Cases on E-Learning Management:

Development and Implementation

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Chapter 5
Video Gaming for STEM Education

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EXECUTIVE SUMMARY

The focus of this chapter is how video games can be utilized for instructional purposes, specifically in the STEM areas (Science, Technology, Engineering, and Mathematics). Gaming, as an instructional tool, enables educators to create participatory learning activities, assess understanding of complex and ill-formed situations, facilitate critical thinking and problem solving capabilities, and ensure active engagement across the learning continuum for all students. How to use it effectively, however, is a topic of debate among many educational scholars.

In order to create innovative ways to teach classic concepts using video games, instructors need diverse skills: technology skills to access video games that meet the needs of today's learners for active engagement, instructional skills to integrate theory and practice, as well as adhere to the standards of academic rigor, and leadership skills to guide students to higher levels of critical and creative thinking.

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Therefore, this chapter will explore the vast world of video games and the opportunities for instructors to incorporate them into lesson planning. The basis of this empirical work is to align the guiding principles of STEM with the identification of accessible games, based upon learning principles and assessment strategies. The challenge for 21st century educators will be how to bridge the gap between the traditional development of skill sets to meet workforce demands in a dynamically changing global economy that simultaneously creates employees who are capable of innovation, collaboration, and deep critical thinking.

GAMEPLAY AND LEARNING

To this point, there have been many successful implementations of gaming for educational purposes. One example is a study by Rosser, Lynch, Haskamp, Gentile, and Yalif (2007), which was conducted at the Beth Israel Medical Center in New York for the Laparoscopic Skill and Suturing Program. The participants were introduced to Gastrointestinal and Colonoscopy procedures using a specially designed videoscopic surgical environment. The video games were Super Monkey Ball, Star Wars: Racer Revenge, and Silent Scope. Each game tested a specific skill that would be applicable surgical techniques such as depth perception, spatial awareness, task accuracy, precision, and speed. The study found a correlation between video gaming skills and laparoscopic surgical skills "those surgeons whose video gaming exceeded three hours or more per week, had 37% fewer errors and 27% faster completion in the Rosser Top Gun Laparoscopic Skills and Suturing program than did their non-gaming counterparts."

The benefits of using games in all of the STEM areas, not just science, are noted throughout the literature. Implementation of their use is evolving. Some of the hindrances to their incorporation into the total spectrum of best practices for learning are: the cost of the technology, thus insufficient hardware and software, the unwillingness of some educators to try new pedagogical techniques, and the lack of educator training. Most of the articles also point to the lack of empirical evidence to prove that the games actually do impact learning and to what extent.

In 2003, Rollings and Adams defined gameplay as "one or more causally linked series of challenges in a simulated environment" (Kiili, 2004, p. 16). It is these progressive challenges that engage the players and connect them with the game by continually testing their skills and checking for understanding and compliance of the rules before allowing them to advance. By presenting both well-defined and ill-defined scenarios, players must continually re-evaluate their strategies and test contrasting situations to progress through the game's hierarchical intricacies. It is the specific process that provides the educational bridge to learning, not only about the complexities of the game, but also contributes to the player's higher level of critical and creative thinking. It is through exploration and testing ideas in the game that provides results.

The simulations in the games create a highly interactive environment for reflective learning and processing of experiences. According to Clark and Mayer (2008), several principles would be engaged in this process: The Segmenting Principle would have the learning process broken down into phases or manageable chunks where the learners could practice independently and then interact with other players; and, the Personalization Principle would be evidenced by the conversational style that emerges in the gaming community. Mini societies emerge within the game because individual players create unspoken rules. Interestingly enough, much of the dialogue that takes place within the game has nothing to do with the dynamics of playing the game. Players were using this time to bond and form strong social networks. These social networks included players from all around the world, creating a link that fashioned intricate team building between people who would otherwise never interact.

