Education Engagement in Virtual Reality: A Proof of Concept

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ABSTRACT

Students in a classroom are known to lose focus and get distracted easily. This can lead to missing information on the course and learning less. With virtual reality technology becoming more accessible, it opens the door for the use of this technology to address that problem. Our project built a proof of concept educational enhancement tool that shows that students can stay engaged in a virtual reality environment while actively engaging with educational topics like math. We built a virtual reality escape room that had 5 different puzzles ranging from logic puzzles to algebra. It was set in a classroom and the participants could freely move around the room, had access to a calculator, and could enter in answers for puzzles onto a keypad. Two participants tested this proof of concept and reported to feel actively engaged in the topics of the puzzles, which shows that our proof of concept is successful in keeping participants engaged with the topic by putting them in an immersive virtual environment.

Introduction

Our project is to create a virtual reality escape room where the puzzles are all based in math concepts. This project's goal is to be used as an educational enhancement tool. We want this to serve as a tool to actively engage students using math if they are struggling with remaining engaged in a traditional classroom. We found this idea interesting because we both are passionate about education, and wanted to create a tool that could enhance the ability of a student to learn while at the same time gamifying that process.

Going into this project, we were excited to be creative with level design, tricky puzzles, and finding a way to weave in math education throughout the experience. Our initial idea was to visualize complicated mathematical topics like geometry and calculus to the purpose of learning while also gamifying education. As the project went on we debated the idea of how hard these math problems really should be. We decided that because the main goal of this project is to create a proof of concept, we lowered the scope of the difficulty. Our most difficult math problem was finding how many small spheres fit into a cylinder based on dimensions, and our most difficult logic puzzle was a sudoku-like triangle puzzle. These problems were not incredibly difficult but still required the participant to remain actively engaged with the escape room.

The main goal of our room is to create an engaging environment and keep the participants motivated to solve all of our puzzles. By doing this, we aim to create a virtual reality experience that is interesting, immersive, and fun. By achieving this goal, we show that gamifying a math based virtual reality environment could be a viable way to keep students in a traditional classroom actively engaged with the concept if they are struggling to do so.

Related Work

There is a lot of work surrounding education in a virtual reality environment. With the world going increasingly online, it's important to explore all options of educating students, and as these options are explored, it is important to do research on their efficacy. Our project aims to create an educational enhancement tool. We want our project to serve the purpose of actively engaging students in a way that uses their logic and reasoning skills. In order to do so, we referenced two papers to get an understanding of what is important to focus on when designing and developing our project.

1.1

The paper “Motivation, engagement and performance across multiple virtual reality sessions and levels of immersion” written by the authors Wen Huang, Rod D. Roscoe, Mina C. Johnson-Glenbergm and Scotty D. Craig from Arizona State University.

There is an association between higher immersion and positive subjective experiences in virtual reality. Research has shown that the more positive experiences a person has, the higher their motivation to do that task is, and with higher motivation comes a better learning experience. This study's goal was to put data into this claim and investigate the changes in learner’s motivation, engagement, and spatial reasoning across multiple sessions and levels in virtual reality based on how good the immersion is.

The study had a total of 77 adult undergraduate students who were recruited as participants from a university. participants were assigned into three random subgroups. The first group was *Moderate* Immersion where participants used an Oculus Go across all three sessions, the second group was *Higher* Immersion where participants used the Oculus Rift for all three sessions, and the third group was *Transitional Immersion*, where participants used the Oculus Go for the first two sessions, and the Oculus rift for the third session.

The participants learned about the solar system via a program called Titans of Space. This program showed all celestial bodies in the solar system and the appropriate information attached to them. The participants could travel through the solar system, visit all the objects, and read descriptive texts.

In order to measure the participants' performance, a set of quizzes were created. The questions target recognition, recall, understanding, and evaluation. The first question asked the participants to label four celestial bodies. The second and third question asked the participants to describe characteristics about the celestial bodies like their geology, climate, or their orbit. The fourth and fifth questions were also open ended and asked participants to explain what life on a given planet might be like. The sixth question was another open ended question that presented the participants with two celestial bodies and asked the participants to explain which planet they thought was better suited to human life.

There was no statistically significant difference between the prior knowledge of the participants. After the three sessions were complete a clear trend occurred. The researchers compiled the data collected through their quiz questions by deriving a score based off of correct responses and they were summed up across all seven questions. This summing of their data is presented as the mean presence rating, which shows how engaged and motivated the participants were, and how much the participants learned over the sessions. This study found a statistically significant difference in the mean presence rating of the participants when they had a better immersive experience. See figure 1.

