Combining VR and Gamification to Improve Academic Performance

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Abstract

Virtual reality (VR) and gamification are growing trends that have resulted in the increase of college student motivation, engagement, and educational performance. This report outlines the creation of a module, a self-contained unit of an introductory computer science topic, which combines the use of gamification and VR. The module practices the programming concepts of Lists and present them in a gamified VR application. The purpose of this module is to test whether it can improve the academic performance of introductory computer science students. The experiment described in this paper details the test results taken from two groups of participants, those who were able to use the module and those that watched a video about lists. Since I wanted to ensure that my findings were entirely due to VR?s interactive component, both groups of participants completed a 4 question test, that had questions of varying difficulty, before and after finishing their activity. While participants use the module or watch the video, feedback is noted and observational notes describing each participants use of my module and the video are jotted down e.g., how long did they use the module, how many levels did they complete, were they engaged and attentive, and were the confused by the dialogue or task at hand. Based on the data collected, participants that were in the group that watched the video had a larger number of people that were able to correctly answer all of the questions in the final testing section. Therefore, I can only conclude that the module was less beneficial than the video at improving the academic performance of the participant. However, observational data indicates that participants found the VR module more engaging and enjoyable than watching the video.

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1 Introduction

When examining the learning curve associated with student performance in computer science and engineering classes, it is often noted that students who are from other disciplines or have had minimal exposure to the course material usually have more difficulty with the course than do their peers [5]. Research focused on virtual reality has attempted to rectify this, by proposing gamified virtual reality applications to improve the academic performance of students[6].

Virtual reality (VR) is a computer-generated simulation that is interacted with using special equipment. Each VR system has its own unique headphones, controllers, and headset that are used to immerse the user. Within the VR headset, the user is shown display screens as their movements are tracked using special sensors. With each head or body movement that the user executes, the game adjusts what is displayed to the user in an attempt to visually immerse the user. In addition, headphones are used to auditorily immerse the user and controllers help the user navigate the surroundings being displayed to them.

Gamification is the application of game-like elements to non-gaming activities which can help to encourage people to participate and achieve specific goals [6]. There are currently many apps that use gamification. For example, Duolingo, a popular language learning app, applies gamification techniques by allowing users to gain medals and experience that can be used to unlock different application features such as certain lessons or outfits for their avatar [3]. These techniques add a feeling of engagement, encouragement, and satisfaction while improving the users knowledge of a foreign language.

Though gamification is still a growing trend, positive findings have been observed when used in combination with education. To further prove this, I hope to combine gamification and virtual reality to increase college student motivation, engagement, and educational performance. I developed a module to improve the academic performance of Computer Science (CS) students taking introductory CS courses. The module is a self-contained unit of content pertaining to lists. To test the module, an experiment was devised involving two groups of participants, those who were able to use the module and those that watched a video about lists. Since I wanted to ensure that my findings were entirely due to VR?s interactive component, both groups of participants completed a 4 question test, that had questions of varying difficulty, before and after finishing their activity. While participants use the module or watch the video, feedback is noted and observational notes describing each participants use of my module and the video are jotted down. Based on the data collected, participants that were in the group that watched the video had a larger number of people that were able to correctly answer all of the questions in the final testing section. Therefore, I can only conclude that the module was less beneficial than the video at improving the academic performance of the participant. However, observational data indicates that participants found the VR module more engaging

and enjoyable than watching the video.

2   Organization

Section 3 discusses relevant background information that influenced the development of this experiment. This includes related works, existing gamified applications that were influence the VR module developed, and how I choose to gamify the overall module. Section 4 discusses the equipment used throughout the project, the VR hardware and software used, as well as my method of testing. Section 5 discusses the topic selection process for my module, the preliminary designs, the initial and final design, a description of the video used in the module, and the importance of virtual reality. Section 6 provides the data collected from this experiment. Section 7 provides conclusions determined from the data collected from the overall experiment. Section 8 summarizes my research and findings from the experiment. Section 9 details future directions to take the module and experiment.

3   Background

This section discusses related research that examines whether virtual reality and gamification increase students' motivation to understand course content and improves their academic performance, and some existing gamified applications.

3.1   Related Work

Many researchers have studied the benefits of applying VR and gamification to the college classroom setting. The related research papers mentioned in this section focus on increasing student motivation, engagement, and academic performance through various technologies and learning methodologies based on game mechanics and the use of virtual reality.

In one research paper, Villagrasa et al. combined virtual reality with programs such as Sketchfab and Unity, and the Oculus Rift to create immersive worlds that could enhance students architectural designs skills [8]. They believed that gamification and new technologies would boost achievement in 3D architectural subjects for design, and convey and validate any architectural project by enhancing the learning process. In particular, the researchers created and applied an exercise that tested their hypothesis on a building engineer and architectural degree on the subject of "Computer Tools 2" at La Salle, Ramon Llull University, a course that is taught annually with 65 students enrolled.

Villagrasa et al., incorporated problem-based learning and quest-based learning into student collaborative work and mixed teacher support with virtual environments and visualization 3D on the web using webGL [7]. Problem-Based Learning is where students learn about a subject through the experience of solving an open-ended problem. Quest-Based Learning uses game mechanics and game-like learning communities to support student choice within the curriculum. The authors believe that by understanding the role of gamification in education, we can also understand the circumstances in which game elements can drive a students learning behavior. They believed that by doing so, students may then achieve better results in the learning process.

In a paper by Stigall et al., the authors created two gaming modules for teaching object-oriented programming and binary search, and used gaming metaphors to discuss the design, development, and testing of virtual reality instructional modules [6]. Ultimately, the authors created an immersive and non-immersive VR system, incorporated showing C++ source code, UML diagrams, and creative imaging to the user, and used games centered around teaching the user about inheritance, polymorphism, encapsulation, and binary search trees.

All of the mentioned papers claimed to have found some results, which indicated that their use of VR and gamification demonstrated an increase in students' motivation to understand course content, thereby improving their academic performance. For my research, I test the effects gamification and VR have on academic performance, examine a singular introduction to computer science topic, add to the statistical data of existing research, and build upon their findings. I also draw inspiration from Stigall et al., whose research detailed creating a module for a computer science audience and various methods of gamification.

3.2 Existing Gamified Applications

This section examines different aspects that make Duolingo and Human Resource Machine popular gamified applications.

3.2.1 Duolingo

Duolingo is a mobile app that teaches users various natural languages and uses gamification techniques to encourage its continued use [3]. Duolingo features a daily reward system and streak counts for frequent use and a point system that rewards users with Lingots, their version of virtual currency, when they complete lessons. Duo, their bird avatar, can be customized using Lingots that the user has collected. The user can also choose to use their Lingots to unlock bonus skills such as casual speech, flirting, and slang. In addition, Duolingo has a variety of languages and lessons (e.g., Spanish, Korean, German, Irish, and Portuguese) in

which users can race against the clock, a level-up system, a health system than restarts the lesson if you lose too many hearts, and a variety of speaking, listening, translation, and multiple choice challenges. Duolingo has millions of users and various research papers testing the apps overall effectiveness. Frequent phone and email notifications are also used to encourage users to repeatedly use the Duolingo app.

3.2.2 Human Resource Machine

Human Resource Machine is a programming-based puzzle game that does not require programming experience [1]. The player is an office employee and is given jobs/assignment by their boss. In each level, the player must automate jobs by programming their office worker and if they are successful, they will be promoted up to the next level for another year of work. Human Resource Machine employs the use of gamification and teaches programming ideas such as loops, jump commands, and assembly language concepts. In particular, the player is assigned to perform tasks that involve moving objects between an inbox, an outbox, and to and from storage areas. The player is shown their list of instructions on one set of inputs and the expected output, the game tests the list against other randomized sets of inputs and outputs, and finally the game alerts the player if any of their inputs fail. The player's level score is calculated based on how many instructions it took to complete the level and how long it took to process that program on average. The levels incrementally get harder as the player makes more progress and teaches new required concepts over time. The overall game can be completed in a few sittings, doesn't require continued/frequent use to progress through levels, and the user can repeat levels to get a better score.

