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RESEARCH ARTICLE

An investigation of middle school science teachers and students use of technology inside and outside of classrooms: considering whether digital natives are more technology savvy than their teachers

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Abstract The purpose of the study is to investigate the popular assumption that the "digital natives" generation surpasses the previous "digital immigrants" generation in terms of their technology experiences, because they grow up with information and communication technology. The assumption presumes that teachers, the digital immigrants, are less technology savvy than the digital natives, resulting in a disconnect between students' technology experiences inside and outside of the formal school setting. To examine the intersection of these generations and their technology experiences, this study used a mixed-methods approach to survey and compare middle school science teachers' ($n = 24$) and their students' ($n = 1{,}060$) inside–outside school technology experiences, and conducted focus group interviews to investigate any barriers that prevented them from using technology in school. The findings imply that the concept of digital natives may be misleading and that the disconnect between students' inside–outside school technology experiences may be the result of the lack of sufficient teacher training concerning technology integration strategies.

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Introduction

Computers and technology have changed the very nature of the current generation of citizens' lives. This has occurred as these technologies have become more affordable and mobile, and as the most recent generation of students have grown up with these technologies. Given this, this generation is called the Net Generation (Tapscott 1998) or digital natives (Prenksy 2001). The usage of technology, mobile devices and information and communication technology (ICTs) are pervasive in digital natives' everyday lives. This generation is immersed in interactive, immediate and multimodal communication mediated through technology. As a result, many educational researchers have asserted that digital natives have different ways of expressing themselves and different learning preferences because of their immersion with ICT (Prenksy 2001, 2003, 2011; Tapscott 1998). Because of this, they urge schools and educators to respond to the changes of these students' distinctive experiences with technologies in ways that are significant for education, so that teachers can leverage students' already developing capabilities with technologies in ways that will allow them to meet demands of a future workforce in a global information society (Barnes et al. 2007; Brown 2000; Tapscott 2009; Thompson 2013).

The assumption that digital natives have different learning styles and preferences because of their fluency in technology skills has drawn criticism for the lack of empirical evidence (Bennett et al. 2008; Bullen et al. 2008). Digital natives are often characterized as ones who desire to multitask, are oriented to visual media, prefer to work on activities rather than reading texts or following instruction, and are less motivated in the environments that lack technology (Prenksy 2001; Tapscott 2009; Thompson 2013). Although these are common impressions people have about the current generation of students, these claims still lack the support of empirical evidence (Thompson 2013). Some researchers believe that we should not label learners' technology usage based on their age. This is seen as Brown and Czerniewicz (2010) suggest using technology experience as a proxy for judging the appropriateness of technology-driven instruction as opposed to age. These discussions and concerns lead to the following questions which subsequently informed this research: Do school-age students fit into the digital natives' profile? Do school-age students surpass their teachers in terms of using technology in their daily lives? What are teachers' roles in shaping students' technology experiences inside the classroom? Given this, and in order to provide a comprehensive picture of young learners' technology usage, the present study aimed to investigate (1) middle school students' technology experiences inside and outside of school, (2) teachers' technology experiences inside and outside of school, (3) whether there is a disconnect between students' and teachers' use of technology inside and outside of school, and (4) barriers to teachers' technology integration.

Literature review

Young learners' (known as digital natives) technology experience inside and outside of school

In the literature review, we defined "digital natives" as the current generation of teenagers who were born around the year 2000 (currently 13 years and older). This generation of

learners have gone through several technology milestones since 2000, due to the emergence of the following life-changing technologies: Portable digital devices (iPod, 2001), iTune music store (2003), FaceBook (2004), YouTube (2005), GoogleDoc (cloud computing services, 2006), smartphones (iPhone, 2007), and tablet devices (iPad, 2010). These technologies have become an integral part of these digital natives' daily routines and changed their lives in many ways, including retrieving information ubiquitously through mobile technologies, establishing or maintaining relationship through the social networking sites, access to free and reliable productivity tools, and relying on cloud computing applications to deliver services over the internet.

Prenksy (2001) defined digital natives as those born in 1980 or after, and called those born before 1980 digital immigrants. Therefore, previous studies of digital native focused on those who were born between 1980 and 1990. This generation of students is referred to as the first generation of digital natives (Helsper & Eynon 2010). Our literature review focused primarily on learners born after 1990, which Helsper and Eynon (2010) referred to as the second generation of digital natives. It should be noted, the purpose of defining generations of digital natives is not for comparison. It is to provide a concurrent technology usage profile for readers. The student participants in the current research were born after 2000, and as such have been subject to differences in technology and interactions with technology. Therefore, we have considered the student population born after 2000 a third generation of digital natives (Table 1).

The literature discussing the third generation of digital natives was rare at the time the study was conducted. A large portion of literature has centered around college students as digital natives, which provides valuable information about young adults' technology experiences. However, there are distinct differences between the studies done with university students and school-aged students' use of technology (Bennett & Maton 2010). For example, the university student population in most cases have already filtered out those who have social economic disadvantages and because of this are not representative of the broader population (Bradley et al. 2008). Therefore, more studies are required to learn about the inside and outside of school technology usage experience of school-aged students, who are much more representative of the broader population than what is represented by university students.

University students' technology experiences

The call for reformed technology integration in the school setting emerged from claims that digital natives think and learn differently (Prenksy 2001; Tapscott 2009). To further examine this claim, researchers have been exploring digital natives' technology experiences in connection to their learning. Kennedy et al. 2007 surveyed 2,588 freshmen at three universities in Australia about their interests in using web 2.0 technologies (tools designed to facilitate information production and sharing). The results indicated that college freshmen demonstrated diverse technology use, their use of so-called new technology was quite low, and their general use of technology did not meet the proposed assumption of digital natives. Among the same population surveyed, they (Kennedy et al. 2010) reexamined the freshmen students' technology use, and categorized them into four types of users, according to the frequency of technology use: power users (14 %), ordinary users (27 %), irregular users (14 %) and basic users (45 %). The power users and ordinary users fit into the ideal description of the digital natives, but they represented only 41 % of the student population, meaning over half of the students were not immersed in technology as assumed.

