Technology and Equity in Education

71

Mark Warschauer and Ying Xu

Contents

Abstract

The development and diffusion of information and communication technologies (ICT) is having a profound effect on contemporary education, which adds new elements to the long-standing issue of educational equity. This chapter aims to create a broad picture of the relationship between technology and equity in primary and secondary education by summarizing research literature on Socio-economic Status (SES), racial/ethnic, and gender differences related to technology. We organize our review around the framework of technology access, use, and outcomes. Regarding access, it is clear that gaps in home and school technology access are narrowing but still persistent across SES and racial/ethnic

M. Warschauer (✉) · Y. Xu (✉)
School of Education, University of California, Irvine, CA, USA
e-mail: markw@uci.edu; ying.xu@uci.edu

J. Voogt et al. (eds.), *Second Handbook of Information Technology in Primary and Secondary Education*, Springer International Handbooks of Education,
https://doi.org/10.1007/978-3-319-71054-9_76

groups. Regarding usage, youth groups differ in the manners and the extent digital technologies are used at schools and outside of schools. Since there is a wide range of technologies available and groups' usage pattern varies among forms of technology, it is challenging to summarize a single trend of inequality of technology usage. Regarding outcomes, how the differences in access and usage affect the disparities in outcomes remains inconclusive. The challenge for the reader in consuming studies on outcomes of technology is that what is often reported as a result of using technology may in fact just be that two broad factors – technology and learning – are observed to go together but may not cause one another. The technology use may affect learning, or other factors, such as SES, may shape both learning and technology use.

Keywords

Technology access · Technology usage · Achievement gap · Twenty-first-century learning skills · Educational equity

Introduction

The development and diffusion of information and communication technologies (ICT) is having a profound effect on contemporary education, which adds new elements to the long-standing issue of educational equity. In many countries, the issue of educational equity typically centers on the disparities of academic achievement among groups of students, especially groups defined by socioeconomic status (SES), race/ethnicity, and gender. Therefore, when examining the relationship between technology and educational equity, research generally focuses on whether technology may exacerbate or ameliorate the achievement gaps or have no effect.

There are two existing perspectives regarding this relationship. On the one hand, technology access and usage in education are unequal across SES, racial/ethnic, and gender groups. Groups with lower academic achievement are generally less likely to access and use technology and thus may benefit from technology to a lesser extent than their more advantaged peers. This unequal access and usage may result in amplifying existing educational inequality. On the other hand, if deployed effectively, the affordances of technology in providing scaffolding and enhancing engagement can help facilitate learning of students with lower achievement, thus ameliorating educational gaps. Both perspectives are supported by a wide range of research. This seemingly conflicting evidence may result from methodological differences in the studies. For example, studies may be conducted in different contexts with diverse segments of the population and diverse forms of technology or interventions. Therefore, results generated from one study may not hold true in another context.

This chapter aims to create a broad picture of the relationship between technology and equity in K–12 education by summarizing research literature on SES, racial/ethnic, and gender differences related to technology. We organize our review around the framework of technology access, use, and outcomes (cf. Warschauer and

Matuchniak 2010). Research concerned with the inequality of access and usage of technology is generally descriptive, articulating the patterns of technology access and usage among different groups. Studies focusing on the inequality in outcomes prioritize the examination of the causal impact of technology access and usage upon a youth's learning. The challenge for the reader in consuming these kinds of studies is that what is often reported as a result of using technology may in fact just be that two broad factors – technology and learning – are observed to go together but may not cause one another. The technology use may affect learning, or other factors, such as SES, may shape both learning and technology use.

Access

The notion of technology access encompasses two components: physical access to digital devices (e.g., computers, tablets, the Internet) and access to digital content. Physical access to a device is a necessary first step for digital equity, but studies also have suggested that access to content that is both of high quality and educational value is a secondary concern. In this section, we will first examine the gaps in the two forms of access among SES, race/ethnicity, and gender groups and then link these gaps to the related social factors, both in home and school environments.

Access at Home

Home access is defined as a student having access to digital technology at home, regardless of whether it is a shared item in the household. However, despite the steady progress that has been made in boosting home technology access for minority and lower-SES households around the world, access remains unevenly dispersed, even within developed countries.

For example, in the USA, the overall home computer and Internet access divide as well as its evolution over time is well documented by several national reports, among which is the National Telecommunications and Information Administration (NTIA) report, based on the Current Population Survey (CPS). The NTIA report provides the most robust evidence on this issue. In the latest released report, household computer and Internet access continued to show an unbalanced pattern, with Asian or White, higher-SES, metropolitan households more likely to have access than their counterparts (File and Ryan 2014). This finding is consistent with common assumptions, as well as other nationally representative surveys (e.g., Anderson 2015). When longitudinally comparing the NTIA reports over a period of 15 years, we can see that as the technology access rate increases steadily across all groups, the gaps between more advantaged and less advantaged groups are narrowing but remain substantial (White House Council of Economic Advisers Issue Brief 2015).

