Under What Conditions Does Computer Use Positively Impact Student Achievement? Supplemental vs. Essential Use

Cathie Norris
Department of Learning Technologies
University of North Texas
United States
cathie.norris@gmail.com

Akhlaq Hossain
Department of Learning Technologies
University of North Texas
United States
akhlaqhossain@yahoo.com

Elliot Soloway
Department of Computer Science & Engineering
University of Michigan
United States
soloway@umich.edu

Abstract: 1:1 is happening in America's K-12 schools - and happening fast. Laptops are out and mobile devices are in. But if we want to see the needle on student achievement move in the positive direction, we need to learn from the successes and failures of the early 1:1 laptop initiatives. In this paper we examine the 1:1 laptop initiatives from several perspectives; what we see is that when computing devices are used as supplemental tools to the curriculum, no increase is observed; however, when computing devices are used as essential tools, then and only then is the student achievement increased.

Introduction

1:1 (a computing device for each learner) is set to make a major sweep across America's K–12 landscape. Why? Two reasons: (1) Students and their parents are demanding that schools be on the right side of the 21st century—pencil and paper simply is no longer good enough—and (2) the cost of going 1:1 has dramatically been reduced. But, in this second wave of 1:1, we had better learn from the mistakes K–12 made during the first wave of 1:1, lest more money be spent with the same limited impacts.

Briefly, during those 1:1 laptop days, while each and every student had access to a computer, the predominant use of computers was supplemental to the existing and relatively unchanged curriculum. That is, the same instructionalist/direct instruction/didactic pedagogy used before computers were introduced was still being used, but now computers were employed as glorified typewriters and front-ends for Google searches.

In contrast, in this second wave of 1:1—a wave that will gain momentum over the decade—where schools are reporting upwards of 30% improvement in standardized test scores, computing devices are being used as essential to the curriculum, i.e., the students use the devices from 40–70% of the school day and for periods after school as well (Norris, Hossain, & Soloway, 2011b), and the ''active-learning'' pedagogy emphasizes student constructive and collaborative activities (Bransford, Brown, & Cocking, 1999).

The second wave of 1:1 will not be based on laptops, but rather the computing device of choice will be a mobile device, such as a smartphone, a tablet, or a netbook. The cost of the device + network is dropping and, sooner than expected, schools will be able to make use of student-provided devices, and thus schools will not even need to provide computing devices per se— all that schools will need to provide is the Internet access and educational software.

Under what circumstances, then, does computer use lead to increased student achievement? In what follows, we make an argument for the notions of "supplemental tool use" vs. "essential tool use" to explain how

computer use can lead to student achievement gains. First we look at how initial laptop use was, by and large an example of supplemental tool use – and thus gains in student achievement were not observed. In the next section, we use data and analyses from Project RED to illustrate essential use of the computer – that is correlated with gains in student achievement. Next, we apply a Project RED-style analysis to "first wave" studies of laptop use in order to both confirm Project RED's analysis and also to question it, at the same time. We conclude with a prediction about the spread of 1:1.

The First Wave of 1:1 Implementations: The Computer as Supplement

In about 2002, K–12 schools started to implement1:1 laptop programs. Typically, a student would be issued a laptop computer for use 24/7. Maine funded the first 1:1 statewide program in the country. Michigan followed suit, as did schools and districts all around the U.S. While the costs were high, to say the least, the access problem was finally being addressed (Donovan, Hartley, & Strudler, 2007).

On May 4th, 2007, a day that will live in infamy for educational technologists, The New York Times (Hu, 2007) published an article entitled: ''Seeing No Progress, Some Schools Drop Laptops.'' The article said that schools were not seeing increases in test scores that could be attributed to the use of the 1:1 computers, and thus schools were rethinking their expensive, 1:1 programs.

