

Digital Natives, STEM Learning and Video Games

The Case for Using Games to Learn



ABSTRACT

Coindexter.com is an MMO game-based virtual world filled with learning excitement. Students work within a role-playing model to learn STEM concepts by applying critical thinking and problem-solving skills. This paper outlines the research behind the use of video games in K12 education to promote deep understanding of STEM concepts through the inherent learning qualities of video gaming.

“Our students have changed radically. Today’s students are no longer the people our educational system was designed to teach.”¹

“By the time NetGeneration kids reach their 20s, the typical Net Gener has spent over 20,000 hours on the Internet and over 10,000 hours playing video games of some kind.”²

“[Students] born in the early 1990s have never lived in a world without a global network. The most recent kids to enter schools, those born since the early 2000s, have never known a world in which that global network was not accessible from the palm of your hand.”³ (Horizon Report 2010)

Today’s Digital Natives

Young people interact with media multiple times per day, often at the same time. The speed with which today’s youth switch between texting, instant messaging, communicating with each other via social media, and using smart phones for a multitude of purposes can be dizzying for Digital Immigrants. Although Digital Immigrants may see this characteristic of young people as indicative of a short attention span, in fact what is happening is far more complex as evidenced by the amount of time that Digital Natives can focus on a movie – or a video game.

Today’s Digital Natives *view* the world differently. Tapscott⁴ identifies eight norms of the “net generation”: freedom, customization, scrutiny, integrity, collaboration, entertainment, speed and innovation. They are accustomed to a world in which they not only interact, but also collaborate and *create* at will. Wikipedia is a clear example of a massive crowd-sourced knowledge base. This globally ubiquitous, self-monitored site illustrates how traditional views on knowledge and learning have *already been restructured*.

The characteristics of the net generation identified by Tapscott are very similar to the skills that are touted as essential for the 21st century workforce. The Partnership for 21st Century Skills identifies critical thinking, communication, collaboration and creativity as key characteristics

¹Prensky, M., (2001a). Digital Natives, Digital Immigrants, in *On the Horizon*, MCB University Press, Vol. 9 No. 5, October 2001, p. 1. Available at: <http://bit.ly/cq6JPF>

²Tapscott, D., (2009). *Grown Up Digital: How the Net Generation Is Changing Your World*, McGraw-Hill, New York, NY, p. 100.

³Johnson, L., Smith, R., Levine, A., and Haywood, K., (2010). *The 2010 Horizon Report: K-12 Edition*. Austin, Texas: The New Media Consortium, p. 17 Available at: <http://wp.nmc.org/horizon-k12-2010/>

⁴Tapscott, 2009.

that need to be merged with the 3 Rs to ensure that we are preparing today's students for today's workforce.⁵

The Current STEM Skills Crisis

There has been an increasing focus on STEM education in the United States and with good reason. A recent National Academy of Sciences report that assessed the current state of American global competitiveness paints a rather stark picture. The report stresses that the "primary driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science and engineering".⁶

The authors identify three key factors that foster successful innovation:

- New knowledge
- Capable people
- An environment that promotes innovation and entrepreneurship.⁷

At the same time, the US now ranks 40th out of 40 countries and regions in an analysis of EU and US innovation and competitiveness.⁸ While there are a variety of factors unrelated to education that can stifle innovation in science, technology and engineering, there is no doubt that if science, engineering and technological advancement are the keys to economic growth, then it is imperative that we foster STEM skills in school and encourage more students to enter STEM-related professions. Currently, only 16% of students enrolled in American undergraduate programs are studying the natural sciences or engineering.⁹ Many of them will never complete their degree.

It is not enough however, to merely encourage students to pursue higher education in STEM fields. The President's Council of Advisors on Science and Technology (PCAST)¹⁰ and the National Research Council¹¹ have both called for a re-thinking of STEM education as critical to

⁵ www.p21.org

⁶ 2005 Rising Above the Gathering Storm Committee, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5*, National Academies Press, Washington, D.C., 2010, p. 2. Available at: http://www.nap.edu/catalog.php?record_id=12999

⁷ Ibid., p. 44.