Among those with Internet access at home, the conditions of access differ, ranging from access to broadband connections to relying solely on a cell phone data plan. Broadband offers Internet speeds fast enough to facilitate full interaction

with advanced online platforms, while online activities via circular data plan are usually constrained by slower speeds. According to a report by Pew Research Center, for 7% of American youths, cell phones are their only means of accessing the Web (Pew Research Center 2015a). Those who are younger, of lower financial status, and with less education are more likely to fall into this category. Blacks and Latinos are also more likely than Whites to lack other means of accessing the Internet. However, on the positive side, the dramatic increase in smartphone penetration has helped bring the Internet in some form to those who lacked home Internet access (Connected Nation 2013).

While economic constraints tend to be viewed as the primary reason for the divides in home technology access, other social factors also play a critical role in this issue. For example, some literature emphasizes the importance of social support for technology access (DiMaggio et al. 2001). Many immigrant households may lack social networks that would enhance their opportunities to acquire digital access. In contrast, individuals with many friends and relatives who own computers and use the Internet are more likely to do so as well, because their network can help them acquire necessary technology skills, and they have greater return in using technology due to their large social network online. As Ono and Zavodny (2008) pointed out, these network effects to some extent explain why the divides in technology access reflect or even exacerbate the existing social inequality.

Examining inequality in the amount and quality of content available via home digital devices, it is generally hypothesized that youth groups who are more likely to access digital devices tend to be exposed to richer digital content. However, as it is implausible to comprehensively measure the volume and quality of the content a youth may access from their device, most existing research focuses on measuring the access to specific forms of content. For example, recent research has noted an "app gap," which refers to inequality of accessing educational applications on smartphones or tablets (Prensky 2012). These applications are frequently assumed to be beneficial for children. According to a study by Common Sense Media (2013), while wealthier parents load their children's iPads with brain-boosting educational apps, less advantaged parents rarely do so. This divide may reflect parents' perceptions about the value and role of technology. Lin et al. (2012) believed that lower-SES parents may have less confidence in teaching or regulating their children with digital technologies, thus leading to a lower likelihood of equipping their digital devices with educational content.

School Access

Technology investment in schools worldwide has increased substantially in the last two decades, on the rationale that digital access and usage improve learning. However, school divides in technology access have not yet been eliminated. Internationally, the gap in school technology access between developing countries and developed countries is, not surprisingly, large. While school technology access rates have almost reached saturation in some developed countries, such as the UK,

Canada, and New Zealand, many developing countries are just beginning to introduce computers and Internet connections in schools. Within developed countries, gaps are narrowing but still exist. In the USA, for example, high-poverty schools still have fewer students per Internet-connected computer than low-poverty schools, and underrepresented minority students are less likely to have technology access at school than their White counterparts (Snyder et al. 2016). At the same time, only 16% of schools in poor counties (i.e., with county-level median household income less than $35,000) have high-speed Internet connection, whereas the percentage for schools in wealthier regions (i.e., with county-level median household income more than $35,000) is almost four times higher at 62% (Connected Nation 2013).

Similar to home access, school technology access is supported or constrained by economic factors as well as socio-technical contexts, often in ways that heighten educational inequity. Previous lessons have shown that, by merely increasing access to technology, schools may still not be able to take advantage of these facilities (see, e.g., Warschauer et al. 2011). For example, the Los Angeles public school system undertook a $1.3 billion effort in 2013 to give each teacher, administrator, and 640,000 pupils an Apple iPad preloaded with educational software. This program was seen as a way to boost the city's low-income students, who had limited access to digital education tools at schools until the program. However, the program did not achieve its original goal and soon resulted in a breakdown. After an investigation, the US Department of Education (2016) identified a lack of district-wide instructional technology strategy and insufficient instructional support of technology as among the causes of the failure. Recommendations made in the report include the following:

> Require each school to create a clear but light-weight Instructional Technology Plan aligned to individual school improvement goals. . .this plan should ideally include input from all stakeholders and be posted publicly for parents and community input. Pilot approaches for integrating technology professional development as part of the districts' overall professional development strategy.

These recommendations reinforce the complexity of technology integration, which goes beyond simply equipping schools with technological resources.

Usage

What is more critical of course than mere access to technology, both inside and out of school, is whether and how it is used. This is also often related to issues of SES, race/ethnicity, and gender.

Out-of-School Usage

The majority of youths from all SES backgrounds and racial/ethnic groups find ways to use digital technology. According to the research from the Organisation for

Economic Co-operation and Development (OECD), in 2012, disadvantaged students spent at least as much time online as their wealthier peers, on average across 40 OECD countries. However, despite the equivalent time spent online, different groups are found to use different devices and in different ways. Higher-SES teenagers were more likely to use the Internet to search for information or to read news rather than to chat or play video games (OECD 2016). This finding resonates with a survey in the USA, which found that lower-SES youths use technologies more for leisure rather than for learning-related activities, which is substantially different from those with higher-SES backgrounds (Rachel 2012).

This raises the question of whether more time using digital media adds or subtracts educational value. Researchers put forth the concept of the time-wasting gap, which refers to the disparity of time spent online for pure leisure by different population groups. This gap may produce negative effects for the youths who use technologies: the more time spent online, the less gained. Traditionally marginalized groups are believed to be more prone to this situation. Therefore, it is important to take the quality of technology usage into consideration. This is typically discussed around three common types of out-of-school technology usage: media consumption and creation, communication, and video gaming.

