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Exploring the Digital Divide: The Use of Digital Technologies in Ontario Public Schools

Explorer le fossé numérique : l'usage des technologies numériques dans les écoles publiques de l'Ontario

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Abstract

Combining data from a school principal survey with student demographics and achievement data, the present study aimed to develop a much needed understanding of Information and Communications Technology (ICT) use in Ontario's K-12 public schools. Results indicated equitable first-order access to technology in school, early integration of ICT from the earliest grades, frequent application of ICT in day-to-day teaching, and an enabling effect of ICT on additional access to learning resources and distance learning. However, challenges were also uncovered in building technology infrastructure for a small fraction of schools; ensuring home access for schools with lower family incomes, of smaller size or from remote regions; and providing teachers with professional development for choosing online materials and adopting emerging ICT-enabled teaching practice. Furthermore, this study highlighted the importance of parent involvement in ICT use and the potential beneficial linkage between ICT use and student learning achievement.

Résumé

Combinant les données d'une enquête auprès des directeurs d'écoles aux données sur les caractéristiques démographiques et la réussite des élèves, la présente étude visait à développer une compréhension nécessaire de l'utilisation des technologies de l'information et des communications (TIC) dans les écoles publiques ontariennes de la maternelle à la 12e année. Les résultats ont indiqué un accès de premier ordre équitable à la technologie à l'école, une intégration des TIC dès les premières années, l'application fréquente des TIC dans l'enseignement quotidien et un effet habilitant des TIC sur l'accès additionnel à des ressources d'apprentissage et à l'apprentissage à distance. Des défis ont toutefois été mis au jour dans la construction de l'infrastructure technologique pour une petite fraction des écoles, pour assurer l'accès de la maison pour les écoles dont les familles avaient un plus faible revenu, qui étaient de plus petite taille ou dans une région éloignée, et pour fournir aux enseignants de la formation professionnelle pour choisir le matériel en ligne et adopter des pratiques d'enseignements

permettant l'usage des TIC émergentes. De plus, cette étude a souligné l'importance de la participation des parents dans l'usage des TIC et le lien potentiellement bénéfique entre l'utilisation des TIC et la réussite de l'apprentissage de l'élève.

Introduction

Information and communications technology (ICT) is playing an increasingly important role in various social sectors in the information age. Individuals are expected to be equipped with crucial digital competencies in order to effectively participate in the economic, political, and social aspects of this new age. Digital literacies—which include information literacy, media literacy, and ICT literacy—have been highlighted as a pillar of "21st century skills" in a number of influential initiatives (Binkley et al., 2012; Trilling, Fadel, & Partnership for 21st Century Skills, 2009), leading educators to credit digital literacies as an independent school subject (Nan, 2001; Tondeur, Van Braak, & Valcke, 2007). Digital literacies are increasingly being treated as an integral component of teaching and learning in more recent policy documents (e.g., U.S. Department of Education, 2010), reflecting an evolving conceptualization of literacy over the years (Buckingham, 2010). Even more profoundly, the broad and deepening use of ICT among young generations has given rise to a "participatory culture," which continues to redefine the meaning of digital literacies and motivate active reconsideration of current school curricula in this area (Jenkins, 2006).

While using ICT is an important competency for students, ICT could also function as an "enabler" of teaching and learning. Technologies could extend learning to spaces beyond classrooms, allow for new curricula that bring real-world problems into schools, and support new forms of assessment that are more formative and immediate (Bransford, Brown, & Cocking, 2000; Scardamalia, Bransford, Kozma, & Quellmalz, 2012). New technological innovations, such as mobile technologies, open content, learning analytics, educational games, are continuing to garner interest in a range of educational contexts (Johnson, Adams, & Cummins, 2012), showing promise in facilitating active learning, higher-order thinking, collaboration, and knowledge creation. Meanwhile, technologies may readily transform the role of teachers as well, demanding new areas of teacher knowledge and professional development (Mishra & Koehler, 2006). Overall, rich evidence has demonstrated that while being coupled with good teaching and informed by the science of learning, the use of ICT could substantially benefit student learning (Sawyer, 2006).

The Digital Divide in Schools

With the boom of ICT use arises the issue of the "digital divide," which originally refers to the gap between the privileged and underprivileged members of society in terms of ability to access digital tools and the Internet. Given ICT is increasingly mediating social and cultural participation in the information age, such a digital divide could potentially leave many people behind. Yet, this divide is reportedly growing wider (McConnaughey, Everette, Reynolds, & Lader, 1999), reinforcing existing economic inequalities (Norris, 2003) and transferring to other areas including skills of effectively using ICT (van Dijk, 2006). Such a digital divide is also widely reported to exist within schools in both developing (Li & Ranieri, 2013; Yang et al., 2012) and developed countries (Warschauer, 2003); education, which is usually conceptualized

as a tool to mitigate societal inequity of many kinds, is also a contributing factor of the digital divide (Bagchi, 2014).

The digital divide also manifests in households. ICT access at home is linked with family socio-economic status (SES) (OECD, 2007). Taking the United States as an example, the use of computer and the Internet is higher among Whites than among Blacks and Hispanics; students living with more highly educated parents or living in households with higher family incomes are more likely to be able to use computer and the Internet at home (DeBell & Chapman, 2006). Internationally, even though computer and the Internet have reached relatively high diffusion levels across and within OECD countries, the access gap between the highest and lowest income groups had actually expanded in most OECD countries (OECD, 2007).

Conversations about the digital divide have expanded from first-order issues related to technological access to secondary ones concerning opportunities to participate and development of necessary skills and competencies to participate (Zhong, 2011). For instance, research has uncovered substantial variation in online information retrieval skills among individuals (Hargittai, 2001). Studies also find students from low vs. high SES schools use computers in different manners—students in low SES schools use computers more often for drill and practice, whereas their counterparts in higher SES schools use computers more often for writing and activities involving higher-order thinking (Wayne, Zucker, & Powell, 2002; Wenglinsky, 1998). The expanding conception of the digital divide calls for deeper inspection of the ways digital technologies are integrated in classrooms, to include the interaction of new qualities of teacher knowledge (Mishra & Koehler, 2006), beliefs (Ertmer, 2005), and school culture (Ertmer & Ottenbreit-Leftwich, 2010).

Building upon previous research on the digital divide, Hohlfeld, Ritzhaupt, Barron and Kemker (2008) propose a framework to examine multiple levels of digital divide in schools. This framework distinguishes three levels of digital divide (see Figure 1): The first level deals with equitable access to ICT within schools; the second level involves the degree of technology integration in classroom teaching and learning; and the third level addresses the extent to which ICT is used to empower student learning in the school context. This framework could serve as a tool for examining the digital divide in schools by helping us attend to issues at the second and third levels that have been traditionally neglected in conversations about the digital divide.