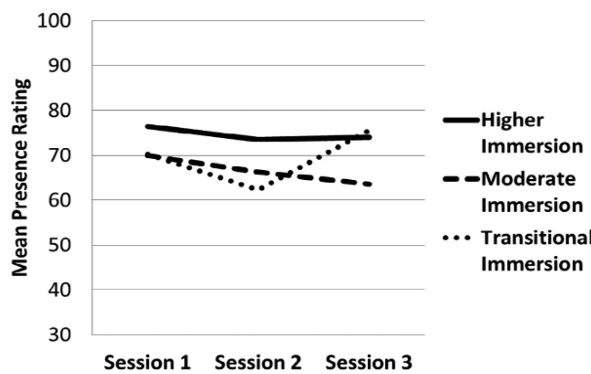

Figure 1

This study relates to our project because our goal is to create an experience that can both educate and engage students. This research study shows that there is a statistically significant difference in the motivation, engagement, and performance of users between a low immersive environment and a high immersive environment. This showed us that it is well worth the time and effort to make the most immersive experience possible. We did this by making sure there was realistic lighting, quality assets for both the classroom environment and the outside environment that could be seen through the windows.

1.2

The paper “A Virtual Tour of the Cell: Impact of Virtual Reality on Students Learning and Engagement in the STEM Classroom” written by the author Jennifer A. Bennett and Collin P. Saunders from Otterbein University.

Education in virtual reality is a heavily studied topic. There is a lot of literature about education for healthcare professionals like how to practice surgeries, but there are relatively few papers on the effect of virtual reality in an undergraduate STEM classroom. There are recent studies that indicate that in STEM classrooms, active learning is rare, and an immersive VR experience that allows students to engage in a very active learning format could be beneficial to a students understanding of a topic.

This study had 65 participants who were sophomore undergraduate students taking a cell biology course. They freely participated in a virtual reality experience called "Journey Inside a Cell" using the HTC Vive. The students were divided into three laboratory sections. Two HMDs were available for student use and the virtual reality experience lasted 12 minutes.

During this experience, participants were able to interact with a cell and its components directly. They could handle the parts with controllers and closely examine each part. At the end of the experience there was a gamification of the learning experience by having the participants shoot antibodies at an oncoming viral assault.

The students then followed their virtual reality experience with a timed cell-sorting challenge. They would work in a group of two and match printed cell parts to the correct labels. One week later, students were asked to complete a survey where they would describe their experience and whether or not they felt it had impacted their learning.

When students were asked the question "Did virtual reality enhance your learning experience in the cell biology course?", 93% of participants said yes. When asked for more information on how, their response could be grouped into three categories. It increased their interest in the material, it gave them a better understanding, and it gave them a new and even better perspective of what they were learning.

When the participants were asked "Did the combination of virtual reality and the timed cell-sorting activity improve your understanding of cellular processes? "70% of participants respond with yes. When asked to elaborate further on why they said yes the primarily mentioned response was that the cell sorting activity helped them recall, process, and reinforce the virtual reality activity. When asked if they think this type of virtual reality activity should be used in a classroom setting, 55% of students strongly agreed, 37% of students agreed, and only 5% and 3% of students were neutral or disagreed, but no students disagreed. To see a chart of the results from both survey questions, refer to figure 2.