Team building is essential to learning, as well as functioning in the workplace. We, as humans, gravitate towards a group for a sense of belonging. The act of even assigning a name to a certain group can form a sense of community. Ellis asserts, "A meta-analysis of team building research found that team building interventions tend to emphasize at least one of four possible components: goal setting, interpersonal relations, problem solving, and role clarification." All of this can be realized within the group dynamics and encouraged with specific gameplay expectations. Clark and Mayer (2008), posits, "To be effective, the goals, activities, feedback, and interfaces of simulations and games must align with the desired instructional outcomes."

Van Eck (2006) states, "Jeopardy-style games, a staple of games in the classroom, are likely to be best for promoting the learning of verbal information (facts, labels, and propositions) and concrete concepts. Arcade-style games… are likely to be best at promoting speed of response, automaticity, and visual processing. Adventure games are likely to be best for promoting hypothesis testing and problem solving." It is critical, therefore, that we understand not just how games work, but how different types of games work and how game taxonomies align with learning taxonomies" (Clark & Mayer, 2008, p. 358).

The common theme found throughout indicates that gaming and its effect on learning is positive. Games are adaptable to almost any subject. They provide immediate responses, experiential learning, and social interaction. They allow for a proactive, exploratory nature and the competition stimulates the students' involvement. Students learn by doing. The games allow for simulations of experiences students might never have the possibility of experiencing in real life. Students who are strong in specific content areas but weak in others can combine their strengths to feel more successful (Cheng, Holmes, Leonard, & Minogue, 2009).

In addition to providing aid to the instructional process, video games can serve as a motivational factor because of the interaction and reward system that a game provides. The rewards that players receive are intrinsic motivation. As players improve specific skills, they are promoted to the next level. This provides positive reinforcement and encourages players to work at specific objectives in order to obtain all of the trophies. From a learning perspective, the reward for the player (the student) is the act of playing the game and continuing to explore new possibilities that the game offers. "Intrinsic motivation tends more to be appetitive, new information arousing a slight interest leading to an appetite for more" (Beswick, 2007). Using video games as a motivator provides an environment that gives the student the desire to learn. They "recast a learning task into one that is game-like which fundamentally alters the experience of the learner… they introduce tension and crises to simulate the real experience for practice" (Neal & Quinn, 2011). Since the skill is placed in context within the game that the learner has to explore, the learning experience becomes immersive. The game serves as practice in the overall learning experience and challenges the learner to stay engaged.

STEM EDUCATION

Brooks-Young (2010) identified top skills that are requisite for today's workers. These skills, collaboration, professionalism, critical thinking and problem solving, were also discussed by the After School Alliance (2007). A call to action is evidenced by the following facts:

- 80% of future jobs will require STEM literacy and skills.
- Students in the United States rank 25th in math and 17th in science among their peers in industrialized countries.
- Only 43% of graduating seniors are ready for college math and 27% are ready for college science.
- 32% of U.S. college undergraduates are graduating with a bachelor's degree in science or engineering.

The last boom in STEM careers happened after the first moon landing and "today, just under half of NASA's scientists and engineers could retire" (Demski, 2009). Since there is a need to increase participation and interest in STEM areas, President Obama issued a national call to action to promote STEM education. As a result, a partnership of industry groups and technology companies was formed to focus on creating video games to promote STEM education. Michael D. Gallagher, CEO of the trade association representing U.S. computer and video game publishers states, "Computer and videogames are one of the most effective ways to reach America's children and encourage them to remain interested in vital STEM principles" (Avonowitz, 2009).

Science

Science is a subject of complex vocabulary, tedious reading, and is, at times, hard to understand. How can we move away from the typical 2D diagrams and pictures and unrelenting vocabulary and use something that makes science fun, interesting, and a little easier to learn? Scientists and educators say video games can reshape education (Cronin, 2009). When they are used to simulate real-world situations, they help students develop critical thinking skills and enhance understanding (Greenemeier, 2009). One example of how gaming can be used in a real-world situation is through CellCraft. In this game, students become cells and have to keep themselves alive. The format motivates students while they are learning the parts of a cell and the new vocabulary associated with cells (Pederson, 2011). Another game being developed for science education portrays how diseases simultaneously affect health in a fictitious city. Students learn how disease is spread and the impact of human interactions (Greenemeier, 2009). While some of these games cost money, others can be obtained free of charge. The free interactive game "Dissect a Frog" from the website Surgery Games provides the detailed experience of performing an actual dissection, complete with guiding the simulated tools to perform the surgery. Students then are required to identify different parts of the frog's anatomy. This game can be used in any level science class or advanced classes of anatomy and physiology.