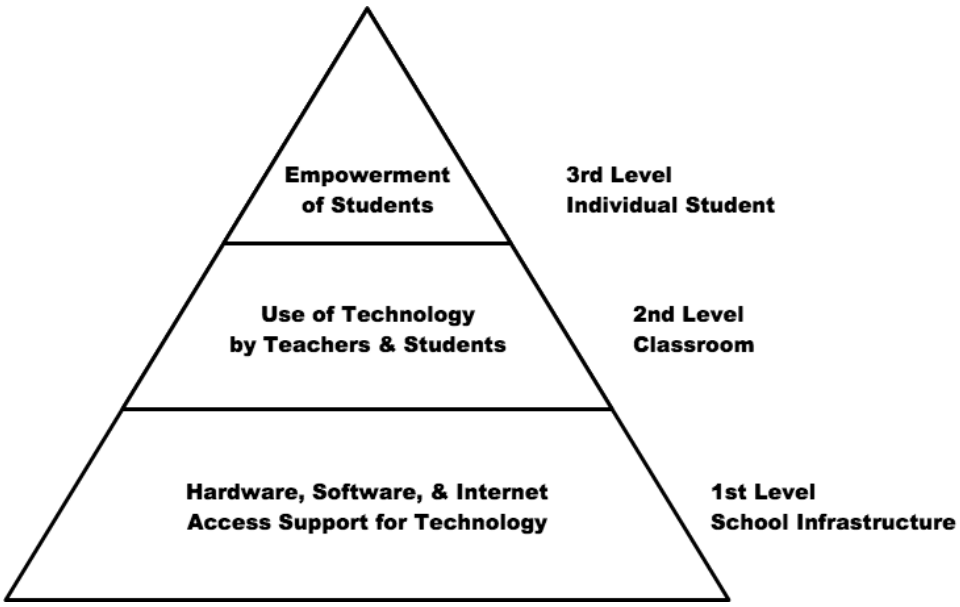

Figure 1. Levels of digital divide in schools (adapted from Hohlfeld et al., 2008).

The Digital Divide in Canadian Schools

Canada is among the countries that share the vision of recognizing digital literacies as an important area of their competitiveness. The competency of using digital technologies has been identified as one of the essential skills for the workspace by the Government of Canada, together with literacy, numeracy, critical thinking, communication, working with others, and so forth (Employment and Social Development Canada, 2013). However, because the unique feature of Canada's province-based jurisdiction, to date there is no national policy on digital learning in place. Policies and strategies of digital learning solely depend on individual provinces and territories. Previous reviews of policy documents have identified both common grounds and extensive discrepancies in the area of digital learning among Canadian provinces and territories (Abrami et al., 2006; Borokhovski et al., 2011; McGreal & Anderson, 2007). For example, ICT competencies have been included in the formal curriculum in Alberta (Alberta Education, 2014), but only get briefly mentioned in Ontario's curriculum standards (Ontario Ministry of Education, 2007), leaving local school boards defining ICT curricula on their own (e.g., TDSB, 2010). Moreover, little empirical research has been carried on to study ICT integration in provincial education systems. While there is widespread acknowledgement of the importance of ICT for today's students and schools, there is little system-wide data about how—and how widely—technology is being used in Canadian schools.

In the meantime, research has confirmed a digital divide for Canadian youth in access to and experience with ICT: Rural, female, and youth with lower SES are less likely to have access to computers at home, and they tend to access computers less frequently and report lower levels of computer skills (Looker & Thiessen, 2003). In each case, levels of parent education are seemingly magnifying the digital divide of children. Such a divide in Canada could be partially attributed to a first-level digital divide observed by Statistics Canada in terms of household (Middleton, Veenhof, & Leith, 2010; Sciadas, 2002; Statistics Canada, 2010, 2013). As found by a recent survey, 83% of households had Internet access at home; however, 98% of households in

the top income quartile had home Internet access, compared with 58% of households in the lowest income quartile (Statistics Canada, 2013). Thus, it is of great public interest to investigate whether schools, especially public schools, are providing enough opportunities for youth to engage with ICT in Canada. Of the same importance is to study how ICT are being integrated in classrooms to support teaching and learning.

The Present Study

The present study seeks to investigate the status quo of ICT use within public schools of Ontario. Because of Canada's unique feature of leaving education entirely within provincial jurisdiction, understanding Ontario, the most populous province in Canada, is of great importance. This study is particularly interested in the digital divide at multiple levels. Following the multi-level model presented above (Hohlfeld et al., 2008), investigation of the digital divide in the present study includes basic access to technologies, teacher readiness, systematic support for ICT use in Ontario public schools, and linkages between ICT use and student success. In particular, this study explores the following research questions: (a) Level 1—What is the status quo of equitable access to technology both in school and at home for public school students across Ontario? In particular, is equitable access linked to SES or geographical backgrounds of schools? (b) Level 2—What is the situation of ICT integration in Ontario's public schools? Specifically, what type of educational tools are being used, how frequent, and for what? (c) Level 3—Is there any evidence of linkages between ICT use and student achievement and empowerment in Ontario schools?

Methods

Participants and Data Sources

To investigate the use of digital tools in Ontario's public schools, survey data were collected from principals of Ontario's K-12 public schools. To uncover possible linkages between the digital divide and SES variables, the survey data were combined with school-level student demographics data from the Ontario's Education Quality and Accountability Office (EQAO); to inspect possible relations between ICT use and student achievement, EQAO student questionnaire data were analyzed. Specifically, data in the present study were composed of three parts.

People for Education School Principal Survey. People for Education (P4E), an Ontario education advocacy group, has been distributing surveys to principals from Ontario's public schools during the past seventeen consecutive years.[1] The survey acts as an information tool for interested parents and Ontario citizens. It focuses on quantifiable resources available in schools across the province, tracking any changes that occur over the years. P4E's annual survey has been asking important questions concerning many aspects of public education in the Ontario context, including early childhood education, special education, aboriginal education, and so forth. For the first time, the 2013 P4E survey included a new section about "Digital Learning and

[1] Where not otherwise cited, the statistics in this report are from People for Education's 17th annual survey of resources in Ontario elementary schools and 14th annual survey of secondary schools (2013-2014).

Technologies in Schools" for both elementary and secondary schools. Table 1 presents the major questions asked in the Digital Learning section, as well as the level of digital divide (see Figure 1) addressed by each of them. Open ended questions were also designed to collect qualitative responses from principals about successes and challenges of ICT integration.

Table 1

Major Questions Asked in the Digital Learning Section of the P4E Questionnaire

Questions	School level	Level of digital divide
When do students start using computers as an integrated part of their learning?	Elementary	2
Where do students access technologies in school?	Elementary	1
Does your school have students without access to a computer with Internet at home?	Elementary & Secondary	1
What are the most likely new learning sources for teachers?	Elementary & Secondary	2
How often do teachers use a blog or other online communication to communicate with parents or students?	Elementary	2
How often do teachers use the following technologies for instruction and/or assignments?	Secondary	2
How many students are earning credits through e-learning?	Secondary	2

In October 2013, surveys were sent to principals in 5642 public schools listed in a school information open dataset available on Ontario's open data repository,[2] through both postal mails and emails containing the link to an online survey system. Translated surveys were sent to French-language schools. Two follow-up reminders were emailed to schools in November and December. A total of 1608 public schools responded to this survey, with a participation rate of over 28% of Ontario's publicly-funded schools, serving over 2 million students. Among those responses, 1349 responses (from 1311 elementary and 297 secondary schools) were valid, which equals 24% of the province's public schools. All of the province's 72 school boards were represented.

