, which serves to build self-esteem and demonstrate commitment to the school, which, in turn, is reflected in higher grades (Coleman, 1988). Students of lower SES are also less likely to finish homework and to express interest in school, which contribute to a lower GPA through teachers' lower preference for students whom they perceive to be less committed (Gorman et al., 2002). Although it is a functional measure of academic achievement, GPA represents both an imperfect measure of human capital and a problematic measure of academic potential.

Standardized exams are intended as measures of academic achievement that eliminate variation in how schools and districts assign grades, including factors such as grade inflation (Godfrey, 2011). Standardized assessments also reduce confounding due to the ability of some students, such as athletes, to receive higher classroom grades through the exchange of social capital for human capital (Broh, 2002). Standardized exams, such as the SAT, are intended as measures of skills acquired in and outside of school (Hannon, 2016). The SAT has also been found to be predictive of cognitive ability (Coyle et al., 2011). However, this does not mean that standardized exams like the SAT are free of bias, or that they are not influenced by non-cognitive aspects of a student's academic development.

Standardized testing was conceived as an objective way to assess the academic merit of students from diverse class, racial, and ethnic backgrounds (Lemann, 1999). In practice, the same socioeconomic factors associated with a lower GPA have been found to be associated with lower performance on the SAT (Dixon-Román et al., 2013). The cumulative nature of life-course experiences, particularly in early life, related to teacher expectations, educational opportunity, and the development of cognitive and non-cognitive skills remains unchanged (Elder, 1994). Some of these early cognitive skills, such as working memory and knowledge integration, account for a disproportionate amount of variation in performance on the SAT (Hannon and Daneman, 2006). And, although the SAT eliminates the influence of some non-cognitive skills, others may be more important. Indeed, skills, such as self-efficacy, academic locus of control, and performance-avoidance goals, are as predictive of SAT performance as cognitive factors (Hannon and McNaughton-Cassill, 2011). Although they are a broader measure of skills than GPA, exams like the SAT are also poor measures of academic potential.

Despite their imperfect nature, in the United States, GPA and performance on the SAT (or the similar American College Testing exam) play an overriding role in determining postsecondary, educational attainment. These measures serve as signals to students (as well as their parents and teachers) about the suitability of postsecondary schooling and are heavily weighted by universities in admission decisions and the awarding of merit-based scholarships. Although they are not the only factors that influence educational aspirations, students with high GPA and SAT scores are much more likely to be encouraged to aspire to higher education (Hossler and Stage, 1992). As such, there is a preponderance of concern about interventions to increase student performance on these measures, such as Internet access to facilitate homework completion, and on the suitability of GPA and SAT scores as criteria in the university admission process.

2.2. Media and human capital

A gap in broadband Internet access may contribute to the deficit in human capital of rural students. Rural areas tend to have lower levels of home Internet access and use. Twenty-two percent of adults living in rural areas say that they never go online; this is more than double the rate of urban and suburban areas (Anderson, 2018). As many as 42 million, mostly rural Americans do not have access to broadband home Internet (Kahan, 2019). In contrast to more densely populated areas, where affordability often drives inequalities in access, in rural areas, additional culpability rests with gaps in the infrastructure to provide fixed broadband (Horrihan, 2019). In some cases, rural households try to overcome a lack of fixed, broadband infrastructure by using mobile phones for wireless Internet access. Researchers have contested whether a mobile phone can substitute for fixed, home connectivity and provide similar outcomes (Reisdorf et al., 2020). In rural areas, cell phone data access can be spotty and congested. Students who are dependent on a cell phone must rely on smaller screens, stingy data caps, and devices with fewer features. Not only are rural residents less likely to have home Internet, but those who do have Internet access tend to go online less often, do less diverse activities online (Perrin, 2019), and are often more skeptical of the value of these technologies (Hamby et al., 2018).

As a result of gaps in access, some point to a "homework gap" between students who can and cannot use the Internet from home (Reisdorf et al., 2019). A recent survey of students in rural Michigan found that 82% of students reported that they sometimes or often receive homework that requires Internet access (Hampton et al., 2020). We expect that students from rural schools who have better home Internet access will have higher levels of academic achievement. That is, students who do not have broadband home Internet access, including those who have slower access or are dependent on a cell phone for Internet access, will have lower classroom grades and perform worse on standardized tests. We focus on the mechanism through which access is related to academic performance. We hypothesize that Home Internet access is not directly related to higher academic achievement. The relationship between Internet access and these measures is likely indirect, through homework completion and interest in school.

H1: Internet access is indirectly related to higher classroom grades and performance on standardized tests through lower rates of homework incompleteness and lower school disinterest.

However, there are mixed findings about the magnitude of the relationship between homework completion and academic performance for middle and high school students. Homework is generally found to have a positive association with class grades and standardized test scores, but the relationship to class grades is stronger than the one to test scores (Cooper et al., 2006). Homework may

play some role in cognitive development or knowledge retention, but homework may primarily signal an interest in school to teachers and is rewarded in the form of higher classroom grades. Given this relationship, as a mechanism to ensure homework completion and support interest in school, the relationship between Internet access and academic performance may be small.

There is also evidence that students with more digital skills perform better on standardized tests for math and reading (Pagani et al., 2016) and receive higher classroom grades (Robinson et al., 2018). Digital skills are obtained through formal educational activities but primarily from experiences with technologies that are less likely to be used in the classroom or valued by parents and teachers (e.g., time on social media, playing video games, etc.) (Scheerder et al., 2017). Eshet-Alkalai (2004) argues that digital skills are more than the ability to operate software and devices and include broader information, socio-emotional, photo-visual, branching, and reproduction literacies. The relationship between these “21st century skills” and cognitive and non-cognitive skills related to performance in the context of schools has not been extensively explored (Silber-Varod et al., 2019). For example, digital skills may have some overlap with those skills associated with performance on standardized tests.

If there is an association between digital skills and cognitive and non-cognitive skills associated with academic performance, there should be a direct relationship between higher digital skills and performance in the classroom and on standardized exams. This direct relationship should be more substantive than the indirect relationship between Internet access and academic performance.

H2: Digital skills are directly and positively associated with higher classroom grades and performance on standardized exams.

Digital skills may have additional indirect relationships to student performance. Digital skills have been associated with a greater interest in learning (Hu et al., 2018), and thus, potentially, a greater interest in school. However, if the relationship between school interest and academic performance is limited to influencing the climate for how teachers reward students who demonstrate interest, the relationship between digital skills and student performance would be limited to slightly higher classroom grades. However, if the indirect relationship between digital skills and academic performance through school interest supports knowledge development, it would also be reflected through higher performance on standardized exams.

H3: Digital skills are indirectly related to higher classroom grades and performance on standardized exams through lower school disinterest.

Access to and use of a variety of media have long been suggested as both essential and detrimental to the human capital of young people. For example, reducing barriers to universal radio and television access was once seen as integral to overcoming inequalities in the delivery of rural education (Slotten, 2000). Yet, there are widespread concerns about the harmful effects of television on academic achievement (Linebarger, 2015b). More recently, the focus has shifted to concerns about the negative effects of using technologies, such as video games and social media (Hampton, 2019; Linebarger, 2015a). On the one hand, inequity in the availability of home Internet service may limit a student’s ability to participate fully in human capital-building activities (e.g., homework or digital skills). On the other, the use of these technologies may have detrimental effects on cognitive and non-cognitive skills.

Arguably, there has been a stronger focus in the literature on the potential detrimental effects of digital media on young people’s academic performance (e.g., Evers et al., 2020; Weis and Cerankosky, 2010), than the potential benefits of Internet access or skills. This focus extends a long line of research on media effects that suggests that through a combination of time displacement and reduced mental effort, time spent using media, such as television, has a negative effect on academic achievement (Shin, 2004). This work has fueled concerns about time displacement and negative, cognitive, and social effects from the use of video games, social media, and related technologies (Adelantado-Renau et al., 2019). Some have attempted to differentiate between supportive and deleterious uses of these media. For example, Robinson et al. (2018) find that classroom grades benefit from “academically useful” online activity at home, but are detrimentally affected through online leisure activities. Other studies with similar measures of time spent in online entertainment activities have found a positive association with performance on standardized exams (Hu et al., 2018). Such conflicting findings and concerns about the negative, social implications of new technologies contribute to a broader, moral panic about the use of digital media (Hampton and Wellman, 2018) that devalues the relationship between these technologies and education (Erstad and Sefton-Green, 2013). As a result of perceived cognitive and non-cognitive damage, some point to a burgeoning, social movement to discourage access and use of digital media at home and school because of their harmful effects (Riley, 2019).

We do not dismiss evidence that suggests that excessive media use can have a negative relationship to human capital. We expect that time on some media are likely to displace some activities that might otherwise support academic performance. There is likely variation across types of media; some media are more detrimental for academic outcomes than others. However, because digital skills are a product of everyday uses of digital media, we also expect that media use contributes to academic performance through digital skills.

H4: The cumulative direct and indirect relationships between time spent on digital media activities and performance on classroom grades and standardized test are positive.