The NYT article (Hu, 2007) pointed to two reasons to explain the lack of impact: (1) There was no educational software— the laptops came with Microsoft Office and a Web browser—and (2) the teachers were not provided with sufficient professional development support, i.e., the teachers were taught how to use the computers, but they weren't taught how to transform their existing paper-and-pencil curriculum into curriculum that took advantage of the affordances of the networked laptops.

Stepping back from the specifics of any particular school's 1:1 implementation, in reviewing the 1:1 studies, (Livingston, 2009; Penuel, 2005) we came to see that the news article (Hu, 2007) was indeed insightful. Oftentimes, the lessons the teachers implemented used the computers as typewriters and encyclopedias; students used their word processors to write reports and used search engines to find information on the Internet. While the teachers did integrate the computers into their lessons, the lessons were, by and large, pencil-and-paper lessons with computers tacked on as a supplement. The computer-based activities took up a very small percentage of time in the total lesson.

Particularly telling was the following sort of question that teachers reported their students asking: "Do we need to bring our computers to class tomorrow?" Inasmuch as the students were issued seven-pound transportable computers, aka laptops, plus bulky text- books, such a question was perfectly reasonable, since the laptops were not used on a daily basis.

Given the lack of professional development and given the lack of educational software, it is not surprising that the teachers created lessons that were generally paper-and-pencil lessons with a little computer activity thrown in. With respect to educational software, for students there has been a dearth of provocative applications. Besides the drill-and-kill programs—Math Blasters was definitely more fun than math worksheets—the only dominant educational app was a concept mapping program called Inspiration, which spawned Kidspiration, a version for the younger crowd. Still further, educational software was not low-cost, let alone free, e.g., Civilization, SimEarth, etc., were $19.95 to $39.95 per copy. Buying a copy of each educational application for each student was prohibitively expensive.

For teachers, there has been an even greater dearth of support software. While there were electronic grade books, there has been precious little support for the teaching and learning processes. In contrast, 2000–2010 has been the golden era for software support for professionals—outside of K–12. Could a professional accountant do a professional job with just a spreadsheet? Could a travel agent do his or her job with just a database? Indeed, today essentially every professional employs a layer of professional software that has been designed to make that professional's job more efficient and more effective: Sales people use CRM systems—customer relationship management systems; journalists use media management systems, etc. In sum, then, the early 1:1 laptop initiatives showed little impact on student achievement. Data did suggest that attendance was up and behavior problems were down (Silvernail & Lane, 2004). Motivation and engagement in 1:1 classrooms definitely showed an uptick—working with computers for the digital generation was much more pleasurable than working with pencil and paper!

The Second Wave of 1:1 Implementations: Computer as Essential

How Use Technology?	Use Technology But Not 1:1	1:1	1:1 Properly Implemented
Report Increased Student Achievement	69%	70%	85%

Table 1. Key finding from Project RED

Project RED (Revolutionizing Education), as reported in eSchool News, has surveyed "nearly a thousand schools with diverse student populations and varying levels of technology integration" (Devaney, 2010). Table 1 summarizes a key finding: Using 1:1 when not "properly implemented" has no more effect than using COWS (computers on wheels), computer labs, etc. Frankly, this is a huge finding, since the cost of going 1:1 is significantly greater than the cost of simply using COWS and labs. Given the Project RED findings, the cost/benefit ratio does not justify moving to 1:1—unless the school does it "properly."

1. Technology is integrated in every class.
2. Principal leads change management.
3. Students use technology daily.
4. Technology is integrated into daily curriculum.
5. Online Assessments.
6. Student to computer ratio (1:1).
7. Virtual field trips.
8. Daily use of search engines.
9. Best practices & tech training for teachers.

Table 2: Project RED Factors: Rank order of key implementation factors

What does "properly implemented" mean? In Table 2, we list, in "rank order," the "Key Implementation Factors" directly from the Project RED press release (Greaves & Hayes, 2010).

