Cell Block: The Creation of a Video Game for Seventh Grade Science Students

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Abstract: Today's classroom model is based on a 19th century industrial model that is not designed to serve the needs of current 21st century students. This paper details the design and creation of a two-dimensional, side-scrolling video game on cell structure and function of the typical animal cell for seventh grade science students in an intermediate school in Hawaii. Students who had a difficult time learning the material presented in traditional methods played the video game in order to review the materials and reinforce their understanding. Results show a significant difference between some students' scores on pre and post assessment data indicating that their understanding of the concepts improved after playing the video game. Observational data from the classroom teacher included in the discussion provide insight on the decline in other students' postassessment scores. Expert and student feedback regarding game play are also discussed.

Introduction

Today, the average college graduate has spent less than 5,000 hours of his or her life reading but has spent over 10,000 hours playing video games and over 20,000 hours watching television (Prensky, 2001b). Prensky has dubbed this population, from kindergarten through college, "digital natives." Digital natives are the generation who grew up with digital technologies such as computers, mp3 players, video cameras, and cell phones.

From the very first computer game invented in 1952, a computerized version of tic-tac-toe (Public Broadcasting Service, n.d.), to the current massively multiplayer online role-playing games, such as World of Warcraft, video games have been influential on our culture (Beck & Wade, 2006). Until recently, much of the research on video games focused on the negative aspects including the effects of violence and the risk of addiction (Chumbley & Griffiths, 2006; Funk, Buchman, Jenks, & Bechtoldt, 2002).

The use of video games in education as an area of research is still in its infancy but more and more educational titles are being created for businesses and the military. Universities are just starting to experiment with different types of video games as teaching tools, mostly because of the time and expense involved with developing video games, especially the sort that marries rich 3D virtual worlds, 5.1 surround sound and creative story lines (Schollmeyer, 2006).

Considering the amount of time per day that digital natives play video games as well as their fluency with digital technologies, it is reasonable to assert that video games can be used as effective teaching tools. There are a number of ways that video games can be

used as teaching tools: integrating commercial off-the-shelf video games, students creating their own games, and educators and developers creating games to be used by students. It is this last integration technique on which this project was focused.

Purpose

The purpose of this instructional design project was to design a video game on cells for seventh grade science students for review and reinforcement at an Intermediate School in the State of Hawaii. The goal of creating the video game was to facilitate the students' time on task and augment the material presented beforehand by the teacher.

Literature Review

The Current School Model

Our current model of schools was created in the late 19th century. Shaffer (2006) offers a description:

> the so-called egg crate school, with identical isolated classrooms, each with individual desks for individual students; age-graded classrooms filled with similarly aged students; the nine-month school year and 5 day school week; the 45 minute school period; and the Carnegie unit, or standardized class of 130 hours of instruction in a single subject. (p. 35)

Despite some reforms, education is still predominantly conducted on this obsolete industrial model and agrarian calendar (Federation of American Scientists, 2006). Shaffer (2006) states that the justifications for the traditional disciplines such as math, science, history and language arts are that these ways of thinking are fundamental in anything students will do when they finish school, but he asserts that these disciplines are not the only way to divide up the world of things worth knowing. Moreover, the blocks of time they are taught in as well as the ways in which they are taught (e.g. lecture and recitation), are not the only ways to learn; neither are the standardized tests of facts and basic skills the only way to conduct assessments of learning. Gee (2005) calls this view, that all academic disciplines are composed of sets of facts or bodies of information and that learning works through teaching and testing such facts and information, a "content fetish."

Today, the goals of education are quite different than they were even 25 years ago. Dede (2005) asserts that there are still too many teachers who design and deliver "one size fits all" content, pedagogy and assessment, with students serving as passive recipients. According to Rieber (2001), expecting everyone to learn the same things, in the same way, and at the same time is not supported by anything known about cognition and learning. He continues by describing learning in school as "regimented, homogeneous, and based more on rewards and threats than curiosity and interest," very unlike our learning experiences prior to and outside of school (Rieber, 2001, p. 2).

So, how does a school system created in the 19th century expect to effectively teach students in the 21st century? According to several researchers (Gee, 2003; Papert, 1998; Prensky, 2001b; Shaffer, 2006; Van Eck, 2006), it cannot.