Finally, we explore the relationship between access to and use of the Internet for the educational aspirations of rural students. Educational aspirations of students reflect the context in which they live and learn. The influence of different factors on student aspirations depends on the expectations, opportunities, and constraints imposed by their environment, their parents, teachers, and peers (Morgan, 2007). Factors, such as GPA and performance on the SAT, play an overriding role in assessing a student’s potential for future, postsecondary attainment. As such, they are highly influential in determining a student’s educational aspirations. In rural communities, other factors, such as extracurricular sports, are also associated with educational aspirations. College sports are seen as a path to upward, social mobility (Holland and Andre, 1987). Yet, the relationship between high school athletics and postsecondary scholarships or participation in college sports and a lucrative career, is more myth than reality (Eitzen, 2005). Compare this to the growing evidence that competence with digital skills contributes to success in postsecondary institutions, job opportunities, and higher earnings (Dijk and Deursen, 2014). Despite evidence that digital skills are important for future employability and postsecondary education, skepticism about Internet use means that broadband access and digital skills are likely to underperform in predicting a rural student’s

postsecondary aspirations.

H5: The magnitude of the relationship between classroom grades, performance on standardized exams, and participation in sport-related extracurricular activities for predicting educational aspirations, will be greater than the relationship between home Internet access or digital skills for educational aspirations.

3. Method

3.1. Sample

Data for this analysis come from a study of students from some of the most rural school districts in the State of Michigan. Between May and June 2019, 3258 students, aged thirteen and older in grades eight through eleven across twenty-one schools and 173 classrooms completed a twenty-minute, in-class survey. They represented 70.6% of students in these grades in fifteen participating, rural, school districts. The rurality of these districts is evidenced by the fact that Michigan townships that are predominately urban have an average population density of 1609 people per square mile, whereas participating districts had population densities between 12 and 225 people per square mile (US Decennial Census, 2010). Eight of the participating school districts provided de-identified, standardized test scores; scores were matched with students' responses to the project survey. Our analysis is based on the scores of the 2597 students who participated in the project survey from those districts that provided test scores. Responses were closely split by school grade (grades 8 = 26.1%, 9 = 26.8%, 10 = 26.1%, 11 = 21.0%) and gender (female = 52.2%).

3.2. Measures

Human capital was operationalized as two measures: a self-reported GPA and national percentile rank on a standardized exam from the SAT Suite of Assessments (SAT). GPA is the combined average grade of a student's last completed courses in English, social studies, math, and science (range 0.00–4.00; $M = 3.13$, $SD = 0.86$). All Michigan students in grades eight through eleven are administered pencil-and-paper, standardized tests that include sections on evidence-based reading, writing, and math. Students in grades eight and nine were administered the Preliminary SAT (PSAT) 8/9, students in grade ten were administered the PSAT 10, and students in grade eleven were given the SAT I. The PSAT 8/9 and the PSAT 10 test the same skills and knowledge as the SAT I and are vertically scaled so that a student who took the PSAT 8/9 would be expected to score the same on the PSAT 10 or SAT, if they had taken any of those tests on the same day (College Board, 2019). Scores are nationally benchmarked with a percentile rank that shows how a student performed relative to students for each grade ($M = 55.84$, $SD = 26.10$).

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. Student reports were validated with data from an optional homework assignment that provided actual measures of Internet speeds at places and on devices students used for homework (Hampton et al., 2020). This 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). They were also significantly higher than those speeds reported as "slow." Students were then classified as having one of four types of home Internet connectivity: broadband (59.8%); a slower connection that might include a digital subscriber line or satellite connection (22.7%); cell phone only access using a data plan (12.8%); or no home access but the possibility to get online at locations outside the home, such as libraries and free Wi-Fi hotspots (4.6%).

Students' digital skills were assessed using a validated, multi-dimensional scale created by Hargittai and Hsieh (2012). This scale was developed based on benchmarking to in-person observations of actual use (Hargittai, 2005), and has been used extensively to explain differences in the use of digital media (e.g., Hargittai et al., 2019; Osmundsen et al., 2021). Participants rated their level of understanding of fifteen items (e.g., wiki, cache, hashtags, etc.) on a 0–4 scale ranging from "none" to "full" understanding. The scale formed two subscales: eight items for Internet skills ($\alpha = 0.87$, $M = 10.28$, $SD = 8.08$) and seven items for social media skills ($\alpha = 0.88$, $M = 21.07$, $SD = 7.08$). Both measures of digital skill were centered for the analysis.²

Online activities were measured as time spent on each medium per typical weekday: none, <1h, 1–2 h, 2–3 h, 3–4 h, 4–5 h, 5 or more hours. Time was recoded in hours based on the mid-point and centered for the analysis; television time ($M = 1.30$, $SD = 1.45$); watching movies and videos on mobile devices (e.g., YouTube, Netflix) ($M = 2.41$, $SD = 1.74$); playing videogames on a computer, console, or mobile device ($M = 1.57$, $SD = 1.76$); surfing the Web ($M = 1.18$, $SD = 1.42$); and chatting online or using social media (e.g., Instagram, Snapchat, Discord) ($M = 2.64$, $SD = 1.92$).³

School-related activities were adopted from the High School Longitudinal Study (Ingels et al., 2011). As with time on media, participants reported time spent "participating in sports activities at or outside of school" ($M = 2.02$, $SD = 1.79$) and "participating in

² Internet skills: advanced search, PDF, spyware, wiki, jpg, cache, malware, phishing. Social media skills: preference settings, meme, tagging, privacy settings, viral, followers, hashtag.

³ Time diary and experience sampling approaches may be more accurate than asking about time spent on a "typical weekday," but the demands on participants made these approaches inappropriate for this study (Hampton, 2017). Given the relatively mundane and common media activities reported, we do not anticipate substantive issues with respondents over reporting communication activities that are low in frequency (Bernard et al., 1984) or a social desirability bias (Arnold & Feldman, 1981).

band, student government, or other clubs or organized activities at or outside of school” ($M = 0.87$, $SD = 1.40$). Educational aspirations were measured by asking students: “As things stand now, how far in school do you think you will get?” Students could select from six categories: “less than high school” to “Ph.D., M.D., law degree, or other high-level, professional degree.” They were coded as number of years of expected education attainment ($M = 15.19$, $SD = 2.89$). Homework incompleteness was measured on a 0–3 scale, “never” to “often,” and for having “gone to class without your homework done” in the past year ($M = 1.55$, $SD = 0.97$). Using the same scale, school disinterest was based on the sum of three items: in the past year, how often did the student “go to class without a pencil or paper,” “go to class without books,” and “go to class late” ($M = 2.71$, $SD = 2.16$). The score was centered for the analysis. A lower score indicated more interest than the average student.

Family income was assessed as a dichotomy: whether a student was eligible for a free or a reduced-price school lunch as part of the School Lunch Program (29.5%). Students from families with income between 130 and 185 percent of the federal poverty line are eligible for reduced priced meals, whereas those with incomes below 130 percent of the poverty line are eligible for a free meal. In the 2018–19 school year, a student from a family of three earning less than \$27,014/year was eligible for a free meal, whereas those from a family with an income below \$30,451/year qualified for a reduced-price meal. Parental education was measured as the highest level of education completed by a parent or guardian, coded in years ($M = 14.87$, $SD = 2.86$). Thirty-two percent of students lived with a single parent/guardian. Twenty-two percent of students identified as non-white, predominately Native American, or of mixed-race. Fifteen percent of students in the sample had an Individualized Education Plan (IEP), which is a formal plan prepared by the school that indicates eligibility for accommodations or special education services.

3.3. Analysis

A series of regression analyses with maximum likelihood estimation were performed to specify a path model in MPlus v8.4 that incorporated the direct and indirect relationships among Internet connectivity, time spent on media, digital skills, school activities, GPA, SAT, and educational aspirations (Fig. 1).⁴ The rate of missing values was low for most variables (0–5%), but higher for internet skills (7%), parent education (8%), and standardized test scores (22.9%). We found no patterns in the data to suggest that the missing values were not at least missing at random. We used the Markov Chain Monte Carlo method to impute missing values, which produced ten imputed datasets of plausible values combined for the analysis, which reflect the uncertainty due to missing values (Yuan, 2000). This is consistent with best practices, which recommend the use of multiple imputation to account for bias that can be introduced through the use of listwise or pairwise deletion. To test indirect relationships, we used the delta method based on “normal-theory” (Muthén and Muthén, 2018).⁵

4. Findings

4.1. Internet access

As documented in Table 1, there is no direct relationship between home Internet access and either GPA or performance on the SAT. As hypothesized (H1), we found that broadband home Internet access is indirectly related to higher academic performance, primarily as a result of less homework incompleteness and less disinterest in school. (A full list of indirect relationships between Internet access, media use, and digital skills can be found in the online appendices, Table S2.) The magnitude of the relationship varies by type of access.

Compared to a student who “rarely” leaves their homework incomplete, a student who “often” does not complete homework (~1.5SD above the mean in homework incompleteness) tends to have a 0.50 lower GPA and scores 3.3 percentiles lower on the SAT. The additional indirect effect of broadband access is small. Because of less homework completion, a student with slower home access tends to have a 0.03 lower GPA (–0.35 percentiles SAT), whereas those students who are dependent on a cell phone have a 0.08 lower GPA (–0.53 percentiles SAT), and those with no access have a 0.06 lower GPA (–0.72 percentiles SAT).