Table 1 Definition of different generations of digital natives

Digital natives	Defined by	Born	Technology prevalent in the generations
First generation	(Prenksy 2001)	1980 or after	Personal Computer, Internet
Second generation	Helsper & Eynon (2010)	1990 or after	Google, iPod, e-mail, chat rooms
Third generation	This current study (2014)	2000 or after	Mobile phones, tablets, cloud computing tools, social networking sites

In the U.K., Jones et al. (2010) surveyed 596 freshmen from five colleagues' classes to investigate students' use of technology and the results indicated that these students' use of the web 2.0 technologies (blogs, wikis, and virtual world) was low. Moreover, their technology use varied significantly. The results thus did not reflect the assumption and predictions ascribed to digital natives with respect to technology use. In a more recent study, Margaryan et al. (2011) conducted a mixed-methods survey with 240 college students from two universities. Students were recruited from one department that demanded high use of technology (i.e., Engineering) and another department that did not demand such a high use of technology (i.e., Social Work). The results suggested that students' use of informal technology might be influenced by the technology demanded in the university courses. The authors also confirmed that these digital natives are not constantly connected with technology as originally assumed.

In the U.S., Hargittai (2010) studied 1,060 college freshmen's experience related to Internet usage. The authors controlled the two variables they believed would most likely affect technology experiences (age and education). They concluded that the premise that digital natives are generally technology savvy is unfounded. Students' socioeconomic status, gender and ethnicity accounted for the variation found in their technology experiences. Several studies reported similar findings and suggested that it is dangerous to assume homogeneous technology experience among digital natives, especially when the assumption might be used to inform education policy (Jones et al. 2010; Thompson 2013).

School-aged students' inside and outside of school technology experiences

Ito et al. (2008) conducted an ethnographic study titled the Digital Youth Project to investigate U.S. middle and high school students' technology usage outside of school. They described teens' use of technology outside of school as versatile, always on, and involving a wide range of technology resources. These teens' technology activities were friend-driven and interest-driven to maintain their social connections and personal communication. Nonetheless, this study focused on those who fit into the "digital natives" profile and therefore cannot represent the entire population of teens' technology experiences.

The school-aged students' technology experiences inside of school is often described as being disconnected from their outside of school technology experiences (Levin & Arafeh 2002). Selwyn (2006) conducted a qualitative study to solicit 84 U.K. high school students' self-described experience of their use of the Internet in school. They found that these students heavily relied on the Internet to search for information to support learning, but their Internet activities were restricted due to the classroom time, lack of sufficient technology resources, or teachers' lack of technology integration plans. Luckin et al. (2009) conducted a mixed-methods survey with 2011 U.K. middle school students, and conducted 60 focus group interviews to investigate how they use ICTs inside and outside of school.

The respondents reported the extensive use of social networking sites (e.g. FaceBook, YouTube), email, instant messaging, and gaming. Other uses of ICTs was not as high as expected (i.e., blogging, editing Wikipedia). Those who were categorized as ICT users mainly used them as tools for research, collaboration, production and publication. As for their school use of ICT, their technology experiences at school were limited. These results are similar to findings from previous studies (Levin & Arafeh 2002; Selwyn 2006). As an example, (Clark et al. 2009) conducted a similar study to investigate U.K. school-aged students' (ages 11–16) ICT experiences inside and outside of school that yielded similar results. They further concluded that these teens did not use ICT in sophisticated ways outside of school. But, these teens did recognize the potential educational benefits that these tools could bring to their academic study and would have liked to use these technologies to support learning inside the school. The reported technologies and related activities inside the school included: writing using Word processing tools, conducting Internet research activities, sending e-mails, preparing presentations, performing drill and practice activities, and using spreadsheet to manage data, even though this activity was found relatively less frequent compared with others (Gulbahar 2007; Kent & Facer 2004; Lei & Zhao 2007). Review of related literature, also suggested that the school-aged students' use of technology outside of schools did not fit the description of Prenksy (2001) "Digital Natives". These school-aged students seemed to have less technology experience inside of school than outside of school; their use of technology outside of school was limited and driven by entertainment and personal interests.

Teachers' technology experiences

The digital natives debate centers around the gap between students' technology experiences inside and outside of school. Teachers are usually put on the spot because they are the "older generation" who are considered less technology savvy compared with the digital natives (Prenksy 2001). To examine this assumption, Guo et al. (2008) conducted a mix-methods study on 2,583 pre-service teachers' ICT competencies. These teachers were enrolled in three different universities in Canada and the U.S., ages ranging from 20 (digital natives) to 40 (digital immigrants, generation born before new technology). The results showed no significant difference in ICT competencies between the digital natives and the digital immigrants. They concluded that "the differences between digital natives and digital immigrants have been exaggerated" (Guo et al. 2008, p.251). Another study by Brown and Czerniewicz (2010) reported similar findings. They pointed out that age is not a determining factor of people's technology skills. The familiarity and experiences in using technology were more relevant to determining the notion of digital natives.

Helsper and Eynon (2010) closely examined how factors such as age, experience, and breadth of using technology related to people's technology fluency. They surveyed 2,350 people from ages 14 to 65. The respondents from ages 14 to 17 fit into the description of digital natives. They had higher ICT competencies and tended to multi-task more in comparison with digital immigrants. However, when the technology activities were related to learning, working or personal interests, the digital immigrants tended to utilize technology as much as the digital natives. Those who were experienced in using technology also fit into the description of digital natives, even though they were categorized as digital immigrants based on age considerations. The authors further indicated that digital natives do demonstrate certain unique traits of technology use, but adults can certainly close the gap if they want to. This led to a recent study conducted by the Pew Research Center on K-12 teachers' use of technology inside and outside of school (Purcell et al. 2013). The

Pew Research Center surveyed 2,067 U.S. middle and high school teachers on their inside and outside of school technology experiences. The result indicated that, compared with the total U.S. adult population, teachers are far more advanced in terms of owning technology gadgets, engaging in Internet activities, and having confidence in their technology skills. The younger teachers (ages 22–34, born between 1980 and 1990) demonstrated similar traits of digital natives, who were more likely to use social networking sites and use technology to pursue their personal interests. As a result, the assumed gap that teachers' lack of technology integration in school should be narrowed because (1) more and more digital natives have joined the teaching careers and (2) teachers in the previous generations do catch up with the technology uses. Beyond the first and second generation digital natives (Table 1), to reflect the current digital natives' technology experiences, we have focused on students born between 1999 and 2001, who were between ages 12 and 14 at the time of the research. They are considered the third generation of digital natives, as they experience the most dramatic innovation in consumer technology compared with previous generations.