Content Consumption and Creation

Children consume content via digital devices in various ways, including viewing videos, browsing websites, listening to music, and reading eBooks. Among these activities, viewing online videos takes primary position. According to multiple sources, the average viewing time for teenage children of online videos may be up to an average of 3 h daily. However, not all groups spend the same amount of time watching videos. A study surveyed 2000 teenagers and discovered that those with low family income and low parent education levels tended to watch online videos 1 h more than their better-off peers (Common Sense Media 2015). Possible detrimental effects of video watching include distraction from time available for reading or studying, as well as negative effects from problematic programming, such as media portrayals of drinking and alcohol advertising.

Children also use a variety of tools to create content, including blogs, websites, videos, fanfiction forums, and programming. Researchers view the practices of content creation as a knowledge construction experience, in which children develop their skills as well as creatively engage with information. However, again, differences exist among groups. Lower-SES youths, while avid content *consumers*, appear to spend less time than higher-SES counterparts in content creation (Pew Research Center 2005; for a more recent study of college students, see Hargittai and Jennrich 2016). Differences in technology access and usage as well as motivation appear to be the factors that underlie and perpetuate differences in online content creation (Blank 2013). This gap in content creation could contribute to social inequality, both by limiting minority youth's opportunity to gain important skills that are necessary in the contemporary workplace and also by rendering their voice and opinions less likely to be heard by the public.

Communication

Digital technologies are seen by teenagers as a tool for social networking with their friends. Communication encompasses a range of older and newer forms of Internet communication such as sending email, instant messaging, blogging, going to chat rooms, and social networking communication. How children use online communication tools varies on two levels – whether they use particular tools or not and in which activities they engage. The variation in these two levels correlates with children's backgrounds to some extent.

Facebook is shown to be the most popular of all the social media platforms among teenagers, and background characteristics do not seem like a strong indicator of whether or not they use Facebook. However, the activities performed do vary along socioeconomic and racial/ethnic lines. Junco (2013) demonstrated that students from lower-SES environments were less likely to use Facebook for communication, connecting, and sharing, i.e., the exact types of activities for which Facebook was created. Another study revealed that lower-SES students were less likely to engage in classroom-related academic collaboration on Facebook than their higher-SES peers (Khan et al. 2014).

Concern thus arises that lower-SES students may not be able to take full advantage of online social networks to help strengthen real-world connections with friends and schools, as they perform activities that are less communication-oriented. Another contrasting view is that lower-SES students, with less social capital in the real world, may benefit from the virtual network more than their better-off counterparts. Relatedly, Wohn and colleagues studied the role of Facebook in the college application process of high school students. The authors found that, for first-generation high school students, Facebook use was associated with higher feelings of efficacy, thus facilitating their college application emotionally and practically. However, Facebook did not provide the same degree of help to students who had at least one parent who graduated from college (Wohn et al. 2013).

Video Gaming

Video games are pervasive among most teens – and, for boys in particular, video games serve as a major venue for the creation and maintenance of friendships. The amount of time teens spent on gaming varies little by family income, education, or race/ethnicity. However, nuances in gaming preferences and behaviors still exist among groups. First, SES appears to play an important role. A study in which 200 high schoolers were surveyed showed that nearly half of the low-SES students preferred sports-themed video game consoles, whereas only 20% of high-SES students reported this preference (Andrews 2008). In contrast, high-SES students were shown to be more likely to engage in literacy practices related to the games they played (e.g., view screenshots, use walkthroughs, post scores), while low-SES students rarely performed these activities (Andrews 2008). Additionally, higher-SES students appeared to be more likely to use networked games to connect with their in-person friends than their less well-off peers (Pew Research Center 2015b). This finding resonates with the results from other studies: higher-SES people tend

to take better advantage of digital technologies for socializing and building relationships.

Regarding gender differences in gaming preferences and behaviors, in sharp contrast with boys' avid interest in gaming, girls generally reject being identified as "gamers." Among girl gamers, the majority reported favor for casual games with fewer challenges. In contrast to the majority of boys, who favored the sports genre, very few girls reported that they enjoyed these games (Andrews 2008). Some scholars suggest that high-challenging video games favored by boys may potentially foster interest for STEM careers, especially in computer science and engineering, or similarly develop technology skills helpful for those careers.

Usage in School Settings

Despite teenagers' frequent home usage of technology, their school technology usage is not paralleled. In most OECD countries, more than 80% of 15-year-olds use computers frequently, yet a majority do not use them much in school, even though most schools are equipped with computers and Internet access (OECD 2010). Among the schools using technology frequently, the ways in which they implement technology into instructional activities differ. It is generally believed that poorer schools tend to use technology for drill and practice activities, whereas in higher-SES schools, technology is exploited fully to enhance students' problem-solving skills (Warschauer and Matuchniak 2010). For example, findings from a recent study showed that students attending low-SES schools were given more limited opportunities to use technology to engage in student-centered critical thinking learning activities, compared with their counterparts in higher-SES schools (Lee 2013). And while computer-based writing and revision is viewed as a valuable activity for enhancing academic achievement (see, e.g., Warschauer 2011), the 2011 US National Assessment of Educational Progress (NAEP) found that only 33% of students who are eligible for free or reduced price lunch use computers very often for writing assignments in school, according to their teachers, compared to 51% of students who are not eligible for the national school lunch program.

