

Mobile Learning: Transforming Education, Engaging Students, and Improving Outcomes

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INTRODUCTION



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Education is at a critical juncture in the United States. It is vital for workforce development and economic prosperity, yet is in need of serious reform. American education was designed for agrarian and industrial eras, and does not provide all the skills needed for a 21st century economy.¹ This creates major problems for young people about to enter the laborforce.

Mobile learning represents a way to address a number of our educational problems. Devices such as smart phones and tablets enable innovation and help students, teachers, and parents gain access to digital content and personalized assessment vital for a post-industrial world. Mobile devices, used in conjunction with near universal 4G/3G wireless connectivity, are essential tools to improve learning for students. As noted by Irwin Jacobs, the founding chairman of Qualcomm, Inc., "always on, always connected mobile devices in the hands of students has the potential to dramatically improve educational outcomes."²

This paper, part of our Mobile Economy Project, looks at ways that mobile devices with cellular connectivity improve learning and engage students and teachers. Wireless technology is a way to provide new content and facilitate information access wherever a student is located. It enables, empowers, and engages learning in ways that transform the learning environment for students inside and outside of school.

Sadly, not every student has access to a computer and the Internet. And given the costs of hardware, it is not affordable for school districts to provide a personal computer to every student. However, most young people have phones, and this provides a real opportunity to transform instruction.

As mobile phones, tablets, and other connected devices become more prevalent and affordable, wireless technology can dramatically improve learning and bring digital content to students. Students love mobile technology and use it regularly in their personal lives. It therefore is no surprise that young people want to employ mobile devices to make education more engaging and personalize it for their particular needs.

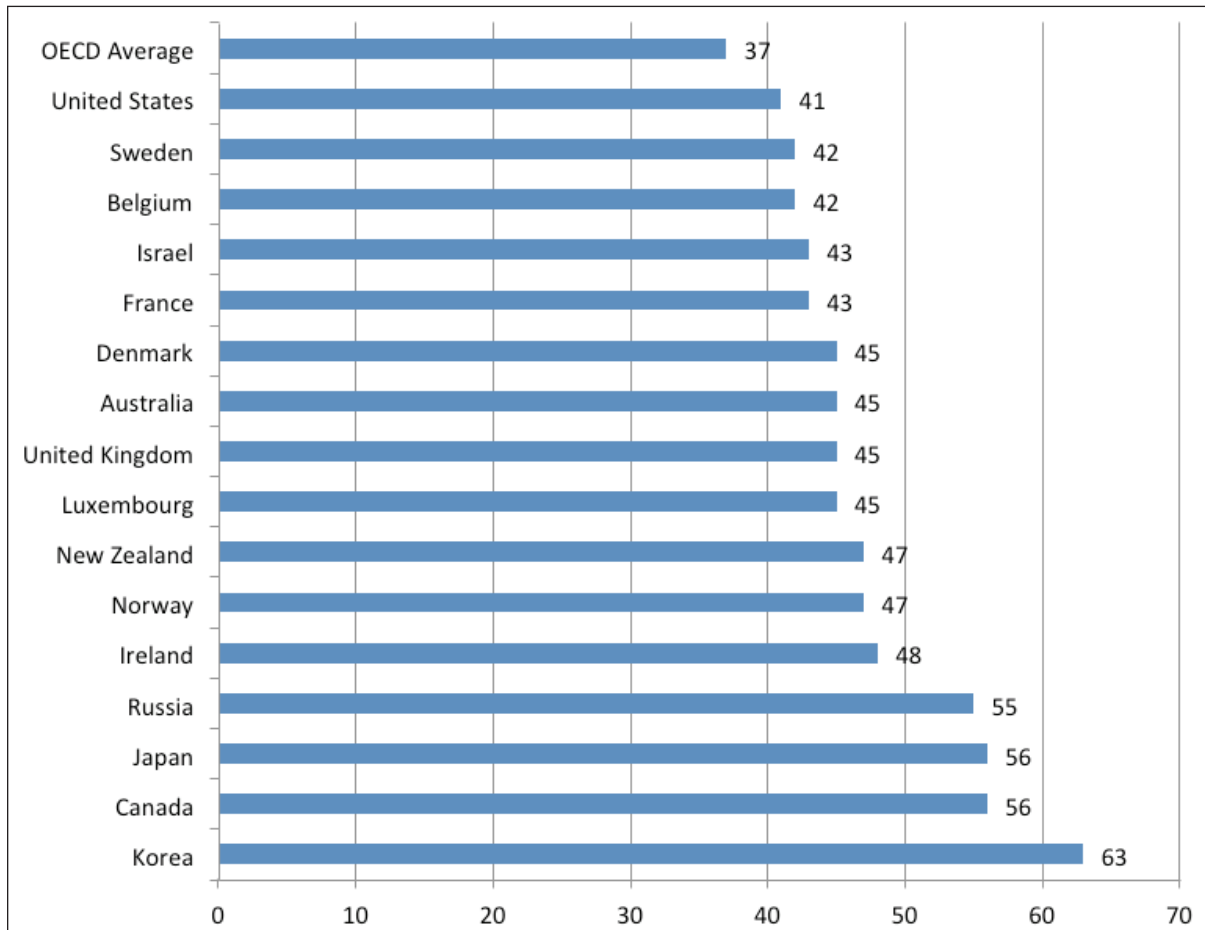
Technology-rich activities can sustain high levels of student engagement and peer collaboration compared to less technology focused activities. Educators need to figure out how to harness mobile platforms for instructional purposes and employ them to boost educational learning. A majority (52 percent) of students in grades 6-12 believe that having access to a tablet computer is an essential component of their ultimate school. Fifty-one percent of school administrators agree with these sentiments as well.³

