More and Better Teaching & Learning Mathematics for ALL via Digital Educational Media & Games

Sarah DeLeeuw

George Mason University

*There are many ways to organize curricula. The challenge, now rarely met, is to avoid those that distort mathematics and turn off students.*

— Steen, 2007

More and Better Teaching & Learning Mathematics for ALL via Digital Educational Media & Games

If it’s up to the President of the United States, EVERY student in this nation will have an e-textbook by the year 2017 (Toppo, 2012)! Realizing this goal requires every child to have an iPad, Kindle or other platform for digital educational media. Digital media via tablets is just one example of the many educational innovations that have gained and maintained attention throughout the past two years, both by students and policy-makers.

As a whole, affordances of educational technologies are outpacing the existing system of education, and the rate of innovation continues to outpace the research on implementing digital innovations in the educational realm. Should we continue to support the existing educational system while we wait for research to inform us? In this paper, I argue that we cannot wait. Rather, we must capitalize on students’ engagement with digital media and seize the opportunity to use the technologies that are engaging our students for a purpose beyond engagement – the purpose of learning.

Indeed, implementing digital innovations without establishing best practices, evidence of impact, and/or expectations requires us to take a chance, which is ironic in a sense because we are products of an educational system that has taught us to avoid the chance of being wrong. The call for a paradigm shift in our nation’s education is not a novel idea. Sir Ken Robinson has been advocating for an educational system that values creative thinkers over good workers since 1998. He concludes both a TED talk and a blog on Edutopia.com with the following call-to-action, “Our task is to educate our whole being so (our children) can face this future. We may not see this future, but they will. And our job is to help them make something of it” (Robinson, 2006).

The irony doesn’t stop there. Robinson purports that the educational system came into being to meet the needs of industrialism. What was then ‘benign advice,’ he deems is now ‘profoundly mistaken’ (Robinson, 2006). The very educational system that was created to prepare students for jobs is actually making them less prepared. Now, it is our job to correct our mistake. The stakes are high. Today, business leaders of America provide evidence that our educational system is failing by reporting a shortage in the workforce (McSherry, 2005). Obama acknowledged this irony in his State of the Union Address, just a few months ago,

I also hear from many business leaders who want to hire in the United States but can't find workers with the right skills. Growing industries in science and technology have twice as many openings as we have workers who can do the job. Think about that--openings at a time when millions of Americans are looking for work. That's inexcusable. And we know how to fix it. (Koebler, 2012)

How WILL we fix it? We might consider the ideas of Sir Ken Robinson. We have to rethink the fundamental principles on which we're educating our children, by acknowledging that intelligence is diverse, dynamic, and distinct (Robinson, 2006). In a world where innovation and original ideas are outpacing education, we must take chances and nurture creativity. Obama addresses the educational crisis in the STEM (Science, Technology, Engineering, and Mathematics) discipline by advocating for more public-private partnerships, more career training at community colleges, and the return of American innovation.

Implementing forms of digital media via tablets, mentioned at the very beginning of the introduction, may be one way that we can leverage the technologies engaging our students to yield learning, especially in the STEM discipline. While supporters of the e-textbooks are enthusiastic about moving classwork onto devices such as tablets to give students the ability to do research, check their work, get feedback from teachers, and offer interactive and engaging environments both inside and outside of school, critics are skeptical and warn that e-textbooks will not be the magic bullet. We must critically consider what content should be on the tablets, how teachers will use it, and how student learning will be assessed, among a plethora of other relevant questions. What will it take to ensure effective and meaningful implementation of digital educational tools?

We won’t know if any particular emerging technology is a more promising approach than any other without taking a chance. However, we can still rely on the things we do know. For instance, we know that two key aspects of successful schools are effective instruction and conditions and cultures that support learning (NRC, 2011). Just two aspects may seem insufficient in encompassing all it takes to achieve successful STEM education, but each aspect is quite broad. According to the National Research Council (2011), effective instruction includes a coherent set of standards and curricula, teachers with high capacity to teach, a supportive system of assessment and accountability, adequate instructional time, and equal access to high-quality learning opportunities. School conditions and cultures that support learning include leadership, professional capacity of faculty, ties with parents and the community, a student-centered learning climate, and focused instructional guidance (NRC, 2011). These are all constructs that we must explore in more depth in order to become more informed and successfully integrate these digital technologies and optimize learning.

**Narrowing In**

**The Focus on Mathematics and Technology**

If our ultimate goal is to prepare our students for future careers, we must encourage creative thinkers. Career opportunities will continue to change as innovation changes the world and redefines the careers themselves. In this moment of time, we have established that there is a particular shortage of trained personnel in the fields of science and engineering, both which require flexible mathematical and technological literacies. STEM is an amalgamation of very complex and intertwined scientific disciplines, but NCTM’s past-president asserts that science, technology, and engineering are fundamentally dependent on the strong mathematical preparation of our students (Shaughnessy, 2012). Yet, there remains a severe disconnect of how we function in our educational system and how we function in the dynamic technologically-rich world we actually live in. The following matter-of-fact passage highlights this disparity:

We now live in the 21st century, although you might not realize that fact if you were a student sitting in a typical mathematics class in most rural or urban school districts in the USA. Outside of school, technology tools and their applications are an integral part of modern life. We use and depend on them for entertainment, information, communication, transportation, commerce, research, comfort, shelter, safety, food production, medical treatment, as well as creative, self-expression and social networking. (Olive, 2011)

Just as we use technology tools in the world we actually live in, we should explore their use in the classroom. Olive (2011) affirms that the use of technology itself for new mathematical knowledge and practices is interconnected with the student, the teacher, and the task. He emphasizes that as educators, we need to investigate how children and young adults are making use of the technological environment in which they live and what they are learning from that use. And then, as mathematics educators, we need to understand how we might harness this technological environment to enhance the learning and teaching of mathematics – both in-school and out-of-school. He outlines seven research topics and questions for technology in mathematics education:

* Learning: How and what do students learn through use of technology?
* Teaching: How and what do teachers teach using technology?
* Curriculum: What mathematics can and should be accessible through the use of technology?
* Design of Technology: How does the specific interface design of a technology impact its use?
* Use of Technology: Actual use may differ from the designed use – how do the different uses affect learning and teaching outcomes?
* New Media for Learning: New networking and social interaction technologies offer new media for learning both inside and outside the classroom. How and what kind of learning may take place in these new media?
* New Media for Teaching: New networking and social interaction technologies offer new media for teaching both inside and outside the classroom. How and what kind of teaching may take place in these new media? (Olive, 2011)

**A Joint Tri-Fold of Mathematical Gaps: the Design Gap, Achievement Gap, & Equity Gap**

It is beyond the scope of this essay to thoroughly consider all of the above questions in the broad arena of technology in mathematics education. For this reason, this essay will focus on the implications of the design and implementation of games for teaching and learning mathematics via mobile devices as one specific means to address the gap in achievement in mathematics, and even more specifically, how it might further address the equity gap among minorities.

**The Root of the Problem**

The National Research Council (2011) has investigated the gaps in achievement of minorities in mathematics and suggested that they “may be linked to deficits in at least three early-developing skills that are usually thought of as peripheral to math learning: executive function, visuo-spatial, and fine motor skills” (NRC, 2011). An experimental intervention focused on building these skills through structured play improved the skills and also improved math scores. These research results serve as evidence for promise that games may be an effective approach to lessen these gaps. The math scores of the high-risk students that participated in the structured play as part of the intervention improved their math scores even though there was no implicit or explicit math instruction in the intervention. It follows then that providing opportunities for play may be more effective in increasing mathematical potential, and ultimately STEM participation, than more direct or earlier mathematics instruction because of its power in developing the aforementioned foundational skills.

**Zooming Back Out**

**How Digital Media in the Classroom is Just a Tiny Piece of the Digitally-Absorbed World**

Students are living and learning in an age of new media – where they give constant attention to the latest scoop on TV, the hottest music for their iPods, newest games for their game systems, instantaneous updates in their online communities and social networks, and they have mobile apps that manage all of these interests simultaneously. These students, between the ages of 8 and 18, are constantly (an average of 7.5 hours a day!) interacting with media – more than ANY other activity besides (maybe) sleeping – according to a popular report, compiled by the Kaiser Family Foundation (Rideout, 2010).

The follow-up report that investigated media use for younger children, those 8 and under, began by noting some fascinating chronological facts. It is now:

20 years after the birth of the world wide web, 13 years after the launch of Google search, eight years since the start of the first social networking site, six years after the first YouTube video, four years after the introduction of the first touch-screen smartphone, three years after the opening of the first “app” store, and just over a year and a half after the first iPad sale — the media world that children are growing up in is changing at lightning speed. Nine-month-olds spend nearly an hour a day watching television or DVDs, 5-year-olds are begging to play with their parents’ iPhones, and 7-year-olds are sitting down in front of a computer several times a week to play games, do homework, or check out how their avatars are doing in their favorite virtual worlds. (Common Sense Media, 2011)

90% of 5-8 year-olds use a computer and 52% a smartphone. Even 39% of 2-4 year-olds use a smartphone (Common Sense Media, 2011)!

**Situating Myself in the Context of the Data**

As my mind takes a personal journey back through these years, I reflect on how I fit into the data: I didn’t watch TV growing up, and I still don't watch TV today. I caved in to social media (Facebook) upon beginning my Master’s degree in 2006, after feeling it’d be easier to keep in touch with high school and college friends. And today, I have a Klout rating of 66, a measure of social influence on a scale of 1-100, where the average score is 20 and becomes exponentially harder to increase as you move up the scale. My true reach (the number of people I influence) is around 8500 and my amplification (how much I influence people) topped out at 100 last month – if that says *anything* about my present interactions with social media. I wish I owned an iPad, but I can’t justify the purchase since I do own an Android tablet. I also own but rarely use my iPod or gaming consoles. And although I was the very *last* to get a cell phone in my group of friends, now I rely on my smartphone, just like the 8-18 year-olds, for everything –to wake me up in the morning, to manage my various personal email accounts, to update my social media, to keep track of my appointments, to pay my bills, to get me from point A to point B via spoken directions, to track my workouts, to satisfy the parking meters in DC, to make dinner and flight reservations, to challenge me in a puzzle while waiting in a line, to replace provide QR codes that replace paper coupons, and to solve definite integrals. I’m interested to know how many hours I interact with media per day today. I know I didn't even sleep 7.5 hours per day in highschool, or now, for that matter, but I may be engaging in media at a comparable rate at today’s teenagers.

So what? Why does it matter how much I am interacting with media per day? I purposefully situated myself within the context of the typical student, and now I will situate myself within the context of the typical teacher in America’s educational system today. Following are data about teachers. There are 3.2 million public school teachers educating the nation’s 49.4 million children attending public PK-12 schools, according to the U.S. Department’s National Center for Education Statistics (NCES, 2011). More than 20% are under 30 years old, yet more than 30% are over 50 years old. More than 25% of teachers are in their first 5 years of teaching, 40% have more than 15 years of experience, and 17% have more than 25 years of experience. Although the age and experience is varied, the majority of teachers are female (84%), white (84%), and have Master’s degrees (56%). (NCES, 2011)

[Sidenote: As the percentage of the population increases that have advanced degrees, the value of an education decreases. However, advanced degrees in STEM do pay off.]

It’s quite apparent that I fit in to the ‘majority’ group of teachers, just as I closely resembled the media usage trends of our students. What is most noteworthy though is the fact that I have situated myself in the context such that I can agree with Olive’s statement firsthand. Technology tools are an integral part of my life today and they have completely changed how I have come to function. However, if I were to visit my former highschool from 11 years ago or my PreK-8 school from 15 years ago, I would observe that little has changed. The classes would function very much like they did when I was a student, and the fact that it is the 21st century would not be apparent in the classroom. (Wait … it *was* the 21st century when I graduated high school, but this only further exemplifies the extent of change in our lives as a result of innovation sans the classroom.)

In any case, children have more access to all kinds of digital media and are spending more time during the day interacting with them than ever before. And mobile media appears to be the “it” technology, from the handheld video games to portable music players to cell phones. Kids like the use their media on the go (Gutnick, 2010). A report from higher education confirms that adults, too, expect to be able to leverage technology to work, learn, and study whenever and wherever they want to (Johnson, 2010). Another report confirms that access to gaming continues to increase, with more than half of households having access and 24% playing games across multiple screens (computer, mobile, game console) (Nielsen, 2012).

How can we expect the growing access to and engagement with digital media to affect education? A recent article on blended learning claims that technology has the potential to bridge the education gap by creating a student-centric education system where each student can learn at a customized pace and path. The author predicts that the majority of students will be engaged in blended learning, where students learn online in schools and where teachers provide guidance. Teachers of blended learning would take on one of three roles: a mentor/motivator, a content expert, or as a case-worker to help students with non-academic obstacles. The author sees mobile applications as an opportunity to extend access to learning to the 70 million children worldwide that don’t have access to primary education. Ultimately, he views education as a means to gaining access to a better life, and sees technology as a means of providing access to education. (Horn, 2012)

Is it worthwhile to integrate technologies into the classroom? Is there evidence of impact that shows promise? What cold, hard facts do stakeholders want before supporting any initiative? You got it. Nothing moves policymakers, teachers, and parents like increased student achievement does. A recent meta-analysis synthesized 40 years of research to answer the question, “Does computer technology use affect student achievement in formal face-to-face classrooms, as compared to classrooms that do not use technology?” The results revealed that the classrooms with integrated technology did indeed outperform the traditional technology-free classrooms. The results also showed that technology use that supports instruction rather than replaces it is more favorable, as is the integration of applications of computer technology at the K-12 level compared to postsecondary (Tamim, 2011). To some, the meta-analysis may be convincing because it includes a variety of studies over a longer period of time. Others may be skeptical since the majority of the educational technologies today didn’t even exist 40 years ago.