The disparity in technology use patterns between higher-SES and lower-SES schools is believed to be a result of the interplay of economic conditions, teachers, social dynamics, and institutional culture differences. Among these factors, the most examined by researchers is teachers' knowledge, including their knowledge of using technology and the knowledge of integrating technology into teaching. First, the computer skills and knowledge of teachers are important determiners of the efficient use of technology. Since teachers in poorer schools are reported to receive less technology training, they may possess lower proficiency in using technology than teachers working in wealthier schools (National Education Association 2008). Second, teachers' knowledge in integrating technology matters. Teachers in poorer schools may have limited opportunities to understand how to use technology in ways that engage students in discourse with peers to collaboratively solve problems (see discussion in Kitchen and Berk 2016). As a consequence, students in these

schools often work in isolation from their peers on digital devices, resulting in limited opportunities to develop their reasoning and conceptual understanding collaboratively.

In addition to the role of the teacher, technical support is another factor that influences technology use. Technical problems, such as slow network performance and inadequate computers, can make it difficult to use technology in classrooms, thus frustrating teachers. In a qualitative study comparing technology use in low- versus high-SES schools, Warschauer et al. (2004) found that high-SES schools tended to invest more in hiring full-time technical support staff than low-SES schools. Additionally, in high-SES schools, technology facilitators were selected from teaching staff, who received intensive in-service technology training. These facilitators provided technical and pedagogical support to their colleagues. Student aids were also trained to help in classrooms. These groups were facilitated by clear channels of cross-communication and coordinated effort. Low-SES schools in this study were less likely to have the same degree of interconnected support networks.

Outcomes

Important outcome measures from technology use include student attitudes, traditional school achievement measures, and twenty-first-century learning skills. A number of studies have looked at the relationship of technology access and usage to these outcomes, but frequently using non-experimental designs that are unable to identify the *causal* effect of technology access and usage from other unobserved differences across students and schools. Therefore, while reviewing these studies, we should keep in mind that the true impacts of technology access and usage on student outcomes may be over- or underestimated.

Attitudes Toward Technologies

As computer technology becomes ubiquitous in schools and the workplace, attitudes toward technology may be as important as skills in using a specific device. Individuals who view computers positively, and are confident about their ability to use computers, will be more likely to learn whatever new skills are required by future technological developments.

There is considerable interest in the literature in studying the influence of gender on technology acceptance. Generally, most of the earlier studies conducted before 2005 showed that males held a more positive attitude toward technology than females. These gender differences in attitudes may be caused by many factors. For example, some research has also suggested that the masculine image of the computer deters females from benefiting from technology, as this has made them less confident or more anxious (Culley 1988). However, a recent research has revealed changing attitudes among female computer users. Dündar and Akçayır (2014) studied 183 high school students in Turkey and found a lack of support for gender

differences in attitudes toward computers. This lack of gender differences in attitudes toward computers could be attributed to the increased use of computers for teaching and learning in schools or in other settings. Females may have been socialized differently in today's digital era to become more comfortable with computers, which may serve as a good starting point to remove barriers to technology training.

Several studies examined differences in attitudes across SES and race/ethnicity groups. The "digitally disadvantaged" groups have been found to have similar beliefs in the usefulness of technology as their more privileged counterparts. Generally, youths believe that they can benefit from interacting with digital technology. For example, English language learner (ELL) students are reported to have high interest in using Facebook, Twitter, and text messaging for literacy learning purposes. These results may reflect their motivation to improve their English language skills through multiple exposures across multiple contexts, since these students typically do not have access to English in their home environment (Li et al. 2015).

Academic Achievement from Home Usage

A large body of research focuses on whether using new technology can help students acquire mastery of academic content. It is common practice for most researchers to use traditional school achievement measures to answer this line of related questions, due to the clarity of these outcome measures as well as their high level of acceptance among educators and the general population. These studies take one of two emphases: either examining the impact of technology availability (e.g., whether a computer is available at home) or the impact of technology use. Since youths can perform a wide array of activities on computers or tablets, the research on effects of technology use generally focuses on a more specific kind of activity such as Facebook use and video gaming, rather than vaguely asking the effects of "computer usage."

The results on the impact of home technology access are inconclusive. A few studies find significant positive effects on various educational outcomes such as grades, test scores, and cognitive skills (e.g., Fairlie et al. 2010), while an almost equal number of studies find evidence of modestly sized to significant negative effects of the use of home computers on educational outcomes (e.g., Vigdor and Ladd 2010).