As a country, we need to educate the next generation of scientists, inventors, engineers, and entrepreneurs. Educating a workforce that is effective in a global context and adaptive as new jobs and roles evolve will help to support our economic growth. Mobile learning makes it possible to extend education beyond the physical confines of the classroom and beyond the fixed time periods of the school day. It allows students to access content from home, communicate with teachers, and work with other people online. The value of mobile devices is that they allow students to connect, communicate, collaborate and create using rich digital resources.

COMPARISON WITH OTHER NATIONS

The United States is at risk of falling behind other countries on educational attainment. Recent studies have found that it ranks 16th among developed nations in percentage of its population aged 25 to 34 years old with tertiary degrees.⁴ As shown in Figure 1, Korea leads these nations with 63 percent, followed by Canada (56 percent), Japan (56 percent), and Russia (55 percent). 41 percent of Americans hold tertiary degrees. This is slightly above the 37 percent average for Organization for Economic Co-operation and Development countries.

FIGURE 1: PERCENT WITH TERTIARY DEGREES



Source: McKinsey Global Institute, "Game Changers: Five Opportunities for US Growth and Renewal", July, 2013, p. 111.

There are other signs as well. Some analysts have examined the Programme for International Student Assessment (PISA) test scores of 15-year olds in 65 countries put together by the Organisation for Economic Co-operation and Development. Their work has found that the United States ranks 14th among selected countries in educational performance. In aggregating test scores in reading, mathematics, and science literacy, American students have scored 496, well below the 545 for Hong Kong, 543 for Finland and Singapore, 541 for South Korea, and 529 for Japan.⁵

An analysis of international data by researchers at Harvard University concluded that "the gains within the United States have been middling, not stellar. While 24 countries trail the U.S. rate of improvement, another 24 countries appear to be improving at a faster rate. Nor is U.S. progress sufficiently rapid to allow it to catch up with the leaders of the industrialized world."⁶

Others have pointed out that the United States has made some recent gains. For example, an analysis by Tom Loveless, senior fellow in the Brown Center on Education Policy, of Progress in International Reading Literacy Study (PIRLS) and Trends in International Math and Science Study (TIMSS) showed that American students had gains in math, reading, and science, while Finish pupils had declines in educational performance.⁷ While American scores have increased by 17 points since 1995, U. S. fourth graders, with a score of 541, still rank below five Asian countries in mathematics (Singapore at 606, Korea at 605, Hong Kong at 602, Chinese Taipei at 591, and Japan at 585).⁸

In an effort to make sense of these findings, Harvard Education Professor Martin West has investigated the source of cross-country differences in educational performance. According to his analysis, “the evidence is clear that the American education system ranks in the middle of the pack, at best, among industrialized countries.”⁹

Many reasons have been given to explain U.S. performance: educational expenditures, state differentials, student diversity, parental education, and cultural factors, among others. West believes that closing the domestic achievement gap is very important and stresses the importance of improving the quality, and not necessarily the quantity, of education that students receive.¹⁰

Regardless of which data are studied, the bottom line is that America has work to do in the education area. Students in a number of other countries are performing at higher levels and generating outcomes that threaten long-term economic prosperity in the United States. Unless we do a better job of school innovation, future generations will not experience the economic well-being of the current generation.

We are already seeing some signs of this in international competitiveness. For the first time in recent memory, non-U.S. innovators were awarded more patents (96,000) than Americans (93,000). This represents a major turnaround from a decade earlier, when American innovators were responsible for 57 percent of all the patents awarded.¹¹

CHALLENGES FACING U.S. EDUCATION

American education faces a number of different challenges. As noted below, this includes the need for better infrastructure, personalized content, embedded assessment, and professional development of teachers.

BETTER DIGITAL INFRASTRUCTURE

When it comes to infrastructure, many Americans think of highways, bridges, and dams. Historically, those items have consumed the bulk of government infrastructure spending. For example, the United States spent \$425 billion to construct the 47,000 miles of the interstate highway system.¹²

Yet in the digital world, having universal, high-speed mobile networks is crucial for economic development. Educational institutions need these platforms, as do libraries, hospitals, businesses, and non-profit organizations. It is just not enough to provide fixed connectivity within schools, libraries, and hospitals. The connectivity must be available wherever students and teachers happen to be. Cellular connectivity, with its near universal coverage, can truly promote learning, entrepreneurship, medical care, and business productivity.