⁸ Information Technology and Innovation Foundation, *The Atlantic Century: Benchmarking EU & U.S. Innovation and Competitiveness*, February 2009. Available at: <http://www.itif.org/files/2009-atlantic-century.pdf>

⁹ Rising Above the Gathering Storm Committee, 2010, p. 49.

¹⁰ The President's Advisory Council on Science and Technology (PCAST), *Report to the President, Prepare and Inspire: K-12 Education in Science, Technology, Engineering and Math (STEM) for America's Future*, Executive Office of the President, Washington D. C., 2010. Available at: <http://1.usa.gov/bEfEhC>

¹¹ Committee on Highly Successful Science Programs for K-12 Science Education, Board on Science Education and Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education, National Research Council, *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*, National Academy Press, Washington, DC, 2010. Available at: http://www.nap.edu/openbook.php?record_id=13158&page=R1

ensuring that we have the STEM-skilled workforce we need in the future. Not only do we need today's students to become tomorrow's scientists. *All* students will need to use STEM-related skills in order to be successful.

*“Personal and social decisions in the 21st century increasingly require scientific and technological understanding. Whether about health, the environment, or technology, a certain level of scientific understanding is vital to informed decision-making”.*¹²

And yet, according to 2009 NAEP scores¹³, only 34% of 8th graders tested at or above proficient in mathematics.¹⁴ In science, only 30% of 8th grade students scored at or above the proficient level. In high-poverty schools, the situation is worse, with only 8% of students scoring at proficient or above in science. Internationally, the U.S. is also lagging behind other countries in math and science proficiency. The 2007 Trends in International Mathematics and Science Study (TIMSS) places only 10% of U.S. 8th graders as advanced, compared to 25% in China and 32% in Singapore.¹⁵ 30% of young people in America fail to receive a high school diploma¹⁶ and the US is now 20th in high school graduation rate among industrialized nations.

One of the big challenges in encouraging students to pursue STEM related careers in the future is schools' ability to engage these students in elementary school. The National Research Council notes “effective instruction capitalizes on students' early interest and experiences, identifies and builds on what they know, and provides them with experiences to engage them in the practices of science and sustain their interest.”¹⁷

Technology is a major catalyst for innovation in STEM education and PCAST notes the promise of STEM games and simulations in this area.¹⁸

Focus on STEM Education

¹² Ibid., p. 3.

¹³ National Center for Education Statistics National Assessment Governing Board, Institute of Education Sciences, *The Nation's Report Card, Math 2009: National Assessment of Educational Progress at Grades 4 and 8*, US Department of Education, 2010. Available at: <http://nces.ed.gov/nationsreportcard/pdf/main2009/2010451.pdf>

¹⁴ National Center for Education Statistics National Assessment Governing Board, Institute of Education Sciences, *The Nation's Report Card, Science 2009: National Assessment of Educational Progress at Grades 4, 8, and 12*, US Department of Education, 2010. Available at: <http://nces.ed.gov/nationsreportcard/pdf/main2009/2011451.pdf>

¹⁵ Mullis, Ina V. S. et. al., TIMSS 2007 International Mathematics Report, TIMSS & PIRLS International Study Center, Boston College, Boston, MA, 2008. Available at: http://timss.bc.edu/TIMSS2007/PDF/TIMSS2007_InternationalMathematicsReport.pdf

¹⁶ Rising Above the Gathering Storm Committee, 2010.

¹⁷ Committee on Highly Successful Science Programs for K-12 Science Education, 2010, p. 18.

¹⁸ PCAST, 2010, p. 85.

The government also sees a focus on STEM in K-12 education as the key to meeting the globalization challenge and reversing the current trends. Competitive Race to the Top funding included STEM as a priority and the President's Educate to Innovate initiative is directly focused on fostering partnerships between private companies, schools and STEM professionals to improve STEM literacy nationwide.

There is also more of a focus on applied learning and higher order thinking skills than ever before with the implementation of national Common Core Standards across the country. The adoption of Common Core Standards in English Language Arts and Math have necessitated a rethinking of the curriculum taught in schools and the need to incorporate higher order thinking skills and applied learning. It is expected that upcoming science standards will follow suit.

