6.2 Using Game Development to Engage Students in Science and Technology

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Abstract. Game design workshops, camps and activities engage K-12 students in STEM disciplines that use game engine and development tools. Game development will have students create games and simulations that will inspire them to love technology while learning math, physics, and logic. By using tools such as Gamemaker, Alice, Unity, Gamesalad and others, students will get a sense of confidence and accomplishment creating games and simulations.

1.0 NOMENCLATURE

STEM : Science, Technology, Engineering, and Math
NPC : Non-Player Character, computer controlled character
GUI : Graphical User Interface
STEP : Science and Technology Enrichment Program.

2.0 WHAT'S THE PROBLEM?

In this day and age of science and technology, students are struggling more than ever with math, science, and technology. There are several countries across the world that have noticed a decline in their math and science scores over the last couple of decades. Almost 30 percent of students in their first year of college are forced to take remedial science and math classes because they are not prepared to take college-level courses[1]. The United States has addressed this by creating "*A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System." [1]* Other countries have taken similar steps in addressing this decline.

> *"The United States possesses the most innovative, technologically capable economy in the world, and yet its science, technology, engineering, and mathematics (STEM) education system is failing to ensure that all American students receive the skills and knowledge required for success in the 21st century workforce.... To succeed in this new information-based and highly technological society, all students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past.... Strengthening STEM education across the nation is critical to maintaining a high quality of life for our citizens and ensuring that Americans remain competitive in international science and technology. Public awareness and action are critical to addressing this crisis."* [1]

To respond to this many schools have taken a look at their curriculum and teaching methods and modified their methods to focus on test questions more than the course material [2]. This is not a long-term solution; it just addresses the symptoms (the test scores) rather than the cause (the lack of student understanding).

2.1 Why is this happening?

Over the last fifty years or so what has changed? Why is this becoming a problem? The reasons differ quite a bit for each region in the world. However, as reviewed below, some reasons transcend regional differences.

One of these reasons is the perception that STEM topics are too hard and the student will fail at them. The test is not the problem, but the subject. Before even getting started, many students have already given up. Math has the biggest stigma; most students start their struggle here and this leads to a similar problem in their future science, engineering and technology study since they are based on math.

Another big reason is the real-world examples used in current textbooks and classes. The examples used are not necessarily real-world from the student's point of view and can be hard to understand.

Students are affected greatly by peer pressure, and the majority of the STEM curriculum falls in an unpopular category. This gives students even less motivation to want to succeed in these areas of their studies.

School systems everywhere are being strained with smaller budgets and more students, making it difficult for students to get the help they need. Students learning the material don't get enough help figuring out how to solve the problems that are given to them and how to estimate possible solutions. In the end, many students just turn in a number hoping that it's correct.

These are just a few of the bigger reasons for the decline in STEM education and a need for improvement. This does not account for many other reasons that might be political, cultural, or other in nature.

2.2 Overcoming the Problem

These problems of getting the next generation to like and be good at STEM and see it as a viable possibility for their future careers can be overcome. We have noticed while teaching game and simulation development for over ten years that many of these problems can be overcome fairly easily with the right tools and activities. We take a look at alternative solutions that get students to learn while having fun and making their own games.

2.2.1 The Subject of Game Development

Game development has a great appeal to the majority of the younger students, and this by itself is enough to increase students' confidence in themselves. They consider themselves experts at games from day one. Younger students also have a key knowledge of how a video game works, and they know what needs to be on the screen to verify that everything is working properly, and can check their own solutions. The average student in the United States has over five thousand hours of gameplay experience [3] giving them confidence when checking their solutions. All this time and experience with video game start them off with a mental preparation for success and very often a passion for video games. Many of them have also played video games that they modified or created new levels for with the games built-in editors. These built-in editors, however, are not very good for teaching because they have been simplified to let anyone create their own levels easily and often lack documentation.

The subject of video games also creates a peer-pressure environment that motivates students to do better. They strive to create games that will impress their peers in the classroom and friends outside of class. Often students will put in more time in making and polishing a game or a simulation than they would anything else in their studies.

We have seen at ECPI that the game and simulation courses have an attendance rate ten percent higher than other technical classes in their major. This also improves their pass rate in these courses by a similar percentage. We have also seen this same trend with camps that we have offered to high school students compared to camps in other fields [4].