There is a well-established link between Internet access and economic development. A World Bank study of 120 nations between 1980 and 2006 undertaken by Christine Qiang estimated that each 10 percentage point increase in broadband penetration boosts gross domestic product by 1.38 percent in developed nations and 1.21 percent in developing countries.¹³ In other words, it is crucial to provide digital infrastructure that can propel economic development and boost productivity.

According to the Federal Communications Commission National Broadband Plan, the United States should boost download speeds to at least 100 Mbps for businesses and households by 2020 and 1 gigabit per second for anchor institutions in local communities, i.e., schools, hospitals, and libraries.¹⁴ This kind of network would not come cheap. Government officials estimate that it would cost around \$350 billion to develop a universal, high-speed Internet network.¹⁵

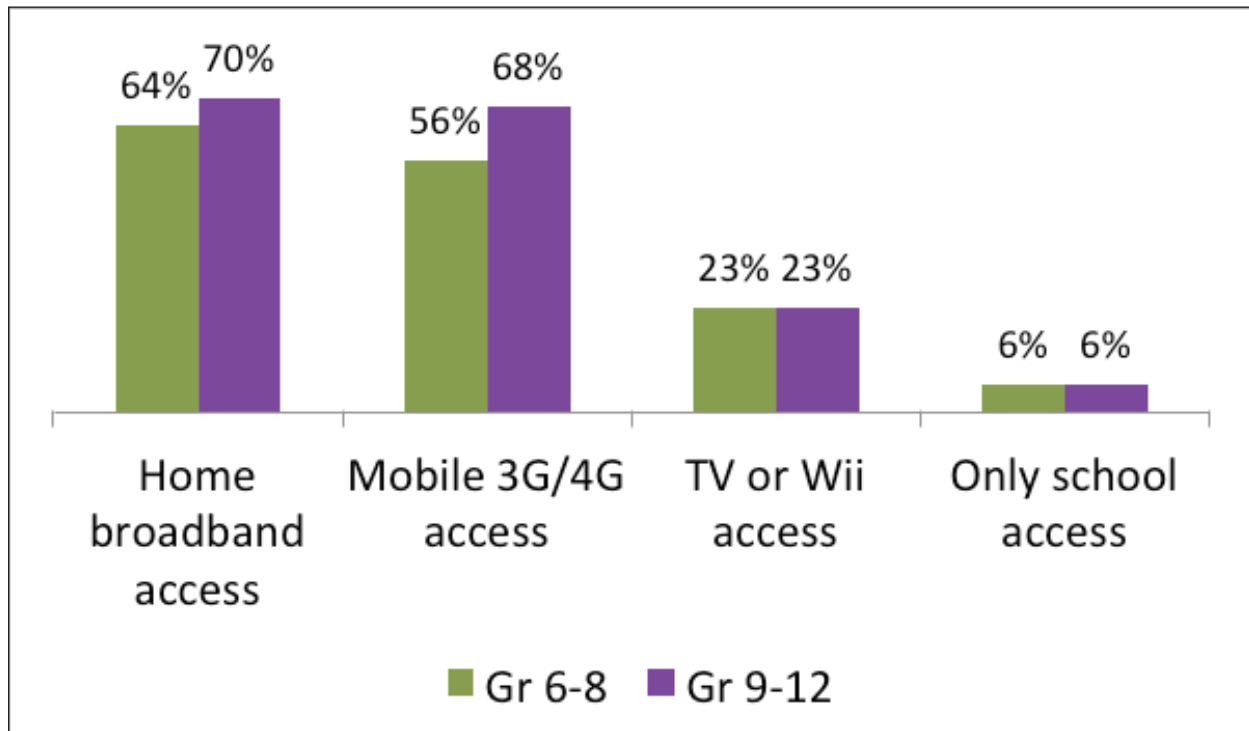
The focus of much of the National Broadband Plan was fixed access, but in a chapter devoted to education, the Plan also recognized the importance of cellular access. One of the Plan's recommendations was that "The FCC should initiate a rulemaking to fund wireless connectivity to portable learning devices. Students and educators should be allowed to take these devices off campus so they can continue learning outside school hours."¹⁶

Moreover, in 2011, the FCC funded 20 pilot projects around the country in a program called "Learning On the Go". The purpose of the pilots was to begin funding for devices and cellular connectivity through the E-rate program, in line with the afore-mentioned recommendation. The pilots lasted for a year, and it is time to expand this program.