If we step back from the specifics of Project RED's findings, we see how important the daily use of computers (i.e., use various pieces of software) "in the core subjects" is. In other words, increased time on task is one of the factors that leads to increased student achievement (Stallings, 1980). We do hasten to point out that factor #4 includes "… in core subject classes." The factor doesn't just say more time using the computer; indeed, there have been studies that show that more computer use leads to poorer student performance (Stross, 2010). The key is that the pedagogy driving the students' use of the computer has changed from an instructionalist/direct instruction/didactic pedagogy to one where the students are more active in their learning.

While there are doctrinaire pedagogical approaches that emphasize social-constructivism, and while Project RED is indeed mute on the exact pedagogy employed in classrooms where there were reports of significant gains in student achievement, it is our conjecture that the teachers were not doctrinaire, but opportunistic: The teachers were comfortable letting loose their reins and allowing their students to be active learners. Clearly, more research is needed to identify the pedagogies that are being used in classrooms where student achievement gains are seen in conjunction with significant amounts of time spent using computing devices.

Using the "supplemental versus essential" terminology, then, we would argue that the Project RED data support the argument that when computers are used as essential tools in the curriculum, e.g., daily use with active learning pedagogies, that is when computers "move the needle," that is when students experience increases in achievement.

Most interestingly, Project RED points out that not one school reported using all of the top six factors! The "daily use" mentioned in factors 3 and 4 continues to be a challenge. In order to use the 1:1 infrastructure daily, the teachers would need to rethink their curriculum, since their existing paper-and-pencil curriculum is based on a didactic, instructionalist pedagogy that does not lend itself to students working independently of the teacher. And, inasmuch as teachers and schools/districts have already invested in developing their existing curriculum, they are loathe to throw it out and start again. Rather, it has been our experience in dozens of schools all around the country that teachers take their existing curriculum and simply add activities that incorporate the computer, which they feel does accomplish the goal set forth by their administrators, i.e., "integrate the computer into your curriculum."

Candidly, it is not just the non-trivial cost involved in rewriting the curriculum that stops districts from doing the rewrite—and stops districts from using their 1:1 infrastructure on a continuous, daily basis. The issue

goes to the heart of school change: The nature of the curriculum and the nature of the instruction will need to change if the school is going to use the computers on a daily basis (Bain & Weston, 2011). Those teachers who are already using a more project-based/problem-based/ inquiry-based pedagogy, where the emphasis is on student-centered exploration, tend to find it easier to transform their existing curriculum into one that takes full advantage of the affordances of a networked environment.

In sum, then, in order to move the needle and increase student achievement, 1:1 implementations must be "proper," according to Project RED, which means that the computing devices must be seen as essential, not supplemental.

First Wave Revisited

After combing the research literature, we found nine studies of 1:1 computer use that reported student achievement impact. Interestingly, it was not easy to find studies that actually reported what we feel are critical "details," e.g., what subjects were the computers used in, how long did the students use the computers for that subject, what was the impact on student achievement of that computer use, etc.

Unlike many educational research studies, six of the nine studies were methodologically rigorous. For example, each of the six studies had a control group and an experimental group; in each of the studies, one major factor that was varied was the "use – or not - of a computer 1:1". The curriculum in the six studies was the same for the control group as it was for the computer-using group; and the instructional strategies were more or less the same in both conditions. While methodologically different, the Fried (2008) and Zucker & Hug (2007, 2008) studies did provide enough detailed information so that we were able to include these studies in our categorization scheme.

Although these "first wave" of 1:1 SBR-level studies were carried out before Project RED introduced their criteria into the community's discourse, we decided to use the Project RED criteria to re-analyze these first –wave studies with the hope that we might be able to better understand the findings in these studies.