When discussing 21st century skills and STEM it is important to remember that many Digital Natives are already using 21st century skills and collaborating and innovating on their own terms via social media and increasingly sophisticated video games. *It's what they do when they are not at school.* The challenge for educators is to reflect the world of today's students and engage them with the 21st century tools students use every day. The crisis in STEM skills development and workforce readiness provides a clear opportunity to marry the world of the Digital Native and the required skills for a globally competitive workforce with the *content* that is taught in schools.

Video Games, Applied Learning and STEM

Research into the effects of gaming offer some insight into why Digital Immigrants insist that Digital Natives are different. Video gaming has become an embedded modern leisure activity since the 1970s. Over this time, video games have continued to become more sophisticated, life-like and interactive, and kids are playing them more than ever before. Research shows that gamers are more adept at processing, tracking, and monitoring visual information than non-gamers and these skills improve when non-gamers begin using games.¹⁹

Not only do Digital Natives have better visual perception, it is now being argued that through video games, new ways of thinking are evolving such as the ability to:

- Process a large amount of complex information quickly
- Identify relevant and irrelevant information
- Process information in parallel
- Access information via imagery first.²⁰

¹⁹ Green, C. S. & Bavelier, D., *Action Video Game Modifies Visual Selective Attention*, Nature, Vol. 423, May 2003.

²⁰ Klopfer, Eric, et. al., *Using the Technology of Today, In the Classroom Today*, Education Arcade, MIT, 2009, p. 6. Available at: http://education.mit.edu/papers/GamesSimsSocNets_EdArcade.pdf

And yet the schools of today remain largely unchanged from decades ago at a time when 30% of young people in this country never finish high school. That number can reach 50% in some urban environments. In order to be ready to learn, students must be engaged. What better way to foster an interest in STEM than using the mediums that they are so interested in when they are not in school?

If motivation to learn is the cornerstone of engagement, then video game designers have much to offer educators since “*motivation itself* is the expertise” that they possess.²¹ Games that aren’t interesting don’t last long in the marketplace.

Digital game-based learning (DGBL) has come a long way from the early days of MathBlaster and Reader Rabbit. The sophistication of game design today enables players to interact with the gaming environment in ways that provide unprecedented opportunities for STEM learning. DGBL offers the ability to take a student into a virtual reality in which they can become the scientist, explorer or ruler of the virtual world. Simulation games allow players to *create* the virtual world and within it test hypotheses and understand complicated inter-relationships and their outcomes. Massively-multiplayer online role-playing games (MMORPG) allow players to assume roles, interact with each other, share knowledge, work for or against each other, and form alliances in order to advance in the game. The MMORPG world has its own culture, economy and rules that exist and continue to evolve even when the player is not engaged in the game. These games can also be open-ended “sandbox” games in which users do not need to follow a linear sequence of challenges. Rather they have the freedom to explore and choose their challenges as they wish. All of these genres have much to offer STEM instruction as they provide an environment within which applied learning is easily fostered and in which educators can nurture the learning process through the inherent taxonomy of gaming.

Gaming to Learn

Research into video games show that games inherently employ a variety of good learning principles. When these gaming principles are applied to subject area content, supplementing instruction with video games can be effective and engaging for students.

Over the last decade, an ever-increasing body of knowledge has emerged about the learning systems inherent in successful video games.

Gee provides a useful list of learning principles inherent in all good games.²² They include:

- Identity – through the gaming identity of the player, games immediately engage the player's sense of self, a critical factor in fostering deep learning

²¹Prensky, M., Digital Game-based Learning, ACM Computers in Entertainment, Vol. 1, No. 1, October 2003, Book 2, p. 1.

²²Gee, J. P., *Good Video Games and Good Learning*, Phi Kappa Phi Forum, V 85, No. 2.