The River City Research project, with funding from the National Science Foundation, has developed an interactive computer simulation to help middle level science students learn scientific inquiry and 21st century skills. One particular article states: "A variant of the *River City* ecology game diminished the learning gap between D and B students to the point where nearly all students were performing at the B level" (Mayo, 2009). All of the articles that apply say similar positive things when it comes to the use of video games and learning academic subjects. Unlike lectures, games can be adapted to the pace of the user because complex tasks are presented first as a small core experience that is practiced multiple times before being extended into a longer, more complex sequence. Another reason is due to how the content is reinforced through continuous, immediate feedback. In addition, seeing visual progress through points, awards, levels and titles can also boost confidence and self-efficacy. Lastly, learner control and navigation through activities and tasks can prove an important feature of effective learning games.

A study evaluated a Multiplayer Educational Gaming Application (MEGAs) covering key genetic concepts in a high school biology course. MEGAs are teacher created for instructional purposes with the classroom teacher as the primary game author. This is convenient because the teacher can make modifications and adaptations at any time. The study focused on how the game impacted the understanding of genetics and engagement in science class activities. It compared the impact of using the game as opposed to traditional instructional methods. The question they posed, "Is genetics difficult to teach and learn?" Can MEGAs help? The MEGA was used only as a review for a unit test. The study used a posttest only control group. The control group used traditional review strategies. The two groups of students reviewed for an identical unit test. The test performance showed no difference in achievement, but the study also used the Protocol for Classroom Observations to observe student engagement. The group using the MEGA was more engaged and was more motivated to interact longer. The game was a "hook" that got the learners to participate (Cheng, Holmes, Leonard, & Minogue, 2009).

The MEGA study authors noted its limitations. The empirical research about the impact of video games is limited at this time. The Federation of American Scientists advocate a study to determine "… how the addictive pizzazz of video games can be converted into serious learning tools." There will soon be 75 million Americans 10-30 years old that grew up on video games and 45 million households that have video consoles. They note the success of using games in training the military and suggest that interactive games be exploited to teach children (Feller, 2006).

Technology

The world of technology is rapidly expanding and encompasses many fields in the market today. Emerging trends such as mobile technology and cloud capabilities has tremendously impacted the way we live and play. In terms of learning applications, a skilled instructor would use the best of existing pedagogical methods while embracing new ones to ensure the best possible outcomes for students.

The Nintendo Wii is an end product of great research and step-by-step development using improvement iterations. It was this drive to give players a chance to be part of the game by being immersed in a fun and interactive manner that ultimately became a cross-channel technology phenomenon. In addition to academic benefits, there can also be physical benefits of using video games. The Nintendo Wii's balance board allows the user to stand and move around in order to perform various tasks within the game. For example, the game titled "Wii Fit" coaches and encourages the user to perfect a variety of yoga positions varying in difficulty levels. One of the Wii Fit games requires a user to lean from side-to-side in order to navigate a bubble through a rocky water terrain. Lean too much one way or not enough another direction and the bubble threatens to hit the wall and burst. Instructors could use the

Wii Balance board to teach children in need of physical therapy to balance while playing intuitive and entertaining games (Rice University, 2011). As a rehabilitation device, the Wii is relatively new; however, it is improving outcomes for patients with a wide range of physical or cognitive conditions. Gaming platforms, such as the Xbox Kinect, have also harnessed the ability of motion capture that allows the users to move their body and act as the game controller. Thus, encouraging physical movement promotes a healthier lifestyle.