Regarding whether home technology access may benefit underrepresented students' learning, one field experiment study that offered low-income high school students the opportunity to own home computers provides a compelling test (Fairlie and London 2012). Fairlie and his colleague conducted a randomized control experiment with 1,123 students in grades 6–10 attending 15 schools across California, USA. Although the experiment substantially increased computer ownership and usage without changing school technological environments, the research found no evidence that home computers had an effect (either positive or negative) on any educational outcome, including grades, test scores, credits earned, attendance, and disciplinary actions. A follow-up survey was conducted to provide information on several less-commonly measured intermediate educational inputs and outcomes such

as homework effort and time, receiving help on assignments, software use, and computer knowledge. Consistent with the previous findings, access to a home computer did not yield any impact on these measures. This result indicated that computer ownership alone is unlikely to have much of an impact on short-term schooling outcomes for low-income children.

Another line of study regarding the association between different forms of technology use and academic achievement also finds mixed results. This may be because different forms of technologies each have their own unique affordances and thus generate different effects on users. Common themes explored by the researchers include video gaming, social media, and digital homework. Generally, nonacademic usage of technology (e.g., passive gaming, SNS) negatively relates to academic achievements, while home technology usage for educational purposes (e.g., serious gaming, accessing to educational information) is reported to have positive effects on academic performance (Biagi and Loi 2013).

Only a handful of studies investigated the effect of home technology usage on minority, low-SES teens. Jackson et al. (2006) conducted a longitudinal study to examine the impact of home Internet use on low-income family teenagers' academic performance. Participants were 140 teenagers, mostly African-American (83%), mostly boys (58%), and mostly living in single-parent households (75%) in which the median annual income was $15,000 or less. During the 2-year study, participants' Internet use was continuously recorded, including time spent online, numbers of domains visited, and numbers of emails sent. Findings indicated that children who used the Internet more achieved higher scores on standardized reading tests and higher grade point averages (GPA) than did children who used it less.

Academic Achievement from School Usage

Studies on the effects of school technology usage are more likely to adopt experimental design than those on home technology usage. Most existing literature is based on non-nationally representative samples and tests the effect of a specific kind of technology/intervention. Since these studies are highly contextualized, the results may not be interconnected. Several meta-analysis reviews have attempted to depict a broad picture from these mixed studies. For example, Zheng et al. (2016) reviewed 65 journal articles and 31 doctoral dissertations published over a period of 15 years (2001–2015) in order to examine the effect of one-to-one laptop programs on teaching and learning in K–12 schools. Based on a subset of these studies that met the requirements for meta-analysis, they found an overall significant positive average effect on academic achievement with effect size of 0.16. Significant positive impact on achievement was also found in the subareas of English, writing, math, and science.

Another important question is whether the use of laptops by diverse learners helps bridge the achievement gaps among student groups. The positive impact of school technological programs on disadvantaged students was identified in a number of studies (see, e.g., Warschauer et al. 2014). However, these positive goals for at-risk

learners are not achieved in all programs. For example, a study in the USA explores the impact of one-to-one computing on student achievement in Ohio high schools as measured by performance on the Ohio Graduation Test (Williams and Larwin 2016). The sample included 24 treatment schools that were individually paired with a similar control school. Overall, examining the full sample, student performance and content-specific achievement in math, reading, science, social studies, and writing were not significantly affected by the introduction of the one-to-one program. However, when broken down into demographic groups, the results show that Black students in the treatment group performed lower than their peers in control groups.

These contradictory results initiate further investigations into the reason why technology access and usage generate distinct impacts on disadvantaged learner populations. Wenglinsky (2005) noted that "the drill and practice" activities favored in low-SES schools tend to be less effective, whereas the constructive integration of technology disproportionately found in high-SES schools achieves positive results. The author argues that it is not whether the schools use technology, but rather how they use it that makes the great difference. If used appropriately, technology does have the potential to enhance low-achieving students' learning through various pathways.

Some studies offer insight into how to maximize the benefits of technology for disadvantaged students. For example, some have found that when students are engaged in content creation projects involving technology, they demonstrate stronger engagement, self-efficacy, and attitudes toward school, thus enhancing their academic achievement (see, e.g., Sadik 2008). This may especially benefit disadvantaged students. Content creation projects include a wide array of activities such as engaging in multimedia content creation to communicate ideas about the material they are studying by creating reports, graphic representations of data they have researched or developed, websites, slides presentations, video production, digital storytelling, and other means. Darling-Hammond et al. (2014) described a technology-rich classroom for at-risk students, in which the teacher used one-to-one computers with wireless Internet connection to engage students in "word processing, spreadsheet, database, web page production and presentation software in a variety of contexts" (p. 9). Results showed that the students in this particular classroom ultimately outperformed other higher-tracked classes in their school in the state tests. According to the authors, the process of content creation allows students to develop their personal and academic voice with the scaffolding of technology. Due to their affective involvement with this process and the novelty effect of the medium, students are more engaged than in traditional assignments.

Citing research by Reeves (2004) and others, Warschauer (2011) argues that informational writing is a critical level for improving academic achievement among at-risk students and that technology-based writing instruction is thus especially valuable for promoting educational equity. He and his colleagues provide evidence from school districts with technology-based writing forms that have helped bridge performance gaps (Warschauer et al. 2014; Zheng et al. 2013).