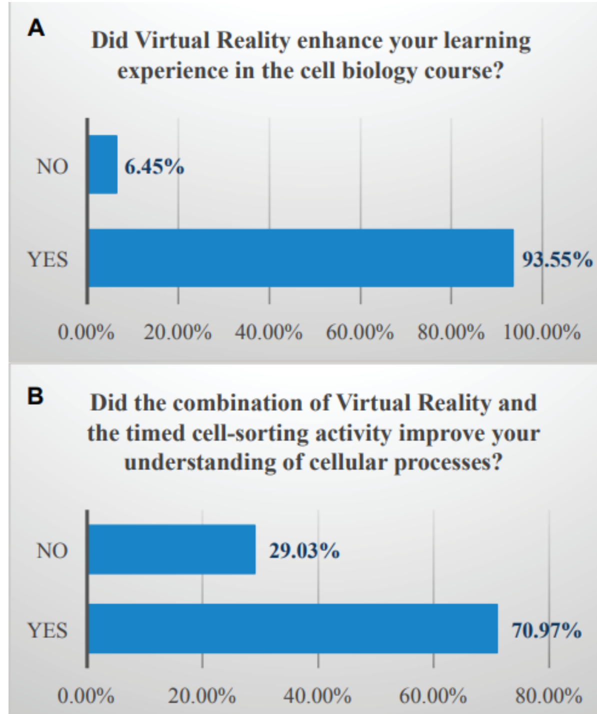

Figure 2

This paper showed that there is a perceived impact on the ability to better understand material. For the future this study recommends that there needs to be additional research to verify that this outcome is more than a perception.

This research relates to our work because the goal of our project is to create an engaging environment that can be used as an educational enhancement. It shows that students respond positively to educational experiences in virtual reality and that they feel that they are able to improve their understanding of topics through the use of a virtual environment. We are creating an educational enhancement tool as a way to actively engage students with educational content, and this study shows that there is a perceived perception of this kind of activity improving the learning experience of students. We want to be able to confirm these results through assessing the perceived engagement of participants in our virtual environment and see if they hold true when the goal of our virtual environment is to engage students through math and logic puzzles.

Project Accomplishments

2.0

Our goal for this project is to create a proof of concept that a virtual environment can actively engage participants through logic puzzles and show that this active engagement was enjoyable, informative, and effective as a learning enhancement tool.

2.1 Interactions

We Used the Unity3D engine for our project implementation. We were developing for the meta quest devices so we were able to use the Oculus Software Development Kit (SDK). The Oculus development kit gave our project a lot to start with. We could render a simple scene to our headset with proper head and controller tracking without any code written ourselves. This was great for us to start prototyping our project. From there the development kit's teleportation locomotion feature was also utilized. The teleportation locomotion (figure 3) is simple enough to use and can help a user reorient themselves in the virtual environment as well. We also used Oculus's ray interaction to be able to interact with far away objects using the controllers. This was also useful because this project is able to build custom objects like a calculator, large buttons, and other interactable objects without the need to implement ray casting ourselves. Not all necessary interaction came out of the box. We had specific use cases where we needed the ability to turn on and off rigid bodies when the user grabbed objects with the controller which was not provided by the out of the box grab scripts. We created our own grab script that allowed us to have more control over the grabbing ability of the user. Additionally we implemented the ability to throw items like bottles and weights.

Figure 3

2.2 Environment

During our development we focused on creating an immersive environment. We started with some online assets of a pre-built classroom. This was a good starting point for us. However, the room looked very basic and lacked interesting textures. We then focused on adding interesting textures into the room to create depth and realism. We are content with our classroom design, but it is not as immersive as we would have hoped. It still looks basic with solid color walls, but we spent a lot of time and effort on creating the room to look as realistic as possible. This effort improved its perceived immersion.

The room consists of several desks facing a chalkboard like a traditional classroom. Each desk hosts one of the various puzzles needed to escape. There is a chest and a door in a corner of the room that have number pads used to input the answer to either open the chest or the door and continue with the puzzles.

The class room has windows, and to improve immersion we created an outdoor environment that the participants will be able to see. We used Unity's built in terrain system to create rolling hills surrounding a playground (figure 4). The assets for the playground were found on the unity asset store which included slides, benches, swings, monkey-bars, amongst other common park items.

Figure 4

lighting is a very important factor in creating a realistic environment. We used Unity's built in lighting system which dynamically lights a room based on its environment. We gave the scene a skybox with beautiful clouds, and we manually adjusted some of the lighting settings like intensity until we felt that the environment looked the most realistic.

2.3 Tutorial Scene

When our project is opened the user is placed into a tutorial scene. We found this scene important to implement in order to familiarize participants with how to interact with the many features our escape room has to offer.

This scene starts by putting them into the same room that the puzzles appear in, but all the puzzles have been removed. This allows them to navigate around the room using locomotion and get comfortable with the environment. There are a few signs in the tutorial room explaining how the locomotion works and how they can interact with certain objects. A major feature of the escape room is that the person is always carrying a virtual calculator in the room. Using this calculator is not as intuitive as a real world calculator so we wanted players to get comfortable with it. In order for the user to leave the tutorial and enter the real escape room the calculator must be used to solve an easy equation. We then prompt the user to put that answer into the keypad which opens the door and brings the user to the main escape room.