3.3 How I will Gamify the Module

After closely examining Duolingo, Human Resource Machine, and the research papers in Section 3.1, I determined that the use of gamification in Human Resource Machine coincides with the purpose/direction of my project. It not only employs the use of a storyline, levels of increasing difficulty, and a score system, but it also incorporates the use of programming concepts. In contrast, though Duolingo's phone app design allows users a sense of convenience and encourages continual use, my module requires the user to use a computer with certain capabilities in combination with the Oculus Rift. Since I do not have access to multiple Oculus Rifts, my module's setup does not allow for the level of convenience that Duolingo allows, and users would have to schedule in their usage to gain daily access to my module, I would not be able to implement a daily rewards system, notifications, or a true level-up system. Moving forward, I implement gamification techniques similar to those used in Human Resource Machine.

4 Methods

To address my research question, I created a module that can be used by CS college students and tackles one of the more difficult CS topics in introductory courses. To aid in the topic selection process, I examined Union College's Intro to CS survey data which asks participants to rate CS topics on the extent to which they developed the skills or understanding of the various concepts. The module uses gamification techniques, and VR systems and programming software to create virtual environments in which students complete a task geared towards practicing list concepts. I worked with one or more of the intro to CS professors (i.e. CSC 104-01 Robots Rule and CSC 106-01 Can Computers Think), to recruit students to participate in my experiment.

4.1 Equipment

This project requires VR hardware, VR software, and a compatible workstation and testing area. The VR hardware is used by participants and allows them to test and interact with my VR module. Since there is a variety of VR hardware and VR software and they are both pertinent to this project, I considered various products. A Windows system was used to test and develop the module. Testing of my module was conducted in the Cooperative RObotics and Computer-Human Empirical Testing (CROCHET) lab, which is one of Union College's laboratories.

There are many VR programming tools such as Unity, Amazon Sumerian, Amazon Lumberyard, or the Unreal Engine 4, and VR equipment/hardware, which includes headphones, controllers, and the headset. Currently, there exist a wide range of VR systems, which includes the Google Cardboard, the Windows Mixed Reality Headset, the Oculus Rift Virtual Reality Gaming System, and the HTC Vive Virtual Reality System. These VR hardware and software systems have a wide range of compatibility specifications and abilities. Tables of compatibility and current support for these platforms can be found in the Sections A and B of the Appendix.

Since my hypothesis incorporates the assumption that having a visual and somewhat tactile explanation of an introduction to CS topics increases the likelihood of user's understanding of the concept, I decided against picking the Google Cardboard. Though it is cheap to obtain, it does not have pre-paired controllers and also requires participants to already have a cell phone that is compatible with my the VR module I created. This not only introduces the issue of having to predict the type of cell phones that participants have in advance, but may also raises compatibility issues with the VR software. After comparing the information I discovered about the Windows Mixed Reality Headset, the Oculus Rift Virtual Reality Gaming System, and the HTC Vive Virtual Reality System, I noticed the Windows Mixed Reality Headset is a newly released VR

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headset that offers support for VR software developed in Unity, but has yet to develop a vast support forum to answer questions and doesn't have extensive documentation for developers. In contrast, the Oculus Rift Virtual Reality Gaming System and the HTC Vive Virtual Reality System have numerous tutorials and resources that support software development and is supports software written in Unity, Amazon Sumerian, Amazon Lumberyard, and the Unreal Engine 4.

Ultimately, I decided that the best VR headsets to buy was the Oculus Rift Virtual Reality Gaming System since it has a variety of compatible VR software, it is lower priced, has clear documentation, and has numerous example projects and tutorials, which aid in the creation of my VR module since I do not have extensive knowledge on VR development. In addition, I use Unity's free VR software for the development of my module since it has extensive documentation and compatibility with the Oculus Rift Virtual Reality Gaming System [9]. A photo of the Oculus Rift and Windows workstation used to develop the module and facilitate the experiment is shown in Figure 1.
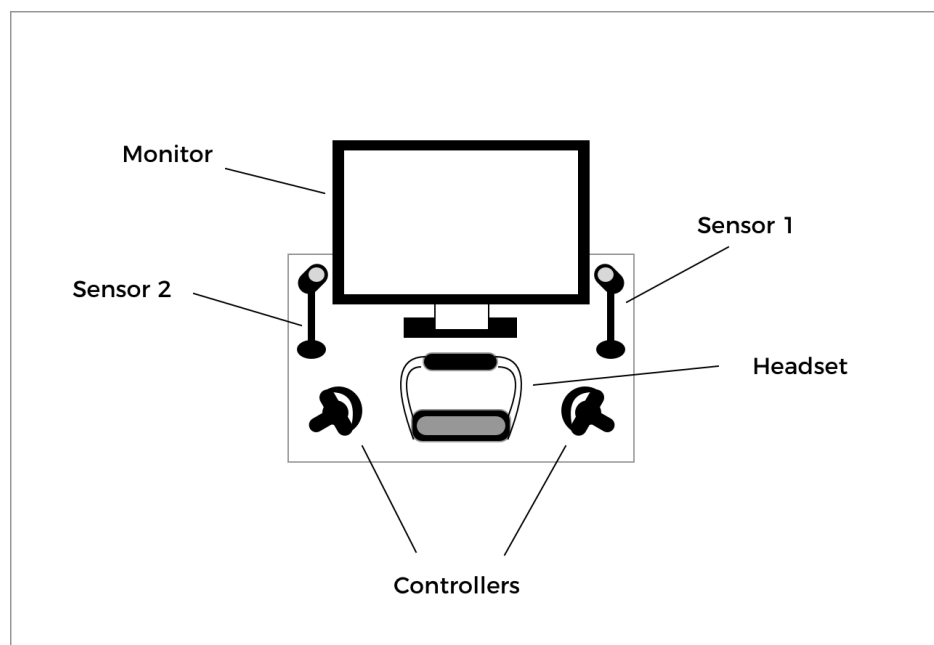
Figure 1: Schematic of the Oculus Rift and Windows workstation.

A photo of the testing area used in the Cooperative RObotics and Computer-Human Empirical Testing (CROCHET) lab can be found in Figure 2. The area marked with white on the ground in Figure 2 was used as the "play area" in which participants that used the VR module were instructed to stand. The "play area" was used to mitigate dangers such as the participant bumping into the furniture in the CRoCHET Lab and/or get tangled up in the wire connecting to the Oculus Rift headset. This play area is present in the real world and in the world virtual world displayed in the Oculus Rift headset.

Figure 2: The area used for the experiments.

4.2 Experiment

To evaluate the module, I collaborated with the CSC 104-01 Robots Rule and CSC 106-01 Can Computers Think spring 2018 professors to recruit intro to computer science students. I hypothesize that collecting data from more than one course helps minimize the influence of varying teaching methods used by professors and give the data collected more validity. I recruited the intro students after they are taught about lists. The reason for this is because I want the experiment to be for enrichment purposes rather explicitly teaching participants. If the participant have some understanding of lists, I can decrease the amount of time that is spent explaining coding concepts that are required to use the module. A total of 16 participants were recruited, however only 14 participants attended the study.