The iPad and its partners in the tablet community have introduced a completely different area of options in the gaming community. Applications that are easy to download and widely accessible, even on the common smart phone, can change how instructors access and distribute learning materials. Instructors that do not have computers or laptops available in their classrooms can still take advantage of the many applications being created just for educational purposes. Applications range from interactive storybooks that feature foreign languages to manuals that teach complex concepts of the law. There are hundreds of applications available to download with many of them offered free.

Diana Darrow, a Reading Recovery teacher and a library media specialist at Bel Aire Elementary in Tiburon, CA, suggests that using iPad applications in the classroom will help instructors meet objectives according to Bloom's Revised Taxonomy. We currently live in a world where information can be accessed everywhere we go; it's to the point where students are suffering from information overload (Darrow, 2011). Overwhelmed by the task of "remembering" what to remember, students simply shut down and lose focus. Simple applications can bring the focus back to important content, allowing students to have fun while they are learning. Many instructors believe that games are made to be enjoyable; yet, when paired with educational concepts, students are energized and even encouraged to reach goals they never thought possible.

In this arena, technology can also be used for student creation and exploration of content. Halo, a game offered through the XBox 360, offers a unique option to its huge fan base. Players create their own maps that they can share with other players. Strict objectives are achieved using a variety of simple and complex programming and creation tools. Some maps have simple goals, like drive a vehicle through an obstacle course or shoot grenades through targets in the distance while maneuvering in a jet pack. When creating scenarios with complex courses, students learn how to develop and manipulate tools is a 3d environment. One particular map editing program called "Sapien" offers an interface where the user can view models and vehicles while playing sounds and running physics in a 3d window. "Sapien is used for many purposes, including the population of characters, weapons, items, scenery objects, and game play and mission objectives" (Gearbox Software, 2007). There are many online communities devoted to creating and completing these complex maps; some of them require complex strategies to complete the mission. An instructor can use the Halo map editor to teach design, 3D modeling, and programming, as well as physics and engineering.

Engineering

Engineering is a rapidly developing field that offers many career tracks: mechanical, electrical and civil to name a few. Curriculum supporting these different tracks can be tedious, offering little variety in the many calculations they must perform. In his article *Simulation Nation: The Promise of Virtual Learning Activities,* Prensky describes how simulation technology allows the learner to try alternatives virtually and see the consequences (Prensky, 2009). This application would be extremely useful for engineers due to the design element of interfacing with reliability and safety issues. Behaviors can also be modeled with simple inputs and "clear sensual outputs."

Getting students excited about STEM careers, especially engineering can be difficult. Algebra, geometry, earth science, and physics taught in the traditional way make it difficult to attract kids to the profession, especially when they've grown-up with the "instant engagement and gratification" of modern digital technology (Demski, 2009). This is leading educators away from textbooks and toward education that uses "real-world interactive scenarios" (Coller & Shernoff, 2009). Starting the inclusion of "serious games" into lesson planning could be introduced to spark interest. "Serious games" is the term used to describe real-world interactive scenarios (Djaouti, Alvarez, & Jessel, 2010). They "recast a learning task into one that is game-like and fundamentally alters the experience of the learner." The skill is placed in context within the game that the learner has to explore; therefore, the learning experience becomes immersive. These types of games serve as practice in an overall learning experience. A "serious game" can challenge the learner to stay engaged, as well as "introduce tension and crises to simulate the real experience for practice" (Neal & Quinn, 2011).

A lesson plan for teaching the binary number system, used by engineers in the design of digital devices, includes use of the Binary Box Game. It was created by the Center for Educational Outreach at Tufts University. The students are "introduced to the concept of binary coding as a language and its practical applications in digital and communication systems" (George, Panetta, & Patel, 2010). Minecraft, a game that forces the player to construct a safe and diverse world, teaches users to survive with the dangers that prowl the landscape. Minecraft was developed by Markus Persson in May of 2009. It is a simple game that appears to be just blocks and a flat landscape. However, it is one of the most top rated games that is always adapting and changing to the players needs. Feedback for changes within the game is welcomed from the community. Markus developed the game on his own in hopes of eventually releasing it as an open source program (Persson, 2009). Minecraft can help teach concepts like architecture, drafting, design, adaptation, social interaction, technical writing, and teamwork.