A student who is 1.5SD above the mean in terms of school disinterest tends to have a 0.16 lower GPA and ranks 2.1 percentiles lower on the SAT. Because of lower interest in school when compared to a student with broadband access, a student with slower Internet has a 0.01 lower GPA, a student dependent on a cell phone has 0.02 lower GPA, and there is no difference for those without access. The indirect relationship to rank on the SAT through school disinterest is similarly small. Slower home access is indirectly associated with a 0.36 lower SAT, whereas those who are cell phone dependent rank 0.54 percentile lower on the SAT.

As depicted in Fig. 2, when the indirect relationships between Internet access and student performance are combined, we find that, compared to students who have broadband access, students who depend on a mobile phone for Internet access do significantly worse than those with slower or no home access. (A list of total direct and indirect effects can be found in Table S3.) The relationship to GPA is relatively trivial, but it is more substantial for performance on the SAT, particularly for students who are dependent on a cell phone. Overall, cell phone-dependent students average 0.12 lower GPAs ($p < .001$) and rank 2.95 percentiles lower on the SAT ($p < .001$).

⁴ It would be desirable to use multilevel modeling in an attempt to control for the interdependence of cases and the possibility that students from the same district have more in common with each other than students who are selected at random. However, the number of groups was too small to generate accurate standard errors (Maas & Hox, 2004).

⁵ The bootstrap method is a preferred approach to test for indirect relationships, but techniques to incorporate bootstrapping into multiple imputation have not been established (Hayes, 2017).

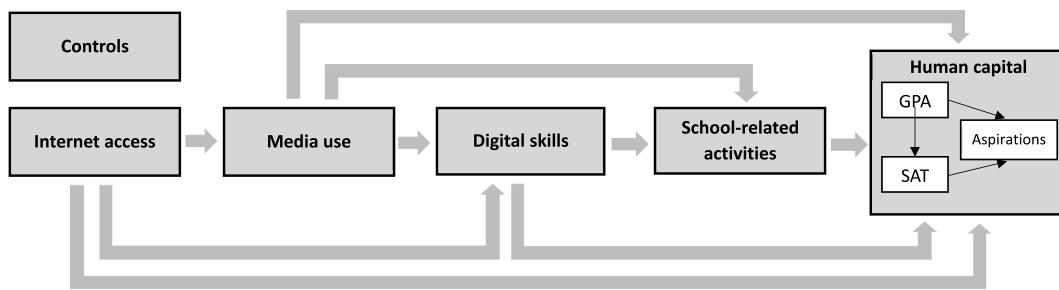


Fig. 1. Theoretical model.

Students with no home access tend to have a GPA that is 0.04 lower ($p < .01$) and rank 0.65 percentiles lower on the SAT ($p < .05$). Students with slow home access have a 0.04 lower GPA ($p < .01$) and rank 0.71 percentiles lower ($p < .01$) on the SAT.

4.2. Digital skills

As shown in Table 1, we find that time spent using digital media is a positive, substantive contribution to digital skills (except for watching movies on mobile devices, which has no relationship). For example, a student who spends 1.5SD more time than average playing video games tends to score 21% higher than average on Internet skills, whereas a student who spends 1.5SD more time than average on social media scores 9% higher than average on social media skills. Time spent on television distracts substantively from both Internet ($b = -0.631$, $p < .001$) and social media skills ($b = -0.459$, $p < .001$). Although time spent on social media supports social media skills ($b = 0.673$, $p < .001$), it is related to slightly lower Internet skill ($b = -0.189$, $p < .05$). We also note that, compared to those with broadband access, students who depend on a cell phone for access to the Internet tend to have substantively lower Internet ($b = -2.43$, $p < .001$) and social media skills ($b = -1.38$, $p < .001$). The same is not true for those with slower or even no home Internet access.

As expected, digital skills are positively associated with GPA. As shown in Fig. 3, we find support for H2, a direct relationship between Internet skills and GPA ($b = 0.009$, $p < .001$), and H3, a small, indirect relationship between Internet skills and GPA through less school disinterest ($b = 0.001$, $p < .01$; see Table S2). We also find an unexpected, but trivial, indirect, positive relationship between social media skills and GPA through time spent on extracurricular sports ($b = 0.001$, $p < .05$). A student who is 1.5SD higher than average in Internet skills would tend to directly and indirectly receive a 0.11 higher GPA ($p < .001$), whereas a student who is 1.5SD higher in social media skills would indirectly tend to average a 0.01 higher GPA ($p < .05$). The cumulative direct and indirect relationship between digital skills - both Internet and social media skills - and classroom performance is relatively small.

Compare this to the much stronger relationship between digital skills and performance on the SAT. Again, we find support for a direct (H2) and indirect relationship through school interest (H3). The total effect of Internet skills on the SAT is such that a student who is 1.5SD higher in Internet skills would typically perform 4.57 percentiles higher on the SAT ($p < .001$). A student who was 1.5SD higher in social media skills would be expected to rank 7.65 percentile higher on the SAT ($p < .001$). A student whose Internet and social media skills combined were 1.5SD higher than the mean would rank more than 12 percentiles higher on the SAT. As a measure of magnitude, a standardized coefficient for the total effect of digital skills on SAT ($\beta = 0.316$) is nearly four times larger than the coefficient for digital skills on GPA ($\beta = 0.086$).

4.3. Time on media

We expected that time spent on digital media would have a positive relationship to academic performance. As shown in Fig. 4, we found mixed support for our hypothesis (H4). As expected, time spent surfing the Web was, through higher Internet skills, indirectly associated with a higher GPA ($b = 0.007$, $p < .01$; see Table S2 and Table S3). However, as illustrated in Table 1, there is a direct, negative relationship from time on video games ($b = -0.029$, $p < .01$) and time on social media ($b = -0.036$, $p < .01$) to GPA. Using a mobile device to watch videos was indirectly associated with a lower GPA, through lower homework completion ($b = -0.014$, $p < .001$). Although not a new medium, watching television (through lower Internet skills), also had an indirect, significant, negative relationship to GPA ($b = -0.005$, $p < .01$). Compared to the average student, those who spend 2.5 h more than average per weekday ($\sim 1.5SD$) on the following media had GPAs that were lower: television (-0.03 GPA, $p < .01$), watching videos on a mobile device (-0.03 GPA, $p < .001$), playing video games (-0.08 GPA, $p < .01$), and chatting on social media (-0.10 GPA, $p < .01$). Those who spend 2.5 h more time than average per weekday ($\sim 1.5SD$) surfing the Web had a 0.02 higher GPA ($p < .01$).

The variables through which use of a specific medium is related to the GPA varied but suggest very small displacements in activities that support academic achievement (e.g., mobile videos through homework incompleteness). However, the relationships between video game use and time on social media were directly related to a lower GPA. These direct relationships suggest the possibility of something other than time displacement, perhaps a negative influence on an unknown third variable, such as self-esteem or psychological distress (Hampton, 2019). Regardless of direction or path, the magnitude of the effect of time on media and GPA was very small (see Table S3; standardized coefficients ranged from 0.01 to 0.09).

Table 1
Path model (N = 2,597).

