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Video Game to Teach Fluid Mechanics (Work in Progress)

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Video Game to Teach Fluid Mechanics

Abstract

The use of video games in teaching can be more productive than traditional educational techniques such as reading books/notes and assigning homework. Implementing course content and assignments in video games can be an effective way of engaging students, especially students of generations Generation Z and Generation Alpha, because they already grew up in the era of technology, spending hours each day on their computers or phones. Implementing games for teaching civil engineering courses such as Soil Mechanics, Fluid Mechanics and Statics have the potential of improving learning and retention among students. Thus, a team of faculty and students from civil engineering and computer science at the authors' university collaborated on an interdisciplinary project titled "Design of Educational Game for Fluid Mechanics" to be used within the civil engineering curriculum at the authors' University. The game consists of a character who tries to escape from a warehouse. To accomplish this task, the main character moves from one room to another by solving fluid mechanics related problems. By nature, fluid mechanics problems, such as energy equilibrium, head loss, pump power, and buoyancy can easily be integrated as part of the storyline in a video game. The faculty and student of civil engineering major narrated scenarios, and the computer science faculty and students implemented the scenario using Unity 3D and C programming interface. This videogame helps students to practice and learn various aspects of fluid mechanics in a more engaging and enjoyable environment. In addition, by playing the game, the student can visualize the real-life application of fluid mechanics. The original prototype was improved through iterative refinement after testing with a few play testers. The game was then used for augmenting the teaching of Fluid Mechanics course among civil engineering students in authors' University in Fall 2021 Semester. The design process of this game, initial evaluation results, and lessons learned from the perspective of civil engineering is discussed in this paper. This paper intends to provide a framework and testbed for related civil engineering educational games in future.

1 Introduction

With technology improving every year, younger generations are exposed to new ways of being educated. Students are constantly being provided with new resources to learn. Video games and phone applications are effective learning resources that can be beneficial to students. Generation Z and Generation Alpha have grown up with technology and spend countless hours on their phone or computers playing games. In the early ‘90s, video games used to be only seen as more of an entertaining way to pass the time than to provide a learning experience, but now game developers are seeing opportunities in games to educate their players. Educational video games can be extremely beneficial to students by providing an interactive and engaging environment.

Video games in classrooms can help students focus and understand concepts more clearly. Mark Griffiths in their research in 2002 noticed that by providing a visual and story shape patterns in a video game, a game developer can help children develop their basic skills including language, mathematics and reading easier [1]. If playing video games already can help enhance someone’s abilities to react, think or understand quicker, games that heavily focus on educational purposes should help students excel in school. Video games are more interactive than a classroom and can help the hands-on learners that struggle with some subjects. Kurt Squire conducted a study that was focused on students learning from video games. Squire discussed the overall findings as, “many of the students who performed well in the game-based unit were just those who felt disaffected from school because they preferred hands-on activities in which they could learn through doing and figure things out for themselves” [2].

Numerous techniques, technologies and models have been provided for students to learn independently, at their own time and pace by introducing content that will make learning enjoyable instead of depending totally on the traditional methods that lay emphasis on quizzes, assignments, and exams [3]. However, traditionally the content presented in this manner use a gamified approach whereby questions are presented within the game design elements in a sequential manner and in most cases, they are designed with the assumption that all students are identical in every respect. Consequently, they do not create enjoyment for students because it shields them away from balancing fun with learning and the entire process is repeated with either different or same questions depending on the type of authoring employed. Project Fluud, which is presented in this paper, challenges the students to solve problems related to fluid mechanics in an interactive way. Project Fluud uses a game-based learning approach whereby learning contents are implicitly embedded in the game to motivate students to learn while playing. This approach has been used to reflect academic content in several ways and has proved to have positive learning effect in various contexts [4, 5, 6, 7]. However, only few civil engineering educational games are available to support the learning needs of civil engineering students [8, 9], and there is need for developing and evaluating more educational games for addressing the specific needs of civil engineering students. Project Fluud was play-tested in the Fall 2021 semester for students in the Fluid Mechanics course. A survey was distributed to students after they played the video game.