21st Century Students

"Our students have changed radically. Today's students are no longer the people our educational system was designed to teach" (Prensky, 2001b, p. 1). Van Eck (2006) suggests that these students require multiple streams of information, are more visually

literate, and prefer quick and frequent interactions with content as well as inductive reasoning. “Digital natives want learning experiences that parallel the exciting and engaging digital formats in which they routinely participate. Yet, most instruction is still ‘tell and test’, in which students take in information passively from reading and lectures, reciting it back in the form of work sheets, reports, and tests” (Federation of American Scientists, 2006, p. 17). Dede (2005) states, “Increasingly, people want educational products and services tailored to their individual needs rather than one-size-fits-all courses of fixed length, content and pedagogy” (p. 8).

How can educators respond to a generation of students who, raised on interactive technologies, expect the same kinds of experiences from their educational medium? One way is through the medium of the video game.

Learning Theories Present in Video Games

For those who have not played many video games, the thought of their value beyond entertainment may seem to be unrealistic. The reality is that most, if not all, video games can make a connection to one or more learning theories (De Castell & Jenson 2003; Egenfeldt-Nielsen, 2006; Van Eck 2006).

Egenfeldt-Nielsen (2006) relates four learning theories that can be the foundation for instructional design in specific genres of video games. The first is behaviorism found in the quiz or drill and practice genre. The second is cognitivism. An example of a cognitivist type of game is a puzzle game such as a tangram, a game where geometric shapes have to be manipulated to fit into the outline of another shape with each puzzle progressing in difficulty. The third is constructionism. Games in this genre are designed to engage the player with the material. Players discuss the game, reflect on the game, and use the game as a means for constructing knowledge. The fourth is a socio-cultural approach. In a socio-cultural approach, video games are not the learning experience themselves, but the vehicles for learning. A socio-cultural view is not one of learning by rote. Gee (2003) says that children learn by playing video games and make sense of things by engaging with others, reflecting, discussing and sharing.

What Can Be Learned Through Video Games?

Educational video games, also known as serious games, represent the constructive application of computer game technology. Corbit (2005) states, “there is a growing knowledge grounded in research that suggests that computer game technology and related media can and should be adapted for constructive educational uses” (p. 18).

A major theme in good game design is that good games are engaging. Prensky (2001a) lists different factors that he believes make games engaging:

- balance - the game is challenging but fair. It is not too hard or too easy
- creativity - it is not formulaic
- focus - it creates fun without distraction
- character - a game has depth and richness from fully developed characters that are memorable
- tension - it makes the player care about the goal of the game and makes it hard to achieve
- energy - movement, momentum and pacing. It keeps one playing. (p. 133-134).

Other strategies of design that engage are role-playing, narrative, challenges, interactive choices, and interaction with other players. Also that players may be required to analyze, synthesize and use critical thinking skills in order to play and execute moves when

playing video games (Dickey, 2005). Good educational video games draw the best from both curriculum design and game design.

Games can be used for both primary learning, where all learning comes via the game, as well as secondary learning, where games are used as supplemental learning tools. If games become integrated into classrooms as primary teaching tools, what becomes of the teacher? Even if games are used as secondary teaching aids, how can teachers integrate them into their teaching? Rieber (2001) explains, "A simple way of understanding serious play in education is with the advice of 'experience first, explain later.' A teacher who follows this advice looks for ways to engage learners in some meaningful experience as early on as possible and then uses this experience as an anchor for later instruction" (p. 4). He sees the teacher's role as a manager or facilitator of education much more important, demanding and satisfying. This is in stark contrast to the teacher's role as a dispenser of information. Teachers can steer students in the right direction as video games are utilized and provide effective guidance to correct any misconceptions and differences in students' gaming experiences. This is not much different from an English teacher who may correct a student's interpretation of certain literary works. The explicit transfer of knowledge from video games allows the teacher to still play a crucial role in the video game classroom.

Method

Curricular Background

According to the Hawaii Content and Performance Standards III (Hawaii State Department of Education, 2005), the topic of cells is covered in the second quarter of the seventh grade school year but the information needs to be retained and built upon in subsequent quarters when topics such as heredity and diversity are taught. Many of the students are able to grasp and retain the material when it is taught by the teacher using various methods such as worksheets, videos, color slides and models. However, according to the science teacher, there are a number of students that just are not able to learn the subject matter as it is usually presented (S. Kamakeeaina, personal communication, February 7, 2007).

In the school chosen as a test site, students in the seventh grade spend approximately three and a half hours per week in science class. Each class session has an average of about 25 students. The total number of students taught by one teacher during the school year is 100 or more students. Science classes at this point are completely integrated and therefore contain a mix of low-functioning students, high-functioning students and English language learners. It is not a matter of whether or not the teacher has the ability to teach the material to all levels of students, but more a matter of time, or lack thereof (S. Kamakeeaina, personal communication, February 7, 2007).