2.4 Calculator and Keypad

Creating the calculator was a difficult process. First we had to find a proper calculator model. We then put that model into Unity and created an empty game object named calculator and made the model a child of it. Within the gameobject calculator we added hit boxes to each input, and made each input have a script named key. The screen then had a script named Logic, and we used an observer pattern where the script Logic observed every time a key was pressed and could get the value of that key. Getting a key to press was difficult. We had to find a way to detect if the built in ray interactions clicked one of our keys. If the click was found it then fired an appropriate function like processNumber, ProccessEqual, ect… We then created appropriate functions to handle the functionality of a regular calculator. We implemented the ability to string multiple operations together, ex 3 * 7 + 12 - 19, the calculator errors out with division by zero, and the calculator can handle floating point numbers.

We also needed a way for the participant to key in values for the puzzles they were solving, for example they needed to be able to input a number for how many jelly beans are in a jar, or a number to open the chest, or number to open the final door. This was implemented after our calculator and because we designed the calculator using an observer pattern, it was easy to change the implementation of what happened every time a key was pressed. Instead of the Keypad having the Logic script, it had its own script that observed its own keys, and could respond to it being the correct input or not. This was extremely useful and made for a more natural way to answer puzzles throughout the room.

These two objects in our project are accomplishments because it took a lot of work to get working. We used concepts from previous courses like 3081W or 5801 by using design patterns, and we thought ahead and made reusable code that made implementing further expansions of functionality easier.

Figure 5

2.5: Puzzles:

Our escape room consisted of 5 different direct puzzles the participant had to solve. Each puzzle's solution leads to a clue to solve the next puzzle, therefore it is necessary for the participant to solve each puzzle in order to complete the escape room. Each puzzle aims to teach the participant a different concept that falls under three categories: spatial reasoning, logic, and mathematical equations.

2.51 Puzzle 1: The Bottles

The bottles is a spatial reasoning puzzle where multiple bottles are sitting upright on a desk (figure 6). There is no indication on what a participant can do to these bottles so it is up to them to figure it out. The first thing we expect the participants to do is to swipe at them and knock them over.

When that is done, there is a chance that one of the off colored bottles will shatter on impact. If it does not shatter on impact, it is up to the participant to figure out that they can throw the bottle against a wall and shatter it that way. Once the bottle is shattered, a note appears that gives the dimensions of the jar. These dimensions are necessary to calculate the amount of jelly beans (spheres) that are in the main jar.

Figure 6

The purpose of this puzzle is mainly to give the user a sense of what is possible in the room. After this puzzle they know they can pick up, throw, and interact with objects around them. This is the only puzzle that lacks a direct math or logic component, but is still a worthy addition to the escape room because it is a very fun puzzle to solve, and with more fun comes more motivation to solve the more complicated puzzles that follow.

2.52 Puzzle 2: Jelly Bean Jar

The jelly bean jar puzzle is the classic puzzle of how many jellybeans are in a jar. In order to solve this problem the jelly beans are represented as perfect spheres. Initially the participant is given the dimensions of the jelly bean, but they must first solve the bottle puzzle to get the dimensions of the jar. It is then up to the participant to figure out how to calculate how many jellybeans can fit into the jar. Eventually the participant figures out they must calculate the volume of the jar and divide that by the volume of the sphere, and that number is the answer that must be inputted into the keypad next to the jar. When this puzzle is completed the sign A=1056, which is necessary information for the final puzzle.

The purpose of this puzzle is to engage the participants in a geometry based puzzle. By being able to see these objects in three dimensions, the participants can better understand how volume in 3D space works as they actively solve these equations. It also gives the participants more practice with these equations in an active learning environment which will better cement their understanding of calculating volume of different shapes.

2.53 Puzzle 3: Triangle

The triangle problem is a sudoku-like puzzle. On the left of the table there are nine blue pucks labeled 9 to 1. The goal of the puzzle is to get each edge of the triangle to add up to the same value. No information is given on how to solve the puzzle, they are only presented with the pads and the pucks which makes this a very difficult logic puzzle. Once the puzzle is completed all the pucks will glow green with either the number 19, 20, or 21. This value will then be used later.

Figure 7

The purpose of this puzzle is to engage the participants in a logic puzzle. We want to give the participants a difficult puzzle that makes them think while also being interactive. They have to actively pick pucks up and move them into the right place while always adding each side and trying different things. This puzzle took the most time for each person that tested our escape room and was reported as difficult but interesting to solve.