	TV	Mobile videos	Video games	Surfing the Web	Social media	Internet skills	Social media skills
Intercept	0.223	0.398	1.05***	0.154	-0.311	-2.562**	-2.698**
<i>Controls</i>							
Female	0.099	0.022	-1.369***	-0.142*	0.744***	-2.577***	1.576***
Grade9	-0.059	-0.133	-0.055	0.066	0.254*	1.125**	0.032
Grade10	-0.151	-0.146	-0.189*	0.28***	0.483***	1.697***	0.348
Grade11	-0.171*	-0.168	-0.277**	0.316***	0.480***	2.698***	0.592
Living with a single parent/guardian	-0.001	0.280***	0.135	0.126*	0.334***	0.456	0.572
IEP	0.020	0.061	0.037	-0.092	-0.015	-1.664***	-2.251***
Free/reduced lunch	0.048	0.154	0.282***	0.138*	0.013	0.032	-0.782*
Minority	0.108	0.105	0.068	0.086	0.077	0.596	-0.228
Parental education (6–20 years)	-0.014	-0.027*	-0.020	-0.017	-0.032*	0.196***	0.160**
<i>Internet Connectivity</i>							
No Internet	-0.023	-0.395*	-0.273	-0.138	0.012	-0.714	-0.687
Cell only	-0.037	-0.150	-0.153	-0.160	0.122	-2.432***	-1.375***
Slow Internet	-0.022	-0.144	-0.106	-0.198**	-0.132	0.017	-0.357
<i>Time on media activities</i>							
TV (0–5.5 hrs) ¹						-0.631***	-0.459***
Mobile videos (0–5.5 hrs) ¹						-0.019	0.108
Video games (0–5.5 hrs) ¹						0.816***	0.292**
Surfing the Web (0–5.5 hrs) ¹						0.819***	0.232*
Social media (0–5.5 hrs) ¹						-0.189*	0.673***
<i>Digital skills</i>							
Internet skills (0–32) ¹							
Social media skills (0–28) ¹							
<i>School activities</i>							
Homework incompleteness (0–3)							
School disinterest (0–9) ¹							
Extracurricular sports (0–5.5) ¹							
Non-sport extracurriculars (0–5.5 hrs) ¹							
<i>Human capital</i>							
GPA (0–4.00)							
SAT (0–99)							
R ²	0.007	0.018	0.164	0.022	0.063	0.161	0.091
	Homework incompleteness	School disinterest	Sport EC	Non-sport EC	GPA	SAT	Educational aspirations ²
Intercept	1.650***	0.016	-0.880***	-0.817***	3.07***	9.959***	9.773***
<i>Controls</i>							
Female	-0.145***	-0.547***	-0.365***	0.345***	0.288***	-0.468	0.684***
Grade9	-0.052	-0.216	-0.030	0.018	-0.117**	-0.937	0.124
Grade10	0.088	-0.002	-0.062	0.123	0.014	-6.428***	0.120
Grade11	0.207***	0.287*	-0.010	0.157	0.057	-16.521***	0.367*
Living with a single parent/guardian	0.135***	0.407***	-0.374***	-0.127*	-0.196***	-2.087	0.019
IEP	0.032	-0.004	0.110	0.039	-0.158***	-11.312***	-0.093
Free/reduced lunch	0.149***	0.202*	-0.263**	0.018	-0.160***	-0.479	-0.217
Minority	0.115*	0.373***	-0.123	-0.001	-0.078*	-0.735	0.231
Parental education (6–20 years)	-0.018**	-0.008	0.086***	0.039***	0.032***	0.685***	0.122***
<i>Internet connectivity</i>							
No Internet	0.219*	0.16	0.258	0.308*	-0.067	-2.086	-0.266
Cell only	0.316***	0.421***	-0.037	-0.160	-0.083	-1.036	-0.254
Slow Internet	0.107*	0.278**	0.090	0.104	-0.020	0.471	-0.269*
<i>Time on media activities</i>							
TV (0–5.5 hrs) ¹	0.003	0.064*	0.026	0.015	-0.00001	-0.152	-0.003
Mobile videos (0–5.5 hrs) ¹	0.057***	0.058	-0.042	0.033	-0.002	-0.042	-0.050
Video games (0–5.5 hrs) ¹	-0.003	-0.002	-0.070**	0.019	-0.029**	0.241	-0.088*
Surfing the Web (0–5.5 hrs) ¹	0.020	0.042	-0.030	0.068**	-0.019	-0.384	-0.06
Social media (0–5.5 hrs) ¹	0.049***	0.111***	0.192***	-0.006	-0.036***	-1.628***	0.023
<i>Digital skills</i>							
Internet skills (0–32) ¹	-0.002	-0.023***	-0.025***	0.021***	0.009***	0.228**	0.022**

(continued on next page)

Table 1 (continued)

	Homework incompletion	School disinterest	Sport EC	Non-sport EC	GPA	SAT	Educational aspirations ²
Social media skills (0–28) ¹	0.005	–0.006	0.013*	–0.005	0.004	0.709***	0.014
<i>School activities</i>							
Homework incompletion (0–3)					–0.252***	1.653*	–0.177**
School disinterest (0–9) ¹					–0.049***	–0.643**	–0.015
Extracurricular sports (0–5.5 hrs) ¹					0.064***	–0.31	0.157***
Non-sport extracurriculars (0–5.5 hrs) ¹					0.005	1.117***	0.075*
<i>Human capital</i>							
GPA (0–4.00)						13.114***	0.870***
SAT (0–99)							0.014***
R ²	0.086	0.069	0.111	0.047	0.304	0.402	0.273

Note: Unstandardized coefficients, ¹ Mean centered, ² Educational aspirations (10–20 years), ***p < .001, **p < .01, *p < .05.

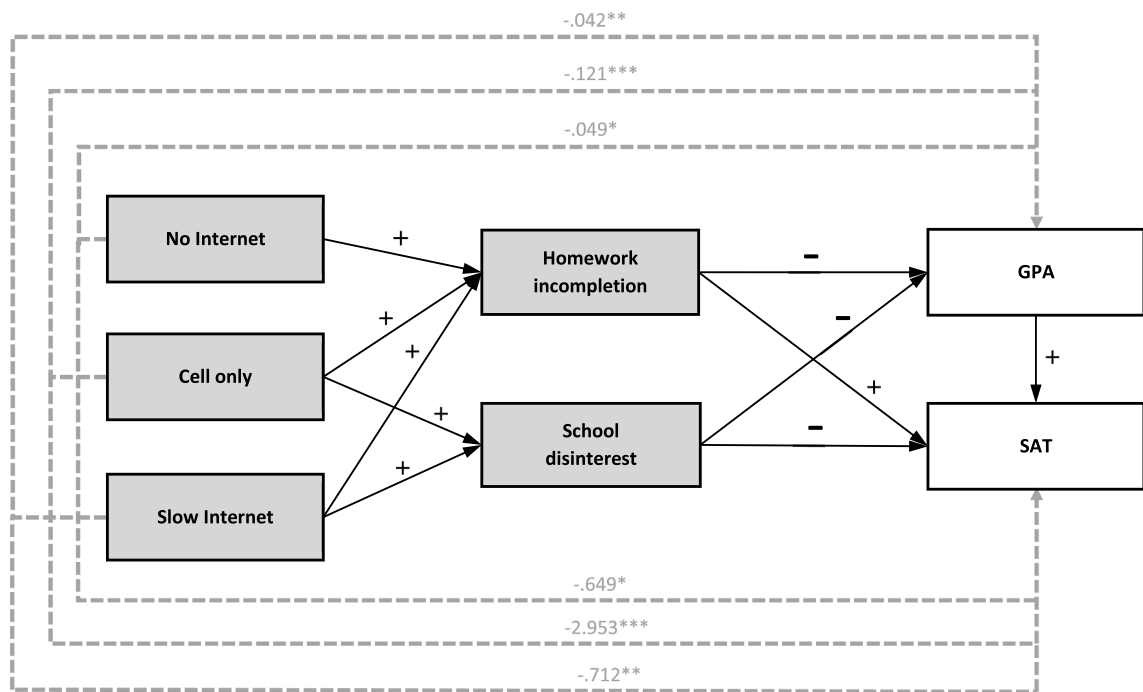


Fig. 2. Relationship between Internet access and student performance (unstandardized coefficients; dotted line represents total indirect relationship).

Time on media was related to performance on the SAT in a similar way, although more substantively in some circumstances. A student who spent 2.5 more hours than average per weekday (~1.5SD) on television (–1.41 percentiles, p < .001), watching videos on a mobile device (–0.24 percentiles, p < .05), and chatting on social media (–4.07 percentiles, p < .001), would be expected to rank lower on the SAT. As with GPA, Web surfing had a positive relationship on the SAT - about 1.38 higher percentile rank for 2.5 additional hours online (p < .001). There was no relationship between time spent on playing video games and the SAT. A comparison of standardized coefficients suggests that the magnitude of time on any media and the SAT is mostly trivial (see Table S3; the standardized coefficients are very small, 0.01–0.03). The exception to this is the relationship between time on social media and the SAT, which is negative, direct, and more substantive (beta = –0.121, p < .001). However, we note that the benefit of social media skills (beta = 0.197, p < .001), as well as combined digital skills (beta = 0.316), to the SAT still outweighed any negative influence of time spent on social media, or time spent on all digital media combined (beta = –.098).

4.4. Educational aspirations

Fig. 5 illustrates the direct and combined indirect relationships to educational aspirations. GPA has the strongest relationship to

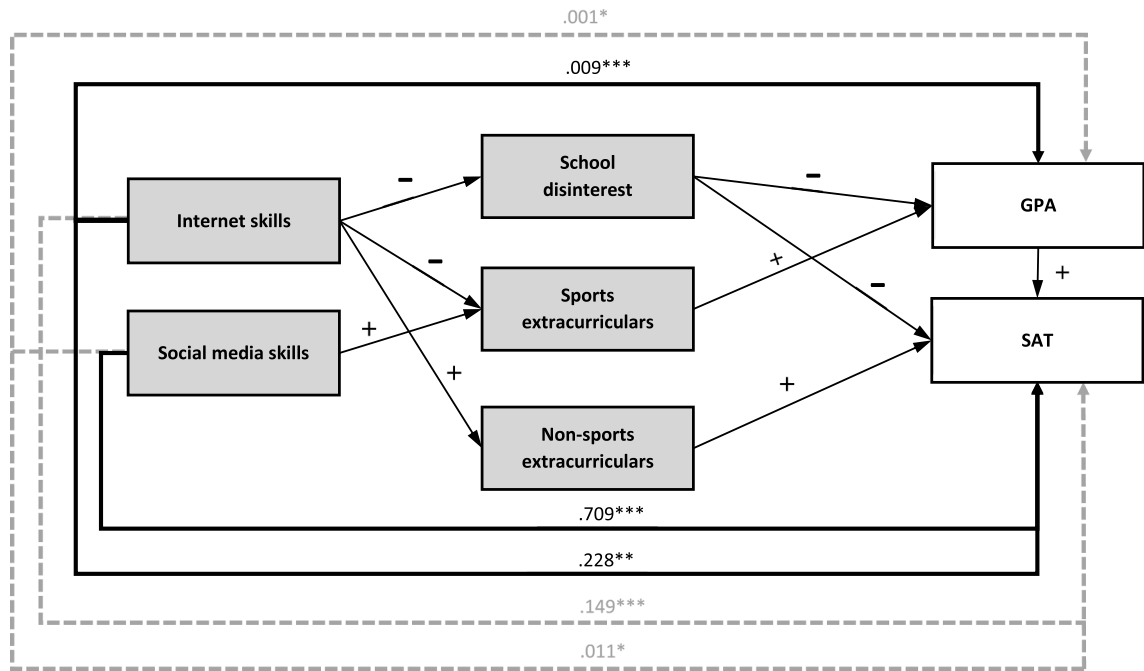


Fig. 3. Relationship between digital skills and student performance (unstandardized coefficients; dotted line represents total indirect relationship).