Twenty-First-Century Learning Skills

Knowledge of core content is necessary, but no longer sufficient for success in postsecondary institutions and workplaces. Higher education and information economics place increasingly high value on people who can use their knowledge to communicate, collaborate, analyze, create, innovate, and solve problems. It is widely believed that technology use plays a pivotal role in helping students develop these so-called twenty-first-century skills. This broad concept can be categorized into three related skill sets: information, media, and technology skills; learning and innovation skills; and life and career skills. Even though we conceptualize twenty-first-century skills as a separate ability from traditional academic achievement for our discussion, these two components are highly correlated.

Ritzhaupt et al. (2013) provided a comprehensive examination of gaps in the three components of twenty-first-century skills among student groups. In this study, a large sample of students were asked to complete a performance-based assessment of digital literacy skills. Five domains were assessed: technology operations and concepts, constructing and demonstrating knowledge, communication and collaboration, independent learning, and digital citizenship. Results showed that high-SES and White students outperformed their counterparts in all domains. It is hinted in the study the divides in twenty-first-century skills may stem from different patterns of school technology use and out-of-school use among student groups.

In school settings, well-implemented technological programs are believed to facilitate acquisition of twenty-first-century skills. In a large-scale laptop program, for example, more than one-third of students reported using laptop from once a week to several times daily to gather and evaluate information, solve real-life problem, and visually present or investigate concepts. Warschauer (2006) interviewed teachers, students, and parents; conducted observations in the classrooms; and analyzed student work. He suggested that these kinds of learning activities may help enhance students' twenty-first-century skills and have important implication to other technology-based interventions.

Another question is whether low-SES schools provide students with equitable supports for achieving such skills compared with high-SES schools. A study demonstrated that students in lower-SES schools had less digital resources, used technology less frequently, and had more limited technical support and service, so as their teachers (Hohlfeld et al. 2008). These differences provided evidence of the existence of the divide in technology literacy among K–12 schools.

Youths could also develop their twenty-first-century learning skills from using technology in out-of-school environments. As at school, whether or the extent to which technology use can help enhance such skills depends on what kinds of activities youths perform with technology. Ito and her colleagues found that some youths are "geeking out" in interest-driven activities, which refers to an intense commitment or engagement with media or technology (Ito et al. 2009) and mastering sophisticated skills such as media literacy, creativity and innovation, communication and collaborations, and initiative and self-direction. Ito's interviews revealed some of the factors that may contribute to what she termed "information magic," including

adequate access to technology, high levels of commitment, and "an advanced media ecology that is finely tailored to youths' interests" (p. 69).

Unfortunately, not all youths benefit from these kinds of digital activities at the same level. There has long been a concern that girls are not gaining the same knowledge and skills about technology that boys are, because of differential attitudes toward technology and use at home. Fields et al. (2014) mapped out the gender difference in the online Scratch community, by far the largest online informal programming community primarily for young programmers aged 11–18, where they post Scratch programs that they create, view and comment on each other's work, and seek and provide help on forums. Drawing on a random sample of 5,000 youth programmers and their activities over 3 months in early 2012, Fields and his colleagues found that girls only represented one-third of all registered members on the Scratch site. The authors then classified the users into four different levels (i.e., beginner, intermediate, advanced, experience) based on their programing work. Girls were dramatically less likely to reach advanced and experience levels than boys. Additionally, since low-SES and minority children are reported to use technology in a less sophisticated way outside of schools (see discussion in Warschauer and Matuchniak 2010), we believe these groups may less likely to gain technology skills from the usage than their counterparts.

Conclusion

The research reviewed above hints at the complexity of equity issues intertwined with the rapid expansion of digital technology and its impact on students' access, use, and outcomes. Regarding access, it is clear that gaps in home and school technology access are narrowing but still persistent across SES and racial/ethnic groups. Regarding usage, youth groups differ in the manners and the extent digital technologies are used at schools and outside of schools. Since there is a wide range of technologies available and groups' usage pattern varies among forms of technology, it is challenging to summarize a single trend of inequality of technology usage. Regarding outcomes, how the differences in access and usage affect the disparities in outcomes remains inconclusive. The lack of concrete conclusion may partially be due to the inherent difficulty of causal inference – that is, to prove access and usage of technology *causes* the change of students' learning outcomes. Additionally, the majority of existing literature concerned with outcomes is based on non-representative small samples and tests the effect of a specific kind of technology/intervention. The mixed findings are thus highly contextualized and noncomparable.

Future research is needed to offer deeper understanding of the relationship of technology and equity. First, descriptive research which only examines SES, ethnic/racial, and gender differences in access and use is important but not sufficient. The inequalities have been confirmed. The future task should be to understand the reason for these inequalities as well as the possible approaches to alleviating the inequalities, other than merely describing the problems. For example, how family contexts or school contexts influence teenagers' technology usage patterns may be an

interesting question to explore. Second, to understand the outcomes of digital technology access and usage, it is crucial to have more studies with rigorous design, such as experimental research (e.g., random assignment, natural experiment) or longitudinal research. Third, researchers may want to further investigate the possible different effects of technology access and usage across SES, racial/ethnic, and gender groups, which may shed light on how technology may contribute to the achievement gaps.