During the experiment participants were divided into two groups, those who were able to use the module and those that watched a video about lists. The general flow of the experiment can be seen in Figure 3 below. Participants were alternatingly assigned to each group in the following pattern: VR, Video, VR, Video. All participants filled out a survey, which can be found in Section D.3 of the Appendix. The survey was uploaded to a Google survey to make it easier to collect data. The purpose of the survey was to gather background information on the participants that have agreed to take part in my study. Once the survey was completed, the participant then completed the test found in Section D.4 of the Appendix. The test portion

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has 3-4 questions of increasing difficulty relating to lists. It is administered before and after participants have used my module/ watched the video. The test has questions of varying difficulty to help gauge each participants depth of understanding before and after using the module or video. After participants have finished the initial test, we then move onto their respective activity (i.e. using the VR module or watching the video). The video chosen discussed topics such as negative indexing, the length of a list, assignment and accessing indexes in a list, that were present in both the VR module and the testing questions chosen [4]. While participants use the module or watch the video, feedback is noted and observational notes describing each participants use of my module and the video are jotted down e.g., how long did they use the module, how many levels did they complete, were they engaged and attentive, and were they confused by the dialogue or task at hand. Once the participant has finished their activity, they complete the test again. It is vital to collect data before and after participants use the module/video because it informs me about each participants base understanding of lists. Once they complete the final testing portion, the participants are debriefed using the script found in Section D.7 of the Appendix.
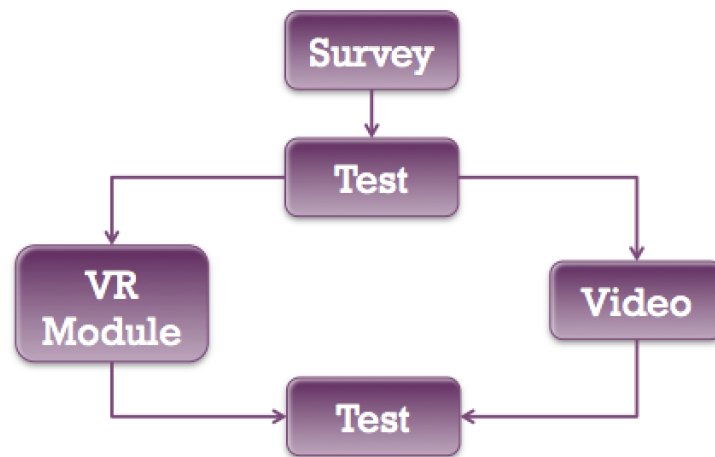
Figure 3: The general flow used for participants volunteering for my study

5 Module

In this section, I discuss the topic selection process for my module, the preliminary and final designs, a description of the video used, and the importance of virtual reality.

5.1 Topics Considered

To aid in the overall topic selection process of my module, I examined Union College's introduction to computer science survey data. The survey was collected over the last three academic years; 2015 - 2017, from 194 anonymous participants who rated their understanding of select CS topics on a scale of 1 - 5; with 5 being an excellent understanding. It is worth being aware that all introductory computer science courses do not teach all of the CS topics included in the survey. For some topics that were given a low rating, it may indicate that that topic was not taught, rather than that participants struggled with that concept. The survey include the following topics (21): arithmetic variables and constants, basic assignment statement, input and output, basic functions, functions and parameters, module creation and definitions, module usage, conditionals, boolean variables, sequences, lists, tuples, iteration and repetition, strings, files, dictionaries, regular expressions and pattern matching, external programs, statistical packages, plotting packages, and GUI interfaces. Since there were rows that contained missing data, an analysis including the rows with missing data and another analysis excluding the rows with missing data were conducted. There was minimal difference between the analyses. Table 1 below details my analysis of the data that excluded the rows with missing data and shows the averages of the ratings given to each topic and the number of times each rating appeared.

Topic	Average	# of 1s	# of 2s	# of 3s	# of 4s	# of 5s
Arithmetic Variables and Constants	3.83	15	10	32	50	68
Basic Assignment Statement	4.25	4	7	22	50	92
Input and Output	4.10	4	14	27	46	84
Basic Functions	4.38	2	4	20	48	101
Functions and Parameters	4.27	2	4	30	48	91
Module Creation and Definitions	3.19	23	33	42	41	36
Module Usage	3.18	21	33	48	40	33
Conditionals	3.93	8	19	24	51	73
Boolean Variables	4.17	4	12	21	52	82
Sequences	3.48	14	19	51	51	40
Lists	3.99	7	13	28	54	73
Tuples	2.37	63	31	47	21	13
Iteration and Repetition	3.74	9	16	40	57	53
Strings	4.18	4	7	26	54	84
Files	3.17	21	30	46	55	23
Dictionaries	2.86	42	28	40	42	23
Regular Expressions and Pattern Matching	2.45	54	41	38	32	10
External Programs	1.97	86	35	31	20	3
Statistical Packages	1.60	113	29	25	6	2
Plotting Packages	1.69	106	33	24	8	4
GUI Interfaces	1.54	120	29	16	6	4

Table 1: Intro to CS Survey Data

While examining the distribution of averages using the data that had rows with blanks excluded, I noted that the ten topics with the lowest averages (in low to high order) were: GUI interfaces, statistical packages, plotting packages, external programs, tuples, regular expressions and pattern matching, dictionaries, files, module usage, and module creation and definitions. Figure 4 visualizes these findings.
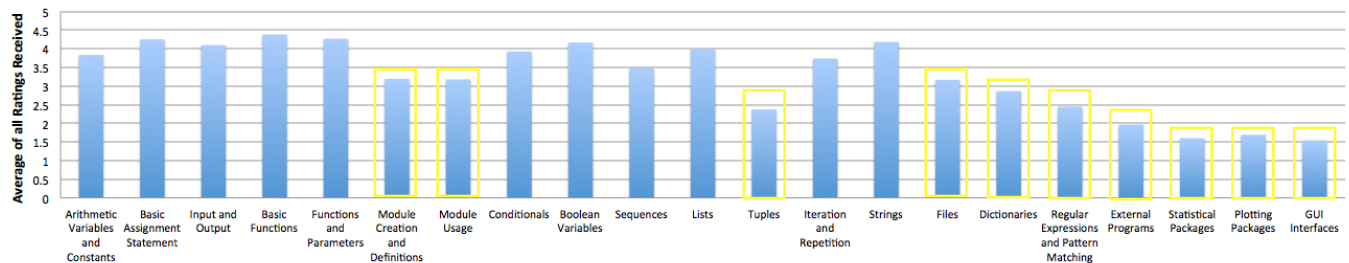

Figure 4: Intro to CS Survey Data distribution of averages (10 lowest averages are highlighted).

While examining the top ten topics ranked with the highest number of 1's using the data that had rows with blanks included, I got the following: GUI interfaces (120), statistical packages (113), plotting packages (106), external programs (86), tuples (63), regular expressions and pattern matching (54), dictionaries (42), module creation and definitions (33), module usage (21), and files (21). Figure 5 visualizes these findings.
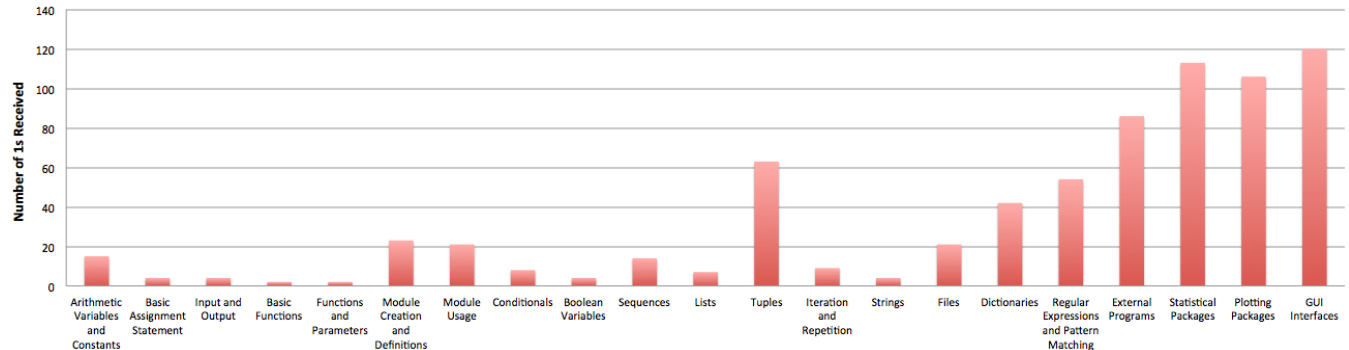
Figure 5: Intro to CS Survey Data distribution of topics given a rating of 1.