The result of the survey is presented in Appendix A. After implementing students’ feedback to improve the game, the game will be used for teaching Fluid Mechanics course in Fall 2022. The effectiveness of the game in students’ learning will be studied in more detail in Fall 2022.

2 Design of Fluud Game Stages

Project Fluud game is designed to give a 3D visual of fluid mechanics related problems and can help hands-on learners further understand the concepts. This would be a much preferable way of studying and learning than traditional classwork or homework for students. The students playing an educational game, such as Project Fluud, would be more engaged and productive in their work due to how interactive the learning experience is.

The game contains ten distinct stages. Each stage consists of one problem that the player must solve. The player is to use their knowledge of fluid mechanics to complete the tasks and progress through the levels. In the following section each stage of the game is explained. It should be noted that after the first trial of the game in Fall 2021, authors noticed that some stages of the game are not well designed and currently they are working to complete the game. The stages that are not complete are not presented in this work in progress paper.

2.1 The Hub world:

The Hub world is where the player first appears in the game. There are doors that the player must go through to access each level. Figure 1 presents the Hub world, in which the student can pick the topic that they want to practice and study.

Figure 1: Hub world

2.2 Pump Power

In this stage students practice concepts of conservation of energy, head of the pump and power of the pump. The game requires the player to determine the power output of the pump for the water to flow through the pipe to the upper tank shown in Figure 2 (Assuming there is no head loss in pipes). On completion, the tank moves downward, and the floor moves upward so the player can move to the next room. Knowing the conservation of energy equation, a student can calculate the required pump head. After calculating the pump head, the student can calculate the power needed for the pump to transfer the water to the tank.

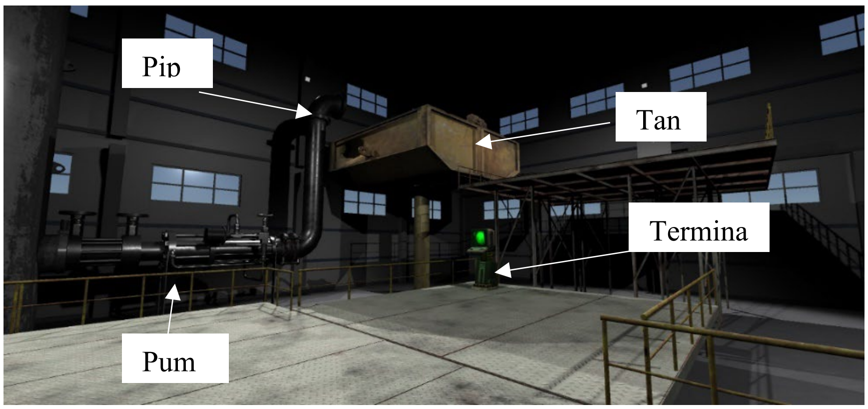

Figure 2: Stage 1- Conservation of energy, head of pump and power of pump

At the terminal necessary information such as height of pipe, specific gravity of fluid, and flow rate of the pump are provided to students and, student can calculate the required power for the pump in horsepower (hp) using Equation 1.

$$Power\ of\ the\ pump\ in\ hp = \frac{SG \times \gamma_w \times Q \times h}{550}$$ ……Equation 1

In which:

SG: Specific Gravity of Fluid

γ_w: Density of Water

Q: Flow

h: Height of the pipe

2.3 Jet Height

In the second stage students practice the concept of conservation of energy. This stage is named Jet Height. As shown in Figure 3, a pipe is connected to a closed tank filled with a known fluid. The player needs to calculate the required pressure inside the tank to raise the water jet to a specific height. Once the player completes the problem at the terminal, the fluid jet elevates a platform to the level that the player is standing. The student can calculate the required pressure inside the tank, by knowing the required height of the jet, and the specific gravity of the fluid. The player can jump on the platform and move to the next level of the game.

