Video Games: A Vehicle For Problem-Based Learning

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Abstract

Since the popularity of video games is at its highest in the high school student age group, it is becoming more critical to find a way to integrate video games into the science classroom. Today's video games are designed around a rich storyline that mimics that of a Hollywood movie. One way to harness the power of video games for science instruction is to design games as problem-based learning scenarios. In this article, we will describe the natural ties that exist between video game creation and problem-based learning. In addition, a snapshot of how one high school teacher designed, created and implemented a video game in a biology class as part of a National Science Foundation project will be presented.

Introduction

Inquiry instruction has long been considered the most effective approach to teaching and learning. Through authentic problem-based activities, inquiry instruction provides real-life experiences that connect prior knowledge to science content. As technology advances become more accessible and user-friendly, the universal design of curriculum provides a flexible approach to integrating technologies for inquiry instruction and meeting the needs a diverse student populations (Curry, Cohen & Lightbody, 2006). In other words, the framework of universal design aims to create educational environments that address the diverse needs (cultural, socioeconomic, ethnic, gender and ability level) of learners, rather than modifying existing curricula to accommodate individual learner needs.

Because today's students are diverse in their learning styles and technology experiences, video games have the potential to meet the growing needs of this diverse population. Video games are immersive virtual environments where game players can interact with objects and visualizations that entertain while providing stealth learning. Virtual environments persuade students to explore beyond the boundaries of given material, allowing for a proactive and exploratory nature, encouraging the student to become a self-reliant learner (Dede, 2004; Taradi, Taradi, Radic & Pokrajac, 2005). This concept is further exemplified through Linn's (2004) four meta-principles to support learning: making science accessible, making thinking visible, helping students learn from each other, and promoting autonomous learning.

In 2003, a movement among educational, governmental, corporate, medical, and military fields started using video games for teaching and training. This movement, known as Serious Games, has changed the way educators viewed instruction to meet the needs of the *Net*

Generation. The games are one of the many ways the Internet has changed how a generation of young people socializes and views entertainment. Today, avid game players willingly pay monthly online game fees as readily as they pay their light bills -- and anxiously wait in line for new video games the way their parents used to queue up for concert tickets (Irvine, 2004). Although video games have been around for over 30 years, it has not been until recently that technology has allowed for the metamorphosis of video games to become descriptive narratives and storylines. Today's video game industry approaches yearly revenue of $15 billion and approximately 3.38 billion hours of game play. The game playing population falls between the ages of 10-34 with the majority of the population between 14-19. Craft (2004) believes the method of instruction embodied in video games has potential for non-self-referential disciplines, particularly science. Games have shown improved motivation and student engagement (Watts & Lloyd, 2000; Wilson & Whitlock, 1997) and improved participation and achievement (Jayakanthan, 2002).

In order to obtain the cognitive and affective benefits of video games in the classroom, a well-designed technology program needs to be grounded in sound pedagogy. The universal design framework seamlessly allows for sound pedagogy through problem-based learning. Because of their rich storylines, games can be created for instructional purposes following the problem-based learning model. Popular commercial video games follow a rigid storyline where a plot thickens through varied scenes and game players interact with computer agents that aid in the movement through a narrative toward a common goal. Today's video games, not unlike their Hollywood counterparts, have various genres. What seem to get the most attention are first-person shooter games. However, the most popular games, especially for girls, are role-play/action-adventure games.

Video games as PBL

Video games in the classroom have the potential to enhance learning, yet few guidelines exist for creating these virtual environments (Pedersen, Lui, & Williams, 2002). Many of the games that have made their way into the classroom follow the drill-and-practice model, emphasizing rote memorization and failing to capture the interest of students (Squire & Jenkins, 2003). How can we harness this medium to enhance science education with pedagogically sound yet entertaining games? When considering how to design these learning environments, it becomes evident that natural ties exist between video game creation and problem-based learning. Problem-based learning is an instructional model whereby learning results from students' efforts to solve a complex problem.

Problem-based learning has its origins in medical education, but is now used in a wide range of disciplines at a variety of educational levels. It is an instructional approach where students are confronted with a problem and challenged to work towards a solution. The problem is complex and ill-structured, and does not provide enough information for a simple resolution. The presentation of fragmented information, along with the students' assumption of roles that provide a connection to the situation, motivates learners through the problem-solving process. In order to solve the problem, students will have to engage in a variety of activities such as observing, gathering information, forming hypotheses, conducting experiments, and analyzing data. As students tackle these activities, they begin to realize that there is no simple or fixed solution to the problem and that their task will be to use the information they have collected to justify the best possible solution.