Science teachers' have great potential to be the innovators and leaders in the use of technology

In this study, we are specifically interested in science teachers' technology experiences inside and outside of school, because science teachers have been at the forefront of technology transition. They are usually the early adopters to integrate technology in labs and physical experiments, hands-on activities, field trips and data collection. Compared with other subject area teachers, they are more likely to engage in technology-integrated practices (Purcell et al. 2013). Scientific practices are intended to promote learners' cognitive skills. Students are expected to apply higher-level thinking skills to learn about the nature of science using scientific methods (Kuhn et al. 2000; Schraw et al. 2006). Technology, when used appropriately, can facilitate students' inquiry based learning (e.g., Linn et al. 2004; Songer et al. 2002). Students can use the Internet, cyber-databases and other online sources to gather information. They can use spreadsheets, virtual labs, and other programs to store, organize, and analyze information. Students can also integrate multimedia elements, web publishing, video and audio editing, as well as graphics programs to create and present information in innovative and engaging ways. Science teachers have ample opportunity to integrate technology to allow students to conduct their work. Furthermore, the National Research Council released the Next Generation of Science Standards in 2013 (National Research Council 2013), urging science teachers to help students practice inquiry skills using cross-curriculum knowledge such as engineering, math, and technology. The goal is to foster the development of students' 21st century skills for college readiness and success in the future workforce. Therefore, it is expected that science teachers integrate technology in their teaching routines, and bridge the gap between students' technology experiences inside and outside of schools.

In the past, we proposed a vision for technology integration in science instruction (Campbell et al. 2010; Hsu et al. 2013) and subsequently received National Science Foundation (Award No. DRK12-1401350 & 1020091) funding to test the assumptions inherent in our established framework, proposing the approach to integrate technology as cognitive tools to support students' learning. This current research is a result of our continuing work. We see it providing some initial information regarding how students and teachers experience technologies inside and outside of formal classrooms in the discipline of science specifically, but more importantly we have chosen to focus this current research

more on what could be discerned about the generational technology profiles both inside and outside of school. Especially, we see this research providing needed information about this third generation of digital natives that can be compared to accumulating research about the first and second generations of digital native (e.g., Helsper & Eynon 2010; Prenksy 2001). Given this, more about our research contexts, participants, instrumentation, and methodologies are shared next.

Methodology

The study employed a mixed methods research approach (Tashakkori & Teddlie 2006), with a quantitative survey, followed by classroom observations and teacher focus group interviews. To help us understand the factors influencing students' technology experiences inside the school, following research questions were developed:

1. How do middle school students' inside and outside of school technology experiences differ?
2. How do middle school science teachers' inside and outside of school technology experiences differ?
3. Is there a gap between science teacher and students' technology experiences inside and outside of school?

Participants

In order to generalize research findings across a range of geographic, social and cultural influences, we conducted the study with twenty-four middle-school teachers from two states, New York and Utah. Their ages range from 23 to 56 (42 % are 21–30 years old, 16 % are 31–40 years old; 25 % are 41–50 years old, and 15 % are above 51 years old). Student participants were 774 eighth grade students from Utah (8 schools) and 305 6th to 8th grade students from New York (10 schools). New York is described as one of the most diverse states in terms of ethnicities (Hsu & Wang 2010), while Utah is one of the states with most singular ethnicity (92 % Caucasian, U.S. Census Bureau 2010). Both teachers and students were surveyed in the year 2012. The teacher and student participants came from tenschools in New York and nine schools in Utah.

Data collection and analysis

The survey data was collected using the Formal and Informal Technology Survey (Wang et al. 2014). The questionnaire consists of three sections: (1) technology ownership; (2) technology experience outside of school and (3) technology experience inside of school (science class). The survey was developed through the following stages. The first step included reviewing literature related to ICTs integration in the classroom to identify observation protocols and identify ICTs that are related to this study. Step 2 was to recommend and examine observation items by five researchers specialized in technology integration, research methods and statistics analysis. Step 3 was to pilot the survey to a class of school-aged students—who were not part of the primary study—and revise the wordings of each item based on the students' feedback. Internal reliability was established

with Cronbach's alpha (Cronbach 1951; Cortina 1993) using the pilot study participants and meeting a target alpha of 0.8.

Descriptive and inferential statistics were adopted to gather meaningful information from the study data. An alpha level of 0.01 was used as the criterion for significant findings. For the full questionnaire, please see appendix A. We assessed whether differences between inside and outside technology use existed in two ways: (i) with a match-pairs *t* test of the mean difference using the 1–5 response scale (1 = never, 2 = once a year, 3 = once or twice a month, 4 = once or twice a week, 5 = almost every day), and, because this scale is only ordinal, (ii) with the Wilcoxon signed rank test (Siegel 1956) for a median difference of 0. Since direction of any significant difference is important, means (and SEs) are provided in Tables 3 and 4, along with the *t* test statistic and it's *P* value. Only the *P* value for the signed rank test is provided so as to observe the strength of agreement between the two methods of analysis.

In terms of the difference between teachers and students' technology experience, we have used the proportional odds model (McCullagh and Nelder 1983) assessment of a between group effect, in addition to the *t* tests for any difference of group means, to reduce concerns that the ordinal nature of the 1–5 response scale for the *t* test might not capture group effects or their direction correctly and because a difference in distribution between student and teacher groups over the response scale was of primary importance. We note here that there was good agreement between these two methods on most but not all items of Tables 5 and 6. Discrepancies between the two analysis approaches were mostly a consequence of teachers all responding "5" or "1 or 2," (for example) while students used the entire 1–5 scale, resulting in lack-of-fit of the proportional odds model in a few instances where there were definitely differences in response distribution between students and teachers. In these instances, the *t* tests are perhaps more useful reliable assessments of a between group difference.

Effect sizes provided in result tables are Cohen's d (Cohen 1988), the (observed) mean difference divided by an estimate of the underlying standard deviation. Effect sizes about 0.2 are usually interpreted as "small," those around 0.4–0.5 as "medium," and those around 0.8–1.0 as "large." Small effect sizes are only likely to be accompanied by statistical significance when the group size(s) is "large" because statistical power is a function of both the effect size and sample size (Montgomery 1976) and thus only when comparing students (between baseline and at the end of a year, for example) did we find statistical significance for "small" effect sizes.

Even though students' demographic information was collected (e.g., ethnicity, gender, social economic status), we found that these factors were not crucial in terms of explaining their technology experience in this study. The majority of students and teachers have access to at least one desktop or laptop at home; and their technology usage did not significantly vary among these factors. Therefore, we focus on the comparison of teachers and students' technology experience inside and outside of schools, regardless of their demographic information.