During my analysis, I included additional concepts from Union College's CSC 10X courses, excluded existing topics that were not relevant to all intro to CS classes, and choose the following topics to possibly pursue: loops, conditionals, binary numbers and ASCII, lists/arrays, strings, recursion, files, dictionaries, and regular expressions and pattern matching [2].

For the selected concepts, I determined that the user may need to know fundamental programming concepts such as basic syntax and semantics, functions and parameter passing, variables, types, expressions, and assignment, and structured decomposition. In addition, they need to understand fundamental

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data structures such as primitive types, lists / arrays, and data representation in memory. Users may also have to familiar with algorithms and problem-solving debugging strategies, problem-solving strategies, and implementation strategies for algorithms.

5.2   Initial Module Design

This section describes my initial module design, which experienced various changes during the development phase, but generally describes the over arching flow of the module.

Due to its ease of translatability to a VR module and engaging preliminary module design, the topic ultimately selected for creation of my module was Lists. The goal of this topic was to create a program that explains to the user how program languages access a specific element of a given list, how it traverses an list, and what happens upon element removal. It also explains that lists have a size, how elements are arranged, out of bound errors, and various other qualities specific to lists. The module is meant for enrichment purposes and reiterates topics that are covered by intro to CS professors and helps to compound the user's knowledge without explicitly teaching them. To achieve this, I designed a gamified VR module that encompassed a storyline, levels formatted in increasing difficulty, and easy to understand game mechanics.

I decided to implement a grocery oriented storyline. In the initial design, the user initially works for a simple fruit vendor that only owns one shelf with 6 slots, which is represented as a list A. In level one, the user must stock the shelves; by adding elements to the list at the beginning of the level and by restocking shelves when customers buy items. Customers that remove items from the list cause the index removed from to become null, which is represented by a "sold out" sign placed in the empty shelf. Customers that request items will do so by having a thought bubble appear over their head (e.g. A[3]). Customers will not ask for items that are "sold out" or not contained by the list. In another level you've procured a second shelf, which is represented as list B with 6 slots, and holds all of the user's vegetables. Similar to the first day, the user is still tasked to stock the shelves two shelves (i.e. list A and list B) and restocks them as customers buy items.

Stocking shelves is simulated by the user picking up fruit from boxes, have the contained fruit's image on front, and placing the fruit on its corresponding shelf. The fruit's corresponding self has a label indicating that it should be placed there. Shelfs can only hold one item and if the user attempts to place more than one item, the shelf will not allow it since its allotted space is filled. If the user were to place fruit on the incorrect shelf, the fruitstand's manager, will angrily complain because you are breaking semantics for one dimensional lists.

In an attempt to subconsciously teach the user about different data structures, I created the following

storyline/levels:

- In one level, the user's supervisor decided that having one item on each shelf is a bit silly and instead wants you to stock each shelf with 10 of that specific item. He hopes that this results in you stocking the shelves less frequently and entices more customers to purchase fruit/vegetables. This is similar to a stack model (first in last out).

- In the subsequent level, when the user goes to restock the shelves, the food at the back has begun to rot. The user's supervisor realized that the older produce that was left towards the back and turned bad. The previous day the user only sold the newest produce, which was always at the front. The supervisor decided to reevaluate their stocking method and organize the produce so that the older items are grabbed first and the newer items are towards the back. This is similar to a queue model.

In later levels, the supervisor decides to open up a real grocery store, which contains multiple shelves and many items on each shelf which corresponds to multidimensional lists with stacks in each index. To preserve mechanics, the users still have to stock shelves at the beginning of each level. In these levels, customers may begin to request specific items on shelves, some customers are super couponers and take all the items on the self (you have to then quickly restock it or you lose money), etc. In addition, these levels encompass the use of a code description that details the customers behavior throughout the day. For example, the Python code in Figure 6 describes that behavior of 10 customers, their identifiable qualities, and what they purchase during that particular level. It allows you to know, which shelves need to be restocked in advance of the customers purchase.

5.3   Final Module Design

Using the Unity game development program and the Oculus Rift the Virtual Reality Headset, I developed a module that followed the flow shown in Figure 7. During the development phase of the module, the initial module design underwent various changes. Certain concepts such as having a "sold out" sign placed in empty shelf indexes to represent it being null, having manager constantly error checking the participants progression of the module, and having customers of varying types (e.g. super couponers) were not implemented in the final module. Some changes were due to time constraints, difficulty of execution, and a greater need for further explaining the objective of each level to participants. In the final module, the opening scenes help to introduce the participant to the manager who teaches them the different tasks they complete in the next level. The manager makes a continual appearance to provide a narrative to the module. Similarly to the storyline provided in the initial module design, the participant is still an employee of a fruit

```
for (i = 0; i =< 10, i ++):
    if (customer.shirt == store logo):
        purchase(A[0][0]);
        purchase(A[2][3]);
        purchase(B[1][2]);
    elif ((customer.glasses == true):
        purchase(B[0][2]);
        purchase(B[1][3]);
        purchase(A[2][1]);
    else:
        purchase(A[1][1]);
        purchase(B[2][2]);
```

Figure 6: Code description that details the customers behavior throughout the day.

store, they stock shelves and serve customers under the guidance of the manager, and end up in a larger grocery store in the final level. Each level teaches the participant a unique concept about lists. In opening scene 1 and level 1, the participant practices basic list assignment and accessing, which is represented by shelves found within the level. They also learn about serving customers. In opening scene 2 and level 2, the participant practices negative indexing and is presented index out of bounds errors. In opening scene 3 and level 3, the participant practices inserting and removing items from multidimensional lists, which is represented by shelves found within the level. In levels 1, 2, and 3, participants were tasked in serving 4 customers using the skills gained from the opening scenes. Throughout the duration of the module notes on the participants questions, comments, body language, and level progression are monitored.

Prior to starting the module, I helped each participant put on the Oculus Rift and adjusted its exterior straps. I then ensured that they could clearly see the main menu of the Oculus Rift, put the controller straps around their wrist, and handed them the left and right controllers. Once that was done, I followed the script for the module instructions, which can be found in Section D.5 the Appendix, and began the first scene that was used to help them practice the controls. During the early development phase, it became evident that participants who have had minimal experience playing video games and are not familiar with the Oculus Rift and its controllers had difficulty completing the tasks required by the module. To increase

13
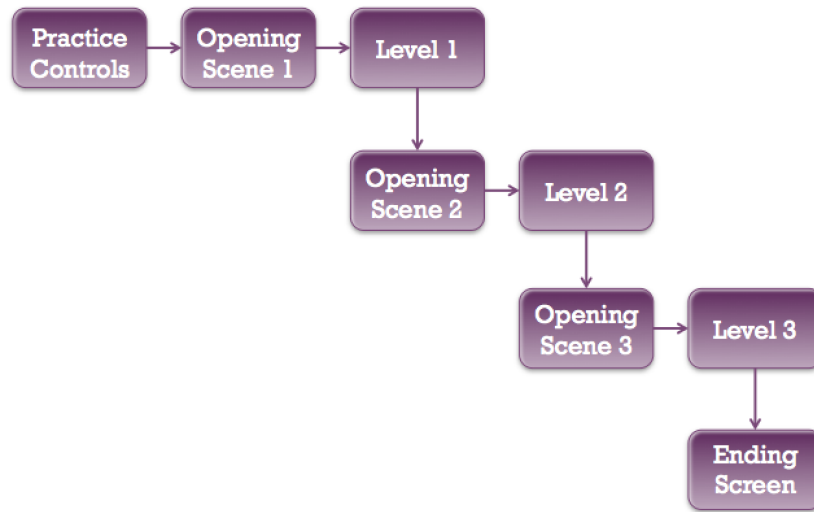
Figure 7: The flow of the levels played in the module.

the participants familiarity and make it easier for them to understand the controls, a practice scene was created. A picture of what this scene looks like can be seen in Figure 8. In the practice scene, the participant is presented with 4 white counters that hold a variety of items that they will later interact with while using the module (e.g. bread, tomato, banana, soda, and chips). They are asked to practice activities such as looking around at their environment, using the left joystick to shift their point of view, using the right joystick to move around, and using the "grip" button to pick up and put down objects. Once they complete the activities mentioned in the module instructions and the participant is ready to move on, we start off in opening scene 1.