Other institutions such as Purdue University, MIT, NASA and more have created games or tools to appeal to the younger generations. They have created these games and tools to bring new blood to their respective industries. Robert Morris University did a survey of fourth graders before and after a STEP camp. The students came to the college four hours every week for eighteen weeks, with their time split equally between technology and sciences [5]. For young students attending camps at ECPI, we found that 36% of the

students surveyed before the camp were interested in a career that involved STEM compared to 68% after the camp. This significant change has to be contributed largely to the students starting to like the subject especially at such an impressionable age.

2.2.2 Math the Building Block

Math, being the building block for science, engineering and technology, needs to be addressed first. Game development can be used to teach math using simple classic games such as Breakout, Space Invaders, and Asteroids. The math, logic, and rules in these games are simple making them the ideal choice. We also start by using a game engine that has a graphical programming language requiring no programming experience, such as Gamemaker or Gamesalad. All this allows us to focus on the logic and basic math.

Recreating and expanding many of the early games can be used to introduce the following math concepts:

- Unit Conversion – by converting screen coordinates to world coordinates in game
- Cartesian Coordinates – Using basic movement to calculate character positions
- Functions – can be taught by using the built-in functions and creating new one for power-ups in games
- Sine, cosine – for player rotation
- Statistics and probability – for creating random distributions for NPC, power ups, and dealing damage

These touch just some of the simpler concepts; many more math concepts can be introduced in similar ways. Some of the more advanced math, such as matrix manipulation and the complex number system, may require a more advanced game engine such as Unity or Torque with some C++ like programming.

Unlike many word problems in math where students struggle to understand the problem, the calculations, and the process for checking a solution, the task is clear and the student can focus on solving the problem. They can check their solution by playing the game and immediately know if there is a problem with their solution. Having these visual cues from the game, they can see what is wrong and can usually solve the problem by themselves most of the time, along the way learning the concepts in greater depth.

In Fig 1 you see one of the games we used to teach the Cartesian coordinate system to fourth and fifth graders based on the classic Breakout game. The students loved the lesson and did not even realize that this involved math. The students set up the ball movement, bat, and blocks in the game using basic GUI commands and using screen coordinates that are very similar to

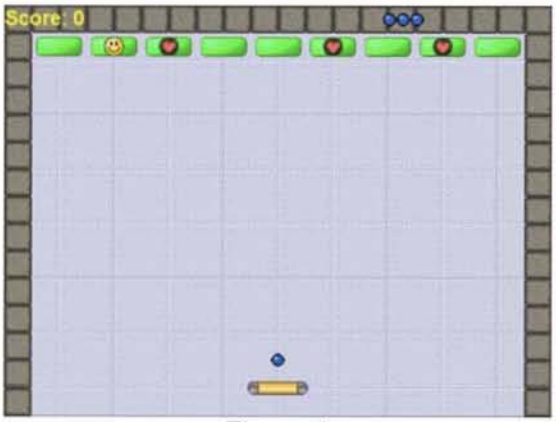

Figure 1

the Cartesian coordinates. Math is where we had the greatest improvement for our third and fourth graders from our STEP program in comparison to their peers from over two hundred students surveyed [5].

2.2.3 Science

Game development requires the direct use of physics, while the other sciences can be included at best indirectly. Most game engines have physics support built in, such as PhysX® and we take advantage of this in our lessons.

The easiest way to start teaching science with games is with Newtonian physics and remaking games such as Super Mario Brothers, Gran Turismo, Donkey Kong, and Lunar Lander. These games can be used to introduce many concepts and formulas such as gravity, acceleration, momentum, friction, mass, force, terminal velocity, torque, and levers. The concepts can be used to compare and contrast using actual physics versus guesstimating, allowing the students to see how the difference affects the behavior of the game. This means more to the student than "real-world examples" or just reading a problem and finding a number that is the solution. When customizing these games, students will be able to manipulate variables such as force, mass, acceleration and time, and get a better understanding of these concepts. Using the game engine will allow them to experiment with variables that would not be safe or even possible in a lab environment.

Other sciences such as biology can also be taught by having the students develop serious games to teach the concepts. These games can range from simple games based on the action genre that students create, to MMO/Adventure type games that will incorporate the science as part of the gameplay that students design. Here are a few games that have used these approaches that students can create:

- "Moon Base Alpha" - NASA's MMO
- "Spore" – Electronic arts
- "Math Blaster" – Davidson (Nintendo and Sega later)
- "The Incredible Machine" – Sierra
- "Marble Madness" - Atari
- "Critical Mass" – Purdue University

Creating some of these games and simulations will require more advanced features in the tools than the most basic game engines can offer, requiring a more advanced tool such as Unity.