In addition to the teacher and student surveys, we developed the semi-structured protocol to conduct the focus group interviews. The focus group results helped us triangulate the survey results and further explore the use of technology inside the science classrooms. Each focus group had three to four teachers. The focus group interview occurred three times during a semester. On the average, the interview lasted for an hour. It was guided by the following topics: use of technology inside of classroom, use of technology outside of classroom, technology practices (having students use technology inside of classroom), successful technology integration examples, technology integration

barriers, and the perceived solution to bridge the gap of technology integration. The focus group results were recorded and transcribed. Two researchers reviewed the transcript and created a set of common themes to code all the responses, which were guided by teachers. For example, in the "teachers' use of technology inside of classroom" category, it includes codes such as "students use Internet to search information" and "students use map tools to locate information." An initial inter-rater reliability between the two coders was calculated with 90 % agreement. 100 % agreement was reached after their discussion of initial disagreements. The final stage of the analysis was developing major themes through data reduction (Miles & Huberman 1994) and identifying exemplar quotes illustrating each theme.

Results

General use of digital devices at home

Data in Table 2 shows that the majority of teacher and student participants used a range of technologies at home (Table 2). The top three technologies used at home by teachers and students were the same, for teachers: cellphone (95.8 %), laptop computer (87.5 %), and desktop (83.3 %) computer; for students: cellphone (74.4 %), desktop (80.9 %) and laptop (69 %). These technologies are pervasive because they support both entertainment and academic work.

Students' inside and outside of school technology experiences (RQ1)

Table 3 reports students' self-reported frequency of using technology inside and outside of the science classrooms.

Findings indicated that for formal learning, tools that they used at least once a week included word processing and web search engines. The outside of school technology they used at least once a week include word processing, social networking sites, YouTube, text messaging, and web search engines. When we compared the frequency of their technology inside–outside of science classrooms, the use of spreadsheets and presentation tools inside the school surpassed the use outside of school; while there was a higher frequency of using most of the rest technologies outside of school (Table 3). In these findings, it can be seen that the science teachers provided sufficient opportunities for students to practice word processing tools and web search engines, which are common classroom technology practices. However, students rarely had chances to practice other tools that further develop their skills in using other productivity and cloud computing tools and creating multi-modal information (e.g. GoogleDocs, mapping tools, or video production). Students' out-of-school technology experiences heavily centered on communication, entertainment, and research web-based information, as the previous literature suggested (Luckin et al. 2009; Selwyn 2006).

Teachers' inside and outside of school technology experiences (RQ2)

Table 4 reports teachers' self-reported inside and outside of school technology experience.

Table 2 Teachers' and students' technology ownership at home

	Teachers' possession ($N = 24$) (%)	Students' possession ($N = 1{,}078$) (%)
Cellphone	95.8	74.4
Smartphone	45.8	43
iPod Touch	37.5	55
Tablet PC	8.3	30.8
Portable music device	75	57.8
Desktop computer	83.3	80.9
Laptop	87.5	69

The tools they used at least once a week inside of school are word processing, spreadsheets, presentations, text messaging, and web search engines. Their outside of school technology used at least once a week were word processing, spreadsheets, presentation, social networking site, YouTube, text messaging and web search engines (Table 4). When compared the frequency of their technology usage inside and outside of school, teachers had higher frequencies of using the presentation tools at school. They had higher frequencies of using most of the rest technologies outside of school, including mapping tools, social networking sites, blogs, YouTube, IM, and text messaging. Similarly, teachers' outside of school technology experiences were much richer than their in-school technology experiences.

Differences of inside and outside of school technology experience: students vs. teachers (RQ3)

When we compared students and teachers' inside–outside school technology experiences, we learned that teachers' frequency of using various technologies was higher than students' both inside and outside of the school, especially when considering productivity tools (e.g., word processing, spreadsheet and presentation). Teachers also reported higher frequencies of using web search engines, both inside and outside of schools (Table 5 and 6).

Teacher focus group (RQ4)

Through focus group interviews, our findings revealed that despite the variations in location, setting, and support (schools, administrators, curriculum), we found evidence that the teachers shared similar technology usage experiences inside of school, had similar perception on students' use of technology inside of school, and encountered similar challenges in integrating technology in school. More specifics about each of these findings are shared next.

Teachers' use of technology inside of school

Findings from focus group interviews revealed that teachers' use of technology inside school corresponded with teacher survey results. Word processing and presentation tools

Table 3 Frequency of students' inside and outside of school technology experiences

	Students (inside of school)		Students (outside of school)		*t*	*P* value*	Effect Size	*P* value**
	Mean	SE	mean	SE				
Word processing tool	3.12	0.039	3.07	0.040	1.16	0.2475	0.04	0.2512
Spreadsheet tool	2.54	0.040	2.14	0.038	9.69	0.00**	0.30	0.0001**
Presentation tool	2.89	0.038	2.61	0.039	6.29	0.00**	0.19	0.0001**
Google Docs	2.43	0.041	2.35	0.042	2.29	0.0221	0.07	0.0155
Mapping tool	2.41	0.040	2.63	0.040	−5.00	0.00**	−0.15	0.0001**
Google Earth	2.48	0.040	2.71	0.040	−5.71	0.00**	−0.18	0.0001**
Social networking tool	1.93	0.043	3.68	0.049	−30.43	0.00**	−0.93	0.0001**
Blog	1.64	0.035	2.08	0.043	−10.76	0.00**	−0.33	0.0001**
YouTube	1.94	0.043	3.88	0.038	−36.68	0.00**	−1.13	0.0001**
Second life/opensim	1.49	0.032	1.74	0.038	−7.08	0.00**	−0.22	0.0001**
Web editing tool	2.13	0.041	2.14	0.043	−0.38	0.7035	−0.01	0.8973
Movie production tool	1.90	0.039	2.14	0.043	−5.76	0.00**	−0.18	0.0001**
IM or video- conferencing tools	1.72	0.039	2.82	0.050	−21.26	0.00**	−0.65	0.0001**
Text messaging	2.07	0.047	3.86	0.048	−30.75	0.00**	−0.94	0.0001**
Web search engines	3.21	0.045	3.93	0.041	−15.20	0.00**	−0.47	0.0001**

$N = 1{,}078$, 1 = never, 2 = once a year, 3 = once or twice a month, 4 = once or twice a week, 5 = almost every day

* *P* value for *t* test that mean difference = 0

** *P* value for the Wilcoxon signed rank test for median difference = 0

Table 4 Frequency of teachers' inside and outside of school technology experiences