According to Project Tomorrow data shown below, 68 percent of high school students say that they access the Internet via a 3G/4G mobile device - including a number of students who don't have broadband access at home.¹⁷ Julie Evans of Project Tomorrow notes that "this is the real story as to why mobile devices can help to solve the home broadband problem." According to her, "even amongst students who say they have high speed Internet access at home, in many cases though students never get to use that access. If there is one family computer that is hard wired for that high speed access, students today need to contend for access with siblings who are also trying to do their homework, parents looking for jobs or doing their own work,

and family entertainment activities using that computer. Students tell us that having their own mobile device that is not a shared device give them better, more reliable access to the Internet than trying to use the family broadband connection.”

FIGURE 2: STUDENT ACCESS BY GRADE LEVEL



© Project Tomorrow 2013

A number of public schools typically do not have sufficient information technology staffing so aren't able to take advantage of recent advances in mobile networks. Many rely on “bring your own device.” This complicates the education IT environment because schools end up with a myriad of devices and operating systems, which makes it difficult to link hardware and connect students to each other. The result is an IT “Tower of Babel” with interoperability problems and poor communications. And, above all, “bring your own device” is only fine for those students who have devices. Those who do not are left behind.

PERSONALIZED DIGITAL CONTENT

If we can take advantage of mobile devices and technology, it is possible to customize educational content for individual students. One of the current problems is that teachers deal with classrooms of very diverse students. Pupils come from different backgrounds, have divergent interests, and learn in unique ways.

In their individual lives, young people are accustomed to personalized content and instantaneous communication. They seek information around the clock and pursue information

that is relevant to their particular interests. Indeed, one of the virtues of mobile devices is their ability to provide personalized digital content 24/7.

We need to think of education as an individualized and year-round activity, not just something that takes place in bulk form within schools between 8:30 a.m. and 3 p.m. Monday through Fridays when schools are in session. Content should be ubiquitous and customized so that students can follow their learning passions and figure out where to get answers to basic questions.

For example, mobile technology provides students the same access to always-on, anytime and anywhere learning via smartphones and tablets with additional benefits including increased functionality, sophisticated graphics and a larger screen allowing students to engage with their learning materials in new and compelling ways.

Some studies show that students are more open to using technology for learning and that they are aware of these new learning tools such as text, illustration, and audio and visual recordings, all of which provide children with a more holistic learning experience. While widespread improvements in technology and communications have modernized some aspects of the education system, mobile has the capacity to accelerate and compound technology's impact by joining massive amounts of information with a student's imagination.

Too often, there is inadequate attention to tailoring educational content to the individual needs and learning styles of students. According to NMC Horizon Report, "the demand for personalized learning is not adequately supported by current technology or practices."¹⁸ Students need ways to tailor the constant flood of contemporary information to their own needs. Software can help them separate the noise from the signal and focus on material that is most relevant to them. In that way, mobile technology can serve as an information filter for students and teachers to help them digest the enormous quantity of information that currently is available.

EMBEDDED DIGITAL ASSESSMENT

A benefit of the digital world is the ability to embed assessment within learning tools. Mobile devices enable detailed metrics on how students approach subjects, the process by which they acquire knowledge, and how quickly they pick up on key concepts and skills. When content is delivered in digital form, it is easy to deploy pop-up quizzes that evaluate comprehension and knowledge.

These kinds of tools free teachers from the mundane tasks of grading rote items and provide immediate feedback for students and parents. Software offers nuanced measures of student attainment. Teachers can develop dashboards that track classroom activities and individual student achievement on his or her learning curve. Students can be categorized into different

groups based on whether they have fallen behind their peers and need remedial attention, are on course with their fellow students, or have mastered current material and need more challenging assignments in order to advance their learning.

Right now, pupils in the first category often don't get the extra attention they need to master key concepts and major skills and those in the third category are bored because they learn quickly and have to wait for the rest of the class to catch up with them. Teachers have to focus on the classroom average because that is where many of the students are in the learning process. Neither advanced students nor those requiring extra help are well-served under the current status quo.

TEACHER DEVELOPMENT

Teachers are crucial to the success of any school reform or learning innovation. As the agents of learning in the classroom, they guide education in ways that are very important. If teachers are provided with the training and funding necessary to employ helpful tools, they will be more effective in transmitting knowledge and skills to their students.

The same is true for principals and superintendents. Those places that have supportive administrators are more likely to use education technology and incorporate mobile devices into the classroom. Teachers take cues from their supervisors and this affects their use of and impact on student performance.

Too often, new technologies are dumped into the classroom with little to guide teachers about their usage or possible benefits. Teachers are expected to learn how to make use of new tools without any assistance or training. Sometimes, and understandably so, they resent the extra time required to figure out new technology or fail to implement it in ways that advance learning. The result is failed experiments and frustration with stagnant educational results.

The alternative way to think about education innovation is professional development of teachers. Like any other profession, teachers need training opportunities that demonstrate best practices and ways to take full advantage of educational innovations. They require instruction on how to use mobile technology and how it can make their lives easier while also engaging students.