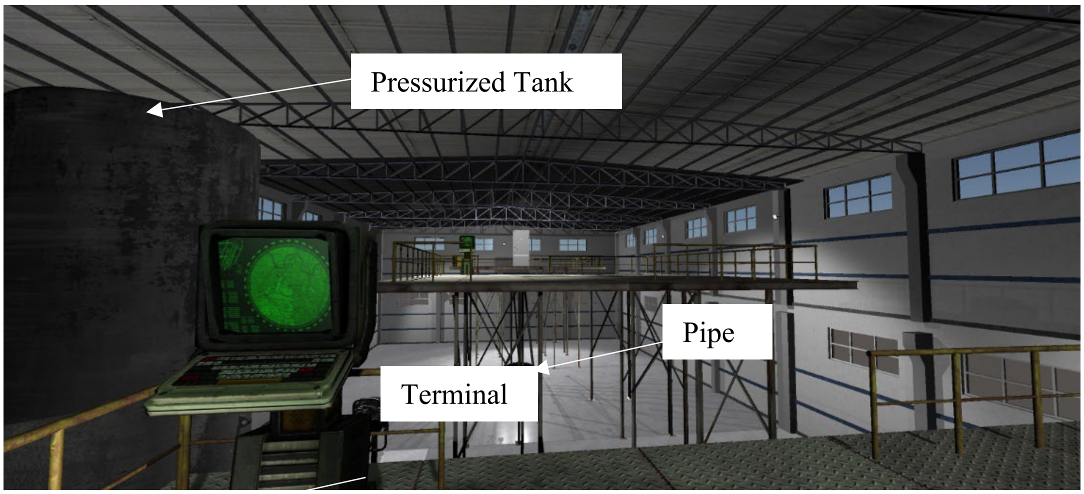

Figure 3: Stage 2 – Conservation of energy, height of the jet

In this stage at the terminal necessary information such as height of water inside the tank, height of jet and specific gravity of fluid inside the tank are provided to student and they can calculate the required pressure inside the tank using Equation 2.

$$Required\ pressure\ inside\ the\ tank\ (psi) = \frac{SG \times \gamma_w \times (h_{jet} - h_{w\ in\ tank})}{144} \ldots\ldots \text{Equation 2}$$

In which:

SG: Specific Gravity of Fluid

γ_w: Specific weight of Water

h_{jet} : Height of jet.

$h_{w\ in\ tank}$: Height of water inside the tank

2.4 Hydrostatic Force

As stage three begins and a timer appears. The player must go to the terminal and complete the problem as fast as possible. Calculating the correct answer will results in opening the door to the next level. If the timer runs out before completing the prompt, the player will be forced to restart the level. This problem focuses on static forces of fluids. In this stage, there is a pool filled with a known fluid. There is a door that keeps the pool closed. The player needs to pick the correct amount of weight that is placed on top of the door. The moment generated by the weight should be equal to the moment of the hydrostatic force of fluid therefore, the door stays closed, and the room does not get flooded.