[2] Contact information for publicly funded schools in Ontario, from Ontario's open dataset: https://www.ontario.ca/education-and-training/ontario-public-school-contact-information. Retrieved in October 2013

School-Level Student Demographics Data from EQAO. The second set of data included school-level demographics shared by EQAO. This demographics dataset contained school-level summary data from the Statistics Canada 2006 census. In particular, for each school the following variables were included: socioeconomic variables, including average family income, parent educational backgrounds, percentage of single parent families, percentage of recent immigrants, and percentage of aboriginal students; and percentage of students with special needs and percentage of students identified as English learners. A unique identification number was provided for each school so that this EQAO dataset could be linked with the P4E survey data.

EQAO Grade 6 Student Questionnaire. This EQAO student questionnaire primarily focused on assessments of student reading, writing and mathematics from the Junior division (Grades 4–6), 2012-2013. This dataset contained a number of variables related to performance of 138,222 Grade 6 students in each of these three areas. Taking writing for example, it reported the extent to which a student *liked* writing, a student thought he or she *is good at* writing, the ability to *use writing to communicate ideas*, the *effort* to become a good writer, etc. Pertinent to the present study of ICT use in schools, this dataset also contained information such as: the frequency of reading or writing on digital devices, time spent on the Internet before or after school, and frequency of using a computer together with a parent. Additionally, demographic data, such as student grade, gender, special needs, and giftedness, were also included in this dataset.

Data Analyses

The present study employed a quantitative research design, with analyses mainly based on descriptive statistics of the dataset. The descriptive statistical analysis was carried out to look at the central tendency and spread of variables, to summarize and present numerical information in a manner that is illuminating and useful for answering research questions. In a few instances, inferential statistical analysis was used to examine hypotheses and to estimate parameters of the population. Additionally, schools were sorted according to their postal codes into geographic regions to examine potential geographical patterns. P4E survey data and EQAO's demographics data were combined on a school-by-school basis to examine patterns of technology access and use based on a number of demographics variables. Comments from principals in P4E survey were used to enhance, elaborate or explain the quantitative results and to shed light on the issues explored in the report.

Results and Discussion

Access to Technology in School (Level 1)

Despite sharp divide in terms of household access to the Internet reported by Statistics Canada (2010, 2013), Ontario public schools provided almost universal access to technologies for students. Among surveyed elementary and secondary schools, 99% of them provided students with access to computers in school. This number was higher than 84%—the percentage of Ontario's households with home Internet access in 2012 (Statistics Canada, 2013). For the 1% of schools without Internet access, we found them not coming from specific regions or representing

specific SES groups. However, we found four of these schools also reporting having students without Internet access at home, raising concern of not serving the needs of some students.

Analysis of survey results indicated most elementary schools provided rich opportunities for students to use technology. In Ontario's elementary schools, the most common place for students to access technology was their own classrooms, followed by libraries, computer labs, and—in a majority of schools—students' own devices (see Table 2). The result implied deeper integration of ICT in teaching and learning, in the sense that access to technologies were predominantly provided in classrooms rather than separate computer labs. In some cases, according to principals, schools had "mobile labs" where sets of computers were moved between classrooms. Issues related to not having enough access to computers reported in earlier studies (e.g., Bauer & Kenton, 2005) were less likely to constrain ICT integration in most Ontario public schools.

Table 2
Where Do Students Access Technologies in Elementary Schools?

Access to technologies in school	Elementary schools
In classrooms	96%
In the library	85%
In a lab	76%
On their own devices	58%

The rise of mobile devices among students and their families was influencing ICT access in school. The adoption of mobile technologies in learning was recognized as an important trend in K-12 education (Johnson et al., 2012), with great promise in promoting motivation (Rau, Gao, & Wu, 2008), sustaining conversations (Sharples, 2002), and supporting seamless learning experiences (Looi et al., 2010). As indicated in Table 2, 58% of elementary schools reported students accessing technologies in school "on their own devices." This result indicated "Bring Your Own Device (BYOD)"—the practice of having "students bring a personally owned device to school for the purpose of learning" (Alberta Education, 2012, para. 1)—has been adopted in Ontario schools. For example, it was reported that one large school board encouraged its 153,000 public school students to bring their smartphones, tablets and laptop computers to class to expand their access to technologies in school. One principal from another school board mentioned that BYOD was helping to improve access to computers for all students, enabling "1:1 Computing" in schools (Bebell & Dwyer, 2010). As reported by another principal: "We also have classes who use the BYOD model so everyone has a device to use, between school and student-owned devices."

However, principals also reported first-level access challenges, including the lack of network infrastructure and slow or unstable wireless access. For example, one school from Northern Ontario did not have the bandwidth to support a lot of Internet activity in the school, making its principal feeling his school was lagging behind. Around a dozen principals also commented on the frustrations of using dated technology and the challenge of staying current given a limited school budget. The issue here is no longer the access to computers and the Internet but the *quality* of access. Notably, access with lesser quality was contributing to second-level digital

divide issues. For instance, one elementary school principal reported that having difficulty with accessing the Internet had been undermining his plan to advance teachers' ICT competencies.

Access to Technology at Home (Level 1)

According to the 2012-2013 EQAO student survey data, 10% of Grade 6 students reported they were not using the Internet either before or after school. Although this non-use could be attributed to parent supervision, chances are that it was caused by the lack of access at home, given 16% of Ontario households did not have home Internet access in 2012 (Statistics Canada, 2013). The P4E data showed 73% elementary and 74% secondary school principals reported that they were aware of having students without access to technology at home, with an additional 16% elementary and 15% secondary school principals not knowing the answer. Further analysis combining EQAO school-level demographics data found that schools with lower family incomes, smaller school size, or from more remote regions were more likely to have students without access to technology at home. The average family income of elementary schools having students without access at home was significantly lower than those schools without such students, $t(113) = 6.00$, $p < .001$, $d = 1.13$ (a large effect of Cohen's d is conventionally .80). Seventy-nine percent of schools with aboriginal students reported having students without home access to the Internet, compared to 70% for schools without aboriginal students. Smaller schools, which were normally located in remote regions (e.g., Northern Ontario), reportedly had more students without access to ICT at home.

To tackle this challenge, some schools tried to provide access at school as much as possible or to provide affordable technology for families to purchase for home or school use. Some schools lent portable devices to students to bring home. In some other cases, schools just decided to send paper copies of materials home.

Early ICT Integration in Elementary Schools (Level 2)

Going beyond the first-level digital divide, the P4E survey also asked about "integral use" of technologies in classrooms. As shown in Figure 2, principals in 79% of Ontario elementary schools reported students started using computers as an integrated part of their learning in kindergarten, with another 12% starting from Grade 1.