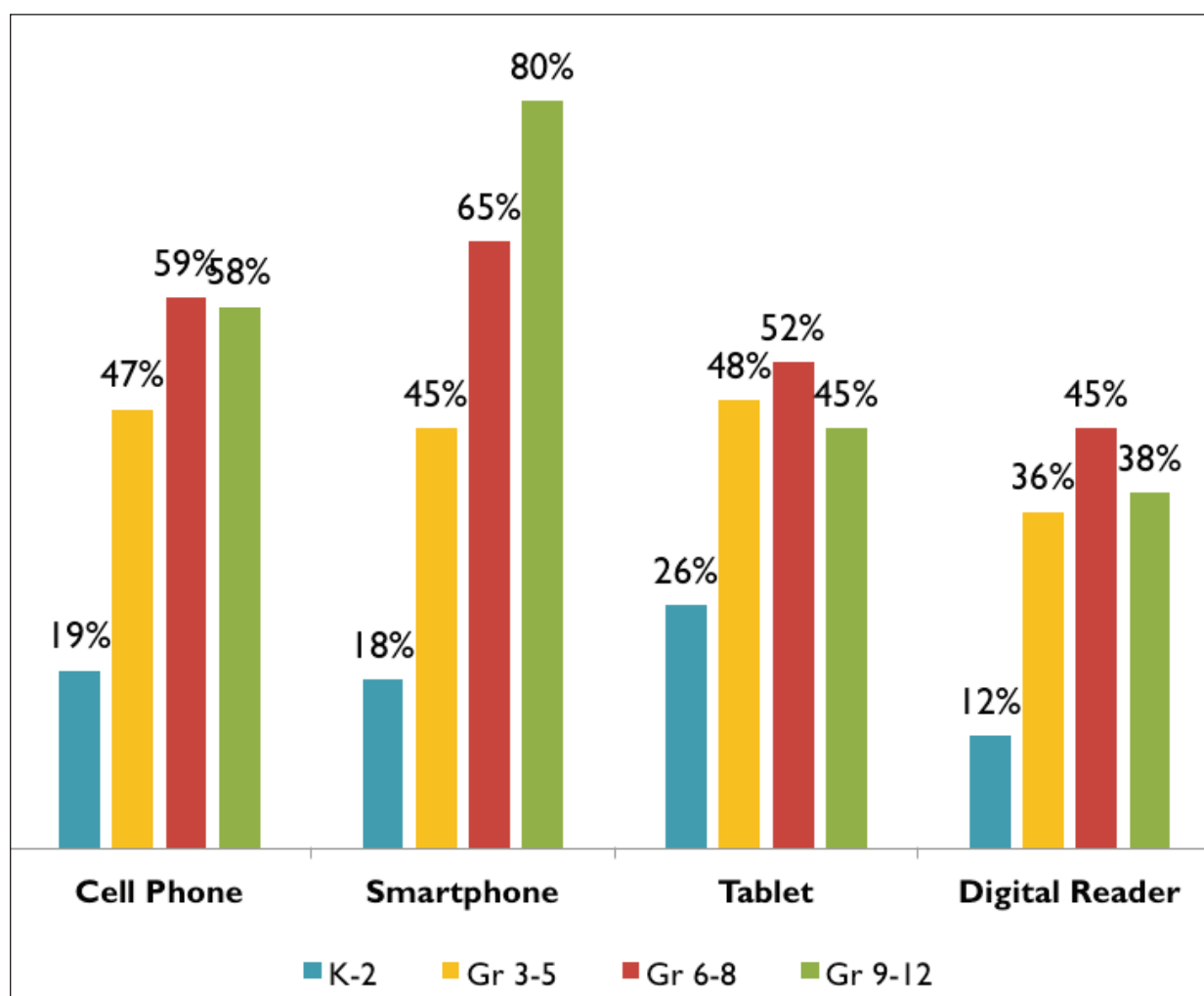
Digital technology helps teachers think about new classroom models. Students can take more responsibility for their own learning, while teachers can focus on more advanced problem-solving and building critical skills for those in their classrooms. The result will be an educational collaboration that is more satisfying for students and teachers.

HOW MOBILE ENABLES INNOVATION

There are a number of ways in which mobile technology enables educational innovation. Research by Project Tomorrow shows how access has improved across various mobile platforms. Eighty percent of high school students said they had a smartphone, 45 percent had tablets, 38 percent had digital readers, and 58 percent had a cellphone.¹⁹

These percentages are up over just a few years ago. In 2008, only 28 percent of high schoolers had a smartphone. And in 2011, only 26 percent of students in grades 6-8 had a tablet computer, compared to 52 percent now.

**FIGURE 3: STUDENT PERSONAL ACCESS TO MOBILE DEVICES
(NOT SCHOOL PROVIDED)**



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To be sure, mobile access is not completely universal—100 percent of teenagers do not own a cell phone since not everyone can afford to provide their children with a phone. Yet, usage has risen dramatically for most students.