Problem-based learning follows a learner-centered paradigm and is more in line with the current movement to reform science education (American Association for the Advancement of Science, 1993; National Research Council, 1996). In problem-based learning, the learning experience imparts knowledge to be used rather than facts to be acquired (Bell, Bareiss, & Beckwith, 1993). Students are confronted with a situation where they assume the role of a stakeholder and through investigation, learn whatever is necessary to arrive at a justifiable solution. Because the task is authentic and their engagement with it has been sustained, students appreciate the utility of the knowledge they are learning and can recognize when this knowledge is applicable (Bransford et al., 1990). Since the new knowledge is encoded in a context that mirrors how it will subsequently be used, it increases the chance that the student will remember and apply what is stored in memory (Barab et al., 2001).

The fundamental ideas underlying problem-based learning are directly related to constructivist ideas of teaching and learning (Pearson, 2006). Learning is an active process requiring mental construction on the part of the learner. Problem-based learning activates prior knowledge and facilitates learning by encouraging students to incorporate new knowledge with their existing knowledge. With this instructional method, learners experience a cognitive conflict, when their way of thinking does not produce what is expected (Savery & Duffy, 1995). According the Piaget, this conflict or perturbation, leads to accommodation and adaptation (Koschmann et al., 1994). The problem-solving process encourages the learner to continually modify and appraise their understanding and guides them to a new sense of equilibrium.

Also at the heart of problem-based learning is the idea that learning is a social process. Cognitive change often occurs as a result of interaction with other students who may hold different understandings (von Glasersfeld, 1989). Since these social interactions with peers may challenge and refine a student's current views, problem-based learning provides students with an opportunity to articulate new knowledge (Koschmann et al., 1994). Social negotiation also occurs when students interact with the teacher. A teacher's role in this process becomes guiding students as they direct their own learning process. A teacher facilitates learning through clarifying, questioning, coaching, modeling, challenging student thinking, encouraging collaboration, monitoring student thinking and dispositions, and providing feedback (Torp & Sage, 1998).

In this remainder of this article we will describe one of the games created by a science teacher, the competency goals the game addressed, and how other K-12 teachers can create video games for problem-based learning instruction. The game design process consisted of identifying a problem, aligning that problem to the state science competency goals, and articulating a narrative that allowed for players to learn science content while immersed in a fun, interactive environment. The narrative had to be a first-person explorer, role-play game with thick descriptions of the setting, storyline, characters, clues and scenes.

The Stolen Fortune of I.M. Megabucks was created in a synchronous, online summer course through North Carolina State University (http://courses.ncsu.edu/ems594/common/ignite/index.html). The course used a virtual 3D chat environment, ActiveWorlds™, which was modified to allow for easy creation of a game in a virtual learning environment. Through a six-week course, graduate students were given instruction as to how to design the game, create a problem-based scenario, and build an environment around the science problem. Because this particular technology was designed in a drag-and-drop environment, teachers did not need to know or learn 3D objects creation or difficult computer programming languages. Simplified action scripting was incorporated into the building environment so game players would get the feel of a commercial game they might be used to playing outside of school. Although centered at North Carolina State, the course is open to any teacher with the desire to learn to create video games as a function of problem-based learning for their science instruction.

The Game Setting

The game, *The Stolen Fortune of I.M. Megabucks*, was designed as an in-class activity to assess student understanding of a biology unit on genetics. The setting is a large mansion (Figure 1) where students are introduced to the crime scene.

Figure 1: The Mansion of I.M. Megabucks

Throughout the game, students are able to teleport to a crime lab to type blood and sequence DNA from samples left behind. The objective of the narrative is to have students play the role of police investigators trying to solve a crime. Students will be asked to solve a mystery using their understanding of pedigrees, Mendelian inheritance, blood types, and DNA fingerprinting.

The Storyline

Mr. I.M. Megabucks and Mrs. I.M. Megabucks have recently died leaving a large inheritance to a number of relatives. They passed away tragically when they were struck by lightning while climbing up a playground's metal slide during a storm. When everyone shows up for the reading of the will, the inheritance is stolen out of the safe. Only family members have access to the combination. There is a small amount of blood left at the crime scene. The only other clue is that the butler saw the crime. He observed a figure wearing a ski mask running out of the room carrying a large bag (presumably full of the inheritance). As the masked burglar rushed by the butler the person gave the "thumb's up" sign. The butler noticed this person had a bent thumb.

Characters and Clues

Mr. I.M. Megabucks: He tells the story of how he and his wife passed away.

Mrs. I.M. Megabucks: She tells the players of the relationship between the family members so that the players can construct a pedigree.

Butler: He gives out the information that the thief has a bent thumb.

Investigator: He helps players by giving them information about thumbs and which thumb type each family member has.

The lab tech: He helps players take the blood sample to the crime lab so it can be typed. He also helps players through the DNA fingerprinting process once the list of suspects is narrowed down.