The main target population of this project was students who had difficulty learning in the traditional methods or those who just needed more time with the material.

Instructional Goal

The goal of this instructional design project was to design and create a video game that would teach the basics of cell structure and function to seventh grade science students for review and reinforcement.

Learning Objectives

1. Given the description of the structures of the typical animal cell, the students will identify the correct structure with 100% accuracy.
2. Given the description of the function of the organelles of the typical animal cell, the students will identify the correct organelle with 100% accuracy.

Target Audience

The target audience of this project was seventh grade science students in a public intermediate school in the State of Hawaii.

Sample Population

The sample population was taken from 102 students on one team of the seventh grade in the chosen school. A team consists of the same block of students who have the same teachers for science, math, English and social studies classes in the school.

The science teacher, who determined which students were in need of review and reinforcement after the completion of the cell unit taught in the second quarter, first screened the students. After determining which students would benefit from the review and reinforcement, they were asked to seek permission from their parents to participate in the study. Approximately 30 students were given permission forms with a total of 17 students in 5 periods who received permission and tested the game. Of the 17 students who tested the game, data was collected from 10 students. Data from the remaining students could not be collected due to student absences on the day of the postgame evaluation as well as missing assignments. The 10 students consisted of two girls and eight boys. Nine students are in the federal free lunch program, two students are English language learners and three students are classified as special needs.

Instructional Analysis

A rapid prototyping model as it is adapted to instructional design was used for this module (Tripp & Bichelmeyer, 1990). After a simple needs assessment and content analysis, objectives were set. In meeting with the science teacher in the test classroom, the objectives were determined in accordance with the Hawaii State Standards as they apply to the information students should learn about the typical animal cell in the seventh grade.

The Design of the Module

The science content of the module was reviewed by the seventh grade science teacher to insure accuracy and consistency with the content taught in the classroom. She has been teaching seventh grade science for over 18 years and has served as the department chair for 16 years. The researcher also has a background in science and was therefore familiar with the content.

The module was designed as an action oriented, two-dimensional, side-scrolling video game. The game module was created on a MacPro using Lightwave 3D, Adobe CS3, and Power Game Factory. The game included six levels, each with its own set of cell organelles or structures to retrieve and enemies to battle. In the game, the students assumed the role of Kekoa, a lymphocyte warrior. The game began with a cut scene in which Central Command issued its prime directive to Kekoa: battle the enemies, all of whom were either a virus or a bacterium, in order to retrieve the cell structures and

organelles so that the cell can be rebuilt. Each level began with a cut scene of dialogue between Kekoa and his assistant, Helper T.C. Squire, who gave Kekoa information regarding which organelles or structures were available in the level as well as which enemy he would have to battle. Each level ended with a message from Central Command with information on the importance of what had been collected and encouragement to continue the quest to collect all the structures and organelles needed to rebuild the cell. When all the structures and organelles were collected, the cell was rebuilt and the game won. The organelles, characters and other objects in the game are listed below in Table 1.

Table 1: Cell Block game elements

Human Characters:	Terrain:
Kekoa - Lymphocyte Warrior	Frozen Tundra/Snow
Helper T.C. - Squire	Desert/Sand
Central Command	Forest/Mountain
Enemies:	Weapons:
Viruses:	Sword
Mosquito - Arbovirus	Potions
Rhinoceros - Rhinovirus	
Giant Chicken - H5N1	Items to Collect:
Bacteria:	Cell Organelles
Slug - Necrotizing Faciitis	Cell Structures
Evil Snowman - Bacillus Anthracis	Extra Lives
Dragon - Streptococcus	Health Power Ups

Data Collection

Quantitative data collected included several worksheets given by the teacher during the cell unit as well as the cumulative points earned by the students at the end of the quarter. These data were used to assess where each student stood in his or her completion and understanding of the materials presented by the teacher during the unit and served as the pregame data. Postgame quantitative data collected included a survey that investigated each student's video game playing habits and an assessment conducted by the researcher. The assessment was conducted as a card matching game in which the students were given two sets of cards, one with the name of the organelle or structure, the other with the definition or description of the function of the structure or organelle.

Qualitative data collected included questions regarding game play, whether the students liked the game or not, suggestions for improving or changing the game and observational data made by the classroom teacher as the students played the game.