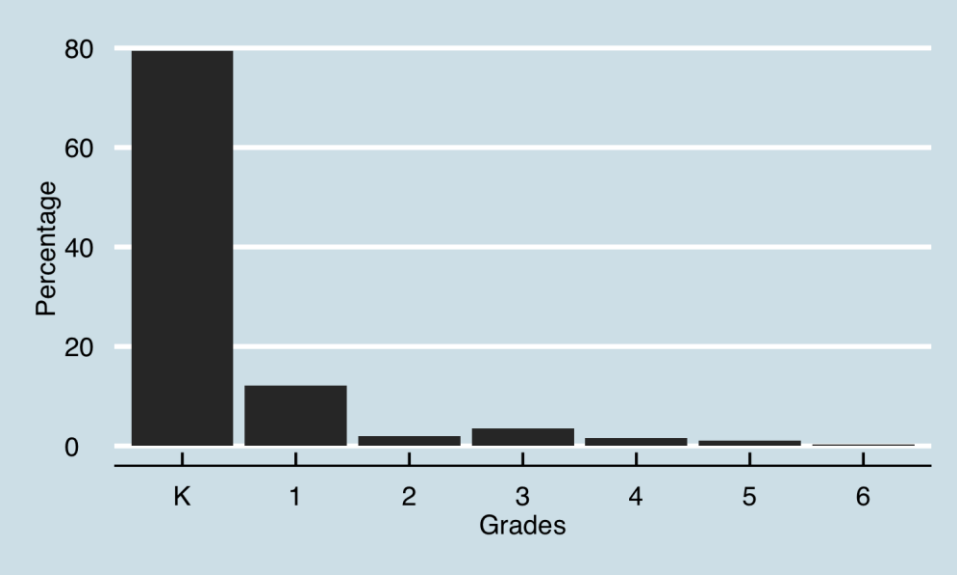

Figure 2. Early ICT integration in Ontario's elementary schools. Elementary school students predominately started using computers from kindergarten or Grade 1.

To validate principals' understanding of "integral use," we further inspected their qualitative comments regarding digital learning. While some researchers have raised concerns that technology is not always well-integrated into teaching and learning (Jenson, Taylor, & Fisher, 2010), comments from the surveys suggested that many principals were aware of this issue and reported an improvement over the depth of ICT integration. As one principal said, "We are beginning to integrate the technology more into our teaching and learning as opposed to it being a subject to itself. The [interactive whiteboard] technology is beginning to be used more. Students and staff are seeing it more as a tool as opposed to a magical machine." Even among the 4% of schools that reported computer use starting in Grade 4 or later, results from follow-up inquiries showed that in many cases students had computer access earlier, but it was only in the later grades that the use became truly integrated into learning. Plausibly, principals were making a distinction between learning the mechanics of ICT and using it as part of student learning. As one principal who had reported: "Primary and Grade 4 students may do occasional assignments with technology and the teacher may use the [interactive whiteboard] at times. The Grade 5 to 8 students use it much more regularly, and it is much more visible in their classes—many individual students have SEA (special education assistive) laptops, and the [technology carts] are regularly moved amongst the Grade 5 to 8 classes."

Use of Technology in Classrooms (Level 2)

Technology is being used in Ontario schools in a variety of ways. In secondary schools, using technology to access additional materials appeared to be the most popular usage. As indicated in Figure 3, a large portion of secondary school principals reported most of their teachers using online videos, external websites, or their own websites for teaching. For example, 43% of the secondary school principals reported being aware of most or all of their teachers using online videos in classrooms.

However, some other technologies widely reported as recent pedagogical innovations were comparatively less commonly used by teachers. For example, game-based learning has gained considerable traction in academia, gaming industry, and educational practice; nevertheless, only 4% of principals reported most or all of their teachers were using it. It was the same case for using social networking tools for instruction: even though a considerable portion of teachers were experimenting with social networking tools—51% of principals reported having teachers using them—they were not widely applied. This could be attributed to a gap that normally exists for systematic implementation of meaningful and rigorous professional development in relation to ICT-based teaching, either for pre-service or in-service teachers (Cuban, 2003). In integrating ICT into teaching teachers are likely to face significant barriers, including lack of confidence, competence, and access to resources (Bingimlas, 2009). Whether current professional development initiatives in place are serving needs of Ontario's teachers is worth further investigation.

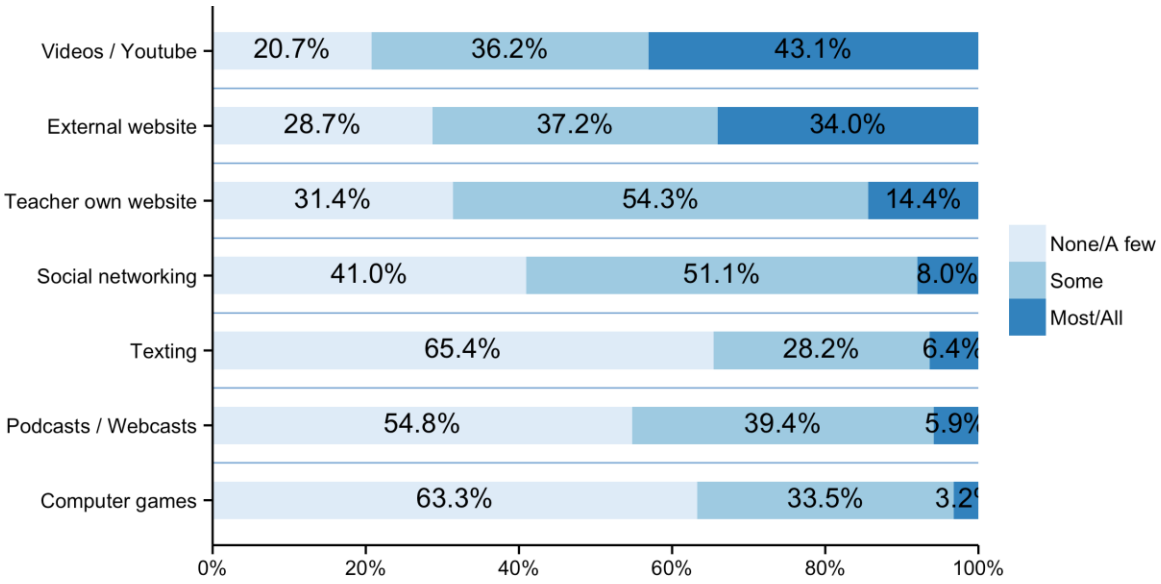

Figure 3. Teacher's use of digital tools in Ontario secondary schools. Online videos and external websites were popularly used among teachers, while computer games were least applied.

Adoption of Digital Learning Resources (Level 2)

Digital tools afford new choices of learning resources in school. Analysis of the P4E survey revealed that with technology both elementary and secondary schools were moving away from textbook dependence. As a principal commented: "Textbooks are not purchased very often anymore." The use of "free online materials" is driving this change, with the use of "free online materials" representing a significant portion of new learning resource acquisition (see Table 3). Specifically, in 36% of elementary schools teachers treated free online resources, rather than print or non-print textbooks, as their first choice when acquiring new learning resources. Although this percentage was lower in secondary schools, just reaching 25%, it was certain teachers were turning to a combination of both print and online materials when they needed new materials.

Table 3
Choices of New Learning Resources in Ontario Schools

Most likely new learning resources for teachers	Elementary	Secondary
New print textbooks or materials	31%	33%
Online resources developed by publishers	19%	22%
Free online materials	36%	25%
Other	14%	20%

This choice of new learning resources reportedly depended on teachers' preferences and comfort levels. This is related to the fact that the decision of which resources get into Ontario classrooms is largely decentralized: The Ontario Ministry of Education sets curricula and approves resources; districts and schools make their own spending decisions. According to P4E survey results, in some cases teachers were "very resourceful" in finding web resources for their own teaching or were able to turn to other staff when seeking quality free online materials. In other cases, schools encouraged teachers to develop their own resources online or use Ontario's online resource repositories (e.g., an Ontario Educational Resource Bank created under Ontario's e-Learning Strategy). Furthermore, in many cases purchases of hardware and software primed the choice of digital content; digital content were increasingly purchased within specific "digital ecosystems," in the form of apps for tablets, interactive whiteboards, or Learning Management Systems. In the meantime, not every teacher was comfortable with this change. "[Teachers] are very resistant and prefer print materials," said one principal. In these cases, teacher professional development is needed to help teachers make sound choices of learning resources that reflect accessibility, quality, and Canadian contexts.