Family members: There are 15 family members lined up in the mansion. When the player knows who committed the crime, the player will go upstairs and select the guilty person. If they are correct, they will warp to the outside of the compound.

The Scenes

Scene one

Players enter the world by teleporting into the garage of a large mansion (Figure 2).

Figure 2: The start of the game

There, they are instructed to click on the cop car where they are briefed about the crime. They then walk up a long walkway to the family graveyard (Figure 3).

Figure 3: The graveyard on the Megabucks estate

They pass two gravestones. When they examine the gravestones, they are able to click on them and read the story and information provided by Mr. and Mrs. I.M. Megabucks. Here, they need to create a pedigree based on the information provided by Mrs. I.M. Megabucks.

Scene two

Players approach the mansion where they find the butler waiting (Figure 4).

Figure 4: Entering the mansion to search for clues

He informs the player that he noticed the thief had bent thumbs. The player is then instructed to go towards the fireplace where an investigator is waiting to tell them more. The investigator tells the players which family members had bent thumbs and which family members had straight thumbs. This helps the player narrow the list of suspects. The investigator also instructs the players to go to the office where a bloodstain was left near the safe.

Scene three

This scene occurs in the office (Figure 5).

Figure 5: Discovering a large blood stain near the safe

Students are instructed to click on the blood smear which teleports them to the lab to test the blood sample.

Scene four

In the lab (Figure 6), a tech provides information about the blood type of each family member.

Figure 6: The lab where students test the blood samples

Players are asked to cross off family members from the pedigree with the incorrect blood type. The list of possible suspects is thus narrowed down. The lab tech instructs the player to click on the computer screen to see the DNA fingerprints created by the remaining suspects and the bloodstain. Once they run the gels and compare them to identify the guilty party, they are instructed to click on the door to teleport them back to the mansion.

Scene five

Once back at the mansion, the players are instructed to walk upstairs and click on the guilty family member from the lineup of family members waiting there (Figure 7).

Figure 7: The lineup of possible suspects

If they are correct, they are teleported outside of the mansion grounds. If they are incorrect, they are teleported back to the first floor of the mansion to try to find their mistake and learn from their error to solve the crime.

Scene six

Once outside, the cop car is waiting to provide students with the motive if they haven't already figured it out. The game concludes with the theme from the television show *Cops* (Figure 8).

Figure 8: The last stage of the game

Conclusion

The expectations set forth for the students of this class were not only met but also exceeded greatly. As most commercial video games cost between $5-$20 million to make, games such as *The Stolen Fortune of I.M. Megabucks* cost nothing to create and more importantly, nothing to play (i.e., use in the classroom). The interface provided for game creation was simple enough for teachers bring their problem–based learning activity to life and still engage students.

To further enhance this experience, assessment agents will be integrated into the next iteration of the course. This will allow teachers to formatively assess student knowledge that can be ascertained through web logs. One outcome that was expected came on the part of the student. Because ActiveWorlds™ was not designed to be a gaming platform; the 3D objects and textures and game play are not as robust as those in commercial games. Further, the artificial intelligence and physics actions innate in commercial games were not present.

Through funding by the National Science Foundation[1], project *HI FIVES* empowers teachers in grades 5-9 to learn to create similar first-person explorer games using an interface similar to that of ActiveWorlds™. However what is different in *HI FIVES* is that the user-interface wraps around the Half-Life2 game engine, providing players a real physics engine and 3D models with which they are accustomed to interacting with.

In conclusion, the integration of *The Stolen Fortune of I.M. Megabucks* provided mixed results. As expected the students were highly engaged in this activity. Observation and interviews suggested a high time on task quotient for the students who engaged with the MEGA as compared to a control class who were exposed to the same material in a traditional laboratory activity. However, the results of end of unit tests were not significantly different between the classes exposed to the MEGA and the classes not exposed. Possible reasons to explain this might are three-fold. First, although the teacher who created the MEGA was instructed by a game design expert, it is possible that she did not assimilate the entire process well enough to show in the core game design. Second, the MEGA was used once and thus the exposure to the virtual experiment might not have been long enough for students to explore and test personal hypotheses. Finally, as previously mentioned the platform in which the MEGA was created did not lend itself to the core game play that is common in commercial game construction and thus the epistemology of the MEGA could not be carried out as planned.

It is the plan of these authors to address these issues during the *HI FIVES* project. From this intervention it is clear that teachers needed longer and more robust exposure to the game design processes and procedures. Most notably, teachers need to be better versed on how to integrate the MEGA into their teaching repertoire. Moreover, *HI FIVES* is implementing student input early in the design process. As teachers are the experts in content and pedagogy, the students are the experts in fun and game play. This is a convergence of business and education in that curriculum design does a market analysis before too much time, energy and money is spent creating material that will not have its intended effect.

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