The National Commission on Teaching and America's Future (NCTAF) has undertaken a study of science, technology, engineering, and math (STEM). It found that "STEM learning teams have positive effects on STEM teachers and their teaching."²⁰ Those who were part of a team were more likely than others to use research-based methods in their courses and make greater use of student inquiry.

These techniques were found to enhance student learning. In partnership with universities across the United States, NCTAF is looking at how mobile applications help with teacher training and support, especially during the first few years of teaching when they need it the most. NCTAF's Teachers Learning in Networked Communities 2.0 (TLINC) initiative uses mobile technology in order to strengthen networks of support and decrease the isolation of new teachers by facilitating communication, collaboration, and access to resources for student teachers while they are still in their preparation phase.

The American Association for the Advancement of Science has launched an "Active Explorer" application that takes advantage of mobile devices to increase student interest in learning, particularly in science. It employs smart phones as data collection instruments for field projects. Teachers create "quests" that provide a way for students to collect data from field experiments or to document their findings for projects. Students in several different Washington, D.C. schools are taking part in this project.²¹

One of the greatest virtues of mobile technology is the way it enables social collaboration. According to a study by the High School Survey of Student Engagement, "the most engaging forms of class work involve collaborative or creative components." Its authors note that "61 percent of students report being excited and engaged by discussion and debate in class."²² Wireless devices represent some of the easiest ways to get students to work together.

STUDENT AND TEACHER ENGAGEMENT

Both teachers and students report positive impact on learning from digital technologies. For example, in the Project Tomorrow survey, teachers see a number of positive benefits from their use of digital instructional tools. 52 percent say their students are more motivated to learn, 36 percent believe their students are developing creativity, 29 percent think the tools encourage problem solving and critical thinking, 7 percent say their students are applying knowledge to practical problems, and 26 percent report students are taking ownership of their own learning.²³

Students are quite positive about the ways they think the use of mobile devices will transform their learning environment. According to a Project Tomorrow Speak Up survey, using a mobile device in school helps middle school pupils increase their learning because 78 percent say it allows them to check grades, 69 percent credit it with helping them to take class notes, 64 percent enjoy its aid in accessing online textbooks, 56 percent say it helps them write papers and do homework, 56 percent use it for calendar updates, and 47 percent indicate it helps them learn about school activities.²⁴

Relying upon a mobile device in school furthermore helps students “leverage the device’s capabilities to increase the personalization of learning process”. Through it, 73 percent say it helps them undertake research “anytime, anywhere”, 63 percent praise the fact they can receive reminders and alerts, 61 percent believe it aids in collaboration with peers & teachers, 54 percent credit it with organizing their schoolwork assignments, and 52 percent say mobile devices allow them to access their school network from home.²⁵

To aid schools in the use of mobile technology and the educational techniques it enables, companies such as Kajeet, a wireless service platform solution provider, are working to provide access to applications and tools to further enhance students’ learning experience through mobile. The Making Learning Mobile pilot program is aiding 120 fifth graders at an underserved elementary school in Chicago Public Schools with the latest Samsung Android tablets to provide 24/7 access to educational resources.

These devices utilize the company’s web-based Sentinel™ platform which manages Internet access, allows students to collaborate on schoolwork from any location and provides teachers with the ability to deliver one-to-one lessons using student safe and regulatory compliant instructional resources. As the majority of these students in the pilot are English language learners, this access provides an unprecedented opportunity for the school and the teachers to extend the learning process beyond the classroom and involve parents in supporting their child’s acquisition of literacy skills.

The Consortium for School Networking (CoSN) has an initiative that is aimed specifically at providing resources and guidance to school IT and technology administrators who are working to implement wireless infrastructure and devices into their district.²⁶ But funding remains a key problem to the realization of these objectives. According to Keith Krueger, the chief executive officer for this Consortium, “most school districts, even those that are affluent, would say they can’t afford the ongoing cost of a ubiquitous technology environment.”²⁷

Some schools have moved forward with their own initiatives, and the results have been powerful. One notable example is in Onslow County, North Carolina with a project known as Project K-Nect. For the past six years, Onslow County School District has experimented with

the use of smartphones and tablets in high school math classes as a way to engage students and produce better achievement. The results show standardized test results were higher in courses where students used mobile devices. Participants reported that they felt better prepared for their final exams and they had increased interest in college and in careers relying upon math.²⁸

THE NEED FOR ACTION

As already noted, there are two critical components to enable mobile learning to reach its full potential—universal availability of mobile devices and universal availability of cellular connectivity for these devices. Moreover, there needs to be progress on building digital infrastructure, expanding digital content, embedding digital assessment, and providing professional development for teachers.