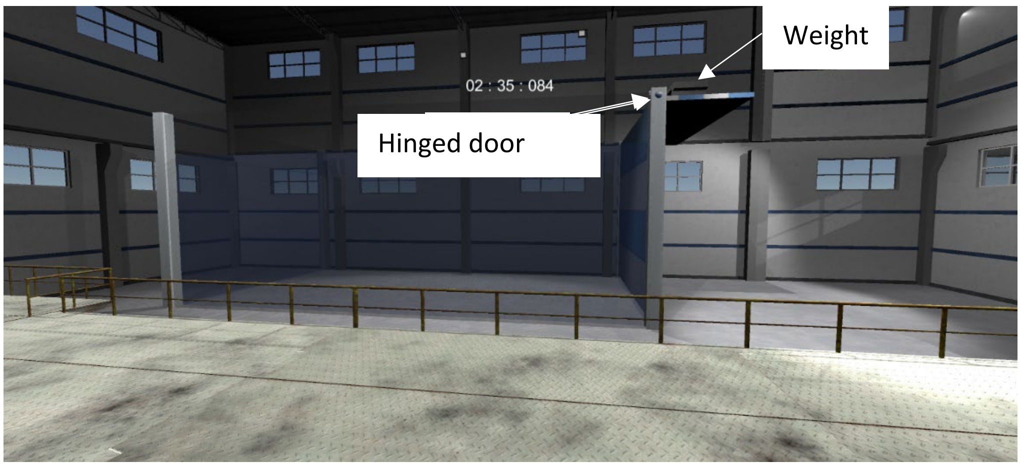

Figure 4: Hydrostatic Force

In this stage at the terminal parameters such as height of water inside the tank, the width of the pool, the elevation of the weight from the ground surface and the distance from the weight to the hinge are given and the student can calculate the required weight using the Equation 3.

$$Required\ Weight\ (lb) = \frac{0.5 \times b \times \gamma_w \times h_w^2 \times (\frac{2}{3} \times h_w + (h_{pool} - h_w)}{x} \text{ ……Equation 3}$$

In which:

h_w= Height of Water

h_{pool}= Height of pool

x = Length of weight to pool

b = Width of the pool

γ_w: Specific weight of Water

2.5 Buoyancy

In this stage, a pool filled with a fluid is located between the player and the exit door. A square platform will appear after interacting with the terminal and calculating the correct answer for this stage. The platform can be used to travel across the pool. The player must use their knowledge of the concept of buoyancy and calculate the side length required for the square pallet to float on the water.

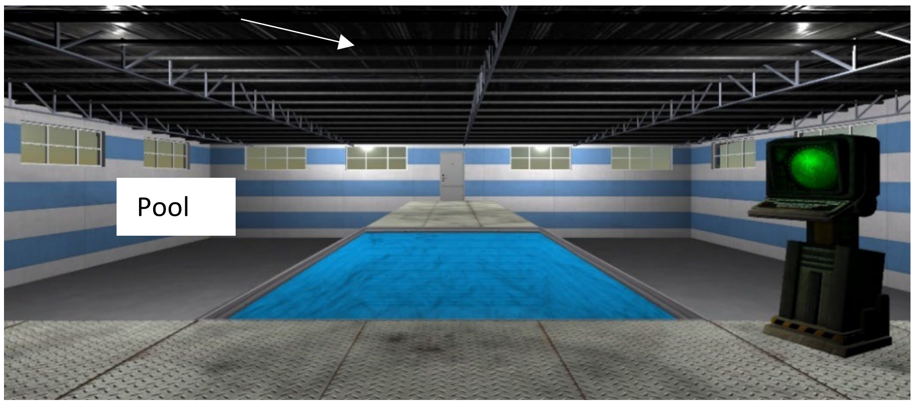

Figure 5: Buoyancy

In this stage at the terminal necessary inputs such as weight of the character, specific weight of the box and fluid inside the pool and thickness of the box are provided for the student. The student can calculate the size of the box using Equation 4:

$$Required\ Width\ (ft) = \sqrt{\frac{W}{t \times (\gamma_F - \gamma_{box})}} \quad \text{......Equation 4}$$

In which:

W: Weight of the character

t: Thickness of the box

γ_F: Specific weight of fluid

γ_{box}: Specific weight of box

2.6 Pump Power & Head loss

In this stage, two concepts of pump head and pump power and head loss are combined. The water must be pumped from Pool 1 to Pool 2 as shown in Figure 6. First, the player must calculate the total head loss due to friction inside the pipe. Then writing the conservation of energy equation, the player needs to calculate the pump head and then the required power for the pump. Once the player inputs the correct power for the pump, the pump will pour water into the Pool 2 and the pallet can now be used to jump across to reach the door.