References

Anderson, M. (2015). *Technology device ownership: 2015*. Pew Research Center. Retreived from Pew Research Center website: http://www.pewinternet.org/2015/10/29/technology-device-ownership-2015.

Andrews, G. (2008). Gameplay, gender, and socioeconomic status in two American high schools. *E-learning, 5*(2), 199–213.

Biagi, F., & Loi, M. (2013). Measuring ICT use and learning outcomes: Evidence from recent econometric studies. *European Journal of Education, 48*(1), 28–42.

Blank, G. (2013). Who creates content? Stratification and content creation on the internet. *Information Communication & Society, 16*(4), 590–612.

Common Sense Media. (2013). *Zero to eight: Children's media use in America 2013*. San Francisco: Common Sense Media. Retrieved from: https://www.commonsensemedia.org/file/zero-to-eight-2013pdf-0/download.

Common Sense Media. (2015). *Media use by tweens and teens*. San Francisco: Common Sense Media. Retrieved from: https://www.commonsensemedia.org/sites/default/files/uploads/research/census_executivesummary.pdf.

Connected Nation. (2013). *Examining school and library broadband. Connectivity. A connected nation policy brief*. Washington, DC: Connected Nation.

Culley, L. (1988). Girls, boys and computers. *Educational Studies, 14*(1), 3–8.

Darling-Hammond, L., Zielezinski, M. B., & Goldman, S. (2014). *Using technology to support at-risk students' learning*. Stanford Center for Opportunity Policy in Education. Online https://edpolicy.stanford.edu/publications/pubs/1241.

DiMaggio, P., Hargittai, E., Celeste, C., & Shafer, S. (2001). From unequal access to differentiated use: A literature review and agenda for research on digital inequality. Social inequality. Russell Sage Foundation. Retrieved from: https://www.russellsage.org/research/reports/dimaggio.

Dündar, H., & Akçayır, M. (2014). Implementing tablet PCs in schools: Students' attitudes and opinions. *Computers in Human Behavior, 32*, 40–46.

Fairlie, R. W., & London, R. A. (2012). The effects of home computers on educational outcomes: Evidence from a field experiment with community college students. *The Economic Journal, 122*(561), 727–753.

Fairlie, R. W., Beltran, D. O., & Das, K. K. (2010). Home computers and educational outcomes: Evidence from the NLSY97 and CPS. *Economic Inquiry, 48*(3), 771–792.

Fields, D. A., Giang, M., & Kafai, Y. (2014). Programming in the wild: Trends in youth computational participation in the online scratch community. *Proceedings of the 9th Workshop in Primary and Secondary Computing Education*, USA, 2–11.

File, T., & Ryan, C. (2014). Computer and internet use in the United States: 2013. In *American community survey reports, ACS-28*. Washington, DC: U.S. Census Bureau.

Hargittai, E., & Jennrich, K. (2016). The online participation divide. In M. Lloyd & L. Friedland (Eds.), *The communication crisis in America, and how to fix it* (pp. 199–213). New York: Palgrave Macmillan US.

Hohlfeld, T. N., Ritzhaupt, A. D., Barron, A. E., & Kemker, K. (2008). Examining the digital divide in K-12 public schools: Four-year trends for supporting ICT literacy in Florida. *Computers & Education, 51*(4), 1648–1663.

Ito, M., Baumer, S., Bittanti, M., Cody, R., Stephenson, B. H., Horst, H. A., . . . Pascoe, C. (2009). *Hanging out, messing around, and Geeking out: Kids living and learning with new media*. Cambridge: MIT press.

Jackson, L. A., Von Eye, A., Biocca, F. A., Barbatsis, G., Zhao, Y., & Fitzgerald, H. E. (2006). Does home internet use influence the academic performance of low-income children? *Developmental Psychology, 42*(3), 429.

Junco, R. (2013). Inequalities in Facebook use. *Computers in Human Behavior, 29*(6), 2328–2336.

Khan, M. L., Wohn, D. Y., & Ellison, N. B. (2014). Actual friends matter: An internet skills perspective on teens' informal academic collaboration on Facebook. *Computers & Education, 79*, 138–147.

Kitchen, R., & Berk, S. (2016). Educational technology: An equity challenge to the Common Core. *Journal for Research in Mathematics Education, 47*(1), 3–16.

Lee, T. L. (2013). *Educational technology and equity: Students access to and use of computers in low-socioeconomic and middle-class socioeconomic schools* (Doctoral dissertation). Retrieved from ProQuest LLC.

Li, J., Snow, C., & White, C. (2015). Urban adolescent students and technology: Access, use and interest in learning language and literacy. *Innovation in Language Learning and Teaching, 9*(2), 143–162.

Lin, C. H., Liu, E. Z. F., & Huang, Y. Y. (2012). Exploring parents' perceptions towards educational robots: Gender and socio-economic differences. *British Journal of Educational Technology, 43*(1), E31–E34.