In the 21st century economy, students need a range of skills beyond traditional math, reading, and writing. As noted by Esther Wojcicki, an English teacher at Palo Alto High School, at a recent conference, an innovation-based economy requires an ability to be self-directed learners, work independently, apply technology effectively, create media products, be adaptable to change, and be good digital citizens, among other attributes.²⁹

Harvard University Education Professor Chris Dede has noted the importance of mobile online learning. “Teaching is like an orchestra. There are many different instruments, and to reach everyone you need to put a symphony of different kinds of pedagogy together. Learning technologies provide a set of instruments teachers can use to achieve that range of instructional strategies.”³⁰

Improved mobile infrastructure is crucial for achieving the full benefits of the technology revolution. We need better capacity in wireless networks so that students and teachers can access content and take advantage of multi-media resources that are coming online. This involves simplifying cell tower construction rules and building faster mobile networks. Chief information and technology officers within education need to think about their future wireless networks. Wifi alone can’t support the bandwidth requirements of heavy multimedia. Instead, high-speed wireless area networks will be required to take advantage of the educational resources that are available.

One thing the federal government should do is reform its E-rate program that helps schools and libraries finance Internet networks and connectivity. The program was founded in 1998 in order to improve telecommunications access. Currently, it does not include funding for WWAN or mobile devices even though there are well-demonstrated benefits for improving devices, connectivity, and infrastructure for educational purposes. As noted previously, the National Broadband Plan recommended that the FCC provide funding through the E-rate program for

mobile devices and connectivity so that learning could occur off school grounds.

This is an important step that will help students and teachers take advantage of the opportunities for mobile learning. President Barack Obama has outlined a national goal “of connecting 99 percent of school students to the Internet through high-speed broadband and high-speed wireless within five years.” According to the FCC, “more than half of the schools and libraries reported that their Internet connections were too slow to meet their needs.”³¹

Some schools are using “bring-your-own-device” policies to overcome the inadequacies of their own financial limitations. While this provides a quick way to boost Internet access, we have to be careful that it does not preclude certain individuals. We have a digital divide based on income levels and must work to insure that all students, regardless of economic background, have access to mobile devices. If some individuals lack access to mobile hardware and software, it robs them of the educational opportunities that are available to their classmates.

Classroom teachers report that they face a number of obstacles in using tablets in schools. This includes Internet connectivity problems, slow speeds, tablet management issues, JAVA challenges, finding free apps that work, and lack of keyboards and peripherals.³² We need better infrastructure, hardware, and training so that schools can overcome these problems.

Teacher development is at the core of educational innovation. Julie Evans, the chief executive officer of Project Tomorrow, notes that “implementation success depends upon the teacher.” We must help teachers learn how to use technology to improve productivity and student outcomes. They need training on ways technology enhances educational attainment and teacher performance. Unless they believe technology improves instruction, teachers are not likely to adopt the new approach and deploy it in ways that will be effective.

A recent report from the McKinsey & Company argued that recruiting high-quality teachers represented one of the most important things we could do to improve educational outcomes. In looking at outcomes from a number of different countries, it found that high-performing nations recruited the bulk of their teachers from the top academic talent of their country. In contrast, only 23 percent of new teachers in the United States come from the top third of their cohort.³³

To improve this situation, the report calls for America to provide competitive compensation (especially in vital math and science fields), increase the prestige of teachers, pay for teacher training, adopt performance pay for teachers, and provide opportunities for career advancement. By elevating the profession of teaching and placing more attention to teacher development, we can increase the odds of raising educational outcomes.

Addressing the need to improve infrastructure, access to devices, and content and improve teacher engagement is important as more and more countries are working to invest in technology to help bring their classrooms into the 21st century.

Today, there is already a wide range of new digital content that is available to students and teachers. This includes instructional games, augmented reality, interactive websites, and personalized instruction. The virtue of electronic information is that it gives students greater control over their curriculum, thereby allowing students to proceed at their own pace and in their own learning styles.³⁴

This digital revolution enables real-time assessment of student performance. No longer do we have to wait weeks for students to receive feedback regarding their skill mastery. Teachers can now embed pop-up quizzes in online content delivery and pupils can be evaluated on an on-going basis. This provides regular, real-time feedback to students and parents and allows teachers to see which students need extra help and which ones need more challenging assignments.

Challenges exist but the results from a wide variety of promising pilot projects and research indicate that students, teachers, administrators and parents are excited about the opportunities and interested in exploring how to effectively leverage these devices and tools to increase student achievement, teacher productivity and home support of learning.

As a country, we are educating the next generation of workers and students in the 21st Century in higher order thinking skills, analysis, synthesis, teamwork and collaboration. The advances seen, and to come, in technology as well as changes in organizational infrastructure show a need for workers to be able to think creatively, solve problems, and make decisions as a team.

Embracing and institutionalizing mobile technology can transform learning. It is a catalyst for creating impactful change in the current system and crucial to student development in the areas of critical-thinking and collaborative learning. Those are the skills that young people need in order to secure their place in the globally competitive economy.

ENDNOTES

Note: I want to thank Elizabeth Valentini for her outstanding research assistance on this project and several reviewers who provided helpful comments on an earlier draft.