A meta-analysis of online learning may satisfy the skeptic’s wishes for more recent findings. Nonetheless, a study conducted by the U.S. Department of Education that considered published research on the effectiveness of online learning for K-12 students revealed similar trends: Students in online conditions performed significantly higher than those learning by means of traditional face-to-face instruction, but instruction combining online and face-to-face elements (blended learning) still offered the highest gains in performance. Collaborative or instructor-directed online learning produced more gains than online learners working independently. Furthermore, elements such as video or online quizzes did not impact the amount students learned. However, allowing learners to control their interactions with media and promote refection did enhance learning. (Means, 2010)

A meta-analysis on integrating computer technologies and a meta-analysis on online learning concur that blended learning is a favorable form of instruction. But what kind of content is optimal? Yet another meta-analysis investigated the impact of games and simulations as compared to traditional teaching methods. Results revealed that games and interactive simulations produce higher cognitive gain outcomes compared to their traditional game-free counterparts (Vogel, 2006). These results were not specific to blended learning, but they did show that the greatest gains were made when the students were granted control to navigate the programs (games or simulations) and control over the sequence of the programs.

A meta-analysis reviewing trends from mobile learning studies was also surprisingly available, even though the publication date in several months into the future. I was most interested to see the synthesis on effectiveness of using mobile devices for the purpose of learning, although I was also interested to learn of the studies related to mathematics and studies related to designing for the mobile platform. Results showed that 86% of the 164 mobile learning studies presented positive learning outcomes. In the discussion, this finding was compared to a separate meta-analysis that reported that game-based learning as well generally has high positive outcomes (Ke, 2009). It was a delight to stumble on such information! However, of the 164 studies on mobile learning, only 3 focused on mathematics, and only one was relevant to the topic of learning mathematics via mobile devices. That study was by Baya’a and Daher (2009), in which they conducted experiments to explore the effectiveness of mobile learning while using mobile phones in an Arab-language middle school in Israel; they found that students responded positively to the use of mobile phones in learning mathematics. (Wu, 2012)

The purpose of sharing the themes evident in meta-analyses that explored the effectiveness of computer technologies, online learning, gaming, and mobile technologies was to exhibit the promise of digital game-based learning, as measured by cognitive gains. Prensky (2007) offers more detailed reasons that further demonstrate promise, such as: motivation to learn topics that are dull and/or difficult to teach, potential to reach millions of learners, opportunities of free-market to spread at epidemic speeds driven my user-evaluated content, disposal of tools to create driven by individual designers (not just publishers), global impact, affordances of the web to generate competitive forums, and variety and anticipation in the realm of learning much like there is for movies, music, and existing forms of games. (Prensky, 2007)

**More Irony in the Inequities of Minorities in STEM**

Beyond the promises evidenced by the meta-analyses and voiced by Prensky, there may also be promise for digital game-based learning via mobile platforms to address the achievement gap of minorities, particularly in STEM disciplines. A 2010 report by the Joan Ganz Cooney Center concluded that lower-income, Hispanic, and African-American children consume far more media than their middle-class white counterparts (Gutnick, 2010). Asian Americans lead smartphone ownership with 67%, while 57% of Hispanics and 54% of African-Americans own them, all significantly more than the 45% of Whites that own smartphones (Nielsen, 2012).

Upon analyzing the gap in STEM, it is apparent that women and minorities are scarcely represented. In an article of Electronic Design, McSherry (2005) asserts that “unless women and minorities are attracted to STEM, the U.S. will not have the trained personnel necessary to meet its needs and maintain competitive in the global economy” (McSherry, 2005).

**Hispanics.**

A report by the Council of the Great City Schools communicates that the mathematics achievement of Hispanic students in large central cities continue to lag behind White students in national public schools, according to NAEP (National Assessment of Educational Progress) data for grades 4 and 8. At least 50 percent of fourth- and eighth grade Hispanic and ELL students in most urban districts scored at below *Basic levels.* Compared to Whites, Hispanic students were more likely to drop out of high school and not graduate. Fewer Hispanic students took Advanced Placement exams and were less likely to graduate from high school on time. Average SAT and ACT scores of Hispanic students were lower than White students. (Simon, 2011)

A study published in Nielsen Wire last month described the U.S. Hispanic population as young, mobile, and growing. Young: The median age of the Latino population is 28 years old, nearly ten years younger than the total market median age of 37 years. Mobile: With respect to technology and media, Hispanics spend 68 percent more time watching video on the Internet and 20 percent more time watching video on their mobile phones than non-Hispanic whites. Growing: Just as innovation continues to rapidly persist, it is expected that the Latino population growth will too. (Nielsen, 2012) The crisis of STEM education is a serious one and the stakes are high. We must be committed to providing equitable access by any means possible for teaching and learning mathematics, a predictor of success in a STEM career. Focus on the Hispanic population is an obvious priority; as their population continues to outpace all others combined, it is inadmissible for their achievement gap to widen on the same trajectory. The younger population that is already interacting with media more than others present an opportunity to get media for the purpose of learning in their hands.

[Sidenote: That is incredible! 🡪 Between 2000 and 2011, the 10-year increase of the Hispanic population was greater than that of all other non-Hispanics combined. Whoa! Further, Hispanics will contribute an even greater share (60 percent or higher) of all population growth over the next five years.]

**Blacks.**

The achievement gap continues to be wide for African American as well. Even as funding increased to support African Americans in obtaining STEM degrees from historically black colleges and universities, achievement did not. A study investigating this disparity attributed the lack of success to African-Americans lack of preparedness for the rigors associated with STEM majors. (Bonner, n.d.) That result too suggests that an intervention must take place well before the collegiate level.

Another study by the Council of the Great City Schools honed in on the achievement of African American males, which continue to be lower than those of White males. To highlight the sheer severity of the achievement gap between African American and White males, consider the following comparisons:

(1) Black males not eligible for free or reduced-price lunch had reading and mathematics scores similar to or lower than those of White males in public schools who were eligible for free or reduced-price lunch.

(2) Large city Black males without disabilities had reading and mathematics scores, on average, lower than those of White males in national public schools with disabilities.

(3) At least 50 percent of fourth- and eighth grade Black males in most urban districts and nationwide scored below Basic levels.

(4) Black males were more likely, compared with White males, to drop out of high school and not graduate. Fewer Black males take Advanced Placement exams or enroll in two or four-year colleges after graduation. And the average SAT and ACT scores of Black males were lower than those of White males. (Lewis, 2010)

There is a clear and critical call for change to cater to African Americans, and the case is as compelling as is the case for the Hispanic population. The African American population is the largest racial minority group in America, with a population of 43 million. They rate higher than average in mobile phone usage. Examining mobile trends of African-Americans further conveys that they have more Smartphone access than the typical American does. Breaking down the usage of their mobile device, we can see that they use the smartphones for mostly texting, email, internet, and social networking. But 33% also use their mobile device to use apps, 31% to download apps, 31% to play games, and 21% to download games. (Nielsen, 2011) Among the suggestions in the report from the Council of the Great City Schools is to ensure that Blacks are exposed to the appropriate level of rigor in late elementary school and encourage interventions (such as instructional programs in the classrooms and afterschool initiatives) that target specific academic and social needs of African Americans (Lewis, 2010).

**Girls.**

What about the girls? Girls are also a minority in STEM careers. An article from *The Journal: Increasing STEM through Technology* reports that girls in the United States aren't any more interested in STEM careers now than they were 10 or 20 years ago, albeit the many efforts to attract and maintain their interest. And even more alarming is the fact that those girls who do take an interest in STEM subjects in middle school and high school choose paths based on other interests in college. (McCrea, 2010) As girls follow suit as an entire gender sustaining an achievement gap in STEM disciplines, promise for harnessing learning through engagement of digital game-based learning via mobile platforms does as well. More than half of tween (8-12 year old) girls play online games for entertainment. Girls spent more than two times as much time playing games this year than last year, and have shown to be especially attracted to games where they can socialize with other girls and create new content (Spilgames, 2012).

**Representation of minorities in games.**

After briefly considering the underrepresentation of particular minorities in the STEM disciplines and the potential promise games and mobile technologies may afford them, it makes sense to also consider the representation of minorities in video games. Research reports that males, whites, and adults are over-represented in as video-game characters. Females, Hispanics, Native Americans, children and the elderly are minorities, according to The Virtual Census (Williams, Martins, Consalvo, & Ivory, 2009).

Herein lies the irony. I knew you would be waiting for it!

Many have suggested that games function as crucial gatekeepers to interest in technology, which translates into education and careers in mathematics and science-related fields (Lin & Lepper, 1987; Williams, 2006). If Latinos or any other groups become disenchanted with games due to poor representation, subsequently they may have less interest in technology and its opportunities for class advancement. Ironically, they would be less likely to become game-makers themselves, helping to perpetuate the cycle. (Williams, 2009)

It may seem somewhat far-fetched to merge Williams’s claim that games function as crucial gatekeepers to interest in technology with Shaughnessy’s contention that mathematics is the crucial gatekeeper and foundation to success in the other three steM (get it?) disciplines to ultimately construct a dual-encompassing position that math games may afford even more promise for greater gains. Even if not for the same reasons, I’m confident that Ron Eglash would support my position. Eglash examines the ways in which information technology, mathematical modeling, and other science and technology practices (STEM) are intertwined with cultural categories such as race, gender, and class, and explores interventions in these relationships. He adds the element of culture to my dialectic of mathematics and technology to construct a “trialectic of computer media, math pedagogy, and culture to provide a meeting place in which the praxis of social change and the theory of cultural critique can generate new forms of hybridity and synthesis” (Eglash, 2006).

The reference to the trialectic is from one of Eglash’s articles on culturally situated design tools, more specifically about web-based applications that allow students to create simulations of cultural art such as Native American beadwork, African American cornrow hairstyles, and urban graffiti that are all based on underlying mathematical principles. Eglash emphasizes redesigning the cultural, computational, physical, and historical worlds as they are redesigning ours with the emergence of new technologies. In a 2009 article, Eglash offers applications that motivate students’ creative explorations in computational geometry to converge with their cultural construction of the self. In this article, Eglash and Bennett extend an accepted definition of cultural capital to define “computational capital” as the concepts, skills, and other resources that facilitate participation in computing activities, education and careers. They go on to posit that hidden sources of computational capital can be found in some cultural practices of disadvantaged groups, and that a suitable learning environment can make this capital available to its owners. (Eglash & Bennett, 2009)

**Transforming Learning with Technology as Technology Transforms Learning**

“We are the Jetsons. Our children are growing up in a world where their toys obey them and their parents converse with the family car.” Yet, “when it comes to understanding the impact of digital media and harnessing their potential so that they can benefit all children, we are more often like the Flintstones.” (Shore, 2008) Irony seems to be a recurring theme that ties the earlier sections of this paper together, so let me capitalize on the opportunity to keep that theme alive in this section as well.

Did you see the movie released in 1987 called *The Jetsons Meet the Flinstones*? If I’ve seen it, I can’t remember seeing it. For the purpose of this paper, all you need is a one-sentence run-down of the plot: Elroy, the Jetsons’ dog, creates a time machine which accidentally results in the Jetsons being sent to prehistoric times (compared to the era of their world which is situated in the future). The Jetsons represent our technology-rich future and the Flinstones represent our traditional technology-free classrooms of yesterday that are still commonplace today. Each and every day we send our students to school, we are sending them back in time. Do you think Elroy would have had the ability to invent a time machine if he were limited to the Flintstones’ resources and educational system? Elroy is a product of the futuristic utopia he lives in that is chock-full of elaborate robotic contraptions and whimsical inventions, and it is clear that his creativity was not quashed. Will there ever be a sequel? It is fun to imagine what *The Flinstones Meet the Jetsons* might be like. Could it be possible for Dino, a product of a world where ‘technology’ consists of stone-age machines powered by birds and dinosaurs, to invent a means that could take the Flinstones forward in time? Although anything is possible, this plot may seem unbelievable, even for the fictional cartoon. But, this should not discourage us. Our students are neither Elroys nor Dinos, neither stuck in the past nor living in the future. The time is now, yet we continue to treat our students like Dinos by preserving stone-age-like classrooms from Bedrock. And although it is impossible to provide our students with the innovations from the futuristic utopia of Orbit City, we can nurture their creativity and provide the technological tools of today that may encourage innovations of the future. It is appropriate here to remind ourselves of Sir Robinson’s line, “We (educators) may not see this future, but they (children) will” (Robinson, 2006).

In this section, we consider the issues, goals, and challenges of integrating technology and transforming learning and our educational system in this county as a whole. It has been established that technology and interactive media are here to stay and not all screens are created equal (NAEYC & Fred Rogers Center, 2012). Already in 2010, over 1.5 million K-12 students were engaged in online or blended learning, with 38 states having virtual schools or online initiatives, 27 states plus D.C. offering full-time online schools, and 20 states providing both supplemental and full-time online learning options (Wicks, 2010).

Our schools cannot run back to Bedrock. (Fortunately, we haven’t yet invented the time machine might allow some reckless policy-maker to do so!) Rather, our schools must embrace Orbit City as a vision for the future, and learn to shape and control this inevitable future by transforming the present. Transformation is not easy. It is harder than rocket science, according to Zucker, a senior research scientist at The Concord Consortium. In his article featured in *On Cue*, Zucker reassures us that schools are already being transformed, but the changes are happening incrementally. He advises that there is no technology will be the “silver bullet” for transforming education, and we are wasting our time if we are searching for such. He emphasizes that “sorting reasonable from unreasonable claims is important if we want others to understand our vision, share it, and support it with resources” (Zucker, 2011). Zucker purports that the incremental changes are already beginning to add up to a significant transformation.