	Teachers (inside of school)		Teachers (outside of school)		*t*	*P* value*	Effect Size	*P* value**
	Mean	SE	mean	SE				
Word processing tool	4.79	0.104	4.58	0.133	1.16	0.26	0.24	0.3633
Spreadsheet tool	3.54	0.233	3.25	0.211	1.66	0.11	0.34	0.1719
Presentation tool	4.04	0.213	3.42	0.255	3.31	0.00**	0.68	0.0039**
Google Docs	2.25	0.290	2.17	0.280	0.40	0.69	0.08	0.8066
Mapping tool	2.00	0.233	2.96	0.175	−3.61	0.00**	−0.74	0.0015**
Google Earth	2.08	0.208	2.21	0.199	−0.62	0.54	−0.13	0.5156
Social networking tool	1.54	0.262	3.79	0.324	−5.97	0.00**	−1.22	0.0001**
Blog	1.42	0.180	1.92	0.216	−2.94	0.00**	−0.60	0.0137**
YouTube	2.25	0.271	3.54	0.170	−4.25	0.00**	−0.87	0.0005**
Second life/opensim	1.04	0.042	1.04	0.042	0.00	1.00	0.00	0.9987
Web editing tool	2.25	0.290	1.88	0.258	1.33	0.19	0.27	0.2451
Movie production tool	1.54	0.180	1.63	0.168	−0.53	0.60	−0.11	0.5547
IM or video-conferencing tools	1.33	0.187	2.67	0.317	−3.82	0.00**	−0.78	0.0024**
Text messaging	3.08	0.500	5.00	0.000	−3.85	0.00**	−0.79	0.0078**
Web search engines	4.38	0.266	4.92	0.077	−2.01	0.06	−0.41	0.125

N = 24, 1 = never, 2 = once a year, 3 = once or twice a month, 4 = once or twice a week, 5 = almost every day

* *P* value for *t* test that mean difference = 0

** *P* value for the Wilcoxon signed rank test for median difference = 0

Table 5 Frequency of inside the school technology experiences: students vs. teachers

	Students (inside of school)		Teachers (inside of school)		*t*	*P* value*	Effect Size	Estimate	*P* value**
	Mean	SE	mean	SE					
Word processing tool	3.12	0.039	4.79	0.104	−15.06	0.00**	−1.23	3.33	0.00**
Spreadsheet tool	2.54	0.040	3.54	0.233	−4.23	0.00**	−0.58	1.31	0.00**
Presentation tool	2.89	0.038	4.04	0.213	−5.33	0.00**	−0.72	1.75	0.00**
Google Docs	2.43	0.041	2.25	0.290	0.61	0.54	0.09	−0.31	0.43
Mapping tool	2.41	0.040	2.00	0.233	1.74	0.08	0.24	−0.55	0.14
Google Earth	2.48	0.040	2.08	0.208	1.89	0.06	0.24	−0.45	0.21
Social networking tool	1.93	0.043	1.54	0.262	1.45	0.15	1.20	−0.93	0.09
Blog	1.64	0.035	1.42	0.180	1.21	0.23	0.15	−0.28	0.55
YouTube	1.94	0.043	2.25	0.271	−1.14	0.26	−0.16	0.56	0.12
Second life/opensim	1.49	0.032	1.04	0.042	8.44	0.00**	0.42	−1.87	0.07
Web editing tool	2.13	0.041	2.25	0.290	−0.43	0.67	−0.06	0.16	0.68
Move production tool	1.90	0.039	1.54	0.180	1.93	0.05	0.23	−0.44	0.29
IM or video-conferencing tools	1.72	0.039	1.33	0.187	2.03	0.04	0.25	−0.75	0.17
Text messaging	2.07	0.047	3.08	0.500	−2.01	0.05	−0.35	1.20	0.02
Web search engines	3.21	0.045	4.38	0.266	−4.35	0.00**	−0.60	1.65	0.00**

Teacher $N = 24$, Students $N = 1{,}060$, 1 = never, 2 = once a year, 3 = once or twice a month, 4 = once or twice a week, 5 = almost every day

* *P* value for *t* test that mean difference = 0

** *P* value for the proportional odds model test for median difference = 0

Table 6 Frequency of outside of school technology experience: students vs. teachers

	Students (outside of school)		Teachers (outside of school)		*t*	*P* value*	Effect Size	Estimate	*P* value**
	Mean	SE	mean	SE					
Word processing tool	3.07	0.040	4.58	0.133	−10.84	0.00**	−1.05	2.47	0.00**
Spreadsheet tool	2.14	0.038	3.25	0.211	−5.19	0.00**	−0.70	1.49	0.00**
Presentation tool	2.61	0.039	3.42	0.255	−3.13	0.00**	−0.46	1.15	0.00**
Google Docs	2.35	0.042	2.17	0.280	0.63	0.52	0.09	−0.25	0.50
Mapping tool	2.63	0.040	2.96	0.175	−1.84	0.07	−0.21	0.43	0.19
Google Earth	2.71	0.040	2.21	0.199	2.45	0.01	0.31	−0.59	0.09
Social networking tool	3.68	0.049	3.79	0.324	−0.34	0.74	−0.05	0.09	0.82
Blog	2.08	0.043	1.92	0.216	0.75	0.45	0.09	−0.04	0.92
YouTube	3.88	0.038	3.54	0.170	1.96	0.05	0.23	−0.67	0.04
Second life/opensim	1.74	0.038	1.04	0.042	12.33	0.00**	0.56	−2.44	0.02
Web editing tool	2.14	0.043	1.88	0.258	1.00	0.31	0.14	−0.03	0.40
Movie production tool	2.14	0.043	1.63	0.168	2.94	0.00**	0.32	−0.52	0.18
IM or video-conferencing tools	2.82	0.050	2.67	0.317	0.49	0.62	0.07	−0.14	0.70
Text messaging	3.86	0.048	5.00	0.000	−24.01	0.00**	−0.74	−0.32	0.44
Web search engines	3.93	0.041	4.92	0.077	−11.36	0.00**	−0.72	2.59	0.01**

Teacher $N = 24$, Students $N = 1{,}060$, 1 = never, 2 = once a year, 3 = once or twice a month, 4 = once or twice a week, 5 = almost every day

* *P* value for *t* test that mean difference = 0

** *P* value for the proportional odds model test for median difference = 0

were the most frequently used applications in developing curriculum related materials. Additionally, the majority of the teachers reported using spreadsheets to assist with administrative tasks, such as keeping track of students' attendance records and their performance assessments. Teachers heavily rely on web browsers for conducting research and email systems for communication purposes. All teachers reported having access to at least a teacher computer station and a SmartBoard or projector in the classroom. When prompted to share their technology integration examples, examples shared by teachers were predominately teacher-centered. For example, they reported using computers and projectors to share the following with students: video clips or images, demonstrate applications (such as simulation tools), or lecture contents. While not as frequently cited, when student-centered approaches were shared, these included: having students work on reports or presentations or conducting Internet research activities.