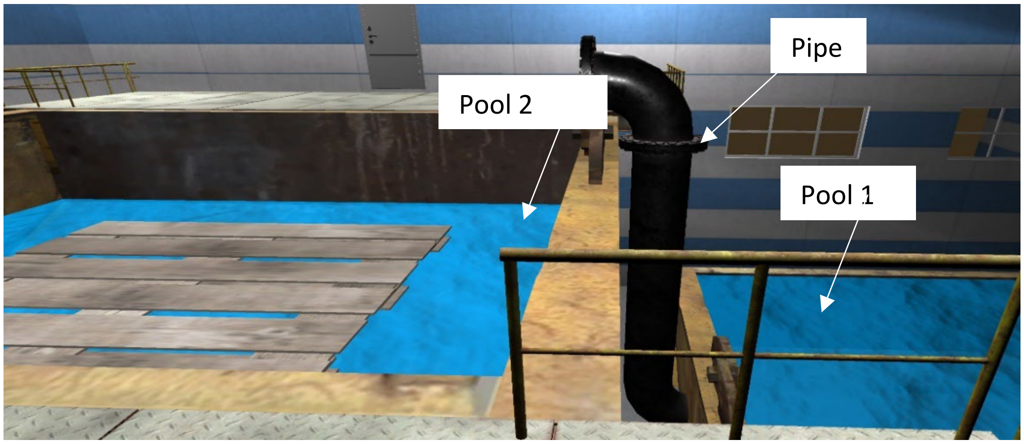

Figure 6: Pump Power with Head Loss

In this stage at the terminal necessary information such as length and diameter of the pipe, Darcy's friction coefficient, water elevation difference between the two tanks and the flow capacity of pump are given. Using the head loss equation shown in Equation 5 and 6, the student can calculate the head loss due to friction inside the pipe.

$$V = \frac{Q}{A} \ldots \ldots \text{Equation 5}$$

$$h_f\ (ft) = f \times \frac{L}{D} \times \frac{V^2}{2g} \ldots\ldots \text{Equation 6}$$

In which:

f= Darcy's friction coefficient

L: Length of the pipe

D: Diameter of the pipe

Q: Flow capacity of the pipe

A: Cross section area of the pipe

At this point students can write the conservation shown in Equation 7 of energy equation and calculate the required pump head.

$$Required\ pump\ head\ (ft) = \Delta h + hf \ldots\ldots \text{Equation 7}$$

In which:

Δh: Elevation difference between the two pools

3 Summary and Discussion:

The video game was play-tested in Fall 2021 in Fluid Mechanics course. Twenty-seven students were asked to participate in this study. The practice took place at the end of the semester when students learned all concepts of Fluid Mechanics course. Students were divided in groups of four or five students per group and were asked to play various stages of the game. Most of the groups were able to identify the problems and finish each stage. However, the instructor clarified couple of stages for all groups to make sure all students are practicing the video game in an enjoyable environment. After solving all problems, the instructor solved each problem for educational purposes. To complete six out of 10 stages and identifying the mistakes approximately 60 to 70 minutes time of the class was used.

Some of the instructor's observations were:

1. Video game was a useful tool to be used as a review session.
2. Although students were not asked to review the course before the class, the excitement of solving each stage encouraged students to go over their notes while playing the video game and review the concepts they learned during the semester.
3. Playing the game as a group was effective. Students were able to help each other to identify problems.

There were two main purposes in play-testing the game,

1. To identify the mistakes and bugs of the game.
2. To collect students' feedback.

Students were able to find mistakes (either computer science related, or civil engineering related), in 4 out of 10 problems. Currently the team is debugging the four stages. Authors are optimistic to implement the game in fluid mechanics course in Fall 2022 semester.

A survey was embedded inside the game. Students were asked to fill out the survey after finishing the game. The result of the survey is presented in Appendix A. Lessons learned from playtesting were used in designing an improved version of the game, which was used in Fall 2022 as a support tool to teach a civil engineering class in authors' university.

Overall, we believe that instructors should adapt their teaching methods to the learning methods of the students. New ways of education are constantly being created and modified for students to provide better learning experiences. Many people enjoy video games and providing an educational game that can help them learn without making it seem like schoolwork could make students more productive. While more studies are ongoing to understand the impact of this game among a broader set of students, the game already shows a potential of helping students learn better, while they balance learning with fun. A game such as Project Fluud can be a great start to learning a subject through a video game. There is a potential to make video games for Civil Engineering courses such as Soil Mechanics and Statics and Strength of Material. Trying the game in Fall 2022, authors would have a better understanding of the effectiveness of using video games in teaching engineering concepts.