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- Production – players are producing their own environment within the game, and in many cases can modify games. Applying these concepts to STEM opens up a world of applied learning opportunities within a safe and risk-free virtual environment
- Well-ordered problems that foster challenge and consolidation – the taxonomy of video games is designed so that players use what they have learned from previously solved problems and build on them to solve more complex problems as players advance in the game. Video games let students master the challenges, and after a period of practice, integrate what they have learned into an even harder challenge. This is exactly what differentiated instruction is trying to achieve
- Fosters systems thinking – Video games require players to consider the inter-relationships of the game and how doing one thing will have an impact on a number of other things in the game. This is the essence of applied learning.
- Explore, Think Laterally, Rethink Goals – gamers are encouraged to use exploration and lateral thinking to evaluate and revise their goals within the game. All of these are good elements of scientific inquiry.

Prensky provides a useful description of gaming and its embedded learning principles by identifying the following levels of learning that occur in video games.²³

- Learning how – Gamers learn by doing. They are in control of their environment and they learn how the game works by using the controller to manipulate the gaming environment. Whether that is firing a bird from a slingshot or manipulating their avatar through a virtual environment, the gamer learns through **practice**.
- Learning What –The first thing a gamer must do is learn the rules of the game. Video gamers don't do it by reading the instructions; they do it by exploring the gaming environment and using trial and error. This skill directly correlates to scientific inquiry.
- Learning Why – Gamers learn strategy playing video games. Through practice and learning the rules of the game, gamers apply that knowledge to advance in the game. They learn life skills in cause and effect, long-term winning versus short-term gains, complex systems behaviors, counter-intuitive results, and the value of persistence. Players are also learning and using skills of collaboration when playing massive multi-player online (MMO) games where they are interacting with other gamers.
- Learning where and when/whether – At these levels, Prensky identifies that gamers are learning important lessons about cultural and environmental differences through their immersion in the virtual world. The rules of one world do not necessarily correspond to another. And finally, at the most advanced level, gaming

²³Prensky, M., *What Kids Learn That's POSITIVE From Playing Video Games*, 2002. Available at: <http://bit.ly/k8JwYd>

teaches gamers about life through the allegory, myth and consequences of the virtual world. It is at these highest levels that video games offer an opportunity to facilitate integrated learning in STEM.

Gee notes that video games can even offer educators an effective learning model to draw from outside of the gaming environment. Video games inherently possess the values of “motivation, clear goals, interpreted outcomes, and immediate and copious feedback.”²⁴ In addition, video games contain an in-built hierarchy of knowledge and skills in which the player must demonstrate mastery before “leveling up”. The assessment is internal.

For example, a traditional learning unit on the human impact on our environment may involve learning about energy, water, weather, pollution and the inter-relationships between all of these. This learning may culminate in a project on a particular topic in which the students create models or conduct tests of local water samples. DGBL offers the ability for students to develop deeper understanding of the human impact on the environment by experiencing it in a virtual world.

Coindexer provides students with this opportunity.

Coindexer: A New STEM Video Game

Coindexer.com is an MMO game-based virtual world filled with learning excitement. Students work within a role-playing model to learn STEM concepts by applying critical thinking and problem-solving skills. An important mission of players on Coindexer.com is to defeat Professor Coindexer’s arch-nemesis, Viktor Poluta, and to protect the city of Econopolis from his environmentally dangerous practices.

As players, students must monitor and maintain a healthy environment by protecting the earth’s natural resources as well as the city’s economic stability.

Students advance through the game by applying STEM skills to maximize their personal positive impact on the virtual world of Econopolis. By doing so, they gain a greater understanding of life, earth, and physical sciences and the potential for both positive and negative human influence on the world’s resources.

Game players use math and engineering skills to create efficient technologies that protect the planet and simultaneously insure its economic and monetary health – the real-life challenge of every human.

²⁴ Gee, J. P., quoted in *Ten Surprising Truths About Video Games and Learning*, Mindshift. Available at: <http://bit.ly/dEsBb2>

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The Coindexer Teacher Control Panel provides performance data that tracks student performance. The data is presented in a simple and intuitive format every teacher will appreciate. Teacher reports provide data for monitoring student understanding of STEM concepts as well as the increasingly complex critical thinking skills required to achieve higher game levels.

By combining STEM concepts with the principles of good learning game design, Coindexer provides an exciting opportunity to use the medium of Digital Natives to enrich STEM learning.