Video Games for STEM Learning: How Does It Work?

Jade Yang

Purdue University Calumet, Hammond, IN, USA

yu.yang@purduecal.edu

Abstract

Video games have arrived as one of the latest educational tools leveraging the fact that they engage the students quickly. When used appropriately, this tool can be especially valuable for those hard to engage subjects in science, technology, engineering and math (STEM). This article reviews some video games used in STEM education that have reportedly resulted in better student learning outcomes. Through the review, we see examples of how to successfully integrate video games into STEM learning. This article also examines some challenges on using educational video games so we can exploit this latest tool more skillfully.

1. Introduction

It has long been recognized that a well-designed game is an effective medium for teaching and learning. In this computer age video games which comprise many forms and combinations of multimedia such as animation, sound and simulation, have generated some phenomenal appeal among people, young and old alike. But not all video games are created equal; while some games are simply harmlessly fun and the violent content in some other video games have been blamed for the increasing violence in our society. Although most of the time people play games merely for entertainment, could positive and serious lessons be learned through playing games?

For many years, corporations, government and the military have taken advantage of the tremendous educative power of simulation and video games [4]. Simulation programs have been developed for safety trainings in hazardous work environments. A range of health education games have been created to help patients to recover as well as to aid the doctors to perform surgeries. The benefits of using simulation in industry are similar to those for academia. Because simulations include video, graphics, text and sound create richer learning experience and emotional arousal, they also enhance feelings of presence and engagement, provide safe practice environment, potentially high degree of interactivity with other users or the system[10].

In the last couple decades much study has been conducted in the educational research community to understand the lure of video games and to find ways to exploit that for teaching. Hence organizations such as “the institute of play” or “the institute of future” and terms like “educational games” or “edutainment” have come into existence[8,9]. There have been video games made for a variety of subjects from humanities and social studies to STEM. For example,

there is the "*Making History*" for learning about history, and games like Civilization and SimCity where students learn how to think strategically as well as gain knowledge in history, geography and urban planning through playing the games. Recently a video game called *IF* has been created for the purpose of teaching sympathy, for players to gain emotional intelligence. The kids will play virtual counseling in a virtual village occupied by cats and dogs who do not get along well. The challenge of the game is to bring the occupants of the village together through listening to each other and managing their emotions[7].

Some characteristics of video games that have contributed to the learner engagement are their interactivity, personalized challenge level, and the reward system. There are a wealth of education literatures[1,2,3] that discuss the ecology between gaming and learning. The focus of the paper will not be one to analyze the relationship between video games and learning. Instead, this paper gives a review of how video games have been used in education for STEM subjects. The purpose is to gain a general knowledge of the essence and challenges in creating and using educational video games so that we can better utilize this powerful technology. This paper is organized as follows. We will first review some example video games for STEM at different educational levels. Then we will discuss the difficulties in designing educational video games and the issues involved in integrating them into the traditional classroom setting.

2. Video Games for STEM

This section reviews several examples of video games and simulation programs used in STEM education. Many video games for STEM learning have been designed for students in K-12 grades. There are games for learning engineering (*Time Engineers*), math (*Martha Speaks Dog Party*), or aeronautics (*Kerbal Space Program*). All those games use 2D or 3D cartoon characters and take the players on an adventure where a set of problems will be encountered and solved by the players.

In higher education, video-game like tools have also been employed in STEM learning. For example, virtual or simulated robots have been used for teaching introductory programming such as CS1112: *Introduction to Computing Using MATLAB* offered at Cornell University[11] or Engineering7: *Introduction to Programming for Engineers* at UC Berkeley[12]. They are used to introduce the college students to computer programming through manipulating the movement of virtual robots. The audience of those classes is made up of more than 75% engineering students and virtual robot programming uses MATLAB, a popular programming tool in the engineering field. In Engineering7 offered at UC Berkeley, students' enthusiasm for the course is heightened through the end of semester robot tournaments. In these tournaments or robot battles two student programmed robots would compete on a virtual map which is similar to playing a multi-player video game. The rules of the game as well as a snapshot of the game are excerpted from the article[12]: "In a robot battle, two student-programmed robots compete head-to-head on a virtual map that holds fuel tanks and bombs. The game ends when the two robots come within five units of each other, at which point the robot with the most fuel is declared the winner. On

each turn the robot must decide how far to move and in what direction. The robot loses fuel as a function of the distance traveled in a single turn. Landing on a fuel tank adds to a robot's fuel supply, while landing on a bomb depletes it."