What are the components of incremental change? What factors should we focus on that will ultimately inform and contribute to the transformation we speak about? Prensky acknowledges various stake-holders. He asserts that teachers and trainers must combine old content with new approaches, that parents must make time to work with kids instead of throwing them the fanciest box on the shelf, and vendors must create easier-to-use creation tools (Prensky, 2007). Zucker agrees that teachers are still the most vital ingredient in good schools, but he adds that good and easy-to-use digital tools are also a critical component (Zucker, 2011). A report by The Joan Ganz Cooney Center also includes the notion of guiding parents, bridging the home, school, and community learning environments, and designing media that warrants intergenerational opportunities (Gutnick, 2010).

The title of a later report also by The Joan Ganz Cooney Center boasts a blueprint for teaching children in a digital age and refers to the transformation as one giant step, made up of five goals, which are, in short: communities of practice as means of professional development, digital media and screen training for early teachers, expanding use of public media as resources for teachers, integrating technology supports into standards-based curriculums, and designing partnerships. (Baron, 2011)

Although most of the aforementioned articles and reports included that research is also a priority, research was not the primary focus. However, the book *Research on Technology and the Teaching and Learning of Mathematics*, devotes a chapter to the role of research and theory. Blume and Heid (2008) contend that research must deliberately anticipate the future and produce both practice-extending research, that which extends and improves current practice, and future-defining research, that which tests the boundaries of what is possible outside the constraints of current technologies and practices. These authors suggest themes for research that include students’ thinking, technical and conceptual aspects of tool use, representations, integration into the curriculum, on and off-computer activities, tool design and development, key content areas and mathematical fidelity, and the capability of technology to engage students in mathematics beyond that which is typical for their level. (Blume & Heid, 2008)

Even with directions for research, most of the important questions about the impact of interactive digital media have yet to be addressed (Shore, 2008). One idea that Shore offers, that seems to not be as well-represented, implies that the children themselves are the stakeholders because they are the learners. It takes their interaction with these new media forms to potentially warrant learning. No matter the efforts made by teachers, parents, designers, and policy-makers, learning is still dependent on the students themselves. Shore highlights that students need to know *how* and they need to know *what*, but in the interconnected world afforded by technology, they also need to be able to understand *with*. The ‘with’ refers to the fact that today knowledge development is a team sport. Interacting with new digital media forms is contingent on the user connecting and interacting with others.

“Kids are doing inventive things with technology and media all the time. And in schools we say: Turn it off, put it away, and don’t do it here” (Shore, 2008). Although we don’t know very much in the grand scheme of things when it comes to learning with digital media, we do agree that learning can happen wherever we are. And we have also been warned by Sir Ken Robinson the great risk in stifling creativity.

In this world of accelerating change, education as we know it – the ‘Turn it off, put it away, and don’t do it here’ kind – just isn’t going to cut it. Exploring the edge requires taking on an entirely new ‘learningscape,’ according to Brown, that replaces the notion of education with the notion of lifelong learning. John Seely Brown, a visiting scholar at USC, more widely known as the former chief scientist and director of research of Xerox Corporation, believes that if we are willing to view learning from this new perspective we will no longer be constrained by resources. He emphasizes the distinction between ‘learning about’ and ‘learning to be.’ He posits that cross-disciplinary approaches that encompass multiple areas of expertise and ways of knowing must become the norm to be able to respond to the dynamic problems the future holds. He too imagines a hybrid model for learning, one that “combines the power of passion-based participation in niche communities of practice with a limited core curriculum for teaching the rigorous thinking and argumentation specific to that field” (Brown, 2006). He suggests that the internet affords a platform for ‘learning to be’ by connecting those that share specific interests, which in turn, leads to pro-amateurs in the niche communities referenced above.

While Robinson advocates for creativity, Eglash for cultural relevance, and McCrea for girls in STEM – to name just a few of those already mentioned that have contributed to related research – we can establish, even in the context on this paper, an example of individuals participating in niche communities based on the themes that they are passionate about.

Narrowing back in on the notion of using games for learning in mathematics education, we hone in on an article by Hoyles, Noss, and Kent (2004), who predicate the evolution of research in their niche of integrating technologies into mathematics classrooms. Together, they proclaim that research on this topic evolves through the design of classroom interventions that feed back into theoretical analysis (Hoyles, Noss, & Kent, 2004). I internalize this as the chicken and egg debate. There must be an intervention to be able to develop theory, yet we must implement our interventions on theory not yet developed.

Klopfer, Osterweil, and Salen advocate for moving learning games forward. They share the view that “as games move from being solely a technological tool to becoming a pervasive culture of play, we may yet unlock generations of curious, confident investigators and collaborators” (Klopfer, Osterweil, & Salen, 2009). They support using games as a hopeful intervention for the future of learning, and also emphasize the importance of creating examples and communities, while continuing to research new models.

**Designing Digital Game-Based Learning for Learning Beyond Engagement**

As we continue researching new models of games, I am especially interested in one particular component – using games for the purpose of learning, beyond the purpose of engagement. “Lots of people pay lot lots of money to engage in an activity that is hard, long and complex. As an educator, I realized that this was just the problem our schools face: How do you get someone to learn something long, hard, and complex and yet enjoy it?” (Gee, n.d.)

Gee notes that while e-learning had a reputation for being dull and ineffective, games have developed a reputation for being fun, engaging, and immersive, requiring deep thinking and complex problem solving (Gee, 2003). I agree and also disagree with Gee; I think that games have the potential to require deep thinking and complex problem solving, but I don’t believe that all games do. And even if games do indeed embody significant learning principles, games cannot be expected to do the teaching and learning all on their own. We as educators and designers still have a challenge. We must continue to “build better game-based pedagogical theories while reciprocally investigating our assumptions about the social organization of schooling” (Squire, 2005).

Squire (2005) acknowledges that games are least engaging if they aren’t educational, and that good games have *enough but not too much* difficulty and complexity, failure and choice. He, like Zucker, reiterates that educators that are hoping that games will be a ‘silver bullet’ because they are exciting and motivating will be disappointed. “The real challenge is not so much in bringing games – or any technology – into our schools but rather changing the cultures of our schools to be organized around learning instead of the current form of social control” (Squire, 2005).

In a previous section, we considered how we must transform learning and the educational system as a whole to cater to the transforming world we are living in. In this section, we will and attempt to uncover the design components that make a game more productive for the purpose of learning. We will consider the implementation and pedagogical components in a later section.

Although we are interested in games for learning and not just games for engagement, let us start by considering Prensky’s list for what makes digital games engaging: enjoyment and pleasure; intense and passionate involvement; structure; motivation; doing; flow; learning; ego gratification; adrenaline; creativity; social groups; and emotion (Prensky, 2007). Prensky (2007) lists learning as one component of engagement, but what are qualities of games that promote learning? “Game-based learning harnesses the advantages of computer games technology to create a fun, motivating and interactive virtual learning environment that promotes problem-based experiential learning” (Tang & Hanneghan, 2011). We don’t want to lose the engagement factor, but we do want to focus on the learning factor.

To react to this age of new media, the commercial industry has capitalized by providing a tremendous variety of games to pique the interest of all types and ages. Digital gaming is a $10 billion per year industry. Already in 2004, before mobile apps, “nearly as many digital games were sold as there are people in the United States” (Van Eck, 2006)! The commercial industry responded quickly and continues to supply the ‘digital natives’ with what they demand. The educational system must as well.

This generation has shown to have become disengaged with traditional instruction. Students require multiple streams of information, prefer inductive reasoning, want frequent and quick interaction with content, and have exceptional visual literacy skills (Van Eck, 2006). As educators interested in maximizing learning goals, we must design games that continue to engage but also prompt learning. As Prensky listed components for engagement, Gee makes a list of learning principles that good games incorporate: identity; interaction; production; risk-taking; customization; agency; well-ordered problems; challenge and consolidation; ‘just in time’ and ‘on-demand’ situated meanings; pleasantly frustrating; system thinking; explore, think laterally, rethink goals; smart tools and distributed knowledge; cross-functional teams; and performance before competence. (Gee, n.d.) Klopfer, Osterweil, and Salen include a list on the freedoms of ‘play’ in their article on moving learning games forward: freedom to fail; freedom to experiment; freedom to fashion identities; freedom of effort; and freedom of interpretation. They also include a list of the four barriers: adoption; design/development; sustainability; and innovation. (Klopfer, et al., 2009)

As Klopfer, Osterweil, and Salen recognize, both opportunities and dilemmas stem from this influx of opportunity to engage and interact digitally. And, although the lists of what makes games engaging and what components yield learning are very helpful, are there standards for measuring the quality of a digital-based game for learning? Although I could not find an explicit evaluation tool for this, I did find that the International Association for K-12 Online Learning Standards to be very applicable. I found the topic areas more helpful in that standards specific to digital-based games for learning could be created for each of the general topics, but the rubrics that were already created for online learning didn’t fit. These six topic areas of the standards for quality follow:

• The Content standards – address items such as learning objectives being clearly stated, content being aligned to appropriate state and national standards, content having sufficient rigor, incorporation of information literacy in the curriculum, respecting copyright, and addressing issues such as academic integrity and privacy;

• The Instructional Design standards – focus on appropriate organization of content, level of student engagement, differentiated learning, higher order thinking skills, and appropriate instructor-student and student-student interaction;

• The Student Assessment standards – identify the need for assessment to be frequent and ongoing, consistent with the course objectives, and helpful to the student in understanding his/her progress in the class;

• The Technology standards – address areas such as ease of navigation, allowing teachers to add content to the course, orienting the student to the environment, technical support, and providing information to students regarding technology requirements;

• The Course Evaluation and Management standards – look at how feedback is obtained about the effectiveness of the course, how the course is maintained and updated, and does the course provider have appropriate authority to offer the course in the locations served; and

• The 21st Century Skills standard – requires the course to emphasize those items the Partnership for 21st Century Skills29 has identified as important skills for today’s society. (iNACOL, 2010)

The content standards communicate what mathematics content the game targets. This would have been a challenge before the release of the Common Core State Standards because not every state ascribed to NCTM’s national standards; each state had their own. But “now, for the first time ever, online-learning programs in different states and different programs have a common framework,” said Susan D. Patrick, the president and chief executive officer of International Association for K-12 Online Learning, or iNACOL. “Now we can start sharing, collaborating, and really refining what we’re doing” (Ash, 2012).

Currently, the Common Core State Standards (CCSS) have been adopted by all states including Washington, D.C. except Alaska, Minnesota, Nebraska, Texas, and Virginia. Besides the Mathematical Content Standards organized by grade level, the Common Core also includes Standards for Mathematical Practice:

(1) Make sense of problems and persevere in solving them.

(2) Reason abstractly and quantitatively.

(3) Construct viable arguments and critique the reasoning of others.

(4) Model with mathematics.

(5) Use appropriate tools strategically.

(6) Attend to precision.

(7) Look for and make use of structure.

(8) Look for and express regularity in repeated reasoning. (Core Standards, 2010)

I favor games rich in both content and require mathematical practices.

In his book *Gadgets, Games, and Gizmos for Learning*, Kapp (200& describes levels of knowledge. There are basic levels of knowledge and higher-level levels of knowledge. The basic levels include declarative, concepts, and rules – where declarative refers to memorization of facts and jargon, concepts are a series of traits that classify an object, and rules express relationships between concepts. These basic forms of knowledge are relatively easy to transfer, and they are hierarchical and prerequisite of higher-level knowledge. These higher-level levels of knowledge can be categorized as procedures, principles, or problem-solving, and are not hierarchical. Procedures refer to an ordered sequence of rules of steps to complete a task, principles are guidelines for behaviors or actions that are not sequential (communication, leadership, ethics, team building, negotiating, and other ‘soft’ skills), and problem solving is the use of previous knowledge to solve a novel situation, an unencountered problem. (Kapp, 2007) Kapp’s higher-level levels of knowledge have many similarities to the CCSS for Mathematical Practices and to NCTM’s Process Standards: [problem solving](http://www.nctm.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=3476&libID=3488), [reasoning and proof](http://www.nctm.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=3482&libID=3494), [communication](http://www.nctm.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=3484&libID=3496), [connections](http://www.nctm.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=3494&libID=3506), and [representation](http://www.nctm.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=3490&libID=3502) (NCTM, 2000), and we can also see that the higher-order thinking skills and ‘soft’ skills are included in iNACOL’s Instructional Design standards.

Educational games and simulations can engage students on higher-level cognitive thinking, such as interpreting, analyzing, discovering, evaluating, acting, and problem-solving (Antonacci & Modress, 2008).

Van Eck also comments on the quality and components digital game-based learning in an Educause Review. He notes that quality is maximized by leaving design of game play up to game designers and the design of learning up to teachers. He also notes that games that are designed to be engaging will tend to privilege that aspect over accuracy and completeness of content. He says that games are effective not because of what they are, but because of what they embody and what learners are doing as they play a game. Games that are too easily solved, according to him, will not be engaging, so good games constantly require input from the learner to provide feedback. (Van Eck, 2006)

The degree of difficulty is one I mentioned from Squire’s work earlier: *enough but not too much* difficulty and complexity, failure and choice. Prensky also considers degree of difficulty in his book *Digital Game-Based Learning*, and there is a quote from a teacher that I think is worth including:

One thing we learned is that the harder you made it, the more kids wanted to do it. They kept wanting more and more game levels, which basically meant harder and harder stuff. It gave the kids real power if they knew the win-state code, which meant that they were the one who was able to master the game at the highest level. THEY were in control. ‘I’m doing this harder stuff because I CHOSE to do it, not because the teacher told me to do it!’ (Prensky, 2007)

The rubric for instructional design standards from iNACOL was not exactly fitting, but the report *Learning: Is there an app for that?* offers the following two broader design principles: (1) Create apps that are developmentally appropriate; and (2) Create apps that sustain children’s interest and learning. They also include that factors such as developmentally appropriate and fresh content, shortened wait times, humorous activities, incentives, goals, and parental involvement can help to sustain interest. (Chiong & Shuler, 2010) The report lists surrounding children with high-quality educational resources as one of the implications for education, although they do not offer a rubric that can be used to evaluate the quality.