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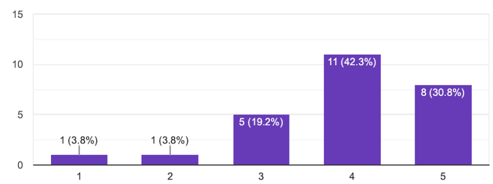
APPENDIX A

Fluid Mechanics Game Survey

27 responses

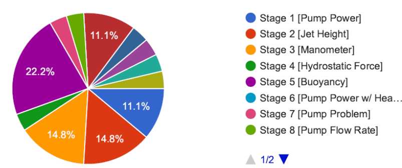
On a scale of 1 to 5, rate how well you enjoy playing digital games,

26 responses



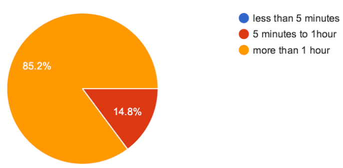
Which is your most favorite level in this game?

27 responses



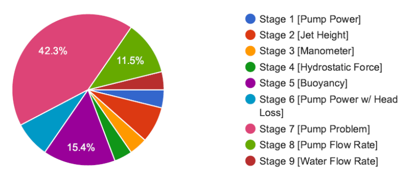
How long did you spend playing "Fluud" Game in total?

27 responses



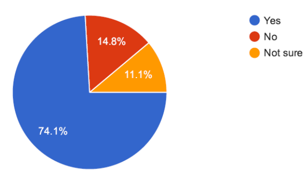
Which is your least favorite level in this game?

26 responses



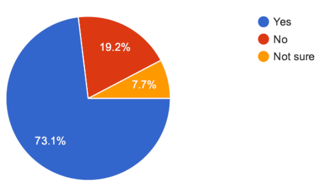
Would you play this to study Fluid Mechanics?

27 responses



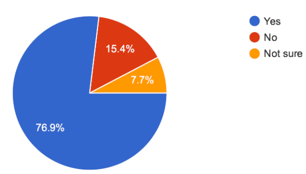
Would you want to play this game as a replacement for a traditional homework assignment?

26 responses



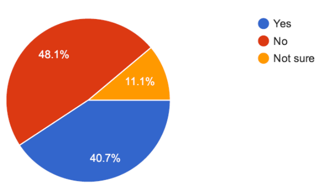
Would you play this to complement your existing classroom curriculum?

26 responses



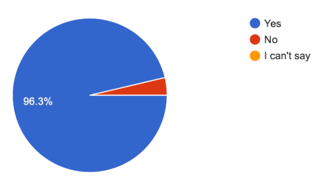
Would you want to play this game as a replacement for a quiz?

27 responses



Do you think this game could be used for educational purposes?

27 responses



What do you consider as the most difficult challenge in playing this game?

25 responses

Figuring out whats going on in the problem

Figuring out the problem and solving

The most challenging part of the game is problem solving.

some of the numbers were very big

nothing

Problem number 7

Moving sensitivity and just having to go back and forth between the screen and the game

Jumping from place to place

Some of the questions were unclear, and there was a lot of conversions

Did you encounter any bugs?

27 responses

no

No

N/A

Number 9 has no units

Yes, problem 9 had bugs.

i dont think so

Mouse sensitivity

Movement sensitivity was really high

One problem has specific gravity as density

Anything else you would want to see in this game?

23 responses

no

No

Design your own pipes/pumps to fit certain variables

I would like to see more problems.

helps to review with everything

more levels

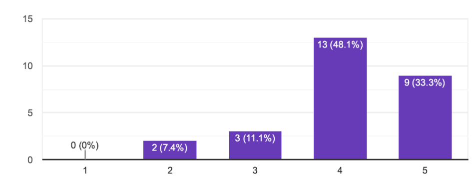
more levels maybe in each section

capillary rise? Force on pipe bend? Hydraulic radius?

N/A

On a scale of 1 to 5, rate how well you enjoy playing digital games

27 responses



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