Supplemental Use is Linked to No Increase in Student Achievement

In studies of 1:1 laptop programs by Fried (2008), Grimes & Warschauer (2008), and Wurst, Smarkola, & Gaffney (2008) there were a number of key commonalities: in each study, the curriculum and the instructional practices used in both the laptop and the non-laptop classes were traditional lecture and textbook-based curriculum and instruction. Moreover, the laptops were primarily used as typewriters for a couple hours per week by each student. Neither the curriculum nor the instruction took advantage of the affordances of a 1:1 laptop setting. In effect the culture in the laptop-using classrooms was the same culture as the non-laptop-using classrooms; in effect the laptops were used as supplements to the existing curriculum and instruction. And, most importantly, in these three studies the laptop-using students show no increase in student achievement when compared with their non-laptop-using colleagues.

	Project RED Factors		1	2	3	4	5	6	7	8	9
(Fried, 2008)	2							E		I	
(Grimes & Warschauer, 2008)	2				E			E			
(Wurst et al., 2008)	2			I				E			
(Bebell & Kay, 2010)	*6*	*+Increase*	*E*		*I*	*E*		*E*		*E*	*E*
(Brown, 2009)	*3*	*+Increase*			*E*	*E*		*E*			
(Gulek & Demirtas, 2005)	*4*	*+Increase*			*E*	*E*		*E*		*I*	
(Lowther et al., 2003)	*3*	*+Increase*				*I*		*E*			*E*
(Zucker & Hug, 2007) (Zucker & Hug, 2008)	9	+Increase	E	I	E	E	E	E	I	E	I
	Total Factors In Play	Student Achievement									

Table 3: Factors in Play in the First Wave 1:1 Laptop Studies

Legend: E = Explicitly mentioned that factor was in play. I = Inferred that factor was in play
+increase = Study Observed Increase in Student Achievement

Here are some observations that were made about the laptop-using students:

- "Laptop use interfered with student's ability to pay attention to and understand the lecture material, which in turn resulted in lower test scores". (Fried, 2008)
- "98% of students used laptops to write papers at school…. Language Arts classes averaged 2.8 hrs. per week (of laptop use in school)…" (Grimes & Warschauer, 2008)
- "Students too easily got distracted using the laptop for internet activities instead of being attentive to the professor". (Wurst et al., 2008)

These three studies affirm a perception actually voiced by some faculty in the Fried, 2008 study: "[the laptops] distract students and detract from learning". Indeed, this comment speaks volumes about the faculty's view of instruction: the teacher is the fount of knowledge and students need to pay attention to the teacher in order to learn. While computers are powerful enabling devices, their enabling power is effectively blocked when used by educators with attitudes like those in these studies.

Essential Use is Linked to Increased Student Achievement

In six of the studies of 1:1 laptop use, significant increases in student achievement were noted. What then was different in these six studies in comparison to the three studies where no increases were observed? Using the Project RED criteria (Table 2), the difference is easiest to see in the studies by Zucker & Hug (2007, 2008).

- In the Zucker studies, the instructional practices of the teachers were fundamentally changed. 90% of the teachers in these two studies agreed with the statement: "I have changed the way I organize classroom activities".
- Students used a number of different software applications (Sketchpad, LoggerPro, Inspiration, etc.)
- And, while the amount of computer use varied by subject matter, students did use their computers for significant amounts of time.

It is interesting to note that the Project RED factors (Table 2) did not include a factor about "teacher change." But, the observation that how the teachers taught changed – from didactic to more project/inquiry-based jumps out of the study. Thus, it would be interesting to go back into the Project RED data to explore how a factor "teacher practices were significantly changed; they practiced didactic instruction less or much less."