Results

Several pieces of data were collected to determine the students' understanding of the material before playing the game. The most logical choice was to use a worksheet that the students completed in class during the cell unit that contained the same information that was presented in the video game and the postgame assessment.

The postgame assessment was conducted as a card matching game. Each student received two sets of cards: one with the name of the cell organelles or structure, the other with the definitions or descriptions of the organelle or structure. The students had to match the name with the description and paper clip the pairs of cards together. The paper clipped cards were placed in zip-top bags, which were numbered by the classroom teacher. The

numbers corresponded to a preset code so that the researcher could determine which cards belonged to which student while preserving the students' anonymity.

Figure 1 shows a comparison of the scores students received on the worksheets and the postgame assessment. Of the 10 students, 6 showed improvement in their scores after playing the video game, 1 student had the same score both before and after playing the game, and 3 students scored lower in the postgame assessment.

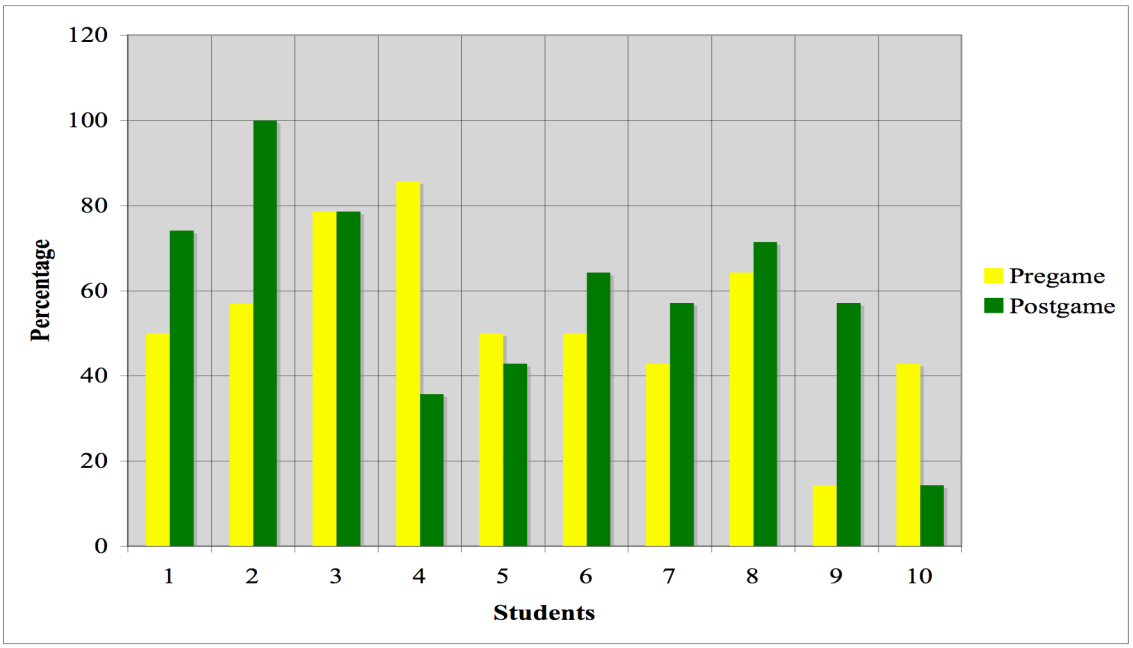

Figure 1. Comparison of pregame and postgame scores.

In order to determine if the difference in the pregame and postgame assessment scores were statistically significant, a *t* test was conducted. The data for the *t* test is shown in Table 2.

Table 2. *t* test data

Mean of Pregame Scores	Mean of Postgame Scores	Difference ($\bar{X}$)	Standard Deviation (Sx)	Sample Size (n)	*t* value	*p* value
53.58	59.55	-5.97	29.291	10	0.6445	.5353

In order to be statistically significant, the *p* value needed to be less than .025. Since the calculated *p* value is .5353, the difference is not statistically different. However, this does not negate the improvements made by 6 of the 10 students.

The video game usage survey results include the number of hours each student plays video games, the types of game systems they play on and the types of games they play. The amount of hours each student plays video games per day ranged from 0.5 hours per day to 5.5 hours per day as shown in Figure 2. According to the data, the students play video games an average of 2.7 hours per day.