Tang and Hanneghan (2011) explore the technological solutions for game-based learning, and propose that model-driven software engineering approaches are promising to facilitate non-technical domain experts (teachers) to plan, develop and maintain game-based learning resources regardless of the intricacies of the game engine/environment (platform) used. This may be productive in bridging the gap between the educational practitioners and the educational tool designers. Still, this model presents the following challenges:

(1) how to enable domain experts – with little computer games development skills – to plan, develop and update their teaching material without going through endless and laborious iterative cycles of software and content development and/or adaptation;

(2) how to choose the right mix of entertainment and game playing to deliver the required educational and pedagogical lesson/teaching material; and

(3) how to reuse existing games software frameworks and associated editing environments for game-based learning. (Tang & Hanneghan, 2011)

Tool designers, while designing the technology for the goal of learning mathematics, must still be faithful to some basic principles of pedagogy, mathematics, and cognitive development. Thomas P. Dick writes about these principles as the fidelity of technological tools. He defines a pedagogically faithful tool as one that the students perceive as (1) facilitating the creation of mathematical objects, (2) allowing mathematical actions on those objects, and (3) providing the evidence of the consequences of those actions. Mathematically faithful, then, is one such that the virtual mathematical object reflects accurately the mathematical characteristics and behavior that the idealized object should have. And cognitive fidelity is defined as being faithful to the students’ cognitive processes – with an emphasis on illuminating mathematical thinking processes rather than arriving at final results as efficiently as possible. (Dick, 2008)

Samara and Clements (2008) offer a process to link the research to software development in the field of mathematics education, to preserve the fidelities Dick described. The process is: draft the initial goals; build an explicit model of students’ knowledge, including hypothesized learning trajectories; create an initial design for software and activities; investigate the components; assess prototypes and curriculum; conduct pilot tests in a classroom; conduct field tests in multiple classrooms; and finally, publish. Samara & Clements’s phases are not specific to games, but we can combine the phases they described with the learning games design principles, as described by Klopfer, Osterweil, and Salen. The principles are not sequential like the phases in the process for development. Rather, they serve as tips for what designers should keep in mind while designing learning games. The principles include:

1. Choose wisely.

2. Think small (sometimes).

3. AAA Educational Games ≠ AAA Entertainment Games.

4. Put learning and game play first.

5. Find the game in the content.

6. Break the mold for where educational games are played. Think about playing them outside of class and discussing in school.

7. Harness the great “soft skill” learning from games but connect it with content.

8. Don’t ignore, nor be too limited by, teacher training and readiness.

9. Play Everywhere and Anywhere.

10. Reduce, Reuse and Recycle

11. Define the Learning Goals

12. Forge Partnerships – between academia, commercial companies, non-profits, foundations and government.

13. Don’t Ignore or Be Too Constrained by Academic / State Standards.

14. Not Just Who But What, Where, When and Why. (Klopfer, et al., 2009)

Klopfer, Osterweil, and Salen offer the list as principles we should be looking to in order to advance the field of educational games. Although they don’t emphasize any more than another, the fifth and seventh resonate most with me. The fifth seems like a simple suggestion to find the game in the content; yet too often, I see math that is forced into a game structure, so much that the math and the game are entirely separate and completely disjoint. Often, the only relevance the math has to the game is that the player must do some sort of math problem to continue playing the game (open a door, for example) or earn a reward of some sort. The goal is to give them an opportunity to use the mathematics in a real context as part of a game, not trick them into doing math while engaging in gameplay. The seventh principle is to harness the ‘soft skill’ learning. This also should be embedded in the game design, and not disjoint from the context. While playing a learning game, we want our students to be engaged in the game while learning both content and learning the ‘soft skills’ we mentioned above – the mathematical practices from CCSS and the process standards from NCTM.

As we conclude this section, we are reminded again that there are multiple perspectives from leaders in the contributing fields. The production, distribution, and play with children’s media involve ongoing tension and intertwining of different genres, social agendas, and educational philosophies. These dynamics include the negotiation between adults and kids performing the genres of academic, entertainment, and construction; the ideals of learning, fun, and creativity; and the politics of enrichment, indulgence, and empowerment. These three genres are tied to different social investments. Academic genres became a vehicle for producing class and educational distinction. Entertainment produces age cohort identity by creating a space of childhood pleasures defined in opposition to adult disciplines. The participation genre of construction supports a subjectivity of creative self-actualization tied to technical mastery. (Ito, 2008) It is in through the construction genre that offers utmost promise to construct mastery while also developing facility with ‘soft skills.’

**The Promise of the Mobile Platform & More on Selecting “Quality” Apps**

So far we have discussed the achievement gap in STEM disciplines and narrowed in on the achievement gap of minorities. We also discussed the value of using technologies, such as games, for learning mathematics and considered some of the implications for design that bring about learning and not just engagement. In this section, we will discuss the value of using mobile technologies to host games for learning that also may show promise in narrowing the achievement gaps.

Just this month a report from a national research project was published concerning how educators are personalizing learning for students. Most relevant here is the use of mobile devices in the classroom. Just from the infographic, it is evident that more than 70 percent of principals and administrators use smartphones and more than half use tablets. With district instructional technology budgets lower than past years, the greatest concern of education leaders is adequate funding. To solve the budget situation, administrators are (46%) using digital textbooks and (42%) using tablets in place of laptops. Principals say that the benefits of using student-owned mobile devices are: (80%) increase student engagement, (58%) extend learning beyond school day, (58%) provide way to personalize instruction, (54%) provide access to e-textbooks, and (45%) improves teacher technology skills. Their concerns for using student-owned mobile devices are: (50%) theft, (45%) network security, (43%) teachers are not trained, (43%) not every student has a device, and (40%) devices could be a distraction. (Speak Up, 2011)

An article from *THE Journal* complements the data from Speak Up nicely with a narrative. The title of the article is Top 5 K-12 E-Learning Trends, and “Cutting the Wires: More Mobile Learning” is the first subheading. Julie Evans, the CEO from Project Tomorrow, a national educational non-profit in California, is quoted in the article, saying that the “leveraging of small, portable devices to facilitate anytime, anywhere, un-tethered learning” is popular right now. It offers the benefits from the 1:1 laptop programs for a lower cost. (McCrea, 2012)

The National Primer on K-12 Online Learning by iNACOL also recognizes mobile learning as “the art of using mobile technologies to enhance learning experiences” and predicts that “smartphones have become a viable way to access the Internet and their popularity will likely increase, becoming the primary connection tool to the Internet for most people in the world in 2020. Smartphones have introduced the concept of the phone “app” which, in some cases, provides an alternative to a browser for accessing Internet content. The changes in how students access web content will likely impact how digital content and course materials are presented” (Wicks, 2010).

It was interesting to learn that the primary concern for using mobile devices was theft, followed by network security and teacher training. Student access to the devices was fourth, and the device as a distraction was fifth. (Speak Up, 2011) iNACOL reported the percentage of students that had access to devices and would also like to use it for school work was most popular in high school compared to middle school or elementary school, but still only 31% of high school students both had a mobile device and wanted to use it for school. (Wicks, 2010) This was reported in 2009, so it would be interesting to know if that statistic still holds. Nielsen reported smartphone penetration by age and income of adults in February of this year, and data shows that smartphones are most popular for younger adults and those that make more money. Still, of the lowest income bracket (<$15,000) for 18-24 year olds, more than half have a smartphone of their own (Nielsen, 2012).

In addition to the reasons described earlier of why the mobile platform may help lessen the inequities that exist for minorities, research has also shown that although many low-income families do not have internet access at home, they do have access to at least one smartphone (Rideout, 2009). More than half of the world’s population now owns a cell phone and children under 12 constitute one of the fastest growing segments of mobile technology users in the U.S. (Shuler, 2009).

In a report by The Joan Ganz Cooney Center, the call to action is to make a shift from *whether to* use these devices to support learning, to understanding *how* and *when* they might best be used. More specifically, how might mobile technologies such as cell phones, iPod devices, and portable gaming platforms be more widely used for learning? Five goals are identified for moving mobile learning forward: learn, develop, promote, prepare, and stimulate. Learning refers to understanding mobile learning as a unique element of education reform, developing to building mobile learning interventions, promoting as in engaging the public and policymakers in defining the potential of mobile devices for learning, preparing to training teachers and learners to incorporate mobile technologies, and stimulating to generating new leadership support for digital learning. (Shuler, 2009)

Before we heed the call to action, it is important to understand what exactly mobile has to offer besides advanced functionalities. Stald (2008) writes about four themes. He states that a major affordance of mobile technologies is the availability, the fact that the mobile is always on, which makes the users always available with no or few communication and information-free moments. Another is the user’s presence during mobile communication, the experience of social presence in public space being invaded by ongoing mobile communication. A third theme is the personal log for activities, networks, and the documentation of experiences – a role that has implications both for relations between the individual and the group and for emotional experience. Last is the fact that mobile is also a tool for learning social norms. In that sense ‘mobile’ is a double entendre. A sixteen-year-old girl expresses, in Stald’s article about mobile identity, that parents usually don’t know how important a tool the mobile has become in young people’s lives. She says they only think about the communicative function, not the social meaning. In this very way, identities are also mobile – changing and developing moment by moment and over time, as very sensitive to the changes in the relations between friends and families, and to the emotional and intellectual challenges experienced and mediated through the use of the mobile phone. (Stald, 2008)

The affordances and themes that mobile has to offer translate into key opportunities, as outlined in a report on using mobile technologies to promote learning. The opportunities are defined as: encouraging “anywhere, anytime” learning, reaching underserved children, improving 21st-century social interactions, fitting with learning environments, and enabling a personalized learning experience (Shuler, 2009). “Anywhere, anytime” learning is possible because mobile devices allow students to gather, access, and process information outside the classroom. They can encourage learning in a real-world context, and help bridge school, afterschool, and home environments. The opportunity to reach underserved children is possible because of the relatively low cost and accessibility of mobile devices in low-income communities. Handheld devices can help advance digital equity, reaching and inspiring populations “at the edges” — children from economically disadvantaged communities and those from developing countries. Mobile technologies have the power to promote and foster collaboration and communication, which are deemed essential for 21st-century success. They can help overcome many of the challenges associated with larger technologies, as they fit more naturally within various learning environments. Last, differentiated, autonomous, and individualized learning are feasible through mobile devices. Because not all children are alike, instruction can be more easily adapted to individual and diverse learners.

Given the opportunities and the great stakes at hand, what apps are out there right now? A later report, also by the Joan Ganz Cooney Center, investigated the apps available in the iTunes Store. Results included that over 80% of the top selling paid apps in the Education category target children. 72% of the top-selling apps target preschool or elementary-aged children now, compared to 47% in 2009. Recommendations include addressing the app gap, creating standards for selection of apps, protecting children as end-users, enabling sustainability and profitability, and setting a research agenda. (Shuler, 2012)

One of the gaps in apps, as we mentioned in the previous section, is in the design of the apps. This month the first app that was also created with an iPad app was released. Although not completely user-friendly or efficient, this advance shows great promise in closing the gap between content specialists and developers. The resulting product was a an iPad game called Cargo-Bot, which managed to become one of the top 10 most downloaded iPad aps in the U.S. and get more than 200,000 downloads in just over a week. Although the person who programmed this app was able to learn to program using Codea in one night, he notes that in order to develop a professional game, you still need to use the actual Apple code and this process took a few months to refine and complete. In any case, this app, and imagine the developments that will surely follow, may bring more people to try to develop apps and increase the quantity and quality of apps available. (Ogg, 2012)

There has also been progress in creating standards. As discussed earlier, the Common Core makes portability possible between states in that it allows the apps to be tagged according to content standards that most all states use. Also as discussed earlier, there is more than a connection to content that must be considered in evaluating the quality of an app. Langwitches offers a Bloom’s Taxonomy for iPads, which remind me in a way of Kapp’s levels of knowledge, yet the levels in the taxonomy are all hierarchical. The levels of the taxonomy begin at remembering and continue on through understanding, applying, analyzing, and evaluating before ending at the highest level of creating. (Langwitches, 2012)

Speaking of creating, it seems that apps themselves on the mobile device are no longer enough. According to an article in Wired, “Whether it’s toy figures, board games or the balls of the future, we are seeing an explosion of accessories that will interact and engage with our mobile devices and consoles. This year we are set to see more and more items that want to talk to your children’s mobile devices” (Donahoo 2012). So, besides evaluating apps, we now have to also consider deciding whether or not these app-cessories are worth our attention and investments.