Perception of students' technology use inside of school

Teachers' perceptions of students' uses of technology inside of school were mostly focused on word processing, presentations, and Internet research activities. A few teachers shared experiences whereby students used social networking sites, created video clips, or designed web sites. Some teachers reported experiences of trying new applications in the classrooms, such as Google Earth or Google Drive. For the most part, teachers expressed a view that many students do not know how to use these "new" technologies. For instance, most students do not know about Google Earth, Google Spreadsheet, Google Drive (cloud computing tools) or advanced features of certain technology, such as the automatic citation function of Research Tools in Google Drive. However, they believed that students could quickly learn how to use these technologies if the teacher scaffolded these experiences and exemplar projects were available for providing guidance. One of the teachers shared his experience of facilitating students in creating charts to show the relationship between variables using Google Spreadsheet:

> The first time you taught them how to use a new tool is most challenging. I had to spend a session just to teach them how to create charts. But once they figure out how to create charts and make them look pretty, they are very engaged and ask me to give them more assignments like this. Some of them even use the technique in assignments that I did not require them to create charts.

In addition, many teachers affirmed that students were more engaged in learning tasks if they were required to use technology. An example of this is seen as one teacher noticed students' increasing interests and motivation when she assigned tasks that involved using the Internet to conduct research:

> When they have a chance to use technology to work on something, they have taken the ownership and become more interested and motivated. I am no longer the center of attention as the provider of information, but rather play the role of facilitator.

Still another teacher expressed concerns regarding students' Internet research strategies and stressed the importance of establishing relevance in learning tasks as technology is integrated in instruction:

> My students tend to be very impatient. When doing searches, they will most likely be inclined to use the first hit that comes up on Google. You have to make the project relevant to them; otherwise they will not be engaged even if they use technology.

Perceived factors impacting teachers' use of technology in school

Most teachers agreed that technology integration is important in the science classroom. When asked to explain the reasons for the gap between their ideal technology integration and their actual classroom practices, five barriers emerged from the interviews: lack of access to technology, lack of time, lack of technology skills and knowledge, lack of integration strategies, and lack of support and resources due to school policy.

Lack of technology or reliable Internet connectivity was the most frequently mentioned challenge of technology integration. Even though all teachers had access to the teacher station or SmartBoard in the classroom, many of their students did not have access to sufficient technology in the classroom. Teachers pointed out how one-to-one computer learning environments were needed to fully realize their ideal state of technology integration, but many times they reported that this was not the case in their classrooms. Instead, normally they would need to reserve the computer lab or secure the school laptop cart at least a week or two in advance in order to make technology integration possible.

The second most cited integration barrier was the lack of time to plan and implement technology-enhanced activities:

> Following the school's curriculum and lesson format has been a huge challenge. We do not have enough time to have students use technology or prepare those who need help to use technology.

Many teachers reported dedicating most of their time preparing for the standardized testing, since results from the testing was part of their annual performance review:

> We have to prepare for state test. Unfortunately, I have had limited access to the computer room/laptops due to recent state tests and our own school doing computerized testing for tracking classes next year.

> I have not had much of a chance to have students use technology in the past month since I have been deep in test preparation for the standardized test. April and May is our test prep time, you cannot do anything else.

For some teachers who had access to one-to-one computer learning environments or who tried to identify time to integrate technology, they expressed a concern with their own lack of sufficient technology skills and integration strategies. They worried about being seen as teachers who "don't know what they are doing" in front of their students, especially when they were testing out new technologies in the classroom. They were also concerned about not being able to solve students' problems when students had technical issues. As one teacher described:

> I might just forget to create an icon, save the file in the wrong directory, or did not upload my files to the folder, and then the file doesn't work. I have to spent time figuring out how to resolve the issues in front of my students. Sometimes it took longer than I thought to solve these problems, not only did the class time was wasted,

> but it made me look dumb. I have to try it many times to make sure it's reliable, and make sure I'm very good at it before I can introduce it to my students. Otherwise I can't help them when they have problems use it.

Some teachers perceived themselves as technology savvy, but they also acknowledged that they still needed to learn technology integration strategies. They reported knowing how to use certain productivity tools to meet their own instructional needs, but they were not sure how to strategically plan and have students use these same tools in the classroom.

> We definitely need to learn how to integrate technology. I attended many technology workshops, but they teach you how to use the technology, not how this can be used in the science classroom. For example, I know how to use Google Earth but I need to know how I can use it in the science classroom and how my students can use it.

Finally, school policy issue was often cited as another barrier to technology integration in schools. This was seen as each school district had their own technology and internet policy. Often, students were not allowed to use certain web sites or personal devices at schools, even if a case could be made for their educational value.

Discussion

School-age students' outside of school vs. inside of school technology experiences

The project's findings echoed with results from many previous studies. The middle school students' technology use outside of school surpassed their technology use inside of school (Clark et al. 2009; Luckin et al. 2009). Students use of web 2.0 tools or ICTs (such as Google Drive, Blogs), assumed to be popular among digital natives, was not found as popular as previously presumed (Jones et al. 2010; Enrique Hinostroza et al. 2011). Our findings did mirror that of others as students' use of technology outside of school for personal interests, social connections, and interpersonal communication were documented (Clark et al. 2009; Ito et al. 2008). Our findings also suggested that students' use of technology inside of school has not changed in comparison with past decades. This was the case even though Internet connections in school have become more and more pervasive (Cuban et al. 2001; Vannatta & Fordham 2004); Wang et al. 2014). Word processing and Internet search activities were the most frequently reported technologies that students used in the classroom. Rarely did students have the opportunity to use tools that could support creativity and productivity, such as blogging, web editing, or movie production (See Fig. 1). This might be due teachers not using them frequently, lack of confidence in facilitating students to use of these tools, teachers not recognizing the educational value of these type of ICTs, or school policy not allowing them to use these types of ICTs or sites. Finally, like others, we found that teachers perceived the difficulty of integrating these ICTs in the classroom because issues around integration are complex and multi-dimensional (Hsu 2011; van Braak et al. 2004)