ICT as an Enabler of Learning beyond the Classroom Walls (Level 2)

One other important role learning technologies play is to extend learning opportunities beyond the walls of schools. Distance education over the Internet has been gaining significant traction over the past years, if not decades. This has been the case for post-secondary education, as reflected by the escalating popularity of Massive Open Online Courses (MOOCs) since 2011 (Pappano, 2012). It has also been the case for K-12 education, as shown by examples such as the Khan Academy (Thompson, 2011). Web technologies are becoming an enabler of learning, playing an important role in providing students opportunities to learn face-to-face or from distance, or in either formal or informal settings.

The Ontario e-Learning Strategy (see: http://www.edu.gov.on.ca/elearning/strategy.html) was created to assist school boards with providing e-learning opportunities for students. One important component of this initiative was to offer e-learning credit courses, taught by e-learning teachers using the provincial Learning Management System, to students who could not be in the physical classroom to learn or wished to access courses during different periods of the day.

According to the analysis of P4E survey, 48% of Ontario secondary schools had students earning credits through e-learning. Schools participating in the survey reported a total of 2599 students

were reported as having earned e-Learning credits, with 21 students on average for each school, accounting for 2.9% of their student populations.

Further inspection found that smaller schools tended to have a higher percentage of students earning credits through e-learning. As southwest and northern regions tended to have smaller schools, schools in these regions were also more likely to have students earning credits through e-learning; compared to the 45% of schools in Toronto that reported having such students, the percentages for southwest and northern regions were respectively 63% and 52%. Thus, online learning appeared to be in demand for students from remote regions or from smaller schools which were less likely have certain unique learning opportunities.

Probing the Tie between ICT Usage at Home and Student Achievement (Level 3)

Since its introduction to teaching and learning, researchers have been attempting to investigate the linkage between ICT and student achievement. Numerous studies were dedicated to supporting or rejecting ICT's effectiveness in facilitating greater learning achievement (e.g., Aristovnik, 2012). Results were mixed, because learning processes are complex and involve many variables such as teachers' knowledge, learners' dispositions and beliefs, and varied conceptualizations of learning by stakeholders. In addition, other factors, such as SES status, family structure, and parent involvement, were recognized as mediating factors of ICT use as well (Janus & Duku, 2007; Lee, 2002). Overall, links between technology and student achievement need to be interpreted with caution and less ambition.

Regardless of these difficulties, probing the "weak" tie between ICT use and student achievement is important for studying the Level 3 (i.e., individual empowerment) of digital divide in schools. In the Ontario context, earlier research uncovered positive linkages between computer use at home and student performance in high-stake standardized tests on literacy (Zhang, Zhao, Chen & Childs, 2012). With access to large-scale provincial data, this study aimed to deepen our understanding in this area.

Before examining the linkage between ICT use and student achievement, descriptive analysis of EQAO student questionnaire data found that on average, Grade 6 students spent 1.86 hours (*SD* = 1.71) using the Internet at home per day. Most of Internet use happened after school, 1.52 hours on average (*SD* = 1.32). No gender difference was confirmed; other factors, such as English being the second language, being enrolled in an ESL program, and being born outside Canada, had a negligible effect on the time spent on the Internet.

The link between Internet use and student performance was investigated using students' self-report Internet activities and their performance in reading, writing, and mathematics (ranging from *Below Level* 1 to *Level 4*) in the EQAO student questionnaire data. Figure 4 illustrates a trend consistent for three subject areas; that is, students having better performance or having greater confidence in reading, writing, and mathematics spent less time on the Internet at home. Interestingly, while using the Internet at home for more than 2.5 hours every day was related to lower performance, non-use also appeared to be disadvantageous. Taking overall reading performance for example, students who spent half an hour on the Internet each day had the highest performance (*M* = 3.02, *SD* = 0.61, approximately *Level 3* in the standardized test), whereas those not using the Internet at all or spent 8 hours had lower performance (*M* = 2.89, *SD*

= 0.67 and *M* = 2.43, *SD* = 0.71, respectively). Plausibly, using the Internet for excessive amount of time could be attributed to poor parental supervision, and non-use could be linked to a lack of access and/or lower ICT literacy of parents.

To investigate the potential mediating effect of parent involvement, further analysis of variance (ANOVA) was conducted, adding variables related to parent involvement reported by the student questionnaire (e.g., talking with a parent about school activities, talking about academic work in school, looking at school agenda together, reading with a parent, using a computer together). On the one hand, results indicated that the more frequently parents talked with students about their school activities or school agenda, the less time students spent on the Internet at home. For instance, students who never talked about school activities with a parent or guardian spent an average of 2.6 hours a day on the Internet, compared to 1.7 hours for students who discussed school activities every day. On the other hand, such parent involvement was also found to be significantly connected to performance in all three aspects (i.e., reading, writing, and mathematics). For example, students who never talked about school activities with a parent had lower performance than those who talked with a parent every day (*M* = 2.60 and *M* = 2.97, respectively). Meanwhile, students who spent more than 3 hours on the Internet showed lower performance, regardless of the extent of parent involvement. Plausibly, using the Internet with less parental supervision or involvement is likely to lead to unwise usage and thus lower academic performance. This mediating effect of parent involvement in ICT use is worth further investigation.

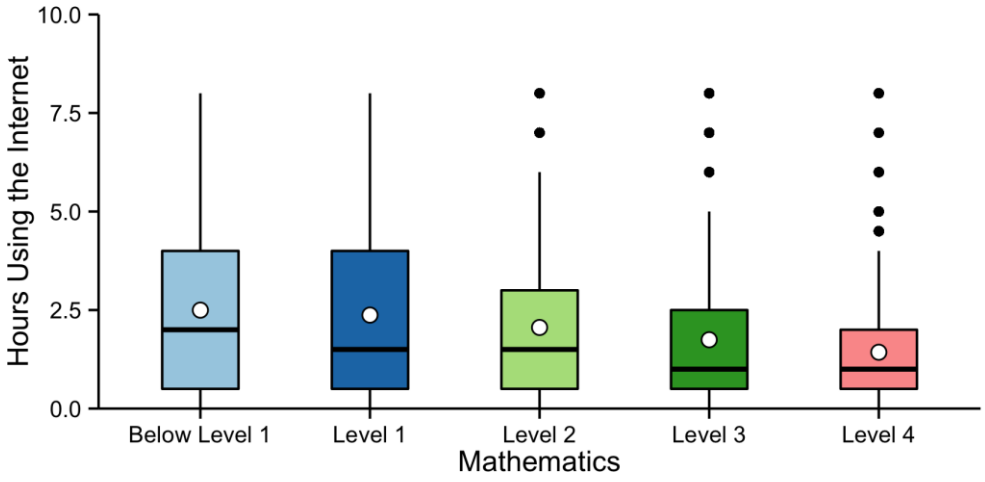

Figure 4. Hours using the Internet and overall mathematics performance. Students with better performance in mathematics spent less time on the Internet at home.