1. Darrell West, *Digital Schools: How Technology Can Transform Education*, Brookings Institution Press, 2012.
2. Irwin Jacobs, "Modernizing Education and Preparing Tomorrow's Workforce through Mobile Technology", paper presented at the i4j Summit, March, 2013, p. 2.
3. Project Tomorrow Speak Up Survey, "From Chalkboard to Tablets: The Emergence of the K-12 Classroom", April, 2013.
4. McKinsey Global Institute, "Game Changers: Five Opportunities for US Growth and Renewal", July, 2013, p. 111.
5. Paul Kielstra, *The Learning Curve*, Economist Intelligence Unit, 2012, p. 19.
6. Eric Hanushek, Paul Peterson, and Ludger Woessmann, "Achievement Growth: International and U.S. State Trends in Student Performance", Harvard Kennedy School Program on Education Policy and Governance & Education Next, July, 2012, p. vi.
7. Tom Loveless, "How Well Are American Students Learning?", Brookings Institution, March, 2013, p. 3.
8. Tom Loveless, "How Well Are American Students Learning?", Brookings Institution, March, 2013, p. 7.
9. Martin West, "Education and Global Competitiveness: Lessons for the U.S. from International Evidence", unpublished paper, p. 5.
10. Martin West, "Education and Global Competitiveness: Lessons for the U.S. from International Evidence", unpublished paper, p. 21.
11. Darrell West, "Creating a 'Brain Gain' for U.S. Employers: The Role of Immigration", Brookings Institution Policy Brief, January, 2011, p. 3.
12. Richard Weingroff, "The Genie in the Bottle: The Interstate System and Urban Problems, 1939-1957", *Public Roads*, Federal Highway Administration, September-October, 2000.
13. Christine Zhen-Wei Qiang, "Telecommunications and Economic Growth," Washington, D.C.: World Bank, unpublished paper.
14. Federal Communications Commission, *Connecting America: National Broadband Plan*, 2010, pp. 9-10.
15. Marguerite Reardon, "The Price of Universal Broadband", *CNET News*, September 30, 2009.
16. Federal Communications Commission, *National Broadband Plan*, Recommendation 11.23.
17. Project Tomorrow Speak Up Survey, "From Chalkboard to Tablets: The Emergence of the K-12 Digital Learner", June, 2013.
18. NMC Horizon Report, "2013 K-12 Edition", New Media Consortium, the Consortium for School Networking, and the International Society for Technology in Education, 2013, p. 10.
19. Project Tomorrow Speak Up Survey, "From Chalkboard to Tablets: The Emergence of the K-12 Digital Learner", June, 2013.
20. Kathleen Fulton and Ted Britton, "STEM Teachers in Professional Learning Communities", National Commission on Teaching and America's Future, June, 2011, pp. 8-9.
21. American Association for the Advancement of Science, "'Active Explorer' Project Turns Cell Phones into Research Tools for Students", 2012.
22. Irwin Jacobs, "Modernizing Education and Preparing Tomorrow's Workforce through Mobile Technology", paper presented at the i4j Summit, March, 2013, p. 10.
23. Project Tomorrow and Blackboard K-12, "2013 Trends in Online Learning", 2013, p. 7.
24. Project Tomorrow Speak Up Survey, "From Chalkboard to Tablets: The Emergence of the K-12 Digital Learner", June, 2013, p. 10.
25. Project Tomorrow Speak Up Survey, "From Chalkboard to Tablets: The Emergence of the K-12 Digital Learner", June, 2013, p. 12.
26. See Consortium for School Networking website at <https://consortiumforschoolnetworking167.edu/division.tv/Default.aspx?q=IsahXh4JBPQIfCcXr07jCyH71H4JEBd8>.
27. Quoted in Wireless EdTech Conference, "Teachers' Views on Mobile Learning in the Classroom", 2013, p. 40.
28. Project Tomorrow, "The Onslow County 1-to-1 Math Initiative: Leveraging Mobile Devices to Transform Teaching and Learning in High School Math Classes", October, 2012 and Qualcomm Wireless Reach, "24/7 Wireless Collaboration and Teaching Enhances Student Engagement and Math Development", July, 2012.
29. Esther Wojcicki, "Designing K-12 Education for the Innovation Economy", paper presented at the i4j Summit, March, 2013, pp. 5-6.
30. Market Watch, "Harvard Prof Chris Dede Encourages Teachers to Embrace Mobile Online Learning", November 16, 2011.
31. Edward Wyatt, "F.C.C. Backs Plan to Update a Fund That Helps Connect Schools to the Internet", *New York Times*, July 20, 2013, p. B3.
32. Julie Evans, "Making Learning Mobile: Stone Middle School Preliminary Data Findings", Project Tomorrow,

June, 2013.

33. Byron August, Paul Kihn, and Matt Miller, "Closing the Talent Gap: Attracting and Retaining Top-Third Graduates to Careers in Teaching", McKinsey & Company, September, 2010, p. 5.

34. Darrell West, *Digital Schools: How Technology Can Transform Education*, Brookings Institution Press, 2012.

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