Figure 8: The scene used to teach the participant the controls for the Oculus Rift.

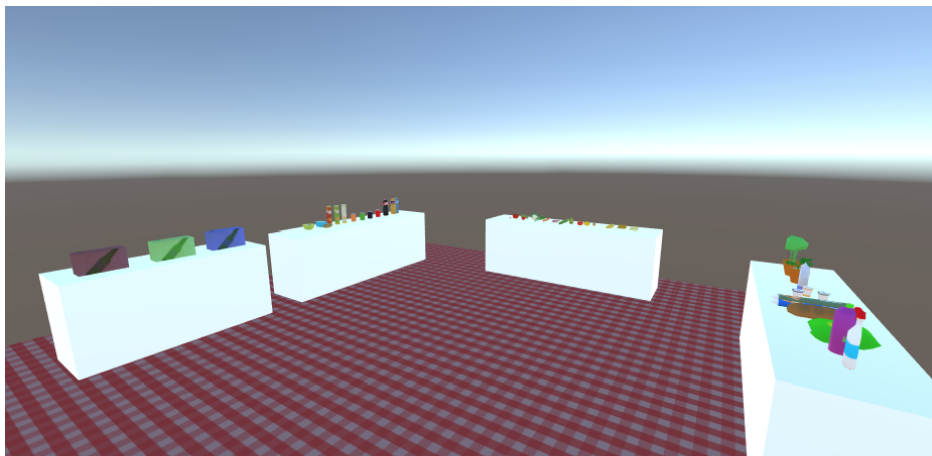In scenes opening scenes 1, 2, and 3, it was determined that the manager mentioned in the initial module design should take a more active role in guiding the participant. The manager was original intended to aid in error detection and notify the player that they stocked shelves incorrectly, however, the manager used in the final module design provides a narration to the participant, checks whether the shelves are appropriately stocked, and teaches the player what tasks they are expected to complete. This form of narration adds the game-like initiative to players and helps to paint the grocery oriented storyline that adds to VR's immersive element. When opening scene 1 begins, the participant is greeted by the manager, who explains different tasks which the player must complete. In this particular scene, the manager greets you and informs you that it's your first day as an employee of the store "Fruit Stands." He then enlist you with the task of stocking the shelves, which are labeled A[0], A[1], A[2], and A[3], with different items from the storage room. The act of stocking the shelves is meant to emulate assignment and accessing indexes in a list. An example of the manager's dialogue can be found in Figure 9. An image of the shelves you must stock is shown in Figure 10.

Figure 9: An example of a request the manager makes in opening scene 1.

In the storage room, a variety of fruits and vegetables are distributed among three shelves. An images of the shelves that contain the fruits/vegetables can be seen in Figure 11. As the player removes any of these objects, a duplicated is put in its place. An example of this is shown in Figure 12.

Once the player stocks all the shelves with the items that the manager requested, the manger checks whether everything was stocked correctly. If the items are not stocks correctly, the manger notifies the participant, but the level continues to progress. The manager then pretends to be a customer by standing in front of the cash register and requests the item in A[2]. The player is them prompted to get the item from
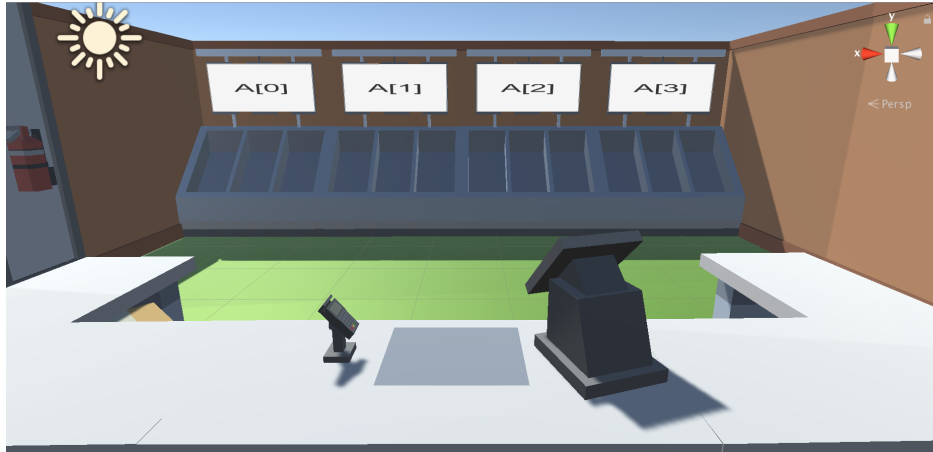
Figure 10: The shelves, which the player stocks for opening scene 1 and level 1.
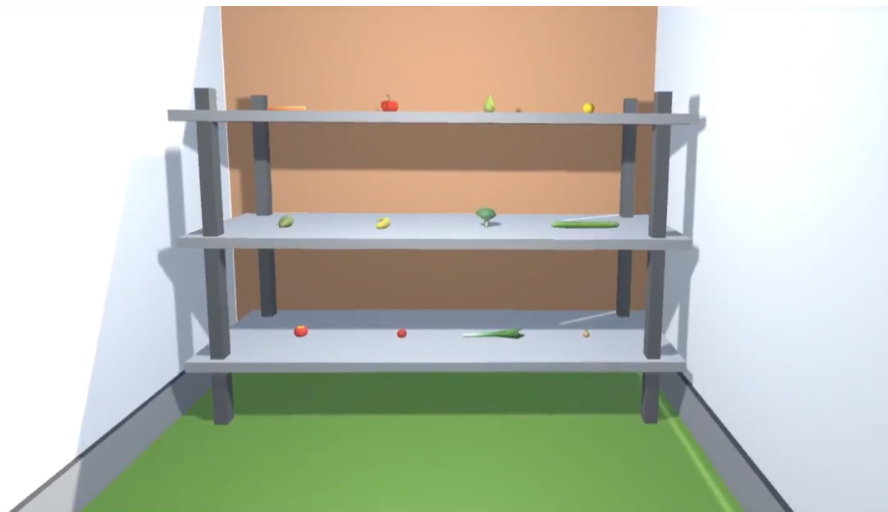
Figure 11: The shelf that can be found in the storage room.

A[2] and place it on the checkout mat next to the register. The manager will then remove the item and thank the participant. Before they begin level 1, the manager tells the participant to be careful because they only have 3 hearts per level and if they incorrectly serve a customer, they will lose a heart. Similar to Human Resource Machine mentioned in Section 3.2.2, I wanted to provide a game-like mechanic that provides a sense of urgency to the participant. If the participant incorrectly served customers and lost all 3 hearts, they would be shown a screen titled "Level Failed" and be asked if they want to try again. The use of a health system also aids in the overall gamification of the module.