National Education Association. (2008). *Access, adequacy, and equity in education technology*. Washington, DC: National Education Association. Retrieved from: https://www.edutopia.org/pdfs/NEA-Access,Adequacy,andEquityinEdTech.pdf.

OECD. (2010). *Are the new millennium learners making the grade? Technology use and educational performance in PISA 2006*. Paris: OECD.

OECD. (2016). Are there differences in how advantaged and disadvantaged students use the Internet? Retrieved from OECD website: http://www.oecd-ilibrary.org/education/are-there-differences-in-how-advantaged-and-disadvantaged-students-use-the-internet_5jlv8zq6hw43-en.

Ono, H., & Zavodny, M. (2008). Immigrants, English ability and the digital divide. *Social Forces, 86*(4), 1455–1479.

Pew Research Center. (2005). *Teen content creators and consumers*. Pew Research Center. Retrieved from: http://www.pewinternet.org/~/media//Files/Reports/2005/PIP_Teens_Content_Creation.pdf.pdf.

Pew Research Center. (2015a). *Teens, social media & technology overview 2015*. Pew Research Center. Retrieved from: http://www.pewinternet.org/2015/04/09/mobile-access-shifts-social-media-use-and-other-online-activities/.

Pew Research Center. (2015b). *Teens, technology & friendships*. Pew Research Center. Retrieved from: http://www.pewinternet.org/files/2015/08/Teens-and-Friendships-FINAL2.pdf.

Prensky, M. (2012). Eliminating the 'app gap'. *Educational Technology*. Retrieved from http://marcprensky.com/writing/Prensky-EDTECH-EliminatingtheAppGap-Jan-Feb-2012.pdf.

Rachel, M. (2012). Wasting time is the new digital divide. *New York Times*. Retrieved from: http://www.nytimes.com/2012/05/30/us/new-digital-divide-seen-in-wasting-time-online.html?pagewanted=all.

Reeves, D. B. (2004). *Accountability in action: A blueprint for learning organizations*. Englewood, CO: Advanced Learning Press.

Ritzhaupt, A. D., Liu, F., Dawson, K., & Barron, A. E. (2013). Differences in student information and communication technology literacy based on socio-economic status, ethnicity, and gender: Evidence of a digital divide in Florida schools. *Journal of Research on Technology in Education, 45*(4), 291–307.

Sadik, A. (2008). Digital storytelling: A meaningful technology-integrated approach for engaged student learning. *Educational Technology Research and Development, 56*(4), 487–506.

Snyder, T. D., de Brey, C., & Dillow, S. A. (2016). *Digest of education statistics 2014 (NCES 2016-006)*. Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Retrieved from: http://nces.ed.gov/pubs2016/2016006.pdf.

U.S. Department of Education. (2016). Retrieved from LAUSD website: http://laschoolreport.com/wp-content/uploads/2015/01/Federal-Ipad-MiSiS-report.pdf.

Vigdor, J. L., & Ladd, H. F. (2010). Scaling the digital divide: Home computer technology and student achievement. *Economic Inquiry, 52*(3), 1103–1119.

Warschauer, M. (2006). *Laptops and literacy: Learning in the wireless classroom*. New York: Teachers College Press.

Warschauer, M. (2011). *Learning in the cloud*. New York: Teachers College Press.

Warschauer, M., & Matuchniak, T. (2010). New technology and digital worlds: Analyzing evidence of equity in access, use, and outcomes. *Review of Research in Education, 34*(1), 179–225.

Warschauer, M., Knobel, M., & Stone, L. (2004). Technology and equity in schooling: Deconstructing the digital divide. *Educational Policy, 18*(4), 562–588.

Warschauer, M., Cotten, S. R., & Ames, M. G. (2011). One laptop per child Birmingham: Case study of a radical experiment. *International Journal of Learning and Media, 3*(2), 61–71.

Warschauer, M., Zheng, B., Niiya, M., Cotten, S., & Farkas, G. (2014). Balancing the one-to-one equation: Equity and access in three laptop programs. *Equity & Excellence in Education: University of Massachusetts School of Education Journal, 47*(1), 46–62.

Wenglinsky, H. (2005). *Using technology wisely: The keys to success in schools*. New York: Teachers College Press.

White House Council of Economic Advisers Issue Brief. (2015). *Mapping the digital divide*. Washington, DC: White House.

Williams, N. L., & Larwin, K. H. (2016). One-to-one computing and student achievement in Ohio High Schools. *Journal of Research on Technology in Education, 48*(3), 143–158.

Wohn, D. Y., Ellison, N. B., Khan, M. L., Fewins-Bliss, R., & Gray, R. (2013). The role of social media in shaping first-generation high school students' college aspirations: A social capital lens. *Computers & Education, 63*, 424–436.

Zheng, B., Warschauer, M., & Farkas, G. (2013). Digital writing and diversity: The effects of school laptop programs on literacy processes and outcomes. *Journal of Educational Computing Research, 48*(3), 267–299.

Zheng, B., Warschauer, M., Lin, C.-H., & Chang, C. (2016). Learning in one-to-one laptop environments: A meta-analysis and research synthesis. *Review of Educational Research, 86*, 1052–1084.