Another game, SimCity 3000, is a simulation game that allows the player to create complex cities using a variety of real-life scenarios. The cities thrive or fail, depending upon the player's decisions. Players can zone specific parts of their city for commercial or residential use, choose eco-friendly power options and provide transportation to their "Sims" that allows for quick and safe commutes. The SimCity 3000 website provides an in-depth teacher's guide that is complete with instructions on how to play the game and use it in the classroom. The lesson plans included can be used to teach a multitude of subjects such as math, history, social studies, and world economics. Jen Deyenberg, a primary teacher in Scotland shares her experiences with using SimCity in her social studies class. She uses the game to teach her students about the effects of government and the responsibilities of lawmakers (Deyenberg, 2010). Normally, subjects like lawmaking can be uninteresting for a class of children. However, SimCity 3000 brings their decisions to life. "A simulation environment allows students to experiment with different approaches and strategies. They immediately see the consequences of their decisions or lack of decision making" (Deyenberg, 2010). SimCity can be used in courses that teach architecture, drafting, design, law, politics, geography, or math.

Mathematics

Many aspects of education, especially mathematics, require repetitive practice. Children learning their multiplication tables may use flash cards or numerous worksheets in order to learn a complex concept. These ideas can be easily adapted to the video game format, where players are encouraged to play over and over again until they master new skills in order to reach new game levels. DimensionM is a computer program that helps students learn math skills like linear algebra. There are comparisons between traditional math instruction and newly developed video games, and many researchers are seeing that students are more successful when learning with video games (Mims, 2010).

Mathematics instruction using mobile technology is becoming increasingly popular, too. Synthetic Vision, an application for the iPad, allows pilots to view flight paths and digital representation of the terrain they are traveling over. The application can be used to teach weather patterns, the terrain of the United States and travel time versus distance. It can also be incorporated into math classes when performing the calculations. Synthetic Vision includes aeronautical charts, weather, and terrain capabilities. This is simulation software that costs around.99 cents. This is an inexpensive alternative to most simulation packages. Applications on the iPad, such as Rocket Math, offer learning objectives like identifying fractions to working with square roots. The purpose of the game is to accumulate points in order to allow the student to turn them in for various rocket parts. Students are eager to obtain the right answers in order to build a better rocket. Video games used for mathematics instruction offer fun incentives and reach the same goals that a worksheet would offer.

DimensionM, the futuristic mathematics series, is used in thirteen middle schools in Texas. Schools in the Plano Independent School District have joined hundreds of other schools across the state in using this technology to help teach mathematics and raise academic achievement scores on high stakes tests. Educators in the Dallas, Texas area liked the program so much they joined the educational gaming movement by purchasing the DimensionM for use in their 35th Annual Mathematics Olympiad. This is the first time software has replaced paper and pencil in the events. The attraction to the games for educators and students alike comes from a design that engages students in a series of quick-paced, immersive missions that are embedded with more than 200 math lessons. During the process of the games, the students accumulate points while they assimilate math concepts learned in the classroom through previous instructions.

The research in mathematics and gaming discusses the advantages of video game use for learning, as well as assessment. Stealth assessment can be described as disguising educational content in such a way that students do not know that they are being assessed because they are engrossed in game play. To accomplish a stealth assessment, Shute, a professor of instructional systems at Florida State, employs video games that have been specially designed to give teachers a way to review how students solve complex tasks while immersed in "virtual worlds." Another game used to assess students' math skills is Math Blaster 9-12. Math Blaster is a video game that requires students to complete a number of levels to collect medallions to eventually win the game. Three levels of this game include Crater Crossing, Banana Splat, and Bridge Builders. The activities included in these levels require direct and immediate application of basic arithmetic operations. Researchers used the game Math Blaster 9-12 to complete a study about whether or not video games boost student-learning gains and enhance the quality of students' overall learning experience. One element researchers investigated was the issue of boredom vs. confusion. Is it better for the student to be bored or confused? They determined that confusion was better because it kept the students engaged. Confusion allows for the students to explore and figure things out, whereas if they are bored, it is likely because the material may be too easy (Rodrigo, 2011).