Figure 2

Fig. 2 was created by ECPI students. It shows the USS Monitor floating in rough seas. Here not only did the students have to create the ship itself, but had to work out the buoyancy and placing the mass of the ship, turret, and engine in the correct locations. After putting all this together, they saw that the stern of the ship sits lower than the bow. They thought that they had made an error but after looking at historical pictures, they saw this was correct.

2.2.4 Engineering

Engineering is a great place to apply the math and physics that the students learned using game development tools for the initial lessons. Game development tools have support for many of the principles needed for engineering. This allows students to create games and/or simulations for building bridges, ships, car, ecosystems, and more. We have had our students create all of these as simulations or games.

However, only some of the examples can be done with basic tools, creating most of these engineering examples require more advanced tools such as Unity, Torque, or Alice. The ones that can be implemented easily are:

- A 2D bridge building game where students have a challenge of building a bridge that spans a river or valley.
- An ecosystem simulation that you set up for a pond where the user has to balance the system so that nothing dies out.
- Simulating traffic at an intersection, stretch of highway, or parking lot to see what bottlenecks are there and look at possible fixes.

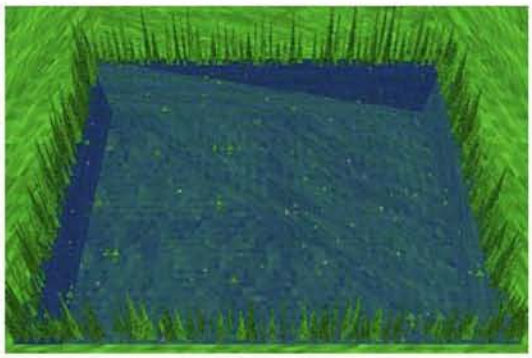

Figure 3

Here you see in Fig 3. a pond simulation that that our students have completed. They have to do the research and get help with biology, not only programming. While creating it, they learn about ecosystems, and after completing the pond, they can experiment with trying to balance it or seeing how easily, an ecosystem can be broken.

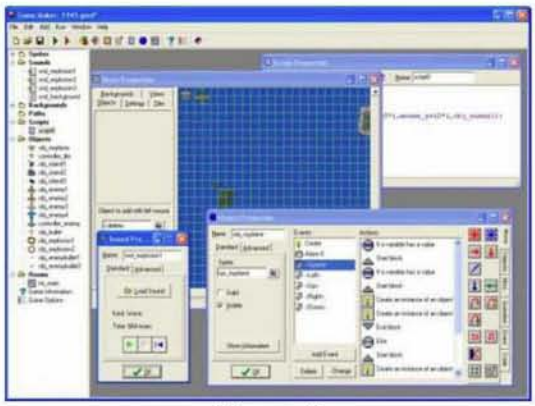

Figure 4

2.2.5 Technology

Using game development tools for teaching the science, engineering and math, teaches technology at the same time by using game development tools. This helps build computer literacy and logic skills with every lesson that the students do.

The computer literacy skills that the students learn in the lessons include: file management, file types, compiling projects, image editing, web research and more. Whatever field the student eventually enters, these skills will be required. While learning the game and simulation tools, the students learn logic, design and programming. These tools introduce students to programming concepts such as functions, variables, inheritance, arrays, and conditional statements.

3.0 RESULTS

With STEM subjects not being the most glamorous in students' eyes, games and game development help address this. The first question to be answered is "Do these activities change students outlook on STEM fields?" We see this happening with all our students, but the ones that are influenced the most are the fourth graders. This is supported by before and after surveys of fourth and fifth graders that show an increase of 32% in their views of science and technology as a career and 38% increase in liking science and technology. These are our most easily influenced group.

The high school students we had in our game development camps were there voluntarily. Camps offering game development were filled to capacity with a waiting list while camps on other STEM topics had seats open, leading to the conclusion that the addition of game development into the curriculum increased student participation. Looking from this perspective game development works to attract high schools students to STEM.

The attendance for ECPI game and simulation classes is just over 10% higher than in other computer science classes for the same students, and their tardiness is reduced as well. All the classes compared started and ended at the same time.

4.0 CONCLUSION

The biggest problem is getting faculty that can teach with the game development tools, especially for the advanced lessons that require the higher-level game and simulation tools. Game development and games will inspire the next generation to like technology. It will make them better at the sciences, engineering and math. The exact size of the benefit is still unknown. However, additional studies need to be done to measure the long-term effectiveness of the initiatives.

5.0 REFERENCES

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