I argue that even with linking content to the Common Core and determining the level for an app according to Bloom’s Taxonomy for iPads, there are still many components that must be considered in assessing the quality of an app. Although I was unable to find a rubric for such, I investigated a few sources that offered collections for the “best of math” apps. For example, Common Sense Media gave 5 stars to games such as Playful Minds, Cash Cow, Numbers League, Sums Stacker, DigitZ, Fractions App, and Algebra Touch. For each game included in Common Sense Media’s collection, a target age is chosen, screenshots of what to expect, along with a section for ‘what parents need to know,’ ‘user reviews,’ and ‘app details.’ There is also a short commentary by the reviewer. There is a key that describes that a green rating for age means it is appropriate, yellow not so much, and orange not age appropriate. There is also a key that shows no, one, two, or three books to denote the levels of engagement and learning. Unfortunately, this rating was not used for the apps in the list. The overall quality was measured in stars, yet a description of what criteria are considered in assigning the star rating was not. However, the commentary and the section on what parents need to know were informative.

Although the rating system seemed incomplete at Common Sense Media, it seemed the other “best of math” apps collections, such as the one from Teachers With Apps and the one from Fun Educational Apps, didn’t offer a rating system at all. Rather they were only a listing of the apps with descriptions.

More promising might be the reviews in *Children’s Technology Review*, that are evaluated according to an instrument that was created by Warren Buckleitner in 1985. His instrument uses ratings from six categories that result in an overall quality rating from 1 to 5 for each product. The six categories are: ease of use, childproof, educational, entertaining, design features, and value. The tools is available on the website so that it can be freely-used to evaluate technology tools for teaching, especially those that haven’t already been included in the publication. In my own critique of the tool, I express three concerns. First, in regards to the educational category, although I realize that this tool is a general tool, I would like to see both content and process standards so that it is evident if the tool is more like the remembering and drill-and-practice or more like the creating, problem-solving, and critical thinking. Second, it seems that there should be a category for instructional supports, a rating that communicates to educators and parents the functionalities that make the tool ready-to-use in a learning context. For example, is there scaffolding built-in, assessment that can be communicated back, or suggestions of questions for students as debriefing? My last concern is that Warren’s tool, even while not including these categories, is fairly long and requires a decent amount of knowledge as a rater, both in content and in the functionalities of technology. I’m skeptical that this tool would help parents or teachers quickly select the best app for learning. I realize that it wasn’t designed for this purpose, but the evaluation tool is offered as one-page downloadable document. It would be fabulous if such a tool could be within the reach of end-users to inform their own decisions upon selecting games for learning, instead of relying on the reviews published in *Children’s Technology Review.*

**Teachers Perceptions, Knowledge, & Pedagogical Support**

As I noted in my critique of Warren’s evaluation tool, using technology for the purpose of learning, especially at the classroom level, takes more than the technology itself. Besides those engaging in the technology, teachers and teaching are critical components. For example, in an article about the one laptop per child project in Birmingham, as a means to decrease digital inequity, results highlighted the importance of having well-trained teachers who supported using the technology themselves. In that study, teachers’ use of the laptops was the primary factor related to the usage and attitudes of students. Those that embraced using the laptops themselves in the classroom facilitated positive attitudes toward technology and its use among students (Cotton, 2011). Further evidence that supports careful integration of technology and trained teachers is from another one laptop per child program adopted in Peru. After spending $225 million to provide 850,000 laptops across the country, only 13 percent achieved a basic standard score in math (Osborne, 2012).

I don’t want to infer here that the 1:1 laptop programs are all bad. So I will at least provide a counterexample, an example of a success story. Three years ago, the superintendent of a district in North Carolina prepared himself for an "innovation dip," a small drop in student performance as educators and students adjusted to the new approach. The opposite happened. The district went from ranking 30th in the state in school performance measurements to fourth. “Students like using relevant tools and materials," the superintendent says. "The kids are more engaged and excited about school. They're doing things in class and saying, 'I will do this in my future.' "(Davis, 2011)

What I liked most about Davis’s article in EdWeek though wasn’t the success story; it was an analogy of a hospital for balancing innovation and accountability in education. Dede, a professor of educational technology at the Harvard Graduate School of Education, compares, “If a hospital with a high death rate refused to try new, modern practices because they'd be unsure of the outcome or there might be a learning curve, ‘people would be upset because they're maintaining a bad situation under the guise of being accountable.’ The translation to education is the same.” Schools are often reluctant to incorporate new technology and apply 21st-century methods because they're worried about a drop in test scores or other risks in shaking up the way things are done. But schools need to think about all the ways they're accountable—not just through scores on state tests, Dede says. Schools are also accountable to students to provide a high-quality education, and to parents and local business leaders to produce students prepared for college and careers. And yes, they're also accountable to state and federal educational leaders in the form of test scores, Dede acknowledges. As a consequence, the approach to balancing innovation and accountability in K-12 schools needs to be particularly thoughtful. (Davis, 2011) Although not included in the article, I’d be interested to know if the teachers in this district in North Carolina had any training or other clear differences from the teachers in Birmingham or Peru.

In their report on moving learning games forward, Klopfer, Osterweil, and Salen recognize the concerns of teachers. They argue that “games can engage players in learning that is specifically applicable to ‘schooling’” and “there are means by which teachers can leverage the learning in such games without disrupting the worlds of either play or school.” The concerns of teachers, according to them, that must be addressed include: their need to cover mandated content areas, a healthy skepticism of new technologies (combined with a lack of infrastructure for these technologies), and an unfamiliarity with games, and no easy route to game competence. (Klopfer, et al., 2009)

Various studies have explored teachers’ attitudes, ideas, and perceptions about using technologies for teaching and learning. Teachers who identify as more comfortable using digital games themselves use digital games more frequently with students, with 50% using them at least two days a week, and elementary teachers reporting higher usage than middle school teachers. Benefits to lower-performing students were popular among teachers. 70% said that digital games increased motivation and engagement with the content, 62% that they are conducive to differentiating instruction, and 60% to personalize instruction, better assess knowledge, and collect helpful data. They also voiced the benefits for all students such as more collaboration and sustained focus. 95% of teachers chose games that were specifically created for educational use, and math games were less popular than literacy/reading games. The majority of teachers first learned about using digital games from an in-service professional development or a self-directed study, with only 12% that learned about digital games during preservice training. (Millstone, 2012)

The aim of an earlier study, specific to mathematics teachers, was to understand their pedagogical thinking, as a prerequisite to stimulating and informing practitioner reflection on the use of technology to support teaching and learning. The themes that emerged related to teachers’ ideas about the affordances of technology in promoting their classroom goals were: ambience enhanced, tinkering assisted, routine facilitated, features accentuated, motivation improved, restraints alleviated, attention raised, engagement intensified, activity effected, and ideas established (Ruthven & Hennessy, 2002). But more generally, when it comes to digital media, parents and teachers are on the same page. Teachers are a bit more optimistic about digital media’s ability to teach certain ideas and so they also see a greater potential for digital media in education, although they too are skeptical about using mobile technologies in the classroom (Growing up Digital, 2008).

Recognizing the overall positive perceptions among teachers, it follows then that we must next consider the professional knowledge that teachers need. Teacher education must meet the challenge of helping teachers come to know the appropriate and constructive uses of technology. Wilson breaks this one question into five smaller questions: What do teachers need? Who can prepare and support teachers? What are the best opportunities for teacher education? What education do teachers need? What is appropriate teacher education in mathematics and technology? (Wilson, 2008)

The International Association for K-12 Online Learning identifies the teacher’s role as guiding and personalizing learning; communication; assessing, grading, and promoting; and developing the online course content and structure. They voice that “to realize full potential, schools will need to invest in the necessary professional development and re-think technology policies that interfere or prohibit students from utilizing current technologies” (Wicks, 2010). They offer a model with the acronym TPAC that stands for technology; people, professional development, pedagogy; adaptive assessment; content and curriculum. TPAC identifies four sectors related to teachers and teaching that must be considered when answering the following three questions: Does the teachers know the content? Does the teacher know how to teach the content? Does the teacher know how to use the technology to teach the content effectively? (Wicks 2010)

TPAC is separate from TPACK although the meaning is quite similar. TPACK stands for technology, pedagogy, and content knowledge, and is well-known among mathematics educators with an interest in technology. TPACK encompasses the specialized knowledge necessary in using tech tools effectively by initially requiring teachers to focus on when, where, and how to incorporate appropriate technologies for teaching and learning mathematics. Although the article I cite that references TPACK is about graphing calculators as tools, it notes that the many uses of handheld technology for learning mathematics inherently involve specialized knowledge (Browning, 2010). TPACK “requires teachers to integrate their understanding of the students, mathematical content, instructional strategies, classroom management, and assessment with careful consideration of how technology impacts the learner and learning process” (Niess, 2008).

In an article about “tech-knowledgy” and mathematics for diverse learners, the author argues that in order to leverage cognitive tech tools for mathematics teaching and learning, teachers must consider the needs of diverse learners and be equipped to support their learning difficulties by taking advantage of this technology. She defines “tech-knowledgy” as the knowledge necessary to use cognitive tech tools effectively to construct mathematical opportunities presented, and design learning tasks with these tools that amplify the mathematics. This “tech-knowledgy” in the twenty-first century requires teachers to consider the best available resources and technology based on research, and discriminate and evaluate these resources to yield the most effective and meaningful learning for students. (Suh, 2010)

In a workshop summary about successful STEM education, the National Research Council provides six lessons for deepening and sustaining teacher content knowledge. These are:

(1) Recognize that it takes time to develop and nurture a productive partnership.

(2) Consider how to engage a range of important stakeholders whose support is important for efforts to deepen teacher content knowledge.

(3) Help ensure that key policies in the system are aligned with the vision underlying the reform efforts.

(4) Design and implement professional development that is not only aligned with the project goals, but is also both feasible and likely to be effective with the teachers in their particular context.

(5) Use data to inform decisions, improve the quality of the interventions, and provide evidence to encourage support for system change.

(6) Work to develop capacity and infrastructure to strengthen teachers' content knowledge and pedagogical skills, both during the funded period and beyond. (Successful STEM Education, 2011)

In this section, we will focus on the fourth lesson, the design and implementation of professional development.

A section of that workshop summary focused on professional learning communities (PLCs) as a form of effective professional development to transform good teachers into great teaching. Research has shown that STEM teachers in PLCs can: increase their discussion of STEM content and how to teach it; learn STEM content; feel more prepared to teach STEM content; enhance their inquiry-oriented teaching methods; and pay more attention to students’ reasoning and understanding. Most appealing to stakeholders is that student learning improved for the content discussed in the teachers’ PLCs. Although little research has been conducted that can clearly link students’ standardized test scores to teacher PLCs, results show some positive gains in mathematics. (Successful STEM Education, 2011)

Scaffolding tasks can also help increase teachers’ comfort and competence with technology. As teachers prepare for a future in which technology continues to evolve, it is essential that they have opportunities to develop proficiency with multiple technologies, according to an article in NCTM’s school journal *Mathematics Teacher*. Using a dynamic technology scaffolding approach, learners (the teachers) with a broad range of mathematical backgrounds and technological sophistication can access powerful mathematical ideas, make new connections, and develop confidence in figuring things out. In addition, they can develop productive habits of mind as they explore, persevere, and problem solve. (Madden, 2010)

Many teachers lament the difficulty of incorporating technology into their mathematics classrooms, for a host of well-documented reasons, according to Zbiek and Hollebrands, including discomfort or lack of competence with technology and uneasiness with the mathematics or the connections that may be part of a technological environment. Consequently, teachers frequently teach technology rather than teach mathematics using the technology as a tool. (Zbiek & Hollebrands, 2008) To counteract this transfer of focus, Madden describes a dynamic technology scaffolding that involves constructing mathematical tasks with three distinct levels of technological engagement. First, learners engage with and explore some type of dynamic physical model representing a mathematical situation. Second, they move to an automated structured simulation environment or an interactive technology demonstration that preserves the characteristics of the physical environment but removes some physical constraints, thus speeding up a process (at this stage, the user has limited ability to control the environment). Third, learners move to a flexible technological construction environment in which they are responsible for creating a dynamic mechanism to simulate the problem while controlling the objects, representations, and relationships with the technological tool. (Madden, 2010) This form of scaffolding mimics the instructional supports teachers may use with their students to best facilitate learning when students are first introduced to a new concept.

Lesson study has also been documented as an effective model for support and camaraderie among mathematics teachers and has even motivated teachers to make time to collaborate and develop technology-motivated lessons after school. One particular study used the model to successfully prepare and support teachers in learning to use PDAs in their mathematics classrooms. Take-aways included shifting the view of technology from an add-on to a powerful vehicle for mathematics learning and investigation and using the lesson-study model for significant sharing, comparison, and mathematical conversations even with individual, self-sufficient mathematical investigations. (Cwikla, 2005)

As Suh included in her article about “tech-knowledgy” tools, teachers must learn how to discriminate and evaluate the technologies to warrant learning opportunities for students. In another article from an NCTM school journal, Soucie emphasizes that although technology can open the door to better teaching and learning, sometimes it is not the most effective tool. After justifying the use of technology in mathematics classrooms, Soucie, Radovic, and Svedrec stress the importance of thoughtful and well-planned implementation:

Students need to learn how to use technology in a meaningful way to become literate. Teachers should take advantage of technology and what it has to offer. Technology can motivate students and can help them visualize mathematics problems. It can enable them to work on more complex tasks that often involve real-life applications of mathematics. It also allows them to move from mere reproduction to exploration and discovery. Students are able to work on more in-depth problems and produce higher-quality work. Learning becomes fun for them. However, to fully take advantage of what technology offers, implementing its use in the classroom has to be thoughtful and well-planned. (Soucie, Radovic, & Svedrec, 2010)

Ball and Stacey promote strategies for judicious technology use in mathematics. First, they promote students’ metacognition, the students’ ability to think about their thinking. A feature of good problem solvers’ metacognition is that they can usually assess the difficulty of a problem accurately in relation to their own skills (Krutetskii, 1969). Ball and Stacey purport that this ability is essential for judicious technology use. Students need to appreciate that it is usually more effective to solve simple problems mentally or by using pencil and paper (instead of with a calculator, for example). (Ball & Stacey 2005) In order to be able to promote students’ metacognition, teachers must be reflective on their own thinking and model judicious use of technology.