The teacher factor, in fact, grows in importance when we look at four studies in this "first-wave". In the four studies listed in italics in the chart, we show the Project RED factors in play in the classrooms. While the studies report increases in student achievement, the number of Project RED factors in play was mixed – more than in the study where student achievement was not observed but less than in the study where it was clear that the computers were used as essential tools. But, in those four studies, there were reports of changes in teacher pedagogy, for example:

- (Babell & Kay, 2010): Fundamental change in teaching was noted; "particularly teaching strategies, curriculum delivery, and classroom management". Technical and curricular professional development and support was provided to teachers to integrate the new technology into their curriculum.
- (Brown, 2009): Three reading strategies were implemented via the mobile devices; to accommodate visual learners, visual & kinesthetic learners and auditory learners. Specific reading material was designed to teach vocabulary, using mobile phones.
- (Lowther, Ross, & Morrison, 2003): Participation teachers received computer integration training. Laptop class teachers placed greater emphasis on "research and project oriented tasks" and "laptop students had greater accessibility to and better skills at using application software geared to solving open-ended learning problems". Also Laptop classes "used more student-centered instructional strategies".

In sum, then, using the Project RED lingo, we would say that in the Fried (2008), Grimes & Warschauer (2008) and Wurst et al. (2008) studies where increases in student achievement were not observed, this was due to the lack of the presence of at least three factors, while in our terms, we would argue that the reason was due to the use of the computers as supplements and not as essential tools. Similarly, using Project RED lingo, we would say that the increases in student achievement observed in the Zucker studies were due to the presence of all the Project RED factors – a situation that Project RED did not observe at any school that reported their data to the project. (Project RED, 2010)!

Now, using Project RED lingo, the six studies where student achievement was observed were due to at least 3 but not more than 6 factors – except in the Zucker studies. However, given the variability in the number of factors in play and the specific factors in play, frankly, the Project RED argument feels weak. Interestingly, though, one

factor that Project RED didn't include in their list – the change in teacher's pedagogy – did seem to play a role in the studies where student achievement was observed to increase. And, there is some rationale for why the "teacher" factor is relevant: as the classroom moved from a didactic to a more project oriented classroom, students typically take on more responsibility for their learning and that in turn typically results in greater engagement, and greater time on task. It is those actions on the students' part that typically are associated with increases in student achievement (Bransford, Brown, Cocking, 2000).

We draw two conclusions from this retrospective application of Project RED-style analysis to the First-Wave of 1:1 laptop-using schools:

- Given the critically important role that the teacher apparently played in 6 of the studies – in essentially all the studies where student achievement was observed to increase, we wonder at the completeness of the list of factors put out by Project RED.
- The notions of supplemental and essential do seem to have some explanatory power; when computers are used by the students as essential tools – as represented by having a large number of Project RED factors in play and/or by teachers changing their pedagogy from didactic instruction to a more project-oriented pedagogy. In so doing this gives the students more opportunity and more responsibility for their own learning – which in turn is significantly enhanced by each student having his or her own computer to use.

Concluding Remarks

Schools all over the world are being challenged to prepare their students for a new world— a global, knowledge-work marketplace (Partnership for 21st Century Skills, 2008). Countries, such as Singapore, which have traditionally scored very high on tests—tests of content, tests of "what"—are realizing that in this new world order a different set of skills is needed (Ministry of Education, 2008). Here in the U.S., where the same tests of "what" have ruled the land in K–12, recognition is dawning that we must prepare—and test—our children differently (ATC21S, 2010). That is, while there are items that must be memorized, we need to prepare students to understand how systems work and, most importantly, we need to prepare students to work both independently and in a team. In order to teach those 21st century skills and that 21st century content—the "how"—we can't be using tools based on 18th century pencil-and-paper.

Project RED (2010) is leading the way towards providing the proof that school districts appear to want to justify the significant effort that is going to be needed to make the shift to 21st century teaching and learning. Integral to that shift is the realization that if schools are going to move the needle—make an impact on student achievement—then using computing devices as supplemental to the existing curriculum is not enough. As long as computing is only supplemental, it will have limited impact on teaching and learning (Norris & Soloway, 2010c, 2011; Bain & Weston, 2011). Moving the needle requires education to use the 21st century technology as other 21st century knowledge-workers are doing, as essential tools. SETDA (State Education Technology Directors Association) in their "Class of 2020: Action Plan for Education" (2008) report suggests that: "computers need to be used continuously and seamlessly…" in the classroom. "Continuously and seamlessly" is more than "integrated into the curriculum" and more even than RED's "use daily."