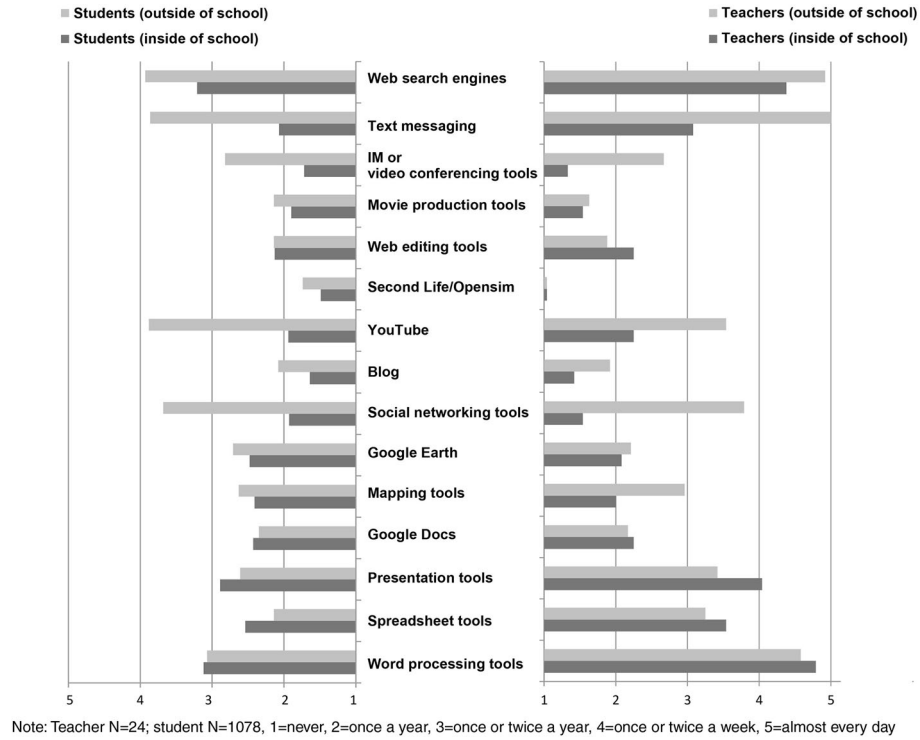

Fig. 1 Teacher and students' technology usage comparsion inside and outside of school

Teachers' technology experiences centered on administrative, curriculum preparation and communication tools

Teachers used technology inside the school for preparing curriculum materials, conducting administrative work, and communication. These results are consistent with a recent national survey conducted by National Center for Education Statistics (Gray et al. 2010). Teachers' outside-school technology use in both studies (i.e., Gray et al. and ours reported here) demonstrated the same pattern. These uses centered on using word processing, web searching and communication. Whether inside or outside of school, teachers rarely used the productivity technology or ICTs, such as Google Drive, Google Earth, web editing, and movie production tools.

Teachers' age did not correlate with any technology usage inside or outside the classroom. The findings indicated that young teachers do not speak the "language of today's students" (Prensky 2003) in the classroom even when they are considered digital natives. They may use technology more frequently for maintaining social connections or pursuing personal interests (Purcell et al. 2013), but teachers' age and or outside-school technology experiences were not identified as key factors affecting teachers' technology integration. This echoes the finding from (Brown and Czerniewicz 2010). Therefore, we cannot take for granted that the gap in technology integration will be narrowed simply because more and more digital natives will be joining the teaching profession into the future.

The myth of digital natives

Our results indicated that today's school-age learners are no more technology savvy than their teachers. The previous assumption used to profile students as digital natives (Prenksy 2001; Oblinger 2003) did not apply to the students in this study. In fact, teachers' technology use experiences surpassed students whether it's inside or outside of school. We found that overall, people's outside-school technology usage is voluntary, problem-driven and attached to personal interests. The frequency of using technology outside of school was an indicator of how technology was part of people's daily routines. In this study, students' used technology outside of school for working on school projects, maintaining social networks, and entertainment. When compared with students, teachers not only demonstrated the same patterns of outside-school technology usage, but also reported significantly higher frequencies of using technologies. The claim that digital natives possess sophisticated knowledge and skills of information technologies (Prenksy 2001; Tapscott 1998, 2009) was thus not supported in this study. Based on our findings, our conclusion align with on those of others weighing in on the digital natives debate: today's school-age students' outside-school technology experiences do not fit the description of the digital natives (Bennett et al. 2008; Kennedy et al. 2010; Margaryan et al. 2011). The disconnect between students' use of technology inside and outside of classroom does not seem to be caused by the difference in technology skills between the students and teachers. Results from this study indicated that teachers use a variety of technologies as often as their students do, even surpass them, whether inside or outside of school. It seems that the claim of digital natives overemphasizes the impact of the time when ICTs were introduced to the world, and oversimplifies the nature of how and why people use technology.

Factors preventing teachers to narrow the gap

Teachers reported five barriers of their technology integration: lack of access to technology resources, lack of time, lack of technology integration skills and strategies, and lack of support and resources of school policy.

Some believe that sufficient technology resources can lead to successful technology integration scenario. Nevertheless, even with full access to technology, teachers' pattern of using technology in the classroom may still remain unchanged (Cuban et al. 2001; Gulbahar 2007). Our teacher focus group interview results also support the claim that resource are not the major key to change teachers' technology practices in the classroom. Most of the teachers instead identified the following two most significant barriers: teachers' lack of knowledge and skills of pedagogical practices, and lack of time to plan for technology integration. These two barriers to teachers' technology integration are common and still need to be addressed (Ertmer 1999; Keengwe et al. 2008; Zhao et al. 2002).

Teachers' knowledge in using technology to facilitate students' learning and their technology skills have been identified as the main barriers of technology integration (Hew & Brush 2006; Hughes 2005). Consistent with previous findings, our study shows that teachers know how to use certain technology to solve personal or work related issues, but they report less frequency in having students use these tools compared with their own use. Put more concisely, it is common for teachers to use technology more often for solving their own administrative or curricular preparation related problems rather than assigning students to use technology for solving the academic problems (Hsu 2011; Muir-Herzig

2004). This explains why, in this study, teachers who were aptly described with the digital natives profile did not employ innovative pedagogical practices in their technology integration.

Time was a critical factor for teachers in learning technology skills, learning pedagogical strategies, piloting and evaluating the learning activities, and aligning these technology uses with school curriculum. However, there is evidence to support all of these demands being met, if teachers receive sufficient and ongoing training of content-specific technology integration strategies (Koehler et al. 2007). Another time related issue is that teachers need to cover the content learning to make sure students can pass standardized assessments. They are willing to create technology learning experience only after they are certain that the time is permitted.

Conclusions

This study contributes to past discussions and debates about digital natives by examining not only school-aged students, but also examining their teachers' use of technology inside and outside of school. The results reinforce directions others have proposed for reducing technology gap identified between inside and outside of school technology usage.

In conclusion, three major findings can be drawn from this study. First, teachers' age and technology skill could not be identified as the cause of the disconnect between students' use of technology inside and outside of school. Teachers depended much more on using technology compared with school-aged students in this study whether it's inside or outside of school. The problem seemed to reside in students' lack of opportunities to practice technology beyond pursuing personal interests.