“When technological tools are available, students can focus on decision-making, reflection, reasoning and problem solving” (NCTM, 2000). That said, teachers must learn how to plan lessons that encourage students to develop problem solving and reasoning skills, make connections among concepts and representations, and communicate their ideas to one another and to their teachers. They must also learn to assess student’s understanding as they engage with technology tools. McGraw and Grant offer structures for encouraging a range of methods and solutions while investigating mathematics with technology. They advise to choose larger and more complex sets of objects that require students to take some responsibility to make decisions about which mathematical objects or relationships to examine and how to examine them. These include opportunities to develop reasoning, problem solving, and communication and opportunities to collect conjectures and arguments produced by students and re-present them to the whole class. They also advise that teachers become more comfortable with mathematical topics and technology tools, a recurring theme. In facilitating lessons, they recommend that instead of reaffirming decisions of students, teachers should reaffirm that decisions are for students to make, and in turn learn from. Teachers should open up lessons to allow for multiple investigation paths, which result in richer learning experiences and more manageable classroom environments. Last, teachers should reflect on the quality of the technology-based lessons. (McGraw & Grant, 2005)

If we focus on just the digital game-based learning, we have to ask ourselves if the amount of potential learning is justified by the amount of work and time that will be needed to implement the game (Van Eck, 2006). Even after results from a 40-year retrospective study showed only small to moderate positive effects on learning and attitude, if an administrator must make a decision of whether or not to invest in such technologies, one of the authors of the study say that the answer should still be yes. This decision is justified by the fact that more recent, sophisticated applications produce greater positive gains. The article uses the example of using technology solely as content provider, such as using an iPad as an alternative for books with no added content would likely not produce positive change. But, “where technology does have a positive impact is when it actively engages students, when it’s used as a communication tool, when it’s used for things like simulations or games that enable students to actively manipulate the environment” (Branswell, 2012).

The potential learning is further supported by research that shows that online games have an impact on the cognitive and social development of young people. The Kaiser Family Foundation (2008) reported that minority youth spend more time with media than white youth. The Pew Internet Life Project reports that minorities outpace whites in use of cell phone data applications. Mobile games for learning have great potential in reaching folks these days, especially minorities who also happen to be victim to the achievement gap in STEM.

Further, there is evidence that digital game-based learning integrated in the classroom results in significantly higher achievement in mathematics when compared with traditional teaching methods without games (Kebritchi, Hirumi, & Bai, 2010). Previous studies have reported that educational computer games can enhance the learning interest of students (Ebner & Holzinger, 2007) and further increase their learning motivation (Burguillo, 2010). Researchers have also indicated that games are an important part of the development of children’s cognition and social processes (Kim, Park & Baek, 2009). Consequently, educational computer games have great potential for helping students to improve their learning performance as well as their learning motivation (Wang & Chen, 2010).

But, just because there is evidence that digital game-based learning has worked and can work, what will it take to make it work for us? In order to make technology work, it must be clear to teachers what the purposes of using technology in the mathematics classrooms are. The cardinal rule of educational technology is if the technology doesn’t do it better, then don’t use it. “The best technology engages the user in something he doesn’t normally have access to.” (Jennifer L. Wells, PBS Mobile) The purpose of using technology in mathematics classrooms, according to Soucie, Radovic, and Svedrec are six-fold: engage students in discovery and exploration, promote higher-level thinking, improve students’ visualization, enable students to engage in real-life applications of mathematics, prepare students for the demand of the century, and make mathematics more engaging and fun. In mathematics, the power of technology enables students to work with real data on real problems, and allows collaboration with teachers of other subjects to make learning even more meaningful and engaging. (Soucie, Radovic, & Svedrec, 2010)

It might also be useful for teachers, and tools designers as well, to know the cognitive changes that occur in tandem with implementing digital game-based learning. Prensky includes a brief list of these dichotomies in his book. The following as organized as pairs of technology vs. traditional: twitch speed vs. conventional speed, parallel processing vs. linear processing, graphics first vs. test first, random access vs. step-by-step, connected vs. standalone, active vs. passive, play vs. work, payoff vs. patience, fantasy vs. reality, and technology-as-friend vs. technology-as-foe. (Prensky, 2007) Another issue that has gained attention is the concept of multi-tasking. Juggling multiple streams of media has become a norm, and rapid task switching has significant costs in speed and accuracy (Wallis, 2010).

In considering all of the affordances and concerns with using technology for teaching, still an overarching theme is to balance education and entertainment. Ito describes three genres of technology tools: academic, entertainment, and construction; respectively the ideals of learning, fun, and creativity; and the politics of enrichment, indulgence, and empowerment (Ito, 2008). To connect youth and games to learning, the construction genre seems most promising for a variety of reasons, including that the distinction between education and entertainment is blurred.

Suh (2010) also includes a table that clearly links the affordances gained by technology to the diverse needs that each addresses. For example, linked representations help make connections more explicit through multiple representations; collaborative learning through games fosters interaction to develop strategies; immediate feedback eliminates error patterns and misconceptions by providing formative feedback for students to self-assess learning; and customizable and replicable tools allow users to adapt them to create their own problems or models (Suh, 2010).

One of the buzzwords associated with technology and mathematics is instrumental genesis. Heid describes this notion nicely in her chapter of NCTM’s yearbook on technology-supported mathematics learning environments. She writes:

Technology mediates learning. Learning is different in the presence of technology. The representations that students access may conceal or reveal different features of the mathematics, and the processes may affect what students process and learn. How a student uses technology is dependent on his or her ever-changing relationship to the technology. As the student develops facility with, and an understanding of, the capabilities of the technology, the technology becomes an instrument that the student can tailor flexibly to specific needs. (Heid, 2005)

Dynamic tools are essential components of the technology toolkit in school mathematics and allow students to experience mathematics kinematically, and as Suh included, students in such technologically rich classrooms develop multi-representational views of mathematical concepts. Also included in Suh’s chart were collaboration and communication. Students are more likely to develop a deep conceptual understanding of mathematics when they interact with and discuss their thoughts with others (Cobb, 2000; Cohen, 1994; Davidson & Worsham, 1992; Vygotsky, 1978). Use of the computer may actually enhance communication among students and increase students’ ability to make conjectures and explore concepts (Fonkert, 2010).

These factors all contribute to a more conceptual understanding. As McGraw and Grant (2005) also included, conceptual conversations are also critical components, and according to Knuth and Hartman (2005), the greatest benefit is that they foster intuition as well as understanding. Conceptual conversations are defined as conversation that has the diminished emphasis on technique and procedures and an increased emphasis on relationships, images, and explanations (Thompson, 1996).

Given that technology is transforming the world and we are dedicated to improve the transform the way we teach, it follows that we must also transform the way we assess mathematics. As we focus on creativity and entrepreneurship, Medberry reminds us that we don’t need to memorize things any more, but we still need teachers to guide our students toward learning the best ways to problem solve. The question is then how to measure that, how to assess problem-solving. As the primary purpose of teaching shifts away from ‘stand and deliver’ and to being relentless about making sure ‘every student graduates ready to tinker, create, and take initiative,’ Medbery says teachers must become disciplined and analytical about identifying students’ strengths and skill gaps, continuously turning classroom data into a plan of action. He notes that accountability is a good thing, but only when you are measuring what matters, and asks, “What if quizzes measured kids’ ability to question, not answer?” Honoring creativity, schools should be producing kids who tinker, make, experiment, collaborate, question, and embrace failure as an opportunity to learn, according to Medbery, and to achieve this, they must be staffed with passionate teachers who are not just prepared to foster creativity, perseverance, and empathy, but are responsible for ensuring kids develop these skills.

**Examples of Implementation & Affordances to Students**

A plethora of research exists that is related to the implementation of technologies in mathematics education, but fewer exist that are specific to digital games-based learning for the teaching and learning of mathematics, and fewer yet via the mobile platform. In his 2011 keynote address on research on technology in mathematics education, Olive references the Dynamic Number Project, the SimCalc project, Logo and Robotics, and both Calculation Nation and Club Penguin, which are web-based gaming environments. NCTM hosts Calculation Nation as a part of Illuminations, a website of lessons, activities, and games funded by Verizon’s Thinkfinity initiative. Calculation Nation, according to its website, “uses the power of the Web to let students challenge opponents from anywhere in the world. At the same time, students are able to challenge themselves by investigating significant mathematical content and practicing fundamental skills. The element of competition adds an extra layer of excitement.” Club Penguin is hosted by Disney and is an on-line, virtual world for young children who interact with each other and the world via their own penguin avatar. The difference, according to Olive (2011), is that Club Penguin has millions of users; he couldn’t find anyone to challenge him at Calculation Nation, although he noted that the games he played were challenging, captivating, and he was involved in thinking about the mathematics.

Although an old example, an article by Steffe and Olive (2002) offer insight on tools designed to provide children contexts in which they could enact their mathematical operations of unitizing, uniting, fragmenting, segmenting, partitioning, disembeding, iterating and measuring. I appreciate that they appreciated the tool for being “very different from the drill and practice or tutorial software prevalent in many elementary schools.” They include examples of how the tools for interactive mathematical activity (TIMA) were used by children to engage in cognitive play and, through interactions with a teacher/researcher and other children, transform that play into independent mathematical activity with a playful orientation. They also include that the role of the teacher is critical – to provoke perturbations that could lead eventually to accommodations in the children’s mathematical schemes (Steffe & Olive 2002).

A recent example of schools using games and online tools is a program called Math-Whizz, which is advertised as being the ‘leading online math tutor.’ One particular article focuses on the program for its ability to deliver the complex requirements of Response to Intervention (RTI) initiatives that are taking hold in schools across the nation to improve the performance of at-risk students. Results from one elementary school showed that fifth graders went from 25 percent at grade level in math before the program to 100 percent after, from 30 to 80 percent for third graders, and from 33 to 58 percent for kindergartners. The CEO of Math Whizz quotes, “Teaching students the fundamental skills and concepts that they need at an early age, in a way that leads them to enjoy math, is key to solving the problems we are facing today. It has been tremendously exciting to witness first-hand the progress schools across the country have been making over the last five years through the winning combination of RTI and Math-Whizz” (Vincent, 2012). Although all of the games that I experimented with on the website seemed to be hardly more than short instructional interactives and drill and practice, it also seemed this was their purpose.

The only research I could find on learning mathematics via the mobile platform was a recent report of a controlled experimental study of Motion Math, a fractions game designed for the iPad, iPhone, and iPod, that investigated whether or not the app improves fractions knowledge and attitudes. The study claims that to date, which was May 2012, no other experimental studies have been conducted to determine the efficacy of any iPad app for improving children’s knowledge. The key findings include:

* Children’s fractions test scores improved an average of over 15% after playing Motion Math for 20 minutes daily over a five-day period, representing a significant increase compared to a control group.
* Children’s self-efficacy for fractions, as well as their liking of fractions, each improved an average of 10%, representing a statistically significant increase compared to a control group.
* All participants rated Motion Math as fun and reported wanting to play it again; nearly all (95%) children in the study reported that their friends would like the game, and that the game helped them learn fractions.
* Taken together, the data from this experimental study offer solid evidence that Motion Math successfully integrates entertainment value with educational value. (Riconscente, 2012)

The study notes that with the advent of mobile technologies such as iPad tablets, new kinds of interactions with subject matter have become possible that have potential for improving learning.that although fractions knowledge is essential for future success in mathematics, national data show that the vast majority of US students fail to become proficient in fractions. As the first controlled study of an educational iPad app, the research indeed marks an important step forward for documenting the potential of new technologies to support learning and engage learners in mathematics and other academic subjects.

Wings, the latest game created by the same folks that created Motion Math, came out May 16, 2012. In this game, players use the accelerometer to control a flying bird who travels across diverse islands, building a nest and winning colorful feathers. Along the way, the bird solves multiplication problems.

Although there is no published research yet, a current project that deserves attention is Math Snacks, designed and developed at New Mexico State University. The developers at NMSU’s Learning Games Lab are working with researchers to create innovative, engaging media that addresses the established gaps in mathematical understanding. Building on pilot animations an previously developed mini-games, the team is creating new tools for use on the Web and mobile devices. The iterative instructional design process integrates research, best practices in educational game development, and extensive user testing with students and teachers throughout the project. The Math Snacks team has conducted extensive research on the gaps, and identified the areas of greatest need. They then identified reasons why this content is difficult for students, addressing students’ attitudes toward math, and providing through games, the engagement, representation, and scaffolding students need as they move from concrete to abstract learning (Chamberlein, 2012). An example of an upcoming game that addresses fractions, decimals, and negative numbers on a number line is called Pearl Diver.

Another project that deserves attention is called Quest to Learn, a charter school in New York City that uses game design as its organizing framework for teaching and learning. Game designers work together with teachers to develop playful curricula and incorporate game elements into the entire school day (Corbett, 2010). In tandem with the creation of gamification projects, they acknowledge that we must develop meaningful assessments of whether they are achieving their aims (Lee & Hammer, 2011). I am interested in the research that transpires. I am also interested in Mobile Quest, a free, week-long summer camp hosted by Quest to Learn where fifth graders discover game design through the use of smartphones. The campers use a variety of design and media tools and work together to use GPS and other mobile technologies to turn New York City into their gameboard.