Once level 1 begins, the player must serve customers by placing the item they requested onto the checkout mat. An example of a customer ordering can be seen in Figure 13. Each customer only waits up to 20
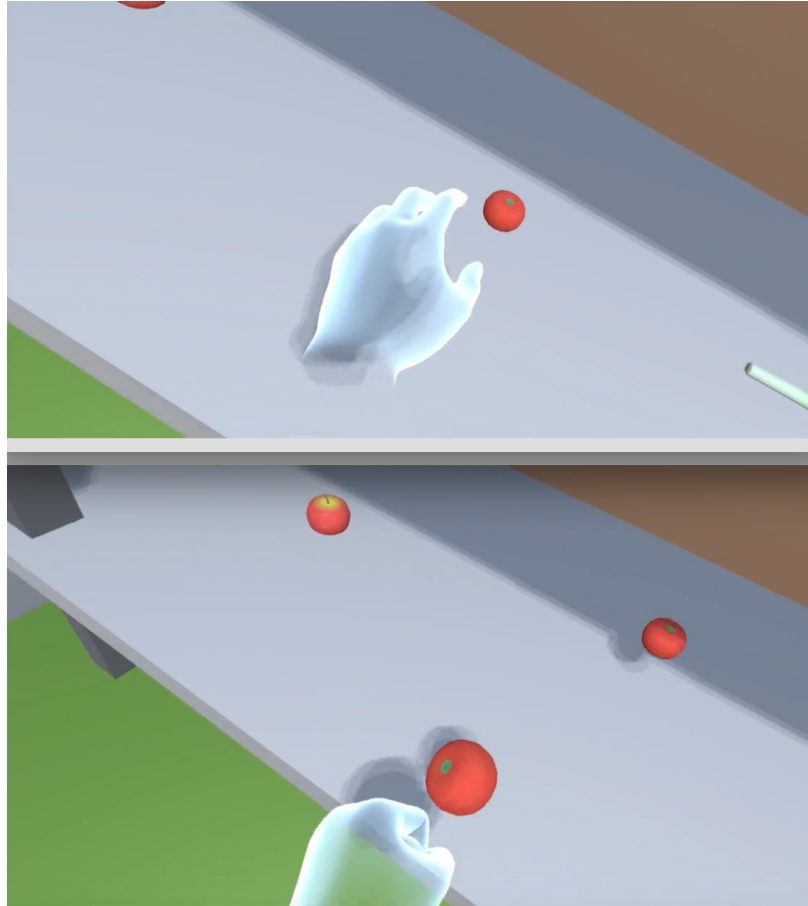
Figure 12: A side by side example of an item duplicating.

seconds before they get impatient and leave the store and the participant sees their hearts decrease. This chain of events again adds to the sense of urgency and further gamifies the module. Once the player has served at least two of the four customers encountered, opening scene 2 will begin.

In opening scene 2, the participant is once again greeted by the manager and instructed to stock the shelves with two of each item requested. Similar to Figure 9, the manager lists out the indexes to place each item. However, rather than using normal indexing, the manager will use negative indexing. To aid the player, the equivalent negative index is displayed above each shelf as shown in Figure 14. Similar to the initial module design, the manager tells the participant to stock 2 of each item on the shelves. Once the player stocks the shelves the manger ensures that each shelve was stocked correctly. He then informs the player that some customers use negative indexing to place orders and that there may be a customer whose order is out of bounds. They then state that since the order doesn't exist within the store's shelves, that customer should be ignored. Once the manager finishes his dialogue, he starts level 2 and the participant needs to serve at least 2 out of the 4 customers using the knowledge gained from opening scene 2. Once

Figure 13: An example of a customer placing an order.

level 2 is completed, opening scene 3 begins.
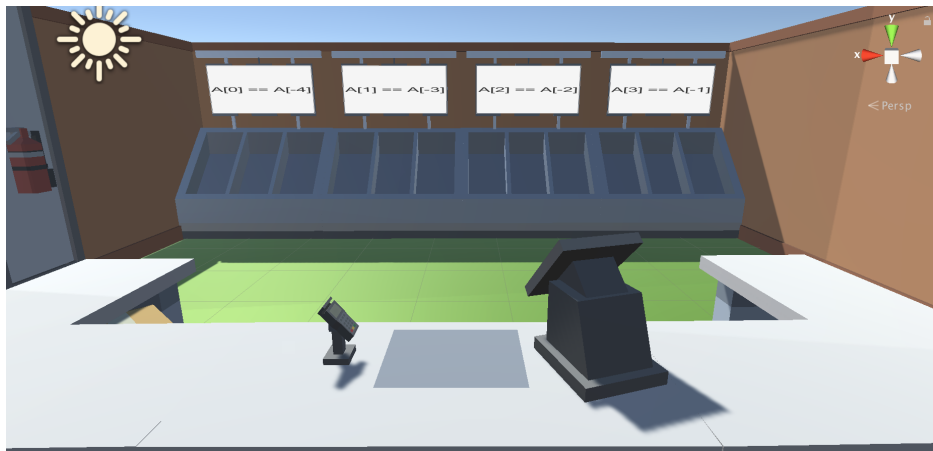
Figure 14: The shelves that the player stocks in opening scene 2 and level 2.

In opening scene 3, the participant is greeted by the manager in the new "Fruit Stands" location that was mentioned in opening scene 2. The manager then explains to the player that the stores customers no longer need to be served and instead take their desired items off of the shelves. The shelves represent a multidimensional list and are labeled A-F and each shelf has indexes [0][0] to [2][2] (i.e. found on shelves B and E) or [0][0] to [2][3] (i.e. found on shelves A, C, D and F). An example of the shelves can be seen in Figure 15.

Each customer has a unique order sheet, which is accessed by pressing the "X" button within 40 seconds of the customer arriving to the store. Every item requested by the customer can be found on the checkout

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Figure 15: The shelves that the player stocks in opening scene 3 and level 3.

counter closest to the store entrance. The manager helps the participant practice by once again pretending to be customer and providing them with his order sheet. The participant must then move the item from the checkout counter and place it in the location indicated by the current order sheet. Rather than using the order sheet described in the initial module design, a simplified order sheet is used. It was noted that the introductory computer science students were not familiar with the language present in the initial order sheet description. Instead, the order sheet contained the following Python code:

```python
if (current_customer == manager) :
order = A[1][3]
if (current_customer == customer1) :
order = A[0][0]
if (current_customer == customer2) :
order = B[1][0]
if (current_customer == customer3) :
order = F[1][1]
if (current_customer == customer4) :
order = D[0][0]
```

Once they have accomplished this task, the manager will confirm that the item was placed in the correct spot and starts level 3. In level 3, the participant must correctly serve 2 out of 4 customers before moving on to the ending screen. The Ending Screen can be seen in Figure 16 below.

An exterior view of the stores the participants interacted in can be seen in Figure 17 and Figure 18.

Figure 16: The final screen seen by the participant.
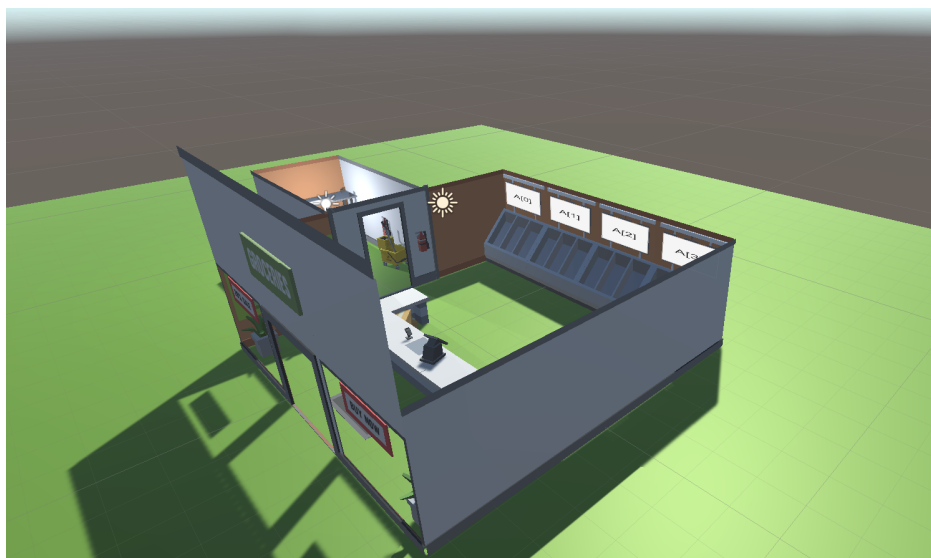
Figure 17: The store used for opening scene 1 and 2 and level 1 and 2.