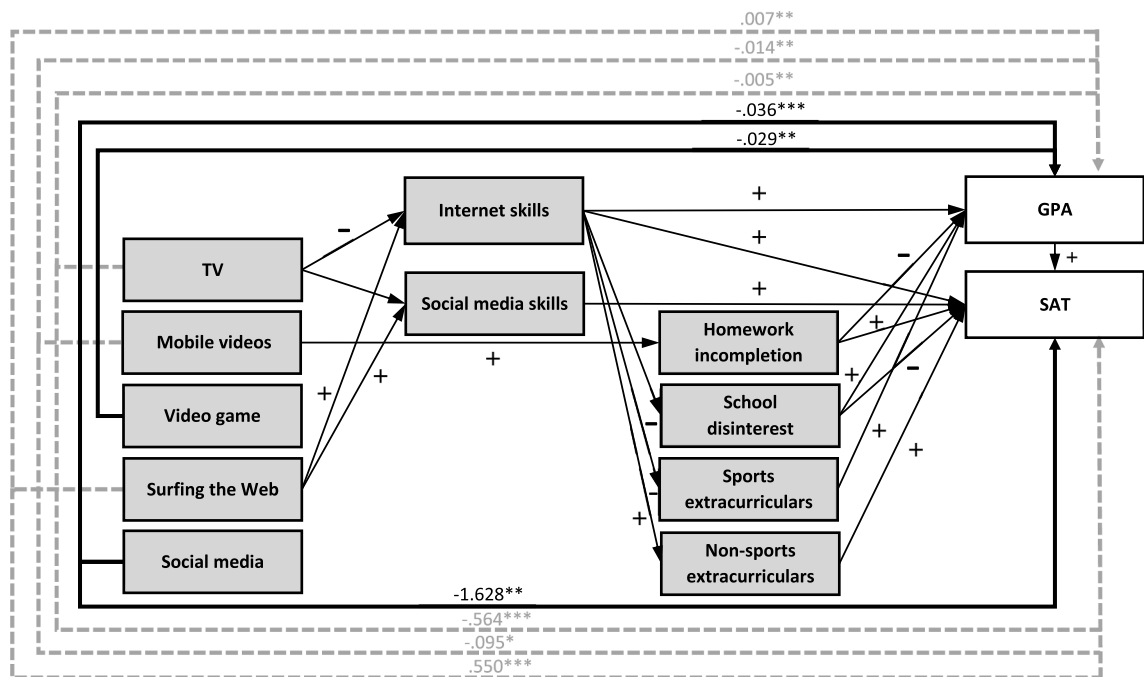


Fig. 4. Relationship between media use and student performance (unstandardized coefficients; dotted line represents total indirect relationship).

educational aspirations (see Table S3; beta = 0.312, p < .001). A student with a 4.0 GPA (1.5SD above the mean) aspired to one additional year of education compared to the typical student in our sample with a 3.1 GPA. Performance on the SAT also had a substantive, positive influence on aspirations (beta = 0.130, p < .001). A student who scored in the 95th percentile on the SAT (1.5SD above the mean) aspired to approximately one-half year more education than the typical student in our sample, who had a 56-percentile rank on the SAT.

In our rural sample, sports are more influential than the SAT (beta = 0.142, p < .001). A student who spent 2.7 extra hours per

weekday on extracurricular sports (1.5SD above the mean) aspired to a little more than one-half a year (0.61) of additional education. This contrasts with a similar achiever in non-sport, extracurricular activities (beta = 0.045, $p < .01$), participating at 1.5SD above the mean (2.1 h), who aspired to 0.19 additional years of education.

Homework completion was directly and indirectly predictive of educational aspirations, such that a student who even “sometimes” left homework incomplete tended to aspire to three-quarters of a year less education than those who never left homework incomplete (beta = -0.142 , $p < .001$). This compares to school disinterest, which is indirectly related to educational aspirations, such that a student who is 1.5SD above the average would be expected to have one-fifth of a year lower educational aspirations (beta = -0.061 , $p < .001$).

As expected, Internet access and digital skill have a modest relationship to educational aspirations. Because students who do not have broadband home Internet complete their homework less often and are more disinterested in school, there is a negative, indirect relationship between access and educational aspirations that is only substantive for cell phone dependence: -0.25 years (compared to slow access, -0.05 years, and no access, -0.04 years). Internet skills are directly related to aspirations ($b = 0.02$, $p < .001$) and, indirectly - predominantly through a higher GPA ($b = 0.01$, $p < .01$; total, $b = 0.03$, $p < .001$). Social media skills, indirectly through higher SAT scores, also have a positive relationship to educational aspirations ($b = 0.01$, $p < .001$). A student who is above average in combined digital skills (1.5SD above the mean on both social media and Internet skills) would tend to aspire to an additional one-half year of education (beta = 0.119, $p < .001$). As expected (H5), traditional predictors of educational aspirations - GPA, SAT, and extracurricular sports - are strongly predictive of higher educational aspirations. Factors such as home Internet access and digital skills are of less importance.

4.5. Conclusions

Rural communities face many challenges in building human capital and raising students' educational aspirations. Our goal was to evaluate a series of competing claims about the value of broadband home Internet, digital skills, and media use for academic achievement and educational aspirations.

We found that Internet access is indirectly related to academic achievement through higher rates of homework completion and interest in school (H1). Although students with broadband access at home leave homework incomplete less often and are generally more interested in school, the relationship to GPA is relatively trivial. However, the relationship between having better home Internet access and performance on a pen-and-paper, nationally standardized, skills assessment - the SAT Suit - was more substantive. Because of lower interest in school and less success at homework completion, students with poorer access to the Internet tend to perform lower on the SAT. This was true of all students who did not have home broadband but was especially pronounced for those who were dependent on a cell phone for home Internet access.

Digital skills are directly (H2) and indirectly through school interest (H3) related to higher classroom grades and performance on standardized exams. We differentiated between digital skills related to general Internet use and those related to the use of social media. Although the relationship between Internet skills and GPA was statistically significant, the effect was relatively small. Similarly, the relationship between social media skills and GPA was significant but trivial. In contrast, the magnitude of the relationship between digital skills and the SAT was substantive and especially so for social media skills. Students with higher digital skills performed considerably better on standardized exams. Digital skills are related to home Internet access through time spent participating in online activities, including social media, video games, surfing the Web, and other online activities that not captured by our study (Scheerder et al., 2017). Students who are dependent on a cell phone for home Internet access experience inequalities in digital skills, likely as a result of limitations inherent to their devices and data services (Reisdorf et al., 2020). Compared to the performance of students who have fixed broadband, students with no home Internet access perform worse, but only marginally worse on standardized assessments than those who are dependent on a cell phone.

We hypothesized that the combination of direct and indirect relationships between time spent on digital media and academic performance would be positive (H4). This was not uniformly the case. Except for time spent surfing the Web, media activities generally had a negative relationship to GPA. However, regardless of the direction, the magnitude of the relationships was small, such that time spent on media was generally inconsequential for classroom grades. In general, the same was true for the relationship to the SAT. The exception is time spent on social media, which had a modest negative relationship with performance on the SAT. It is somewhat of a paradox that social media skills are predictive of higher performance on the SAT, whereas time on social media is related to lower performance on the SAT. We stress that our finding shows that the benefit of social media skills outweighs the negative influence of time on social media.

GPA, time spent on extracurricular sports, homework completion, and performance on the SAT were stronger predictors of educational aspirations than home Internet access, Internet or social media skills (or combined skills), and time spent on any media (or time spent on all digital media combined). This confirms our expectation (H5) that digital media play a relatively minor role in shaping the intent of rural students to pursue postsecondary education.