Quest to Learn reminds me of a discussion by Antonacci and Modress. Although in their article, they write about user-created virtual worlds, the user-created games such as Second-Life share similar features as the game described above that uses NYC as the gamboard. They argue that this functionality significantly changes the nature of a game. “You are no longer playing in an a priori world, constrained and biased by the game developer. The actions of other people make the game open-ended and add complexity and unpredictability.” (Antonacci & Modress, 2008)

SimCalc is the last project I will include here. Even though it is not mathematics via mobile, it is mathematics via technology and there is relevant research. Units in SimCalc consist of a combination of paper materials and software aimed at guiding students in an exploration of real-world contexts and associated mathematics representations, focusing on rate, proportionality, and linear function. SimCalc offers teacher support through a set of teacher notes and professional development that focused on teachers’ mathematics learning and effective implementation of the unit. Designers of SimCalc took into account then-current state standards and assessments in their design of the curriculum and professional development (Knudsen, 2010).

In the full report, findings from the large-scale experiment demonstrate the power of a technology enhanced curriculum to deepen middle school mathematics learning across diverse ethnic and economic settings, an identified gap. The report noted: the SimCalc approach was effective in a wide variety of Texas classrooms, teachers successfully used these materials with a modest investment in training, and student learning gains were robust despite variation in gender, ethnicity, poverty, and prior achievement. In a follow-up experiment, findings showed that students learned more mathematics when their teachers used SimCalc curriculum and software in place of their traditional curriculum. The title of the report really drew me in – SimCalc: A Model for Success – Democratizing the Math of Change – and also offers hope to the field of STEM with the overarching message that “implementing this approach more widely and across grade levels could boost diverse students along the pathway leading to algebra and calculus, a pathway that is widely seen as critical to increasing the number of students prepared to excel in science.” A quote by a SimCalc teacher reads, “This is the type of program that creates innovative and higher-thinking educators – which in turn produces that type of learner.” And a student says, “SimCalc is about figuring out how to figure it out.” (Roschelle. 2007) To me, it seems that SimCalc is a promising program and I wonder if there would be value in modifying and porting any of the content to mobile.

**Putting it All Together: The Stakes are High**

Besides decreasing potential back problems and wasted paper, the digital textbook counterparts would provide ALL students with increased access to real-time information. Furthermore, the tablets offer a platform conducive to flexibly transitioning between multiple forms of multimedia for teaching and learning - embedded videos, interactive applets, and simulations, to name a few. Digital assessments could offer instant feedback to both students and teachers, and the digital content could be delivered in a way that automatically differentiates instruction according to each individual’s mastery.

Supporters of speeding the digital transition contend that, as a nation, we must capitalize on the natural fascination and existing engagement of this generation’s learners in technology. In fact, the number of jobs relying on technology to operate more effectively and efficiently continues to increase.

As we continue to hash out the optimal design model and professional development model, among other issues, we continue to investigate how integrating technology in mathematics classrooms can contribute to more and better mathematics for all.

On the other hand, critics of speeding the digital transition don’t necessarily oppose it, but are cautious of rushing it. They support taking extra time and thought beforehand to ensure a smooth and successful transition. Rather than striving for tablets for every student, critics say we should stay focused on providing *quality* educational content to students and instructional supports to teachers and parents. Until the quality of the content can be ensured and the instructional supports are deemed realistic and sustainable, critics argue that rushing through planning phases in the design, development, and implementation of the digital technologies for teaching and learning could actually be detrimental to student’s success.

Critics question if students are actually learning more, faster, or better with tablets and warn that a tablet is just another educational product whose novelty will wear off as soon as the next ‘latest and greatest’ comes out.

What might be the next ‘latest and greatest’? A recent article in the Wall Street Journal begins: “Picture this: You put on a headset and relax your mind. Soon you begin controlling an object with your thoughts” (Hay, 2012). It is an exciting time in history as we live in an age where technological advances are greater than ever before. We have graduated from a mess of tangled cords to cordless devices and wifi, from cumbersome joysticks to touchscreens and no need for a remote at all (ie. the Kinect). But to imagine playing a game where your mind replaces all physical activity reminds most of us of “something from a late-night science fiction movie or the back of an old comic book” (Hay, 2012), unfathomable to be reality.

I’ll leave you with this. We have all heard the phrase ‘Actions speak louder than words.’ Ponder this: Do the intentions of our mind speak louder than actions? How would *that* change how we assess our students?

eemed so amazing when there was wireless to get over the tangled cords. Then, there was touchscreen and then no need for a remote at all - ie. the Kinect. NOW, you can use your MIND in place of any ACTIONS.   
#Actions may speak louder than words, but NOT louder than your true intentions!!eemed so amazing when there was wireless to get over the tangled cords. Then, there was touchscreen and then no need for a remote at all - ie. the Kinect. NOW, you can use your MIND in place of any ACTIONS.   
#Actions may speak louder than words, but NOT louder than your true intentions!!! :)

References

America’s New Mobile Majority: a Look at Smartphone Owners in the U.S. (2012, May 7). *Nielsen Wire.* Retrieved from <http://blog.nielsen.com/nielsenwire/online_mobile/who-owns-smartphones-in-the-us/>

Antonacci, D.M. & Modress, N. (2008). Envisioning the educational possibilities of user-created virtual worlds. *AACE Journal, 16*, 115-126. Retrieved from <http://www.editlib.org/f/24253>

Ash, K. (2011, January 12). Linking e-courses to “Common Core” academic standards. *Education Week*. Retrieved from <http://www.edweek.org/ew/articles/2011/01/12/15edtech_standards.h30.html>

Ball, L., & Stacey, K. (2005). Teaching strategies for developing judicious use. In National Council of Teachers of Mathematics, *Sixty-seventh yearbook: Technology-supported mathematics learning environments* (pp. 3-16). Reston, NCTM.

Baron, B., Cayton-Hodges, G., Bofferding, L., Copple, C., Darling-Hammond, L., & Levine, M. (2011). *Take a giant step: A blueprint for teaching children in a digital age.* New York: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from <http://www.joanganzcooneycenter.org/upload_kits/jgcc_takeagiantstep.pdf>

Baya’a, N., & Daher, W. (2009). Learning mathematics in an authentic mobile environment: the Perceptions of Students. *International Journal of Interactive Mobile Technologies, 3,* 6–14. <http://thejournal.com/articles/2010/09/08/engaging-girls-in-stem.aspx>

Blume, G. W., & Heid, M. K. (2008). The role of research and theory in the integration of technology in mathematics teaching and learning. In *Cases and Perspectives: Research on Technology and the Teaching and Learning of Mathematics*. (pp. 449-464). Reston: NCTM.

Bonner, F. A., Alfred, M., Lewis, C. W., Nave, F. M., & Frizell, S. (n.d.) Historically black colleges and universities (HBCUs) and academically gifted black students in science, technology, engineering, and mathematics (STEM): Discovering the alchemy for success. *Journal of Urban Education: Focus on Enrichment.* Retrieved from <http://www.cmd-it.org/resources.html>

Branswell, B. (2012, February 20). Study touts benefits of a ‘wired’ classroom. *Montreal: Post Media News.* Retrieved from <http://www.montrealgazette.com/technology/Study+touts+benefits+wired+classroom/6181234/story.html>

Brown, J. S. (2006). New learning environments in the 21st century: Exploring the edge. Forum Futures. Cambridge: Forum for the Future of Higher Education. Retrieved from <http://net.educause.edu/ir/library/pdf/ff0604S.pdf>

Browning, C. A., & Garza-King, G. (2010) Graphing calculators as tools. *Mathematics Teaching in the Middle School, 15,* 481-485.

Buckleitner, W. (1985). Children’s interactive media rating instrument. *Childrens Tech.* Retrieved from <http://childrenstech.com/evaluation-instrument>

Burguillo, J. C. (2010). Using game theory and competition-based learning to stimulate student motivation and performance. *Computers & Education*, *55*, 2, 566–575.

Chamberlein, B. (2012). Trying very hard to make games that don’t stink: User testing at the NMSU learning games lab. *CADRE.* Retrieved from <http://cadrek12.org/resources/presentations/trying-very-hard-make-games-dont-stink-user-testing-nmsu-learning-games-lab>

Chiong, C., & Shuler, C. (2010). *Learning: Is there an app for that? Investigations of children’s usage and learning with mobile devices and apps.* New York: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from <http://joanganzcooneycenter.org/upload_kits/learningapps_final_110410.pdf>

Common Core State Standards Initiative. (2012). Retrieved from <http://www.corestandards.org/the-standards/mathematics>

Corbett, S. (2010, September 15). Learning by playing: Video games in the classroom. *The New York Times.* Retrieved from [www.nytimes.com/2010/09/19/magazine/19video-t.html](http://www.nytimes.com/2010/09/19/magazine/19video-t.html)

Cotten, S. R., Hale, T., M., Moroney, M. H., ONeal, L., & Borch, C. (2011). Using affordable technology to decrease digital inequality: Results from Birmingham’s one laptop per child xo laptop project. *Information, Communication, & Society.* Retrieved from <http://icac.g8four.com/sites/default/files/Cotten,%20Hale,%20Moroney,%20ONeal,%20Borch%20_2011%5B2%5D.pdf>

Cwikla, J. (2005). A vehicle for mathematics lessons: In-service teachers learning to use PDAs in their classroom. In National Council of Teachers of Mathematics, *Sixty-seventh yearbook: Technology-supported mathematics learning environments* (pp. 203-220). Reston, NCTM.

Davis, M. R. (2011, June 15). Schools struggle to balance digital innovation, academic accountability. *Education Week: Digital Directions.* Retrieved from <http://www.edweek.org/dd/articles/2011/06/15/03innovation.h04.html>

Dick, T. P. (2008). Keeping the faith: Fidelity in technological tools for mathematics education. In *Cases and Perspectives: Research on Technology and the Teaching and Learning of Mathematics*. (pp. 333-339). Reston: NCTM.

Donahoo, D. (2012, January 13). 2012: The year of the kids app-cessory. *WIRED*. Retrieved January 24, 2012, from <http://www.wired.com/geekdad/2012/01/kids-app-cessory/>

Ebner, M. & Holzinger, A. (2007). Successful implementation of user-centered game based learning in higher education: an example from civil engineering. *Computers & Education*, *49*, 3, 873–890.

Eglash, R., Bennett, A., O’Donnell, C., Jennings, S. & Cintorino, M. (2006). Culturally situated design tools: Ethnocomputing from field site to classroom. *American Anthropologist, 108,* 347-362. Retrieved from <http://www.cmd-it.org/resources.html>

Eglash, R., & and Bennett, A. (2009). Teaching with hidden capital: Agency in children’s computational explorations of cornrow hairstyles. *Children, Youth and Environments, 19.* Retrieved from <http://www.cmd-it.org/resources.html>

Feistritzer, C. E. (2011). Profiles of teachers in the US 2011. National Center for Education Information. Retrieved from <http://www.ncei.com/Profile_Teachers_US_2011.pdf>

Fonkert, K. L. (2010). Student interactions in technology-rich classrooms. *Mathematics Teacher, 104,* 303-307.

Gee, J. P. (n. d.) Good video games and good learning. *Games for Change.* Retrieved from <http://www.gamesforchange.org/learn/good-video-games-and-good-learning/>

Growing up digital: Adults rate the educational potential of new media and 21st century skills. (2008). *New York: The Joan Ganz Cooney Center at Sesame Workshop.* Retrieved from <http://joanganzcooneycenter.org/images/presentation/growingupdigitalppt.pdf>

Gutnick, A. L., Robb, M., Takeuchi, L., & Kotler, J. (2010). *Always connected: The new digital media habits of young children.* New York: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from <http://joanganzcooneycenter.org/upload_kits/jgcc_alwaysconnected.pdf>

Hay, T. (2012, May 29). Mind-controlled videogames become reality. *The Wall Street Journal.* Retrieved from <http://online.wsj.com/article/SB10001424052702304707604577426251091339254.html>

Heid, M. K. (2005). Technology in mathematics education: Tapping into visions of the future. In National Council of Teachers of Mathematics, *Sixty-seventh yearbook: Technology-supported mathematics learning environments* (pp. 345-366). Reston, NCTM.

Horn, M. (2012, February 20). How “blended learning” and technology can bridge the education gap. *Arabic Knowledge@Wharton.* Retrieved from <http://knowledge.wharton.upenn.edu/arabic/article.cfm?articleid=2785>

Hoyles, C., Noss, R., and Kent, P. (2004). *On the integration of digital technologies into mathematics classrooms.* International Journal of Computers for Mathematical Learning, 9, 309-326.

iPad Apps and Bloom’s Taxonomy. (2012, March 31). *Langwitches Blog.* Retrieved May 8, 2012, from <http://langwitches.org/blog/2012/03/31/ipad-apps-and-blooms-taxonomy/>

Ito, M. (2008). Education vs. entertainment: A cultural history of children’s software. *The Ecology of Games: Connecting Youth,* *Games, and Learning*. Cambridge, MA: The MIT Press. Retrieved from <http://www.mitpressjournals.org/doi/pdf/10.1162/dmal.9780262693646.089>

Johnson, L., Levine, A., Smith, R., & Stone, S. (2010). *The 2010 Horizon Report.* Austin, Texas: The New Media Consortium. Retrieved from from <http://www.nmc.org/publications/horizon-report-2010-higher-ed-edition>

Kapp, K. M. (2007). *Gadgets, Games and Gizmos for Learning: Tools and Techniques for Transferring Know-How from Boomers to Gamers* (1st ed.). Pfeiffer.