But, as RED is seeing and as we are seeing (Norris, Hossain & Soloway, 2011a) on a more anecdotal level, there is real benefit to be gained from going 1:1 using smartphones—not only, as RED observes, do test scores go up but we see students engaging in school at a level that is unprecedented. Given that level of impact, we fully realize that much more research needs to be done before substantiated claims can truly be made. However, we feel that there is ample prima facie evidence to warrant the expenditure of funds to more systematically explore the conjectures raised here.

We have gone on record publically (Norris & Soloway, 2010a) with the following prediction: By 2015 every child in every grade in every K–12 classroom in America will be using a mobile learning device. Research can contribute by informing and shaping the implementation of these mobile technologies. RED (2010) has observed that 1:1, if not properly implemented, offers little benefit over traditional uses of technology. Research can help schools use mobile technologies effectively—and not waste resources. But, regardless of what research does, the rollout will proceed. Mobile technologies are bigger than the Internet. The Internet is a roadway; without a car, a roadway is useless. Mobile technologies are the cars for the Internet. Mobile technologies are giving voice to individuals who otherwise would have none. The momentum behind mobile technologies is unprecedented (Murphy & Meeker, 2011). Mobile technologies are insinuating themselves into every crevice of the consumer world as well as pushing into the business enterprise. They will even invade K–12, which has staunchly resisted change for hundreds of years. Mobile technologies are moving at bullet-train speeds!

References

ATC21S (2010) Status Report as of January 2010, Assessment & Teaching of 21st Century Skills, http://atc21s.org/wp-content/uploads/2011/11/1-Defining-21st-Century-Skills.pdf

Bain, A., & Weston, M. (2011). The learning edge: What technology can do to educate all children. New York, NY: Teachers College Press.

Bebell, D. & Kay, R. (2010). One to one computing: A summary of the quantitative results from the Berkshire wireless learning initiative. *Journal of Technology, Learning, and Assessment*, 9(2), 5-59.

Bransford, J. D., Brown, A.L., & Cocking, R. R. (Eds.) (2000). How people learn: Brain, mind, experience and school. Washington, DC: National Academy Press.

Brown, L. (2009). Using mobile learning to teach reading to ninth-grade students. *Learning*, *5*(1), 105-123.

Fried, B.C. (2008). In-class laptop use and its effects on student learning. *Computer and Education, 50*, 906-914.

Devaney, L. (2010). Study reveals factors in ed-tech success, eSchool News; http://projectred.org/uploads/

Donovan, L., Hartley, K., & Strudler, N. (2007). Teacher concerns during initial implementation of a one-to-one laptop initiative at the middle school level. *Journal of Research on Technology in Education*, *39*(3), 269–283.

Greaves, T., & Hayes, J. (2010). Study shows which technology factors improve learning; http://www.projectred.org/uploads/Press%20Release%20062710% 20v2.pdf .

Grimes, D. & Warschauer, M. (2008). Learning with laptops: A multi-method case study. *Journal of Educational Computing Research, 38*(3), 305-332.

Gulek, C.J. & Demirtas, H. (2005). Learning with technology: The impact of laptop use on student achievement. *Journal of Technology, Learning, and Assessment, 3*(2), 4-35.

Hu, W. (2007, May 4). Seeing no progress, some schools drop laptops. The New York Times; http://www.nytimes.com/2007/05/04/education/04laptop.html?pagewanted=1

Livingston, P. (2009). 1-to-1 learning laptop programs that work, second edition. Eugene, OR: International Society for Technology in Education (ISTE).

Lowther, D.L., Ross, S.M., & Morrison, G.M. (2003). When each one has one: The influences on teaching strategies and student achievement of using laptops in the classroom. *ETR&D, 51*(3), 23-44.