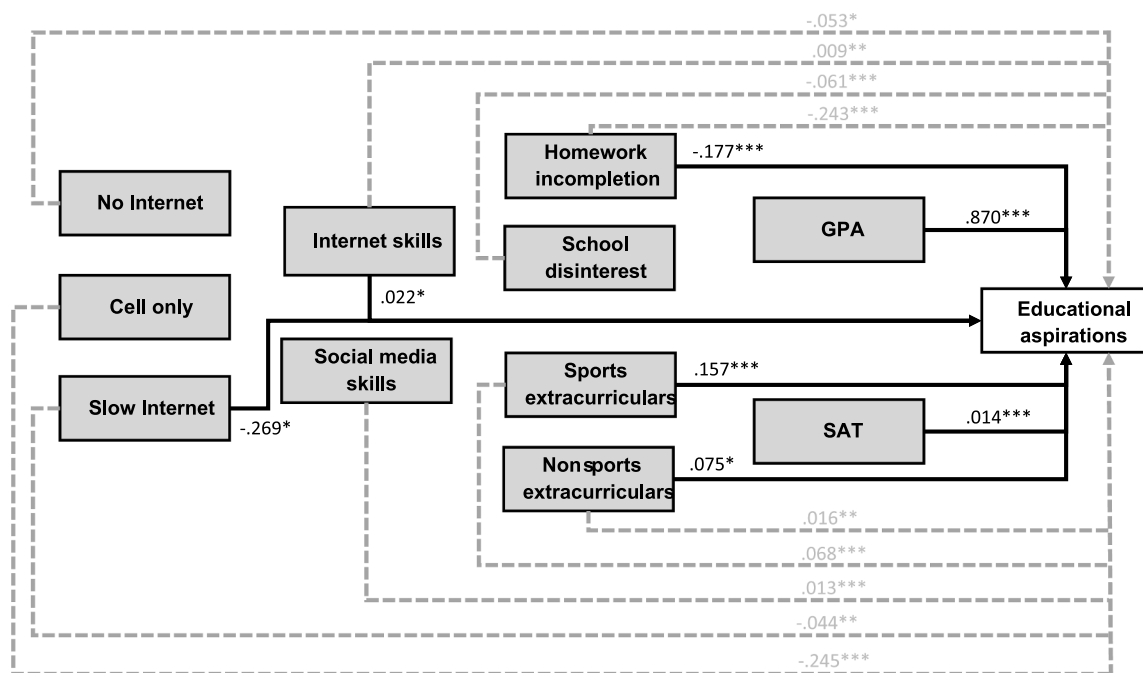


Fig. 5. Direct and total indirect relationships to educational aspirations (unstandardized coefficients; dotted line represents total indirect relationship; mediated relationships not shown).

5. Discussion

Concerns about rural Internet access and academic achievement cannot be separated from how rural students use information, and the value that parents, and teachers place on these activities. The “homework gap” is concerning (Reisdorf et al., 2019), but our findings suggest that the focus on Internet access to improve homework completion or even interest in school may represent a marginal benefit to the academic success of rural students.⁶ A more compelling argument for how Internet access and digital media broadly support academic performance can be found in relation to a student’s digital skills. There is a clear and supportive path between better Internet access, students’ diverse online activities, the skills they acquire, and academic achievement. Yet, beyond the issue of gaps in the rural infrastructure for fixed broadband, the culture of rural America has the potential to impair the beneficial relationship between digital media and human capital. Recent changes in higher education, may only serve to exacerbate these inequalities.

There is a gap in the literature between the study of digital skills and the study of skills in traditional educational contexts (SilberVarod et al., 2019). We expected an association between digital skills and performance in the classroom and on standardized exams. However, we were surprised by the level of differentiation within our findings. We found that digital skills were a stronger predictor of the SAT than classroom grades, and that general Internet skills predicted the GPA, whereas Internet skills and, to an even greater degree, social media skills predicted SAT performance. The human capital literature has long been focused on formal schooling, with limited acknowledgement that “the use of leisure time to improve skills and knowledge is widespread” (Schultz, 1961, p. 1). Digital skills, which are acquired through participation in diverse online activities, are an example of how human capital can be acquired through everyday actions. Thus, it is not surprising that a measure of human capital, such as the SAT that includes skills acquired in and outside of school (Hannon, 2016), would more successfully capture the contributions of digital skills than GPA. However, the disparity between digital skills as a predictor of the SAT compared to classroom performance may also reflect the lack of integration of digital media into core coursework, and a disconnect between how schools and teachers conceptualize knowledge in relation to technology use.

That “social” media skills are predictive of performance on the SAT suggests that social media skills include valuable non-cognitive skills. This raises an interesting contrast with extracurricular sports, which are predictive of GPA but not directly the SAT, presumably as a result of an exchange of social capital in the classroom (Coleman, 1988). Unlike the non-cognitive skills associated with extracurricular sports, those derived from social media may have a more direct effect on academic aptitude. Future work should focus on tying underlying cognitive and non-cognitive skills that makeup digital skills to those found to predict performance on standardized

⁶ Given the limitations of cell phones, future research might focus on variation in types of wireless home access, for example, cell phone dependence vs. a wireless access point with a computer. However, studying such differentiation is becoming more challenging. Students in our sample reported little meaningful variation in device ownership. Nearly all students had a cell phone, and nearly all students with home Internet had a computer, and those without fixed access did not. Multicollinearity prevented us from including device differentiation in our analysis.

exams. These might include working memory, knowledge integration, and performance-avoidance goals. Although our use of path analysis implies time order, the cross-sectional nature of our work should not be interpreted as evidence of causation. Such evidence would depend on the extent to which cognitive and non-cognitive skills, generally considered most malleable at early ages, change over the life course as a result of media activities.

The role that digital media play in the academic performance of a rural student also suggests a need to reflect on the traditional factors that shape a student's educational aspirations. Not unrelated are the factors that institutions use to evaluate a student's potential for postsecondary schooling. We found that the GPA and time spent on extracurricular sports were the two strongest predictors of academic aspirations. GPA and SAT remain the predominant factors that postsecondary institutions use to assess student potential. Should factors such as digital skills play a larger role?

The problem with GPA and SAT as measures of academic attainment and future potential have been well documented. There is evidence of bias in how students of lower SES are assessed on these measures. Our findings replicate these conclusions. Rural students from low-income, minority, and single-parent families had lower classroom grades and standardized test scores (see Tables 1, S1 and S3). An ad hoc analysis finds that roughly one-third of the difference in GPA was explained by higher rates of homework incompleteness, lower rates of participation in extracurricular sports (which typically require a fee to participate), and higher disinterest in school. Factors not included in our analysis explain the remainder: potentially some combination of conforming to lower expectations as a result of stereotyping and a bias in how classroom grades are assigned to students of lower SES (Croizet and Claire, 1998). The relationship between SES and SAT performance was indirect, primarily as a result of lower GPA and lower homework completion and school interest. Similarly, we found no direct relationship between SES and educational aspirations. Students in rural schools who are of lower SES tend to have lower educational aspirations because of their lower GPAs, and, to a smaller extent, lower homework completion, school disinterest, and lower rates of participation in extracurricular sports.

There is a possibility that inequalities in Internet access will serve as an additional factor in the concentrated disadvantage experienced by rural youth of lower SES. SES is a strong predictor of adopting better home Internet access (Robinson et al., 2015). However, unlike most urban and suburban areas, in rural areas, inequality in Internet access is primarily a result of gaps in the infrastructure to provide fixed broadband access (Horrigan, 2019). These gaps were made particularly apparent during the COVID-19 pandemic, and left many rural students without remote learning opportunities. Our findings suggest that even those students whose Internet access improved during the pandemic likely experienced fewer academic gains than peers who already had broadband access, due to preexisting gaps in skill and experience with digital media. Because of the strong relationships between everyday media use, digital skills and academic performance, digital media may also provide a unique opportunity to help rural students overcome inequalities in access to postsecondary opportunities. However, the hurdle is greater than advancing policy interventions to overcoming issues with individual student access.

Existing levels of lower access and use of digital media in rural areas broadly reduce interest and trust in these technologies. As such, parents and teachers likely place less emphasis on these technologies and the students who excel in their use. It is revealing that rural students who spend more time on sports have higher educational aspirations than those with more digital skills. This is true despite the finding that extracurricular sports have no direct relationship to performance on the SAT, whereas digital skills are strongly and directly predictive of rank on the SAT. Similarly, time on non-sport, extracurricular activities has no relationship to GPA, but is predictive of performance on the SAT and is also positively associated with higher Internet skills ($\beta = 0.121, p < .001$). The context of rural communities works to limit the value of digital media to support the educational aspirations of students. Culture is more difficult to change than wires in the ground. Public initiatives to reduce inequalities in access need to focus as much on making visible the value of digital media for individuals and communities, as they do on broadband infrastructure. If the moral panic about the role of technology in society grows (Hampton and Wellman, 2018), the resulting "techlash" has the potential to spread such constraints more broadly (Riley, 2019).

This is of particular relevance for the ongoing debate about the weight that should be given to standardized exams in postsecondary admissions. A growing chorus of voices has suggested abandoning the SAT as a criterion in admissions. Yet, in rural areas, the cumulative biases in academic performance towards students of lower SES originates not on the SAT but in the classroom. Discrepant SAT performance allows students with digital skills to demonstrate additional potential for success in higher education. Other research suggests that, based on their GPA, students who perform higher than expected on the SAT outperform some peers in postsecondary institutions who were admitted with higher high school GPAs (Mattern et al., 2011). Given the bias in rural high school GPA directly associated with lower SES, postsecondary admission decisions based on the GPA alone further advantage those students of higher SES. Through SAT scores, digital skills provide a new road for rural students to demonstrate an important form of human capital. Digital skills are not only predictive of performance on standardized exams and postsecondary success, but also of individual future employability and higher earnings (Dijk and Deursen, 2014). They can also play a role in reducing broader rural economic inequalities (Salemink et al., 2017).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to recognize the support and contributions of our collaborators at Merit Network. This study would not have been

possible without the support and participation of many in the school districts that are the focus of this project. We also acknowledge the capable research support of Megan Knittel.