Video games are powerful motivators. Katie Salen, a game designer at the New School University says, "They drop kids into complex problems where they fail and fail, but they try again and again." In many cases with traditional approaches, kids give up. She cites the fact that only one-third of eighth graders earn "proficient" math scores on national assessment tests. She was part of a group of game designers and experts who worked with the New York City Department of Education to open a new school, Quest to Learn. It is a school of sixth-graders who will learn primarily through video game inspired activities (Locke, 2010). Joel Bleah, a trigonometry, discrete math, and statistics teacher at University High School in Newark, NJ used SimCity to teach geometry and civil engineering using specific teaching standards for New Jersey. Bleah (2005) states, "Research has shown that it is games, not education that is teaching students to think. The digital natives, as this new generation is called, learn differently." He asserts that this generation relates to digital media as opposed to written text. Teachers are taught from the beginning to think about the learning habits of their students and construct instructional modules based upon these unique styles. Gaming systems are changing every year and are introducing new technologies and concepts to this digital generation. Educators must follow suit or risk being left behind.

CONCLUSION

Video gaming in STEM Education is the catalyst to generate participatory learning activities, assess understanding of complex and ill-formed situations, facilitate critical thinking and problem solving capabilities, and ensure active engagement across the learning continuum for all students. Recognizing there is a distinct difference in how content information is now being processed creates an avenue for educators to reshape how students construct knowledge and interact with each other. Vygotsky's (1978) theory of Social Educational Learning posits that social interaction has a fundamental role in the cognitive development process (Meadows, 1998). Therefore, the strategies involved in the learning process through interactive video game play provide opportunities for each participant to construct new knowledge through dynamic social interactions. Students build upon their prior knowledge and internalize new information while engaging with other players. This interaction meets their psychological learning requirements and keeps them engaged in game-based learning with other players. Surowiecki (2004) referred to these interactions as the "concept of collective intelligence or the wisdom of the crowds" (McLoughlin & Lee, 2007, p. 10). In this context, learners are in control of the method of information discovery, its distribution, modification stimulating and engaging environment that is the essence of participatory learning through social interaction. Today's learners represent a culturally diverse population seeking flexibility, active engagement and a stimulating learning environment for their educational experience.

Video gaming, as a teaching methodology, provides a multiplicity of scenarios to discover innovative ways to instruct classic concepts in science, technology, engineering, and mathematics. The benefits of using games in all of the STEM areas are noted throughout the literature; however, most of the research points to the lack of empirical evidence to prove that the games actually do impact learning and to what extent. Implementation of their use is evolving. Some of the hindrances to their incorporation into the total spectrum of best practices for learning include, but are not limited to, the cost of the technology, insufficient hardware and software, the unwillingness of some educators to try new pedagogical techniques, and lack of educator training.

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KEY TERMS AND DEFINITIONS

Gaming: Participants play a video game, either as an individual or against other players. Dynamic social interactions can take place in a physical setting (i.e. a classroom or at home with players next to each other) and/or in an online environment.

iPad: The iPad is a tablet computer manufactured by Apple.

MEGA: This term is used to define a Multiplayer Educational Gaming Application. MEGAs are teacher created for instructional purposes with the classroom teacher as the primary game author. This is convenient because the teacher can make modifications and adaptations at any time.

Simulation Games: These types of games create a highly interactive environment for reflective learning and processing of experiences.

STEM: This term is used to define the following academic areas: Science, Technology, Engineering, and Mathematics.

Wii: The Wii is a video game console manufactured by Nintendo.

Xbox: The Xbox is a sixth-generation video game console manufactured by Microsoft.