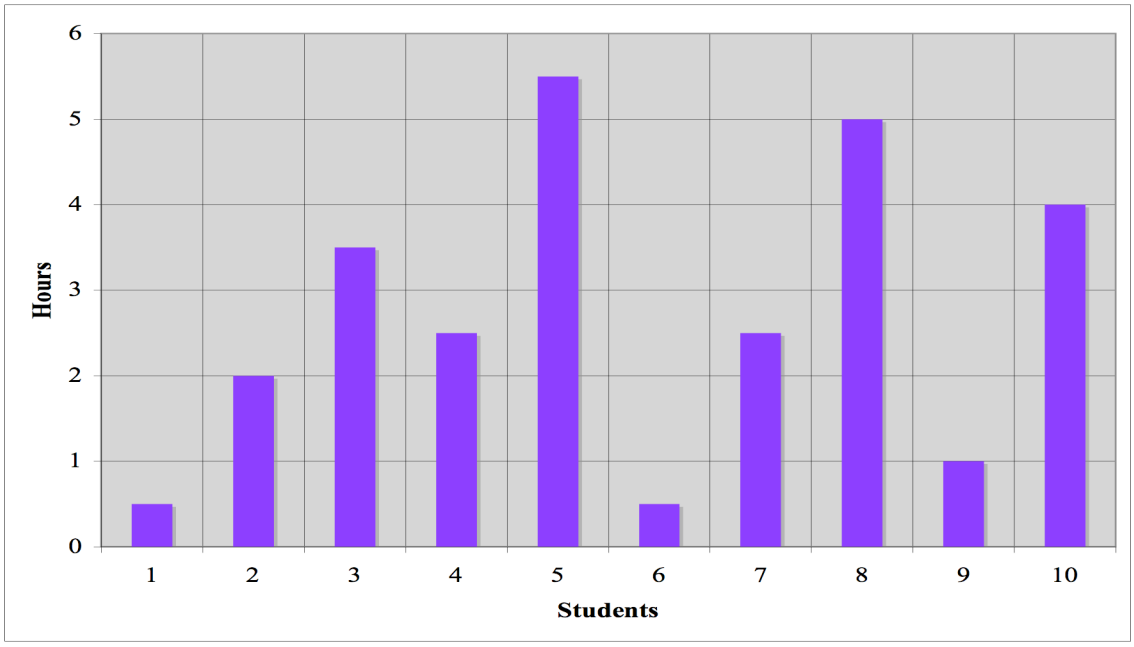

Figure 2. Reported hours per day the students play video games.

On the video game usage survey, students reported playing on a number of systems with the most popular being Microsoft's Xbox 360, Nintendo's Wii and Sony's Playstation 2 followed closely by Sony's Playstation 3 and Nintendo's DS systems. The types of games the students reported that they play included sports, racing or flying games, action, adventure, role-playing, shooting and strategy games.

In trying to discover why some students did well on the post-game assessment and others did not, a comparison of the amount of hours per day that each student plays video games and their post-assessment scores was graphed as shown in Figure 3.