5.4 Video

For participants that were not placed in the group that used the VR module, they were expected to watch a video describing concepts pertaining to Python Lists. The video chosen discussed topics such as negative indexing, the length of a list, assignment and accessing indexes in a list, that were present in both the VR module and the testing questions chosen [4]. The video was 12 mins 44 seconds and a typical video resource that participant can come across on the internet. The video was played in full screen and displayed a Python

Figure 18: The store used for opening scene 3 and level 3.

coding shell as the narrator discussed different concepts of Lists and provided relevant examples. The narrator did stumble over their words and had an accent, which was comprehendible to all participants. Throughout the duration of the video notes on the participants questions, comments, and body language were monitored. The instructions given to video participants can be found in Section D.6 of the Appendix.

5.5 Importance of Virtual Reality

The purpose of my thesis is to test whether gamification and VR help increase college student motivation, engagement, and educational performance. VR not only presents a colorful interactive visual representation to the user, but also encourages a deeper understanding of lists. In comparison to the standard paper approach of drawing an list and using symbols or numbers to represent elements stored in the lists index, the VR model can create a virtual representation of elements. In the case of my module, VR can visually show the user an orange, provide the user the ability to pick up and put down the orange, and allows the user to store the orange/ remove the orange from a shelf, which represents an lists index. It also gives the orange spatial properties that restrict other items from being placed in a shelf (index) that already has an item. These spatial and visual qualities cannot easily be represented on paper, however, VR uses inherently learned concepts that the user understands in everyday life (i.e. you cannot add more items to a container that is already full). In addition, VR can depict a relatable everyday example to introduce familiarity (i.e. a grocery store or fruit stand) and provides a game-like initiative to the user to teach concepts with a new approach. VR also visually shows known qualities of lists such as the cause effect relationship of how items are ordered, the size of a list, the action of adding and removing items, different types of lists, and provides a more engaging and tactile approach to hardcoded qualities of lists. One other quality that VR can show

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better than the standard paper approach is immediate feedback, which will guide the user towards proper solutions. In the VR module used for the experiment, the participants receive feedback when they incorrectly serve a customer, incorrectly stock the shelves, or made too many errors and ultimately failed the level.

6 Data

From the 14 participants that volunteered for my study, I was able to collect various data using my survey. Of the 14 participants, 8 were freshman, 1 was a sophomore, and 5 were juniors. In addition, their majors/minors were the following: 1 economics-chinese, 1 computer engineering, 1 electrical engineering, 2 managerial economics, 1 neuroscience, 1 physics, 1 bio chemistry, 1 computer science, 1 mathematics/computer science, 2 biomedical engineering, and 1 undeclared. 10 participants were from the CSC 104-01 Robots Rule course and 4 participants were from the CSC 106-01 Can Computers Think course. A total of 4 students took Computer Science courses prior to enrolling at Union College. Only 2 participants stated that they have a family member whose occupation requires them to work with/understand Computer Science topics.

Using the test results collected from the participants the used my VR module, I created Table 2 and 3. Using the test results collected from the participants the watched the video about Lists, I created Table 4 and 5.

VR Module	Test 1: Q1	Test 1: Q2	Test 1: Q3	Test 1: Q4
Subject 1	✓	✓	✗	✓
Subject 3	✓	✓	✓	✓
Subject 5	✓	✓	✗	✗
Subject 7	✓	✓	✗	✓
Subject 9	✓	✓	✓	✓
Subject 11	✓	✓	✓	✓
Subject 13	✓	✓	✓	✓

Table 2: Test 1 results for vr module participants

7 Results

From the testing data collected from 14 participants of varying Introductory Computer Science courses, I was able to draw the following conclusions:

- 4/7 VR module participants correctly answered all four test questions during the first and second

VR Module	Test 2: Q1	Test 2: Q2	Test 2: Q3	Test 2: Q4
Subject 1	✗	✓	✗	✓
Subject 3	✓	✓	✓	✓
Subject 5	✓	✓	✗	✓
Subject 7	✓	✓	✓	✓
Subject 9	✓	✓	✓	✓
Subject 11	✓	✓	✓	✓
Subject 13	✓	✓	✓	✓

Table 3: Test 2 results for vr module participants

Video	Test 1: Q1	Test 1: Q2	Test 1: Q3	Test 1: Q4
Subject 2	✓	✓	✗	✓
Subject 4	✓	✓	✓	✓
Subject 6	✓	✓	✗	✓
Subject 8	✓	✓	✓	✓
Subject 10	✓	✓	✓	✓
Subject 12	✓	✓	✓	✓
Subject 14	✓	✓	✓	✓

Table 4: Test 1 results for video participants

Video	Test 2: Q1	Test 2: Q2	Test 2: Q3	Test 2: Q4
Subject 2	✓	✓	✓	✓
Subject 4	✓	✓	✓	✓
Subject 6	✓	✓	✓	✓
Subject 8	✓	✓	✓	✓
Subject 10	✓	✓	✓	✓
Subject 12	✓	✓	✓	✓
Subject 14	✓	✓	✓	✓

Table 5: Test 2 results for video participants

testing portions.

- The 2 VR module participants that originally incorrectly answered a question during the first testing section, were able to answer those questions correctly in the second testing portion.

- 5/7 of VR module participants answered all questions correctly during the second testing portion.

- 5/7 video participants correctly answered all four test questions during the first and second testing portions.

- The 2 video participants that originally incorrectly answered a question during the first testing section, were able to answer those questions correctly in the second testing portion.

- 7/7 of video participants answered all questions correctly during the second testing portion.

After running a T-test on the data sets collected, I recorded the following results:

- The p-value of the Test 1 dataset and the Test 2 dataset of the participants that used the VR module was approximately 0.693. This p-value is high (greater than 0.05), therefore the probability that the observed results is due to random chance is high. There is no significant difference between the initial testing result and final testing result taken from participants that used the VR module.

- The p-value of the Test 1 dataset and the Test 2 dataset of the participants that watched the video was approximately 0.155. This p-value is high (greater than 0.05), therefore the probability that the observed results is due to random chance is high. There is no significant difference between the initial testing result and final testing result taken from participants that watched the video.

- The p-value of the Test 2 dataset of the participants that used the VR module and the participants that watched the video was approximately 0.077. This p-value is high (greater than 0.05), therefore the probability that the observed results is due to random chance is high. Though the calculated p-value was close to the standard deviation cut off, there is no significant difference between the final testing result taken from participants that used the VR module and those that watched the video.

Since a majority of participants correctly answered questions 1-4 during the testing portion, I could not determine whether using the module produced a correlation that increased the likelihood that participants would provide the correct solution to previously incorrect questions. One change that may provide more concrete evidence that the module can improve the academic performance of Union College introductory computer science students is to start running testing immediately after participants have learned about lists. Due to time constraints, I began testing during Week 9 of the academic semester and received many participants that correctly answered all test questions in the first attempt.

Though I was unable to obtain statistical significant data, which verified that the module can improve the academic performance of participants, I did take notes on the comments and body language observed for each participant. Though it is observational data, all of the participants that used the VR module were thoroughly engaged, asked many questions, made sound effects as they accomplished tasks, and stated that they though the module was "cool" and "fun." In contrast, the students that watched the video would focus on watching the video and slowly become less attentive. They would become fidgety, begin tapping, look around the room, sigh out loud, and repeatedly check how long was left to watch before the video was complete. Once all the participants that watched the video were finished with the study, I allowed them to use the module. All of the participants were excited to use the module and some even commented that it was more interesting than the video.

These observations allow me to conclude that participants found the VR module more interesting and enjoyable than watching the video. However, I also noted that three participants commented that they experienced slight nausea and disorientation once they reached the third level of the module, but choose to continue the experiment. This may be a concern for the length of the study while implementing future concepts/works. In addition, some participants missed parts of the manager dialogue by asking questions regarding where a particular button on the controller were or simply looking elsewhere while using the module. This may have threatened the validity of the data. Another validity threat present is me remaining in the room and answering the participants questions. Some participants asked questions which other did not and my answers to those questions may have provided unfair guidance. If the module/video solely guided the participant without my assistance, this validity threat would be minimized.