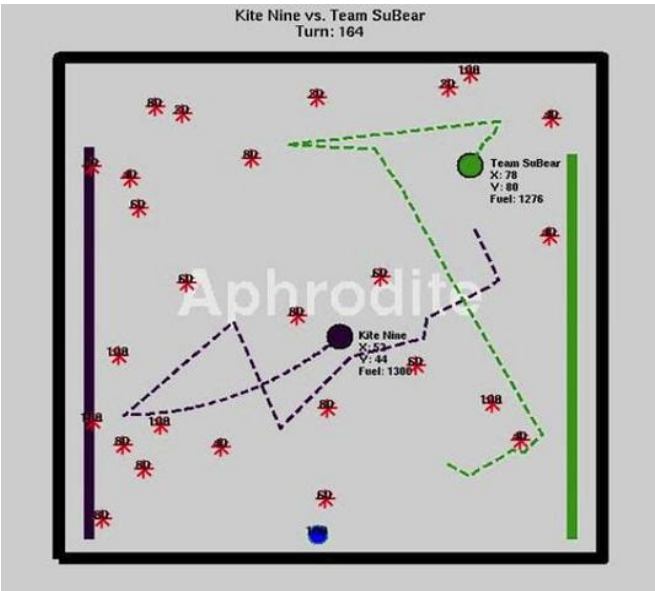

Figure 1. A tournament battle between two robots (the green and purple circles) showing their paths (dashed lines) as they avoid bombs (red asterisks) and seek out fuel tanks (blue circles). Copyright 1994-2015 by The MathWorks, Inc.

The virtual robots and their environment used in those classes are two-dimensional representations of the physical world. Three-dimensional, more realistically simulated robot programs for STEM learning have also been created, such as the Robot Virtual Worlds from Carnegie Mellon University and STEM Virtual Robotics by Cogmation Robotics corporation. They have been used at K-12 as well as at the college level.

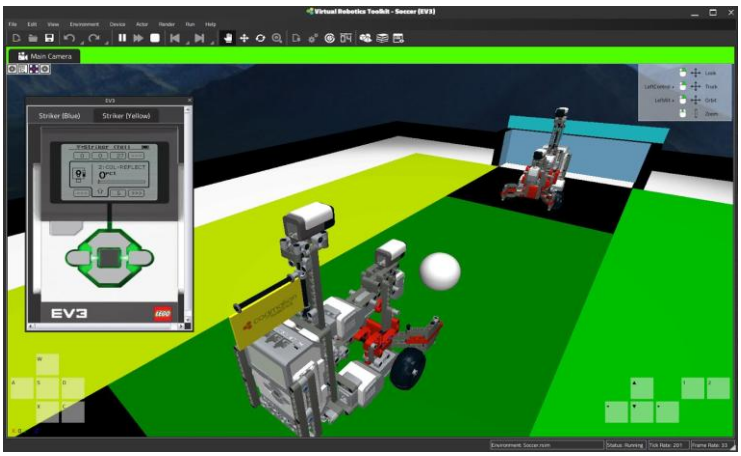

Figure 2. Multi-robot challenges from Virtual Robotics Toolkit. Copyright 2013 by Cogmation Robotics Inc.

3. Discussion

There are several common genres in contemporary video game design such as first person shooter, role playing, action, adventure, sports, racing and strategy. But regardless of the genre, every game should have a narrative or storyline[6]. To create a compelling game is to create a compelling narrative. So far narratives seem to be different for different subjects. For example, an adventure game (i.e. a hero's journey) maybe a suitable narrative structure for learning problem-solving but may not be suitable for other types of learning such as history.

In one study[5], an experiment is presented showing that adding a game-based computer assisted instruction to a traditional linear presentation of material may not result in a better learning outcome than a non-game-based instruction for all subjects. For example, the result suggests that the students involved in the experiment using just the traditional program learned more in the math subject compared to those using the program augmented with gaming attributes. One possible explanation of the outcome is the sharp division between the learning and game content. The participants might have rushed through the learning material in order to reach the game more quickly. As a result, they may have failed to pay adequate attention to learning. So the conclusion is that the connection between the material to be presented and game play experience should be seamless and non-disruptive.

Simulation programs have proved to be an effective educational tool in the past several decades and simulation-based learning games (such as virtual robot programs) can provide a seamless connection between the learning material and game play because the simulation itself is educational[5]. For example, how the virtual robots will behave depends on how students solve the problem.

Two dimensional virtual robot programs used in introductory programming courses at UC Berkeley and Cornell have gained obvious success among the engineering students. However to attract students from all background, using a more realistic 3D model and simulation will likely be more effective as it can aid in comprehension of abstract concepts and complex ideas better[13,14]. So for a general education course, using three-dimensional more realistically simulated robots may be more engaging and effective for STEM learning.

4. Conclusion

There is strong evidence that video games can be powerful aids for teaching and training. It changes the learning from the traditional model of students passively receiving information from the teacher to one where students actively apply their knowledge and skills to solve problems. The interactive multi-media presentation of information manifested in educational video games has shown great promise for that purpose. However some key questions remain to be addressed: How to create compelling narratives to support different types of learning? How to integrate video games with traditional classroom teaching seamlessly? How to find the balance between

using video games and traditional instructions in teaching and training?

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