Funding

This work was in part supported by a Michigan Applied Public Policy Research grant from Michigan State University's Institute for Public Policy and Social Research.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.tele.2021.101666>.

References

- Abel, J.R., Gabe, T.M., Stolarick, K., 2014. Skills across the Urban–Rural Hierarchy. *Growth Change*, 45(4), 499–517. <https://doi.org/10.1111/grow.12067>.
- Adelantado-Renau, M., Moliner-Urdiales, D., Caverro-Redondo, I., Beltran-Valls, M.R., Martínez-Vizcaíno, V., Álvarez-Bueno, C., 2019. Association between screen media use and academic performance among children and adolescents: a systematic review and meta-analysis. *JAMA Pediatrics* 173 (11), 1058–1067. <https://doi.org/10.1001/jamapediatrics.2019.3176>.
- Alvidrez, J., Weinstein, R.S., 1999. Early teacher perceptions and later student academic achievement. *J. Educ. Psychol.*, 91(4), 731–746. <https://doi.org/https://doi.org/10.1037/0022-0663.91.4.731>.
- Anderson, M., 2018. About a quarter of rural Americans say access to high-speed internet is a major problem. Pew Research Center, Washington, DC. <https://www.pewresearch.org/fact-tank/2018/09/10/about-a-quarter-of-rural-americans-say-access-to-high-speed-internet-is-a-major-problem/>.
- Arnold, H.J., Feldman, D.C., 1981. Social Desirability Response Bias in Self-Report Choice Situations. *Acad. Manag. J.* 24 (2), 377–385. <https://doi.org/10.5465/255848>.
- Bernard, H.R., Killworth, P., Kronenfeld, D., Sailer, L., 1984. The problem of informant accuracy: the validity of retrospective data. *Ann. Rev. Anthropol.* 13 (1), 495–517.
- Bleakley, H., 2010. Health, human capital, and development. *Ann. Rev. Econ.* 2 (1), 283–310. <https://doi.org/10.1146/annurev.economics.102308.124436>.
- Broh, B.A., 2002. Linking extracurricular programming to academic achievement: who benefits and why? *Sociol. Educ.* 75 (1), 69–95. <https://doi.org/10.2307/3090254>.
- Brookhart, S.M., Guskey, T.R., Bowers, A.J., McMillan, J.H., Smith, J.K., Smith, L.F., Stevens, M.T., Welsh, M.E., 2016. A century of grading research: Meaning and value in the most common educational measure. *Rev. Educ. Res.*, 86(4), 803–848. <https://doi.org/https://doi.org/10.3102/0034654316672069>.
- Coleman, J.S., 1988. Social capital in the creation of human capital. *Am. J. Sociol.* 94, S95–S120.
- College Board, 2019. PSAT 8/9: Understanding Scores. Princeton, NJ.
- Cooper, H., Robinson, J.C., Patali, E.A., 2006. Does homework improve academic achievement? A synthesis of research, 1987–2003. *Rev. Educ. Res.*, 76(1), 1–62. <https://doi.org/https://doi.org/10.3102/00346543076001001>.
- Coyle, N., Snyder, A., Pillow, D., Kochunov, P., 2011. SAT predicts GPA better for high ability subjects: implications for Spearman's law of diminishing returns. *Personality Individ. Differ.* 50 (4), 470–474. <https://doi.org/10.1016/j.paid.2010.11.009>.
- Croizet, J.-C., Claire, T., 1998. Extending the concept of stereotype threat to social class: the intellectual underperformance of students from low socioeconomic backgrounds. *Pers. Soc. Psychol. Bull.* 24 (6), 588–594. <https://doi.org/10.1177/0146167298246003>.
- Danziger, S.K., Kalil, A., Anderson, N.J., 2000. Human capital, physical health, and mental health of welfare recipients: co-occurrence and correlates. *J. Social Issues*, 56(4), 635–654. <https://doi.org/10.1111/0022-4537.00189>.
- Dijk, J.V., Deursen, A.V., 2014. Digital Skills: Unlocking the Information Society. Palgrave Macmillan.
- Dixon-Román, E.J., Everson, H.T., McArdle, J.J., 2013. Race, poverty and SAT scores: Modeling the influences of family income on black and white high school students' SAT performance. *Teach. Coll. Rec.* 115 (4), 1–33.
- Duke, N., Macmillan, R., 2016. Schooling, skills, and self-rated health: a test of conventional wisdom on the relationship between educational attainment and health. *Sociol. Educ.* 89 (3), 171–206. <https://doi.org/10.1177/0038040716653168>.
- Echazarra, A., Radinger, T., 2019. Learning in rural schools: Insights from PISA, TALIS and the literature (OECD Education Working Papers, No 196, Issue. <https://www.oecd-ilibrary.org/content/paper/8b1a5cb9-en>.
- Eitzen, D.S., 2005. Upward mobility through sports? The myths and realities. *Sport in contemporary society: An anthology*, 249–256.
- Elder, G.H., 1994. Time, human agency, and social change: perspectives on the life course. *Social Psychol. Quarterly* 57 (1), 4–15. <https://doi.org/10.2307/2786971>.
- Entwisle, D.R., Hayduk, L.A., 1988. Lasting effects of elementary school. *Sociol. Educ.* 61 (3), 147–159. <https://doi.org/10.2307/2112624>.
- Erstad, O., Sefton-Green, J., 2013. Digital disconnect? The 'digital learner' and the school. In: Erstad, O., Sefton-Green, J. (Eds.), *Identity, Community and Learning Lives in the Digital Age*. Cambridge University Press, pp. 87–106.
- Eshet-Alkalai, Y., 2004. Digital literacy: a conceptual framework for survival skills in the digital era. *J. Educ. Multimedia Hypermedia* 13 (1), 93–106.
- Evers, K., Chen, S., Rothmann, S., Dhir, A., Pallesen, S., 2020. Investigating the relation among disturbed sleep due to social media use, school burnout, and academic performance. *J. Adolescence*, 84, 156–164. <https://doi.org/10.1016/j.adolescence.2020.08.011>.
- Faggian, A., Partridge, M., Malecki, E.J., 2017. Creating an environment for economic growth: creativity, entrepreneurship or human capital? *Int. J. Urban Regional Res.*, 41(6), 997–1009. <https://doi.org/10.1111/1468-2427.12555>.
- Godfrey, K.E., 2011. Investigating Grade Inflation and Non-Equivalence. Research Report 2011-2. College Board. Princeton, NJ.
- Gorman, A.H., Kim, J., Schimmelbusch, A., 2002. The attributes adolescents associate with peer popularity and teacher preference. *J. Sch. Psychol.* 40 (2), 143–165.
- Green, J., Liema, G.A.D., Martin, A.J., Colmar, S., Marsh, H.W., McInerney, D., 2012. Academic motivation, self-concept, engagement, and performance in high school: key processes from a longitudinal perspective. *J. Adolescence*, 35(5), 1111–1122. <https://doi.org/10.1016/j.adolescence.2012.02.016>.
- Hamby, S., Taylor, E., Smith, A., Mitchell, K., Jones, L., 2018. Privacy at the margins| technology in rural Appalachia: cultural strategies of resistance and navigation. *Int. J. Commun.* 12, 21. <https://ijoc.org/index.php/ijoc/article/view/7052>.
- Hampton, K.N., 2017. Studying the digital: directions and challenges for digital methods. *Ann. Rev. Sociol.* 43 (1), 167–188. <https://doi.org/10.1146/annurev-soc-060116-053505>.
- Hampton, K.N., 2019. Social media and change in psychological distress over time: the role of social causation. *J. Comp.-Mediated Commun.* 5 (24), 205–222. <https://doi.org/10.1093/jcmc/zmz010>.
- Hampton, K.N., Fernandez, L., Robertson, C.T., Bauer, J.M., 2020. Broadband and Student Performance Gaps. Quello Center. Michigan State University, East Lansing, MI. <https://doi.org/10.25335/BZGY-3V91>.
- Hampton, K.N., Wellman, B., 2018. Lost and saved... again: the moral panic about the loss of community takes hold of social media. *Contemp. Sociol.* 47 (6), 643–651. <https://doi.org/10.1177/0094306118805415>.