2.54 Puzzle 4: Homework

The Homework puzzle was a hand drawn piece of paper placed on top of the desk. The paper was written in the style of a bored student taking notes during algebra class. The paper is full of red herrings. It mentions the quadratic formula, factoring, amongst other things that are ultimately meaningless to solving the escape room. The main interest of the homework is the equation written in the middle, (32x-16x)/2 = 3904 . The intended course of action for this puzzle is for the participant to look at this piece of paper, ignore the red herrings, and solve for X.

The purpose of this puzzle is to make the participant solve for x, a basic algebra problem. It keeps the participant engaged because they have to use our built in calculator and solve for x. It also reinforces basic ideas on how to solve algebraic equations.

2.55 Puzzle 5: Scale

On one of the desks there is a scale, but there is nothing around the scale that can interact with it. That is until the participant solves both the triangle and homework puzzles. These puzzles give answers that when added together, as indicated by the sign on the chest, opens the chest in the corner of the room (figure 8). Once that chest is open, there is a large red button on the inside that the participant can press. Once pressed, 7 weights are dropped onto the table with different weight values.

The participant is given no instructions. Once they put a weight on one end of the scale they will see that the scale tips in whatever direction that has the most weight. It is implied that the goal of this puzzle is to balance the scale by putting different weights on each side. There are two known solutions to this puzzle, one where the weights add up to 72 and one where the weights add up to 68. There could be more, but as long as the weights are equal on both sides the scale will balance. Once the scale is balanced, a sign pops up that says B = 1652. This value is used in the final puzzle.

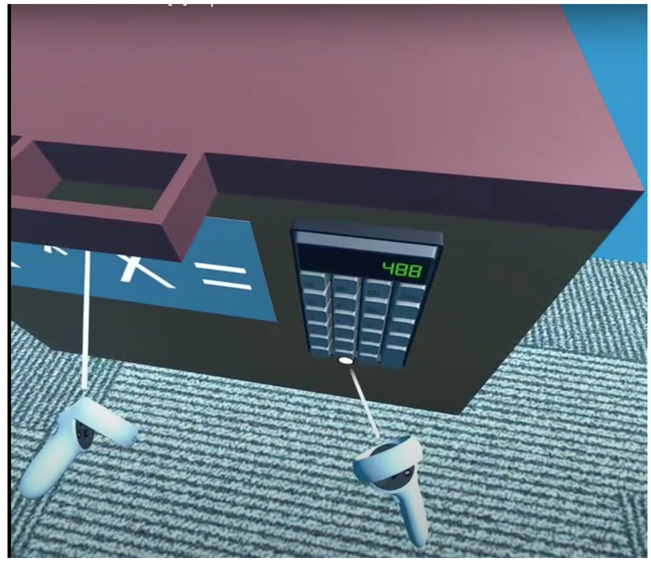

Figure 8

Figure 9

The purpose of this puzzle is to engage the participant by constantly adding 7 different numbers in different ways until they found a common sum, and by doing so engages them in basic addition, solving two sides of an equation until they equal the same value.

2.56 Final Escape

The final escape is very simple, but it requires every single puzzle in the room to be solved before it can be solved. The jelly bean jar puzzle ended with the prompt A=1056. This puzzle required that the bottle puzzle be completed as well. The scale puzzle ended with the prompt B=1652. This puzzle required that the triangle and homework puzzle be solved as well. Next to the red door there is a sign that says 'A+B =' and the equal sign points to the keypad next to the door. When the participant keys in the answer, 2728, the door opens and the escape room is completed (figure 10).

Figure 10

2.57

We feel very accomplished being able to complete these puzzles. It took a lot of work coming up and agreeing with which puzzles we should implement, and then it took a considerable amount of work implementing them. Each implementation came with its own challenges, and we are proud of coming up with solutions to complete each puzzle, and that the flow of the room works, is natural, and can be completed.

Project Assessment

3.1

In order to assess our project we had two of our peers play test it. We had each participant start in the tutorial room and gave them no guidance on what to do next. They completed the tutorial and went into the main escape room. Once there they were allowed to explore as they please and start solving the problems.