The debate about digital natives has lasted for over a decade. The current generation of students having had access to a society more saturated and dependent on technology should be more technology savvy than when the concept of digital natives was introduced in 2001 (Prenksy 2001). In this study, the students we surveyed were considered the third generation of the digital natives. Technology access and ownership has become even more pervasive for them. Presumably, they should demonstrate their dependence on using technology in daily problem solving, productivity, and learning, especially in comparison to a decade ago. Our second finding shows, to date, not much change in how students use technology inside of schools can be detected. School-age students may be fluent in using entertainment or communication technologies, but there is evidence that the guidance is needed to support their learning how to use these technologies to solve sophisticated cognitive problems.

Students' technology experiences can be shaped and influenced by the use of technology inside the school (Ng 2012). This further suggests the need to explore the educational values of ICT, and provide high quality training to prepare teachers' with the knowledge and skills in technology integration strategies. Our third finding indicates that most students are not familiar with ICTs (or web 2.0 tools); but once teachers introduce students to a new technology to support learning, they can quickly learn how to use it and they are eager to use more technology in schools. In our study, both teachers and students have rich outside of school technology experience, but their technology experiences were not replicated in the classroom. School related tasks usually require students to use technology limited to researching information and writing papers. Rarely do teachers provide opportunities to allow students to use technology to solve problems, enhance

productivity, or develop creativity. In other words, the gap between students and their teachers is not fixed. In many ways, it is determined by the requirements teachers place on their students to make use of new technologies and the ways teachers integrate new technologies in their teaching.

The Organization for Economic Cooperation and Development (2013) surveyed 166,000 adults age 16–65 in 24 countries on their fluency in three set of skills: literacy, numeracy, and using technology to solve problems. The result revealed that U.S. young adults rank poorly in these skills compared with people of the same age from countries with similar level of development (p.97). The study also pointed out that U.S. adults ages ranging from 55 to 65 years old performed only average compared with other countries; but young adults ranked even lower in comparison to their counterparts in other countries. And, this was mainly attributed to young adults from other countries making significant progress in improving their proficiency in these skills (p.108). There is therefore a pressing need to improve U.S. school-age students' fluency in using technology to solve problems, especially as they represent the next generation of young U.S. adults.

To bridge the gap of students' technology use inside and outside of school, we, like others propose focusing on preparing and supporting teachers' development of content-specific technology integration strategies (Jimoyiannis 2010; Koehler et al. 2007). Students should be prepared to use technology to support their higher order thinking skills. This refers back to our proposed framework to encourage teachers to integrate technology as cognitive tools (Campbell et al. 2010). The school setting is the only institution that might create the needs to shape and facilitate students' technology experience. The study shows that the interpretation of what is "digital natives" may be changing as a range of new technologies take off and become embedded in social life and in school setting. This study captures the processes of change that are taking place inside and outside of school for both students and teachers. In addition, it reflects the cultural shift in the digital native generations. Further research and institutional practices are needed to examine the pedagogical practices where technology is seen as indispensable tools to support students' cognitive skills in content learning and to create a learning environment that values teachers' effort to develop students' productivity, creativity and higher-order thinking skills.

Limitations

The conclusions of this study are based on the sample of 24 science teachers and 1,078 middle school students. We had a relatively small teacher sample. Moreover, these subjects were recruited from 18 different schools in two states and may not fully represent the overall population of students and teachers. Thus, caution is needed when making generalization or inferring from these results. However, findings drawn from this study are consistent with other similar studies. Therefore, we assume that the sample is still representative to a degree. The second limitation is that the study relied on participants' self-reported data and interviews. The results may not reflect the accurate description of their actual use of technology.

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Formal/informal technology use survey

4. Overall, how often do you use the following technology OUTSIDE of SCHOOL (e.g. at home, library, bus, friend's house)?

1=Never 2=Once a year 3=Once or twice a month 4=Once or twice a week 5=Almost every day	1 ☹	2	3 😐	4	5 ☺
4-1. Computer installed Word processing tool (e.g. Word, Pages)	☐	☐	☐	☐	☐
4-2. Computer installed Spreadsheet tool (e.g. Excel)	☐	☐	☐	☐	☐
4-3. Computer installed presentation tool (e.g. Power Point, Keynote)	☐	☐	☐	☐	☐
4-4. Google docs	☐	☐	☐	☐	☐
4-5. Maps (e.g. Google Map, MapQuest)	☐	☐	☐	☐	☐
4-6. Google Earth	☐	☐	☐	☐	☐
4-7. Social networking tool (Facebook, MySpace)	☐	☐	☐	☐	☐
4-8. Blog	☐	☐	☐	☐	☐
4-9. Youtube	☐	☐	☐	☐	☐
4-10. Second Life/OpenSim	☐	☐	☐	☐	☐
4-11. Web editing tool (Google Site)	☐	☐	☐	☐	☐
4-12. Movie production tool (iMovie, MovieMaker)	☐	☐	☐	☐	☐
4-13. Instant messengers or video conferencing tools (e.g. Skpye, Facetime, MSN)	☐	☐	☐	☐	☐
4-14. Text messages (cellphone text, text messaging apps)	☐	☐	☐	☐	☐
4-15. Web search engines (e.g. Google, Yahoo, Bing)	☐	☐	☐	☐	☐

5. Overall, how often do you use the following technology AT SCHOOL?

1=Never 2=Once a year 3=Once or twice a month 4=Once or twice a week 5=Almost every day	1 ☹	2	3 😐	4	5 ☺
5-1. Computer installed Word processing tool (e.g. Word, Pages)	☐	☐	☐	☐	☐
5-2. Computer installed Spreadsheet tool (e.g. Excel)	☐	☐	☐	☐	☐
5-3. Computer installed presentation tool (e.g. Power Point, Keynote)	☐	☐	☐	☐	☐
5-4. Google docs	☐	☐	☐	☐	☐
5-5. Maps (e.g. Google Map, MapQuest)	☐	☐	☐	☐	☐
5-6. Google Earth	☐	☐	☐	☐	☐
5-7. Social networking tool (Facebook, MySpace)	☐	☐	☐	☐	☐
5-8. Blog	☐	☐	☐	☐	☐
5-9. Youtube	☐	☐	☐	☐	☐
5-10. Second Life/OpenSim	☐	☐	☐	☐	☐
5-11. Web editing tool (Google Site)	☐	☐	☐	☐	☐
5-12. Movie production tool (iMovie, MovieMaker)	☐	☐	☐	☐	☐
5-13. Instant messengers or video conferencing tools (e.g. Skpye, Facetime, MSN)	☐	☐	☐	☐	☐
5-14. Text messages (cellphone text, text messaging apps)	☐	☐	☐	☐	☐
5-15. Web search engines (e.g. Google, Yahoo, Bing)	☐	☐	☐	☐	☐

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