Even though time spent on the Internet was connected to lower performance, when it came to more specific activities related to reading and writing, the use of technology had a seemingly positive effect. Taking writing as an example, students who write emails, texts and instant messages more often, tended to perceive themselves as better writers, as shown in the distribution of percentages illustrated in Figure 5. Similar linkages were found between writing emails and students' actual writing performance, as well as between frequency of reading emails

and reading performance and reading confidence. This finding did not contradict the findings from the previous paragraph; rather, it highlights potential benefits of using the Internet for more academically relevant activities such as reading/writing emails.

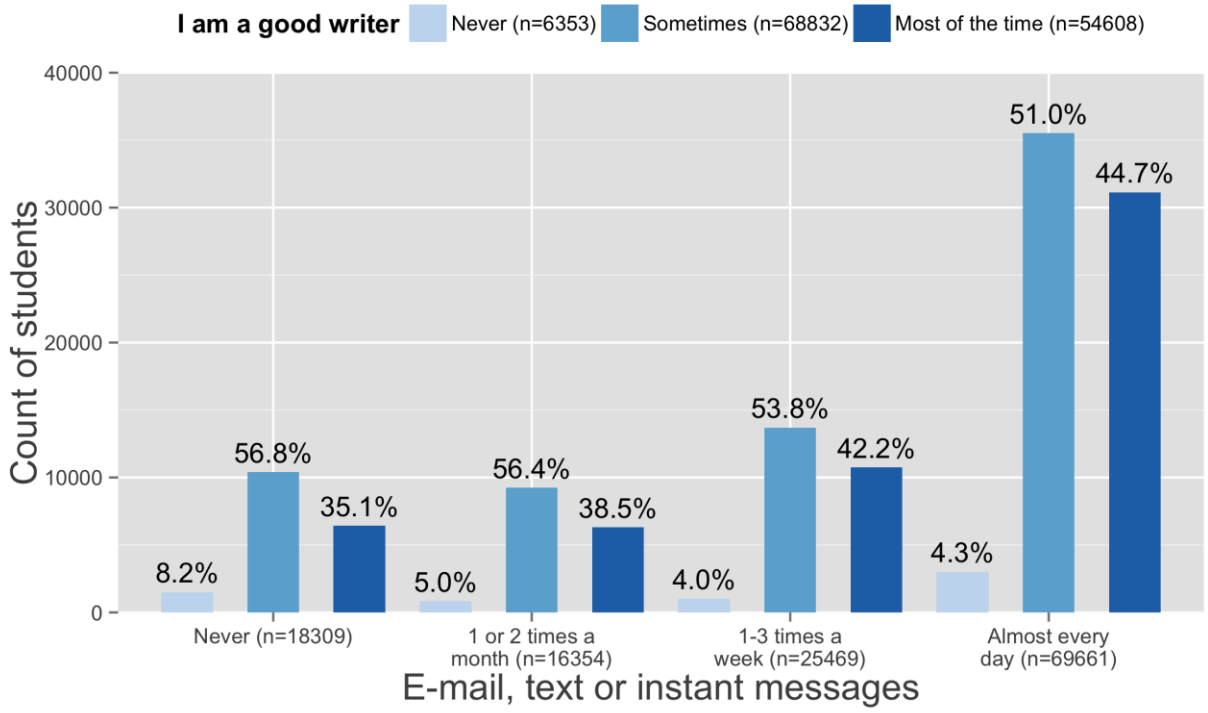

Figure 5. Confidence in being a good writer and the frequency of writing in email, text, or instant messages. Results indicated that 44.7% of students writing email, text or instant messages *almost every day* (*n* = 69661) were confident in their writing *most of the time*, while only 35.1% of students who *never* wrote email, text or instant messages felt confident *most of the time*. Meanwhile, compared with students *never* wrote email, text or instant messages, a lower percentage of students writing email, text or instant messages *almost every day never* felt being a good writer.

Discussion and Conclusions

The present study aimed to investigate the general patterns of ICT integration in Ontario's publicly funded schools and their potential linkages with student academic achievement and individual empowerment. Given that digital literacies are becoming increasingly important in the so-called information age, it is of significant public interest to examine this area and to probe possible "digital divides" within the public education system, in order to inform policy making and future research. Grounded on a multi-level digital divide conceptualization (Hohlfeld et al., 2008), this study highlighted current challenges of ICT use in public schools, together with interesting trends and opportunities.

The first-level digital divide was less evident in Ontario's public schools, in contrast to what was found earlier in Florida (Hohlfeld et al., 2008). This study showed that schools provided almost

universal access to computers and the Internet for students. Most schools provided multiple opportunities for students to access ICT, in classrooms, computer labs, and/or libraries. A majority of elementary schools also reported having students bringing in their own devices, reflecting a trend of BYOD and 1:1 computing in Ontario's public schools. However, in some rare cases, schools reported not having Internet access; this gap was not linked to specific regions or SES statuses. Meanwhile, three-quarters of school principals were aware of having students without Internet access at home; this first-level digital divide was found to be connected to schools with lower family incomes, smaller school size, and geographical remoteness. In addition, schools were also facing first-level digital divide challenges including the lack of network infrastructure and unstable wireless access.

Investigating the second level digital divide found a majority of schools integrating ICT in classroom teaching and learning from the earliest grades. In their open-ended responses, principals were aware of the distinction between *learning how to use technologies* and *using them as part of student learning*, confirming a considerable depth of ICT integration in Ontario's public schools. One important area of using ICT in Ontario's public schools was related to learning resources. Technology allowed schools to move away from textbook dependence; many teachers were using a combination of both print and online materials when they needed new materials. One-third of schools would opt for free online materials when acquiring new learning resources for teachers. When investigating specific learning technologies, those related to accessing additional materials (e.g., online videos and external websites) appeared to be most popular. However, some other technologies widely reported as recent pedagogical innovations, for example, game-based learning and social networks, were less commonly used among teachers. This finding reflected substantial individual differences among teachers in terms of comfort levels with new technologies. Professional development is needed to help teachers make sound decisions on digital resources and integrate ICT and related teaching techniques in schools (Bingimlas, 2009). Given that teacher professional development around technology integration is mainly moderated by local school boards in Ontario, efforts should be made to ensure that all teachers are receiving equitable opportunities to advance their digital literacies and integrate technology in their teaching.

Almost half of Ontario's secondary schools reported having at least one student earning credits through e-learning. Digital technologies played a role in expanding learning opportunities, especially for students in smaller schools and schools from remote areas.

This study also explored the complex relationship between ICT use and student performance in high-stake standardized tests. A consistent trend was identified for three subject areas including reading, writing and mathematics: Students with better performance or greater confidence in reading, writing, and mathematics seemed to spend less time on the Internet, while not using the Internet at all appeared to be disadvantageous as well. However, more academic-related activities on the Internet (e.g., reading or writing an email) were found to be connected to higher confidence or performance in reading or writing. This result was consistent with earlier findings that academic-related computer use would have a better chance of facilitating student learning (Tien & Fu, 2008). Further analysis implied a potential mediating effect of parent involvement in the relationship between ICT use and academic achievement—parent involvement could result in wiser, more academic-related use, and thus more benefits for learning. Further micro-level investigation is needed to study these relations.