We often told the participants that they could take breaks if they wanted to but no one did, which showed us that the participants were engaged throughout the experience. Once they were hooked on a puzzle they stayed in the environment in order to solve it. One participant spent nearly 20 minutes on the triangle sudoku problem alone and was actively engaged the entire time. Both participants were interested in the puzzles and completing them, and were actively doing math the entire time. They were engaged not only in the immersive environment we created but also the math topics that we wanted them to be engaged with.

Each participant completed the course and after we asked them to rate their experience and total immersion, both gave an honest 7 out of 10. They said that they felt that each puzzle had its difficulty and it was that difficulty and drive to solve the problem that made them stay engaged.

We also asked each participant to rate the individual puzzles in the room. Both participants mentioned grievances with the triangle puzzle for being too ambiguous. When it came to the physics based puzzles like the bottle puzzle and the scale puzzle both participants had positive feedback. This indicates that the physics based puzzles felt realistic and were engaging. Our participants had solid math backgrounds which helped them jump right into the puzzles. Our tutorial room was effective enough in guiding them to interact with the room successfully without assistance. We appreciated the feedback given and based on it we have determined that our proof of concept is successful in what we set out to accomplish.

This playtest shows that our proof of concept is capable of keeping people engaged in a virtual environment while the main mode of engagement is math related. Our goal for this project is to create an education enhancement tool, something that can be used to engage students in an educational way. Through our playtests we showed that the participants were engaged and therefore our proof of concept shows promise that it can be used in the way we intended it.

Limitations and Future Work

4.1: Limitations

This project was intended to be a proof of concept. We wanted to create a minimal viable product that could show that a math based game can be engaging and also enhance the learning experience of the participants. This however came with challenges that limited the experience that participants had.

We know through our related research that immersion is very important, but unfortunately we had bugs that took people away from the immersion. For example, as time went on the collision box of the player and the reference points of the player's controller drifted from the actual location of the player. This led to the inability to interact with the calculator or the keypad. This made us have to restart the escape room, effectively breaking the immersion.

The triangle puzzle would also not work all of the time. It seemed almost at random that certain gray pads would not accept a blue puck, and the only way to solve this problem was to restart the escape room, again breaking the immersion.

Our project was also too broad to be applicable to a single classroom subject. We had puzzles spanning topics such as geometry, algebra, and logic puzzles. If this tool is to be used as an educational enhancement that both helps students want to remain more engaged with the topic they are learning, then the puzzles should be more singularly focused on a single subject. We did not do this because we thought that in a proof of concept it would be useful to have a wider variety of puzzles, but if this were to be used in a classroom, the puzzles would have to be more focused.

4.2: Future Work

For the future, we would like to make a more complete version of our proof of concept. It would be great to have an entire school modeled with each classroom dedicated to a theme like algebra, geometry, calculus, physics, and so on. That way, if this tool was to be used in a classroom it could be more applicable to what subject was being taught. It would also be a nice addition to add some randomness into the puzzles. This way the rooms have replayability because the numbers are different each play through.

With the creation of a complete product, we would then want to create an actual experiment to see if this tool could be used as a way to keep students who are disengaged from a traditional classroom setting and keep them engaged with a topic. It would be interesting to have an experiment done at a local high school over the span of a month where students who were not engaged or struggling with topics had the chance to use our program. We could then see if this affects their motivation to learn the topic, their engagement in class, and their performance in their respective course.

Division of Labor

5.1

The labor of this project was divided equally among both Jason and Luke as the project went on. We would work collaboratively to come up with an idea for a puzzle and how to string them together. When we had a direction we would divide it into separate tasks. For example, we knew we wanted to create the scale project and have an environment, so Jason implemented the scale puzzle while Luke created the playground and grasslands outside. Or when Luke was working on fixing the bugs in the keypad / calculator, Jason was working making the classroom environment more immersive by fixing the lighting and finding better assets to use. We also utilized peer programming by sitting next to each other in the VR lab in Keller Hall whenever we worked on the project. This made it so if at any point either of us needed help we could talk to each other.

Conclusion

The main goal of this project was to create a proof of concept that showed that a virtual reality escape room based on math puzzles could be used as an educational enhancement tool to improve engagement with a given classroom topic. The development of this product was difficult, but very interesting and rewarding. Through our playtests we confirmed that the product we created was engaging and informative, and we are confident that building out a fully functional product to test in a real learning environment would be an interesting research topic that could lead to a very useful application of virtual reality in improving the engagement of students with any given educational topic.

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