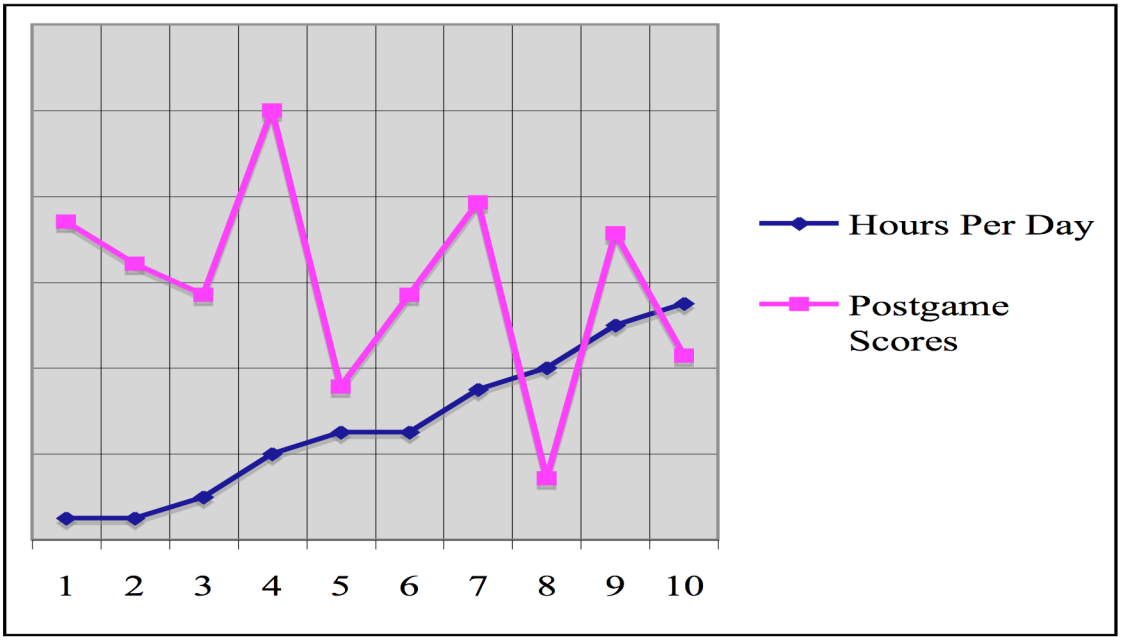

Figure 3. Comparison of hours per day vs. postgame scores

In this study, there seems to be no correlation between how much time students spend playing video games and how well they did on the postgame assessment.

Discussion

What factors exist that could explain why the difference in the means of the pregame assessment and the postgame assessment scores are not statistically significant, especially if there is no apparent correlation between how many hours a student plays video games and their post-game assessment score? The answer lies in a number of possibilities.

One possibility is the game. There were limitations with the game engine that did not allow certain things. For example, only two-dimensional objects could be used. In addition, the game engine was only capable of producing games that are side-scrollers. In side-scrolling games, the player starts at a point to the left of the screen and keeps moving to the right until the level is complete. Finding the objects may not have been challenging enough since action is linear. A decision to present the crucial learning information as cut scenes instead of using in game dialog boxes may also be a factor, especially since at least one student figured how to skip the cut scenes. There were also glitches in the finished game that may have caused the students some problems and therefore diminish their game playing experience.

Another possibility is the students and their approach to the game. Observations made by the classroom teacher were that some students were more enthusiastic about playing the game. In her opinion, these students were more intense in their game play, noticed more of the details, and paid attention to all parts of the game. Upon comparison of her observations and the students' postgame assessment scores, she noted that the students who performed well on the postassessment were those in this category. These same students also discussed the game with each other and offered each other tips and techniques for moving through the levels.

One more possibility was time. The students were given as much time as possible to play the game, but playing the game was only a small part of the overall school time activities. Some students may have rushed through the game because of this lack of time. Though some students played the game at least twice, some only got to play it once. But, playing a game once or twice does not allow for a firm absorption of the material.

Yet another possibility lies in how the assessments were conducted. Even though the postgame assessment was conducted without paper and pencil, it may not be an effective way to assess what learning is accomplished through video games.

So, what improvements can be made to this game, or any that is custom designed, in order to insure that effective learning takes place? The students, subject matter experts and the literature offer several suggestions.

The students suggested that the game be three-dimensional, that the levels be made longer and that the information be presented in the game instead of as cut scenes. They also suggested that another weapon, such as a crossbow, be available and that the potions have different effects to distinguish them. In addition, they suggested that the player be able to choose between a male or female character and that the character be customizable.

The subject matter experts also suggested that the information be presented in another way in the game instead of as cut scenes that need to be read. They also suggested that there be vertical attacks instead of just horizontal attacks by the main character.

Alexander (2008) suggests that games can be used as learning objects. He defines learning objects as simply "digital objects from which learners can learn and that can be repeated" (p 64). According to Martínez-Ortiz, Moreno-Ger, Sierra, and Fernández-Manjón (2006), assessment should be built into video games. Van Eck (2006) points out that students need to be given enough time to promote good flow present in good games. He explains that flow happens when we lose track of time as we are engaged in any given activity and that is when we are performing at an optimum level.

Conclusion

Although the success of this study cannot truly be determined without long term observations, revisions of the game and retesting with more students, at least six of the students had success demonstrated by the increase in their understanding after playing the video game. As for the rest of the students, possible reasons for a decline in their postgame assessment scores were offered and suggestions regarding improvements discussed.

Even with the less than desired results, there were other benefits to all of the students' experience. They had more opportunity for time on task, they were engaged in a multimedia form of content delivery, and they had fun. Playing the game also sparked collaboration amongst the students wherein they helped each other by sharing game hints and discussed the game even when they were not actively engaged in playing the game.

Future options for study include revising the game according to the suggestions, testing on more groups, and using larger sample sizes to get a better picture of the efficacy of using a customized video game to deliver required material.

As our world turns more towards digital solutions and video game sales continue to increase (NPD Group, 2009), their use in education may be one answer to the question of how to engage today's 21st century learner.

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