The present study is the first effort to broadly survey the digital divide in Ontario's public schools, with a goal to provide timely and original evidence to inform provincial policy and school practice related to ICT integration. In order to bridge these three levels of digital divide, a number of steps need to be taken. First of all, resources need to be directed to schools that currently do not have adequate infrastructure for equitable ICT access. Second, the wide variation in teachers' use of technology uncovered in this study suggests a continual need for high quality professional development to help teachers integrate ICT to support classroom teaching and learning. We need to rethink the breadth of professional developed currently offered by school districts, especially to support the choice of digital learning resources and the integration of emerging technologies. Third, for digital resources in particular, while it was encouraging to learn the broader adoption of open educational resources, efforts are also needed to ensure that online materials chosen by teachers and school librarians support the curriculum, reflect a Canadian perspective, and are responsive to the Ontario context. Fourth, given the importance of parent involvement, schools need to engage families in the dialogue of digital literacies, not only to ensure equitable home access to ICT, but to encourage the beneficial use of technologies at home. Finally, more in-depth research into the level-three digital divide is needed to investigate the linkages between ICT use and student success, especially in areas reflecting emergent understandings of digital literacy.

These results also point towards a few limitations of this study. First, this study was conducted in Ontario, one province of Canada which has its own geographical, cultural and demographic uniqueness. Hence, the results may be not generalizable to other Canadian provinces, or other countries. The second limitation is related to having school principals being the targeted respondents of the P4E survey. Even though in many cases the survey was completed in consultation with knowledgeable school personnel, questions addressing issues such as specific use of technology by teachers could undermine the validity. However, it should be recognized that insights gained from principals in this study complement other data sources such as the EQAO student questionnaire by bringing school-level data into consideration. Finally, because of the length limit of the P4E School Principal Survey, the range of questions asked was limited. Many questions might seem "shallow" in nature, and many important questions—such as those related to the ways technology is used (Attewell, 2001) and students' digital skills (Hawkins & Oblinge, 2006)—remained unasked. These limitations point towards substantial future work in order to understand the digital divide at multiple levels, and to find ways to address them through stakeholder participation.

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References

Abrami, P. C., Bernard, R., Wade, A., Schmid, R. F., Borokhovski, E., Tamin, R., … Others. (2006). A review of e-learning in Canada: A rough sketch of the evidence, gaps and

promising directions. *Canadian Journal of Learning and Technology/La Revue Canadienne de L'apprentissage et de La Technologie*, *32*(3). Retrieved from http://www.cjlt.ca/index.php/cjlt/article/view/27

Alberta Education. (2012). *Bring your own device: A guide for schools*. Retrieved from http://education.alberta.ca/media/6749210/byod%20guide%20revised%202012-09-05.pdf

Alberta Education. (2014). *Information and communication technology program of study*. Retrieved from https://education.alberta.ca/teachers/program/ict/programs.aspx

Aristovnik, A. (2012). The impact of ICT on educational performance and its efficiency in selected EU and OECD countries: A non-parametric analysis. *Turkish Online Journal of Educational Technology*, *11*(3), 144–152. Retrieved from http://www.tojet.net/articles/v11i3/11314.pdf

Attewell, P. (2001). The first and second digital divides. *Sociology of Education*, *74*(3), 252–259. doi:10.2307/2673277

Bagchi, K. (2014). Factors contributing to global Digital divide: Some empirical results. *Journal of Global Information Technology Management*, *8*(3), 47–65. doi:10.1080/1097198X.2005.10856402

Bauer, J., & Kenton, J. (2005). Toward technology integration in the schools: Why it isn't happening. *Journal of Technology and Teacher Education*, *13*(4), 519–546. Retrieved from http://www.editlib.org/p/4728/

Bebell, D., & Dwyer, L. M. O. (2010). Educational outcomes and research from 1:1 computing settings. *Journal of Technology, Learning, and Assessment*, *9*(1), 5–15. Retrieved from http://ejournals.bc.edu/ojs/index.php/jtla/article/view/1606

Bingimlas, K. A. (2009). Barriers to the successful integration of ICT in teaching and learning environments: A review of the literature. *Eurasia Journal of Mathematics, Science & Technology Education*, *5*(3), 235–245. Retrieved from http://www.ejmste.com/v5n3/eurasia_v5n3_bingimlas.pdf

Binkley, M., Erstad, O., Herman, J., Raizen, S., Riple, M., Miller-Ricci, M., & Rumble, M. (2012). Defining 21st century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 17–66). Springer. doi:10.1007/978-94-007-2324-5_2

Borokhovski, E., Bernard, R., Mills, E., Abrami, P. C., Wade, C. A., Tamim, R., … Surkes, M. A. (2011). An extended systematic review of Canadian policy documents on e-Learning: What we're doing and not doing. *Canadian Journal of Learning and Technology/La Revue Canadienne de L'apprentissage et de La Technologie*, *37*(3), 1–30. Retrieved from http://www.cjlt.ca/index.php/cjlt/article/view/589

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school: Expanded edition*. Washington, DC: The National Academies Press.

Buckingham, D. (2010). Defining digital literacy. In B. Bachmair (Eds.), *Medienbildung in neuen Kulturräumen: Die deutschsprachige und britische Diskussion* (pp. 59–71). Wiesbaden, Germany: VS Verlag für Sozialwissenschaften. doi:10.1007/978-3-531-92133-4_4

Cuban, L. (2003). *Oversold and underused: Computers in the classroom*. Boston, MA: Harvard University Press.

DeBell, M., & Chapman, C. (2006). *Computer and Internet use by students in 2003 (NCES 2006-065)*. Washington, DC: National Center for Education Statistics.

Employment and Social Development Canada. (2013). Skills definitions and levels of complexity. Retrieved from http://www.esdc.gc.ca/eng/jobs/les/definitions/index.shtml

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development*, *53*(4), 25–39. doi:10.1007/BF02504683

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*(3), 255–284. Retrieved from http://files.eric.ed.gov/fulltext/EJ882506.pdf

Hargittai, E. (2001). Second-level digital divide: Mapping differences in people's online skills. *First Monday, 7*(4). Retrieved from http://firstmonday.org/issues/issue7_4/hargittai/index.html

Hawkins, B. L., & Oblinge, D. G. (2006). The myth about the digital divide. *Educause Review*, *41*(4), 12–13.