- Hannon, B., 2016. General and non-general intelligence factors simultaneously influence SAT, SAT-V, and SAT-M performance. *Intelligence*, 59, 51–63. <https://doi.org/10.1016/j.intell.2016.07.002>.
- Hannon, B., Daneman, M., 2006. What do tests of reading comprehension ability such as the VSAT really measure?: a componential analysis. In: *Focus on Educational Psychology*. Nova Science Publishers, pp. 105–146.
- Hannon, B., McNaughton-Cassill, M., 2011. SAT performance: understanding the contributions of cognitive/learning and social/personality factors. *Applied Cognitive Psychology* 25 (4), 528–535. <https://doi.org/10.1002/acp.v25.4.1002/acp.1725>.
- Hardy, J., Wyche, S., & Veinot, T. (2019). Rural HCI research: Definitions, distinctions, methods, and opportunities. *Proceedings of the ACM on Human-Computer Interaction*, November 2019, Article 2196. <https://doi.org/10.1145/3359298>.
- Hargittai, E., 2005. Survey measures of web-oriented digital literacy. *Soc. Sci. Comp. Rev.* 23 (3), 371–379. <https://doi.org/10.1177/0894439305275911>.
- Hargittai, E., Hsieh, Y.P., 2012. Succinct survey measures of web-use skills. *Soc. Sci. Computer Rev.* 30 (1), 95–107. <https://doi.org/10.1177/0894439310397146>.
- Hargittai, E., Piper, A.M., Morris, M.R., 2019. From internet access to internet skills: digital inequality among older adults. *Univ. Access Inf. Soc.* 18 (4), 881–890. <https://doi.org/10.1007/s10209-018-0617-5>.
- Hayes, A.F., 2017. *Introduction to Mediation, Moderation, and Conditional Process Analysis: A Regression-Based Approach*. The Guilford Press, New York.
- Holland, A., Andre, T., 1987. Participation in extracurricular activities in secondary school: What is known, what needs to be known? *Rev. Educ. Res.* 57 (4), 437–466.
- Horrigan, J., 2019, August 14. Analysis: Digital Divide Isn't Just a Rural Problem. *Daily Yonder*. <https://dailyyonder.com/analysis-digital-divide-isnt-just-a-rural-problem/2019/08/14/>.
- Hossler, D., Stage, F.K., 1992. Family and high school experience influences on the postsecondary educational plans of ninth-grade students. *Am. Educ. Res. J.* 29 (2), 425–451.
- Hu, X., Gong, Y., Lai, C., Leung, F.K.S., 2018. The relationship between ICT and student literacy in mathematics, reading, and science across 44 countries: a multilevel analysis. *Comp. Educ.*, 125, 1–13. <https://doi.org/https://doi.org/10.1016/j.compedu.2018.05.021>.
- Ingels, S.J., Pratt, D.J., Herget, D.R., Burns, L.J., Dever, J.A., Ottem, R., Rogers, J.E., Jin, Y., Leinwand, S., 2011. *High school longitudinal study of 2009 (HSL: 09): base-year data file documentation*. NCES 2011–2328.
- Kahan, J., 2019. It's time for a new approach for mapping broadband data to better serve Americans. <https://blogs.microsoft.com/on-the-issues/2019/04/08/its-time-for-a-new-approach-for-mapping-broadband-data-to-better-serve-americans/>.
- Lemann, N., 1999. *The Big Test: The Secret History of the American Meritocracy*. Farrar, Strauss and Giroux, New York.
- Linebarger, D., 2015a. Contextualizing video game play. *Psychol. Popular Media Culture* 4 (4), 375.
- Linebarger, D., 2015b. Educational media: potentials for learning. In: Wright, J. (Ed.), *International Encyclopedia of the Social & Behavioral Sciences*, 2nd ed., Elsevier, pp. 246–254.
- Maas, C.J.M., Hox, J.J., 2004. Robustness issues in multilevel regression analysis. *Stat. Neerl.* 58 (2), 127–137.
- Masters, R.K., Link, B.G., Phelan, J.C., 2015. Trends in education gradients of 'preventable' mortality: a test of fundamental cause theory. *Social Sci. Med.*, 127, 19–28. <https://doi.org/https://doi.org/10.1016/j.socscimed.2014.10.023>.
- Mattern, K.D., Shaw, E.J., Kobrin, J.L., 2011. An alternative presentation of incremental validity: discrepant SAT and HSGPA performance. *Educ. Psychol. Measur.* 71 (4), 638–662. <https://doi.org/10.1177/0013164410383563>.
- Morgan, S.L., 2007. Expectations and Aspirations. In: G. Ritzer (Ed.), *The Blackwell Encyclopedia of Sociology* (pp. 1528–1531). Blackwell. <https://doi.org/https://doi.org/10.1002/9781405165518.wbeose085>.
- Muthén, L.K., Muthén, B.O., 2018. *Mplus User's Guide Book (Eighth Edition)*. Muthén & Muthén.
- Nandi, S., Thota, S., Nag, A., Divyasukhananda, S., Goswami, P., Aravindakshan, A., Rodriguez, R., Mukherjee, B., 2016. Computing for rural empowerment: enabled by last-mile telecommunications. *IEEE Commun. Mag.* 54 (6), 102–109. <https://doi.org/10.1109/MCOM.2016.7498095>.
- Napoli, P.M., Obar, J.A., 2014. The emerging mobile internet underclass: a critique of mobile internet access. *Inf. Soc.* 30 (5), 323–334. <https://doi.org/10.1080/01972243.2014.944726>.
- Osmundsen, M., Bor, A., Vahlstrup, P. B., Bechmann, A., Petersen, M.B., 2021. Partisan polarization is the primary psychological motivation behind political fake news sharing on Twitter. *American Political Science Review*, 1–17. <https://doi.org/doi.org/10.1017/S0003055421000290>.
- Pagani, L., Argentin, G., Gui, M., Stanca, L., 2016. The impact of digital skills on educational outcomes: Evidence from performance tests. *Educ. Studies*, 42(2), 137–162. <https://doi.org/https://doi.org/10.1080/03055698.2016.1148588>.
- Perrin, A., 2019. Digital gap between rural and nonrural America persists. *Pew Research Center*, Washington DC. <https://www.pewresearch.org/fact-tank/2019/05/31/digital-gap-between-rural-and-nonrural-america-persists/>.
- Reisdorf, B.C., Fernandez, L., Hampton, K.N., Shin, I., Dutton, W.H., 2020. Mobile phones will not eliminate digital and social divides: how variation in internet activities mediates the relationship between type of internet access and local social capital in Detroit. *Soc. Sci. Comp. Rev.* <https://doi.org/10.1177/0894439320909446>, 0894439320909446.
- Reisdorf, B.C., Yankelevich, A., Shapiro, M., Dutton, W.H., 2019. Wirelessly bridging the homework gap: Technical options and social challenges in getting broadband to disconnected students. *Educ. Inf. Technol.*, 24(6), 3803–3821. <https://doi.org/https://doi.org/10.1007/s10639-019-09953-9>.
- Riley, N. S. (2019). The real digital divide isn't about access to the Internet. *Washington Post*. <https://www.washingtonpost.com/opinions/2019/04/18/real-digital-divide-isnt-about-access-internet/>.
- Robinson, L., Cotten, S.R., Ono, H., Quan-Haase, A., Mesch, G., Chen, W., Schulz, J., Hale, T.M., Stern, M.J., 2015. Digital inequalities and why they matter. *Inf., Commun. Soc.* 18 (5), 569–582. <https://doi.org/10.1080/1369118X.2015.1012532>.
- Robinson, L., Wiborg, Ø., Schulz, J., 2018. Interlocking inequalities: digital stratification meets academic stratification. *American Behavioral Sci.*, 62(9), 1251–1272. <https://doi.org/10.1177/0002764218773826>.
- Roscigno, V.J., Crowle, M.L., 2009. Rurality, institutional disadvantage, and achievement/attainment. *Rural Sociol.*, 66(2), 268–292. <https://doi.org/10.1111/j.1549-0831.2001.tb00067.x>.
- Salemink, K., Strijker, D., Bosworth, G., 2017. Rural development in the digital age: a systematic literature review on unequal ICT availability, adoption, and use in rural areas. *J. Rural Studies*, 54, 360–371. <https://doi.org/https://doi.org/10.1016/j.jrurstud.2015.09.001>.
- Scheerder, A., van Deursen, A., van Dijk, J., 2017. Determinants of Internet skills, uses and outcomes. A systematic review of the second- and third-level digital divide. *Telematics Inf.*, 34(8), 1607–1624. <https://doi.org/10.1016/j.tele.2017.07.007>.
- Schultz, T.W., 1961. Investment in Human Capital. *The American Economic Review*, 51(1), 1–17. <http://www.jstor.org/stable/1818907>.
- Shin, N., 2004. Exploring pathways from television viewing to academic achievement in school age children. *J. Genetic Psychol.* 165 (4), 367–382. <https://doi.org/10.3200/GNTP.165.4.367-382>.
- Silber-Varod, V., Eshet-Alkalai, Y., Geri, N., 2019. Tracing research trends of 21st-century learning skills. *Br. J. Educ. Technol.*, 50(6), 3099–3118. <https://doi.org/10.1111/bjet.12753>.
- Slotten, H.R., 2000. *Radio and television regulation: broadcast technology in the United States, 1920-1960*. JHU Press, Baltimore, MD.
- Weis, R., Cerankosky, B.C., 2010. Effects of video-game ownership on young boys' academic and behavioral functioning: a randomized, controlled study. *Psychol. Sci.* 21 (4), 463–470. <https://doi.org/10.1177/0956797610362670>.
- Yuan, Y.C., 2000. Multiple imputation for missing data: Concepts and new development. *Proceedings of the Twenty-Fifth Annual SAS Users Group International Conference*. Vol. 267. No. 11.