Ke, F. (2009). *A qualitative meta analysis of computer games as learning tools.* IGI Global.

Kebritchi, H., Hirumi, A., & Bai, H. (2010). The effects of modern mathematics computer games on mathematics achievement and class motivation, *Computers & Education, 55,* 427-443.

Kim, B., Park, H. & Baek, Y. (2009). Not just fun, but serious strategies: using meta-cognitive strategies in game-based learning. *Computers & Education*, *52*, 4, 800–810.

Klopfer, E., Osterweil, S., & Salen, K. (2009). *Moving learning games forward: obstacles, opportunities, and openness.* Massachusetts Institute of Technology: The Education Arcade. Retrieved from <http://education.mit.edu/papers/MovingLearningGamesForward_EdArcade.pdf>

Knudsen, J. (2010). *Scaling up SimCalc project: Design and development of curriculum units and professional development.* SRI International. Retrieved from <http://math.sri.com/publications/Simcalc_TechReport_07.pdf>

Knuth, E. J., & Hartman, C. E. (2005). Using technology to foster students’ mathematical understandings and intuitions. In National Council of Teachers of Mathematics, *Sixty-seventh yearbook: Technology-supported mathematics learning environments* (pp. 151-164). Reston, NCTM.

Koebler, J. (2012, January 25). *Obama pushes STEM in state of the union.* U.S.News & World Report. Retrieved from <http://www.usnews.com/news/blogs/stem-education/2012/01/25/obama-pushes-stem-in-state-of-the-union>

Krutetskii, V. (1976). *Psychology of mathematical abilities in schoolchildren*. Chicago: The University of Chicago Press.

Lee, J. J. & Hammer, J. (2011). Gamification in Education: What, How, Why Bother? *Academic Exchange Quarterly*, 15.

Lewis, S., Simon, C., Uzsell, C., Orwitz, A., & Casserly, M. (2010, October). *A call for change: The social and educational factors contributing to the outcomes of black males in urban schools.* The Council of the Great City Schools. Retrieved from <http://www.cgcs.org/cms/lib/DC00001581/Centricity/Domain/27/Call_For_Change.pdf>

Madden, S. R. (2010). Designing mathematical learning environments for teachers. *Mathematics Teacher, 104,* 274-282.

McCrea, B. (2012, February 2). 5 K-12 e-learning trends. *THE Journal: Transforming Education through Technology.* Retrieved February 13, 2012, from <http://thejournal.com/Articles/2012/02/02/5-K12-E-Learning-Trends.aspx?p=1>

McGraw, R., & Grant, M. (2005). Investigating mathematics with technology: Lesson structures that encourage a range of methods and solutions. In National Council of Teachers of Mathematics, *Sixty-seventh yearbook: Technology-supported mathematics learning environments* (pp. 303-318). Reston, NCTM.

McSherry, J. (2005). Challenges persist for minorities and women*. Electronic Design.* Retrieved from <http://www.cmd-it.org/resources.html>

Means, B., Toyama, Y., Murphy, R., Bakia, M., & Jones, K. (2010). *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies.* U.S. Department of Education: Center for Technology in Learning. Retrieved from <http://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf>

Medbery, J. (n. d.). *Reinventing education to teach creativity and entrepreneurship.* New York, NY:Co.Exist. Retrieved from <http://www.fastcoexist.com/1679771/reinventing-education-to-teach-creativity-and-entrepreneurship>

Millstone, J. (2012) *Teacher attitudes about digital games in the classroom.* New York: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from <http://www.joanganzcooneycenter.org/images/presentation/jgcc_teacher_survey.pdf>

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. Teaching and Teacher Education, 21, 509-523.

New U.S. Smartphone Growth by Age and Income. (2012, February 20). *Nielsen Wire.* Retrieved February 23, 2012, from <http://blog.nielsen.com/nielsenwire/online_mobile/survey-new-u-s-smartphone-growth-by-age-and-income/>

Ogg, E. (2012, May 7). 5 questions with the creator of the first iPad-made iOS game. *Apple News: Tips and Reviews.* Retrieved May 7, 2012, from <http://gigaom.com/apple/5-questions-with-the-creator-of-the-first-ipad-made-ios-game/>

Olive, J. (2011). *Research on Technology in Mathematics Education: Theoretical Frameworks and Practical Examples.* Presented Korea Society of Educational Studies in Mathematics Conference. Seoul, South Korea.

Osborne, C. (2012, April 9). One Laptop per Child: Disappointing results? *ZDNet.* Retrieved from <http://www.zdnet.com/blog/igeneration/one-laptop-per-child-disappointing-results/15920>

Preparing the next generation of STEM innovators: Identifying and developing our nation’s human capital. (2010, May 5). *National Science Board.* Retrieved from <http://www.nsf.gov/nsb/publications/2010/nsb1033.pdf>

Prensky, M. (2007). *Digital Game-Based Learning*. Paragon House.

Principles and Standards (2000). The National Council of Teachers of Mathematics. Retrieved from <http://www.nctm.org/standards/default.aspx?id=58>

Quillen, I. (2011, June 15). Educators evaluate learning benefits of iPad. *EdWeek: Digital Directions.* Retrieved from [www.edweek.org/dd/articles/2011/06/15/03mobile.h04.html](http://www.edweek.org/dd/articles/2011/06/15/03mobile.h04.html)

Riconscente, M. (n. d.). *Mobile learning game improves 5th graders’ fractions knowledge and attitudes.* Los Angeles: GameDesk. Retrieved May 3, 2012, from <http://www.gamedesk.org/reports/MM_FINAL_REPORT.pdf>

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). *Generation M2: Media in the Lives of 8- to 18-Year-Olds.* Kaiser Family Foundation. Retrieved from <http://www.kff.org/entmedia/mh012010pkg.cfm>

Robinson, Sir Ken. (2006). Selected readings retrieved from <http://sirkenrobinson.com/>

Roschelle, J., Tatar, D., Shechtman, N., Hegedus, S., Hopkins, B., Knudsen, J., & Stroter, A. (2007). *Scaling up SimCalc project: Can a technology enhanced curriculum improve student learning iof important mathematics?* SRI International. Retrieved from <http://math.sri.com/publications/SimCalc_TechReport_01.pdf>

Roschelle, J., Tatar, D., Shechtman, N., Hegedus, S., Hopkins, B., Knudsen, J., & Stroter, A. (2007). *Scaling up SimCalc project: Can a technology enhanced curriculum improve student learning iof important mathematics?* SRI International. Retrieved from <http://math.sri.com/publications/Tech_Report2_FINAL.pdf>

Ruthven, K., & Hennessy, S. (2002). A practitioner model of the use of computer-based tools and resources to support mathematics teaching and learning. *Educational Studies in Mathematics, 49,* 47-88.

Sarama, J., & Clements, D. H. (2008). Linking research and software development. In *Cases and Perspectives: Research on Technology and the Teaching and Learning of Mathematics*. (pp. 113-130). Reston: NCTM.

Shaughnessy, J. M. (2012, February 12). STEM: An advocacy position, not a content area. NCTM *Summing Up.* Retrieved from <http://www.nctm.org/about/content.aspx?id=32136>

Shore, R. (2008). *The Power of pow! wham!: Children, digital media & our Nation’s future. Three challenges for the coming decade.* New York: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from <http://joanganzcooneycenter.org/upload_kits/cooney_challenge_advance_1_.pdf>

Shuler, C. (2012). *iLearn II: An analysis of the education category of the iTunes app store.* New York: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from <http://joanganzcooneycenter.org/upload_kits/ilearnii.pdf>

Shuler, C. (2009). *Pockets of potential: Using mobile technologies to promote children’s learning.* New York: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from <http://joanganzcooneycenter.org/upload_kits/pockets_of_potential_1_.pdf>

Simon, C., Lewis, C., Uro, G., Uzzell, R., Palacios, M., & Casserly, M. (2011, October). *Today’s promise, tomorrow’s future: The social and educational factors contributing to the outcomes of Hispanics in urban schools.* The Council of the Great City Schools. Retrieved from <http://www.cgcs.org/domain/27>

Soucie, T., Radovic, N., & Svedrec, R. (2010). Making technology work. *Mathematics Teaching in the Middle School, 15,* 467-471.

Speak up 2011: National findings K-12 teachers, librarians, and administrators. *Project Tomorrow.* Retrieved from <http://www.tomorrow.org/speakup/pdfs/SU11_PersonalizedLearning_Educators.pdf>

Squire, K. (2005.) Changing the game: What happens when video games enter the classroom? *Innovate,* 1. Retrieved from <http://www.innovateonline.info/index.php?view=article&id=82>

Stald, G. (2008). Mobile identity: Youth, identity, and mobile communication media. *Youth, Identity, and Digital Media*. Cambridge, MA: The MIT Press. Retrieved from <http://www.mitpressjournals.org/doi/pdfplus/10.1162/dmal.9780262524834.143>

State of the African American Consumer. (2011, September). *The Nielsen Company.* Retrieved from <http://www.nielsen.com/content/dam/corporate/us/en/reports-downloads/2011-Reports/StateOfTheAfricanAmericanConsumer.pdf>

Steen. (2007). Retrieved from <http://www.corestandards.org/the-standards/mathematics>

Steffe, L.P., & Olive, J. (2002). Design and use of computer tools for interactive mathematical activity (TIMA). *Journal of Educational Computing Research, 27,* 55-76.

Successful STEM Education: A Workshop Summary. (2011). *National Research Council.* Retrieved from <http://www7.nationalacademies.org/dbasse/Successful_K12_STEM_Education_PDF.pdf>

Suh, J. (2010). Tech-knowledgy & diverse learners. *Mathematics Teaching in the Middle School, 15,* 440-447.

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research, 81,* 4-28. Retrieved from <http://rer.sagepub.com/content/81/1/4.full.pdf+html>

Tang, S. & Hanneghan, M. (2011). State-of-the-Art Model Driven Game Development: A Survey of Technological Solutions for Game-Based Learning. Journal of Interactive Learning Research, 22, 551-605. Chesapeake, VA: AACE.

Technology and Interactive Media as Tools in Early Childhood Programs Serving Children from Birth through Age 8: Position Statement. (2012, January). *National Association for the Education of Young Children and the Fred Rogers Center for Early Learning and Children’s Media.* Retrieved from <http://www.naeyc.org/files/naeyc/file/positions/PS_technology_WEB2.pdf>

The state of online gaming among tween girls in the US. (2012) *Spilgames.* Retrieved from <http://www.spilgames.com/wp-content/uploads/2012/05/StateOfGamingTweenGirls_US_Q1_2012.pdf>

Toppo, G. (2012, February 1). Obama wants schools to speed up digital transition. *USA Today.* Retrieved from <http://www.usatoday.com/news/education/story/2012-01-31/schools-e-textbooks/52907492/1>

Trends in U.S. Video Gaming – the Rise of Cross-Platform. (2012, March 9). *Nielsen Wire.* Retrieved from <http://blog.nielsen.com/nielsenwire/consumer/the-latest-trends-in-us-video-gaming/>

Van Eck, R. (2006). Digital game-based learning: It’s not just the digital natives who are restless. *EDUCAUSE Review, 41,* 16-30. Retrieved from <http://net.educause.edu/ir/library/pdf/ERM0620.pdf>

Vincent, K. (2012, February 15). *Whizz education: Schools tapping technology to make and measure math gains.* Seattle, WA: PR Web. Retrieved from <http://www.prweb.com/releases/2012/2/prweb9196733.htm>

Vogel, J. J. & D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis*. Journal of Educational Computing Research, 34,* 229-243.

Wallis, C. (2010). *The impacts of media multitasking on children’s learning and development.* New York: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from <http://joanganzcooneycenter.org/upload_kits/mediamultitaskingfinal_030510.pdf>

Wang, L. C. & Chen, M. P. (2010). The effects of game strategy and preference-matching on flow experience and programming performance in game-based learning. *Innovations in Education and Teaching International*, *47*, 39–52.

Wicks, M. (2010). A National Primer on K-12 Online Learning. *International Association for K-12 Online Learning.* Retrieved from <http://www.inacol.org/research/docs/iNCL_NationalPrimerv22010-web.pdf>

Williams, D., Martins, N., Consalvo, M., & Ivory, J. D. (2009). The virtual census: representations of gender, race, and age in video games. *New Media & Society, 11,* 815-834. Retrieved from <http://dmitriwilliams.com/VirtualCensusFinal.pdf>

Wilson, P. S. (2008). Teacher education: A conduit to the classroom. In *Cases and Perspectives: Research on Technology and the Teaching and Learning of Mathematics*. (pp. 415-426). Reston: NCTM.

Wu, W & Y. J., Chen, C., Kao, H., Lin, C., & Huang, S. (2012) Review of trends from mobile learning studies: A meta-analysis. *Computers & Education, 59,* 817-827.

Young, Mobile and Growing: The State of U.S. Hispanic Consumers. (2012, April 17). *Nielsen Wire.* Retrieved from <http://blog.nielsen.com/nielsenwire/consumer/young-mobile-and-growing-the-state-of-us-hispanic-consumers/>

Zbiek, R. M., & Hollebrands, K. (2008). A research-informed view of the process of incorporating mathematics technology into classroom practice by in-service and prospective teachers. In *Cases and Perspectives: Research on Technology and the Teaching and Learning of Mathematics*. Reston: NCTM.

Zero to Eight: Children’s Media Use in America. (2011). Common Sense Media. Retrieved from <http://www.commonsensemedia.org/sites/default/files/research/zerotoeightfinal2011.pdf>

Zucker, A. (2011). Transforming schools: Is it rocket science? *On Cue.* Retrieved from <http://www.concord.org/research/articles-and-papers>