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 and Education*, *51*(4), 1648–1663. doi:10.1016/j.compedu.2008.04.002

Janus, M., & Duku, E. (2007). The school entry gap: Socioeconomic, family, and health factors associated with children's school readiness to learn. *Early Education & Development, 18*(3), 375-403. doi:10.1080/10409280701610796a

Jenkins, H. (2006). *Confronting the challenges of participatory culture: Media education for the 21st century*. Boston,MA: MIT Press. Retrieved from http://www.newmedialiteracies.org/files/working/NMLWhitePaper.pdf

Jenson, J., Taylor, N., & Fisher, S. (2010). *Critical review and analysis of the issue of "skills, technology and learning"*. Toronto, Canada: Ontario Ministry of Education. Retrieved from https://www.edu.gov.on.ca/eng/research/Jenson_ReportEng.pdf

Johnson, L., Adams, S., & Cummins, M. (2012). *NMC Horizon report: 2012 K-12 edition*. Austin, TX: The New Media Consortium. Retrieved from http://redarchive.nmc.org/publications/2012-horizon-report-k12

Lee, J. (2002). Racial and ethnic achievement gap trends: Reversing the progress toward equity? *Educational Researcher*, *31*(1), 3–12. doi:10.3102/0013189X031001003

Li, Y., & Ranieri, M. (2013). Educational and social correlates of the digital divide for rural and urban children: A study on primary school students in a provincial city of China. *Computers & Education*, *60*(1), 197–209. doi:10.1016/j.compedu.2012.08.001

Looi, C.-K., Seow, P., Zhang, B., So, H. J., Chen, W., & Wong, L.-H. (2010). Leveraging mobile technology for sustainable seamless learning: A research agenda. *British Journal of Educational Technology*, *41*(2), 154–169. doi:10.1111/j.1467-8535.2008.00912.x

Looker, E. D., & Thiessen, V. (2003). Beyond the digital divide in Canadian schools: From access to competency in the use of information technology. *Social Science Computer Review*, *21*(4), 475–490. doi:10.1177/0894439303256536

McConnaughey, J., Everette, D., Reynolds, T., & Lader, W. (1999). *Falling through the Net: Defining the digital divide*. Washington, DC: National Telecommunications and Information Administration, US Department of Commerce. Retrieved from http://www.ntia.doc.gov/report/1999/falling-through-net-defining-digital-divide

McGreal, R., & Anderson, T. (2007). E-learning in Canada. *International Journal of Distance Education Technologies (IJDET)*, *5*(1), 1–6. doi:10.4018/jdet.2007010101

Middleton, C. A., Veenhof, B., & Leith, J. (2010). *Intensity of internet use in Canada: Understanding different types of users*. Statistics Canada, Business Special Surveys and Technology Statistics Division. Retrieved from http://www.statcan.gc.ca/pub/88f0006x/88f0006x2010002-eng.htm

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *The Teachers College Record*, *108*(6), 1017–1054. Retrieved from http://www.tcrecord.org/

Nan, G. (2001). ICT education and cultivating creative talents (I). *E-Education Research*, *8*, 42-45. Retrieved from http://www.oriprobe.com/journals/caod_4852.html

Norris, P. (2003). *Digital divide: Civic engagement, information poverty, and the Internet worldwide*. London, United Kingdom: Taylor & Francis. doi:10.1080/0810902032000118249

OECD. (2007). Broadband and ICT access and use by households and individuals. *OECD Digital Economy Papers, No. 135*. Paris, France: OECD Publishing. doi:10.1787/230666254714

Ontario Ministry of Education. (2007). *The Ontario Curriculum Grades 1-8: Science and Technology*. Retrieved from http://www.edu.gov.on.ca/eng/curriculum/elementary/scientec.html

Pappano, L. (2012, November 2). The year of the MOOC. *The New York Times*. Retrieved from http://www.nytimes.com

Rau, P.-L. P., Gao, Q., & Wu, L.-M. (2008). Using mobile communication technology in high school education: Motivation, pressure, and learning performance. *Computers & Education, 50*(1), 1–22. doi:10.1016/j.compedu.2006.03.008

Sawyer, R. K. (Ed.). (2006). *The Cambridge handbook of the learning sciences*. New York, NY: Cambridge University Press.

Scardamalia, M., Bransford, J. D., Kozma, B., & Quellmalz, E. (2012). New assessments and environments for knowledge building. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 231–300). Dordrecht, Netherlands: Springer. doi:10.1007/978-94-007-2324-5_5

Sciadas, G. (2002). *Unveiling the digital divide*. Statistics Canada. Retrieved from http://www5.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=56F0004MIE2002007

Sharples, M. (2002). Disruptive devices: Mobile technology for conversational learning. *International Journal of Continuing Engineering Education and Life Long Learning, 12*(5), 504–520. doi:10.1504/IJCEELL.2002.002148

Statistics Canada. (2010). *Internet use by individuals, by type of activity*. Retrieved from http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/comm29a-eng.htm

Statistics Canada. (2013). *Canadian Internet Use Survey, 2012*. Retrieved from http://www.statcan.gc.ca/daily-quotidien/131126/dq131126d-eng.htm

Toronto District School Board (TDSB). (2010). *TDSB ICT Standards: Digital Learning for Kindergarten to Grade 12*. Toronto, Canada: TDSB. Retrieved from http://schoolweb.tdsb.on.ca/Portals/elearning/docs/ICT%20Standards.pdf

Thompson, C. (2011). How Khan Academy is changing the rules of education. *Wired Magazine, 126*. Retrieved from http://www.wired.com/2011/07/ff_khan/

Tien, F. F., & Fu, T. T. (2008). The correlates of the digital divide and their impact on college student learning. *Computers and Education, 50*(1), 421–436. doi:10.1016/j.compedu.2006.07.005

Tondeur, J., Van Braak, J., & Valcke, M. (2007). Curricula and the use of ICT in education: Two worlds apart? *British Journal of Educational Technology*, *38*(6), 962–976. doi:10.1111/j.1467-8535.2006.00680.x

Trilling, B., Fadel, C., & Partnership for 21st Century Skills. (2009). *21st century skills: Learning for life in our times*. Available from http://21stcenturyskillsbook.com/book/

U.S. Department of Education Office of Educational Technology. (2010). *Transforming American education: Learning powered by technology*. Retrieved from https://www.ed.gov/sites/default/files/NETP-2010-final-report.pdf

Van Dijk, J. A. G. M. (2006). Digital divide research, achievements and shortcomings. *Poetics*, *34*(4-5), 221–235. doi:10.1016/j.poetic.2006.05.004

Warschauer, M. (2003). Demystifying the digital divide. *Scientific American*, *289*(2), 42–47. doi:10.1038/scientificamerican0803-42

Wayne, A., Zucker, A., & Powell, T. (2002, September). *So what about the 'digital divide' in K-12 schools? Educational technology and equity in U.S. K-12 schools.* Paper presented at the Telecommunications Policy Research Conference, Arlington, VA.

Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics.* Princeton, NJ: Educational Testing Service. Retrieved from https://www.ets.org/Media/Research/pdf/PICTECHNOLOG.pdf

Yang, Y., Hu, X., Qu, Q., Lai, F., Shi, Y., Boswell, M., & Rozelle, S. (2013). Roots of tomorrow's digital divide: Documenting computer use and Internet access in China's elementary schools today. *China & World Economy*, *21*(3), 61–79. doi:10.1111/j.1749-124X.2013.12022.x

Zhang, J., Zhao, N., Chen, B., & Childs, R. (2012, May). *The relationship of home computer use with students' cognitive skills and literacy*. Paper presented at the Canadian Society for the Study of Education Annual Conference, Waterloo, Canada.

Zhong, Z.-J. (2011). From access to usage: The divide of self-reported digital skills among adolescents. *Computers and Education*, *56*(3), 736–746. doi:10.1016/j.compedu.2010.10.016

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