Ministry of Education (2008) MOE Launches Third Masterplan for ICT in Education, http://www.moe.gov.sg/media/press/2008/08/moe-launches-third-masterplan.php, Singapore

Murphy, M., Meeker, M. (2011)Top mobile internet trends, http://www.businessinsider.com/mary-meeker-matt-murphy-2011-2#-1 , Feb.

Norris, C., Soloway, E. (2010a) Why Is Mobile Technology Different From Other Technology? Among many other reasons, students will be using their own devices. *District Administration Magazine*, Feb. http://www.districtadministration.com/article/why-mobile-technology-different-other-technology

Norris, C., Soloway, E. (2010b) Mobile learning pioneers special section - Innovative leaders take the phone and run: Profiles of four trailblazing programs. *District Administration Magazine*, June, http://www3.districtadministration.com/viewarticle.aspx?articleid=2419

Norris, C., Soloway, E. (2010c) What Will Move the Needle? Only one technology has the potential to make an authentic impact on student achievement. *District Administration Magazine*, July. http://www.districtadministration.com/article/what-will-move-needle

Norris, C., Soloway, E. (2011a) Mobile Devices as Essential Tools: Carts of laptops haven't raised student achievement—and neither will carts of iPads. *District Administration Magazine*, April, http://www.districtadministration.com/article/mobile-devices-essential-tools

Norris, C., Hossain, A., & Soloway, E. (2011b). Using smartphones as essential tools for learning: A call to place schools on the right side of the 21st century. *Educational Technology*, *51*(3), 18-25.

Partnership for 21st Century Skills (2008) 21st Century Skills, Education & Competitiveness: A resource and policy guide, http://www.p21.org/storage/documents/21st_century_skills_education_and_competitiveness_guide.pdf

Penuel, W. R. (2005). Research: What it says about 1-to-1 learning. Cupertino, CA: Apple Computer, Inc; http:// www.ubiqcomputing.org/Apple_1-to-1_Research.pdf.

Project RED Reports (2010) The technology factor: Nine keys to student achievement and cost-effectiveness, http://www.projectred.org/uploads/PREP11/ProjectREDPreview.pdf

SETDA(2008) Class of 2020: Action Plan for Education, State Educational Technology Directors Association, http://www.setda.org/c/document_library/get_file?folderId=270&name=DLFE-296.pdf

Silvernail, D. L., & Lane, D. M. M. (2004). The impact of Maine's one-to-one laptop program on middle school teachers and students: Phase one summary evidence. Portland, ME: Maine Education Policy Research Institute, University of Southern Maine.

Stallings, J. (1980). Allocated academic learning time revisited, or beyond time on task. *Educational Researcher, 9*(11), 11-16.

Stross, R. (2010). Computers at home: Educational hope vs. teenage reality; http://www.nytimes.com/2010/07/11/ business/11digi.html?_r=1&pagewanted=print

Wurst, C., Smarkola, C., & Gaffney, M.A. (2008). Ubiquitous laptop usage in higher education: Effects on student achievement, student satisfaction, and constructive measures in honors and traditional classrooms. *Computers & Education, 51*(4), 1766-1783.

Zucker, A.A., & Hug, S.T. (2007). A study of the 1:1 laptop program at the Denver School of Science & Technology. Denver, CO: Denver School of Science & Technology.

Zucker, A.A., & Hug, S.T. (2008). Teaching and learning physics in a 1:1 laptop school. *Journal of Science Education and Technology, 17*, 586-594.

Acknowledgements

Portions of this paper appeared earlier in Education Technology Magazine in an article entitled: Using Smartphones as Essential Tools for Learning: A Call to Place Schools on the Right Side of the 21st Century, Cathleen Norris, Akhlaq Hossain, Elliot Soloway, Educational Technology Magazine, May/June 2011