8   Conclusion

In this report, I detailed my creation of a VR module, meant for enrichment, that practices different concepts relating to list accessing, adding, removing, negative indexing, and multidimensional lists. I also explained why I decided to use Unity and the Oculus Rift for the creation of the module, how I selected the overall topic of my module, my final design for the module, and how I tested the module. The module itself implements distinct programming concepts of lists and translates them into a gamified VR application. The purpose of the module is to test whether it improves the academic performance of Union College Introductory Computer Science students. Based on the data collected, participants that were in the group that watched the video had a larger number of people that were able to correctly answer all of the questions in the final testing section. Therefore, I can only conclude that the module was less beneficial than the video at improving the academic performance of the participant. However, based on observational data, the participants that used the VR module were more engaged since they made sound effects as they advanced through levels, were more inquisitive about how the module worked, and said comments such as "that was really cool."

9   Future Work

A few concepts that I hope to pursue as future work are to incorporate audio/narration to make the manager more engaging and to repeatedly encourage participants to read/ think out loud. While running my experiment, I observed that participants would miss or forget parts of the managers dialogue unless they were reading the dialogue out loud. If the manager would narrate their dialogue, I hope that the instruc-

tions become more clear to participants so they require less participation and the VR immersive component is not disturbed due to me answering questions. Some other concepts that I would like to pursue as future work are to have more than one level incorporating negative indexing and to incorporate more activities for the participants to complete. Participants that used the VR module commented that it was interesting and enjoyable to play, but seemed to have difficulty absorbing the negative indexing component. If the negative indexing level was extended or had more activities, it may become more memorable to participants. Other concepts that I would want to implement include implementing the module closer to when the participants first learn about lists and including questions of greater difficulty for the testing portion. I believe that if the experiment was ran closer to when participants learned about lists, I would have a greater variation in my results. When I choose to run my experiments, participants got a majority of the testing questions correct, but if the testing questions had a greater difficulty then many participant would not have correctly answered all of the questions. Hypothetically, this along with having a greater participant pool may provide statistical data that can verify that the module improves the academic performance of participants. A few other improvements I would want to pursue are having more variation in customers used in the module, running testing in a larger room that allows the Oculus Rift sensors to properly track the participant, and to extend the module to include more CS topics. Having customers with varying behaviors will make the VR component of the experiment more engaging and having a larger room will help improve the immersive experience. Extending the module to include more CS topics would test the limits of how well the module improves the academic performance of participants, but I would first want to implement the previous concepts mentioned into to the existing module and have some concerns about the module becoming too long and causing the participants greater disorientation or nausea.

10 Acknowledgements

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Appendices

A VR Hardware Comparison

VR Hardware				
	Google Cardboard	**Windows Mixed Reality Headset**	**Oculus Rift Virtual Reality Gaming System**	**HTC Vive Virtual Reality System**
Compatible OS		**Windows:** Windows 10	**Windows:** Windows 7, 8, 10 **Mac:** OS X Yosemite, El Capitan, Sierra (Note: Requires the Oculus Rift Runtime for OS X; runtime support for OS X is legacy only)	**Windows:** Windows 7 SP1, Windows 8.1 or later, Windows 10
Controllers	An additional Bluetooth Wireless Controller can be purchased	Motion Controllers (Same for all Headset Versions)	Oculus Touch or Xbox 360 controller for Rift, and the Gear VR Controller for mobile development	HTC Vive Controller (Wired/ Wireless)
Platform support	Mobile Phone (4 inch to 6 inch screen size)	PC	PC SDK and Mobile SDK (Oculus Go and Samsung Gear VR)	PC
Estimate Cost	$15	**Version:** Acer Headset $399, Samsung HMD Odyssey $499, Lenovo Explorer $399, HP Headset $449, and Dell Visor $499.	$399	$599
What's In the Box?	A Viewer	Headset and Motion Controllers	Headset, Touch Controllers, and Two Sensors	Headset, Controllers, and Base Stations
Comments		Compatible with Unity. Limited to the Microsoft Store and Microsoft's built-in Windows 10 apps for now.		

Table 6: VR Hardware Comparison

B   VR Software Comparison

VR Software				
	Unity	**Amazon Sumerian**	**Amazon Lumberyard**	**Unreal Engine 4**
Compatible OS	**Windows:** Windows 7 SP1+, 8, 10 **Mac:** OS X 10.9+	Web Browsers (e.g. Chrome and Firefox)	**Windows:** Windows 7 64-bit; Windows 10	**Windows:** Desktop PC with Windows 7 64-bit **Mac:** Mac OS X 10.9.2 or later
Cost	Free	12 Month Free Preview. Charged based on the amount of storage used (3D assets you store), the volume of traffic generated by your scene, and the costs of any other AWS services (Amazon Web Services). No upfront costs or minimum fees.	Free. You only pay standard AWS (Amazon Web Services) fees for the AWS services they choose to use. No seat licenses, royalties, or subscriptions required.	Free. Use for free, pay 5% when you ship
Support	VR, 2D and 3D support	VR, AR, 2D, and 3D support	VR and 3D	VR and 3D
Scripting Language	C# and JavaScript	JavaScript, HTML, WebGL, and WebVR	C++, Lua, DirectX, OpenGL	C++
Platform Support	All major mobile, VR, desktop, console, and TV platforms plus the Web	Oculus Rift, HTC Vive, and mobile devices (ARKit)	Oculus Rift, HTC Vive, OSVR, and PlayStation VR. (Also compatible with: PC, Xbox One, PlayStation 4, iOS (iPhone 5S+ and iOS 7.0+), and Android (Nexus 5 and equivalents with support for OpenGL 3.0+))	All VR platforms in addition to PC, Console, and Mobile. (Windows PC, PlayStation 4, Xbox One, Mac OS X, iOS, Android, VR, etc.)
Comments	A wide variety of tutorials, documentation, and games have been created using this software. Fairly popular and "easy" to use.	You must request an invitation to participate in the preview and can only use it once accepted.		

Table 7: VR Software Comparison

C Budget

Majority of my funding will be endorsed by the Student research Grant Committee and the Union College CS Department. The projected total cost of my thesis is $430. The Table 8, provides a breakdown of all anticipated expenses within my thesis:

Item	Description	Cost
VR Hardware	Oculus Rift Virtual Reality Gaming System	$399 (30% of this cost will be funded by the CS department)
Study Subject Payments	Estimating that there are 30 participants and each is given a payment of $5	$150

Table 8: Budget Breakdown

D Subject Study Scripts

D.1 Consent Form: Module

Hello and thank you for participating in my virtual reality and gamification study. My name is Shinell Manwaring and I will be administering this study. In this study you will be using a module that I developed to explain the behavior and ideology of Lists, you will also answer a short survey, and take a short test before and after using the module.

The aim of today's study is to test how well a VR module can teach an Intro to Computer Science topic. During the study I will be asking you to complete a series levels using a Oculus Rift Virtual Reality headset and controllers. I will briefly go over how to use the Oculus before we begin. The module will prompt you to complete various tasks relating to Lists and guide you through each level. I ask that you please think aloud, that is narrate what you are doing and why you are doing it. As well as anything regarding your thoughts, feelings, and confusions about this module. While using the module, your gameplay will be not recorded. Should you have any question, please direct them towards me. I will do my best to answer, but if I cannot answer during the study, I will answer them after.

While using the headset you may experience disorientation or nausea from prolonged wearing of the VR headset. You might also bump into the furniture in the CRoCHET Lab and/or get tangled up in the wire connecting to the headset. To mitigate this danger, a border has been drawn in the CRoCHET Lab to indicate the "play area." This border will be present in the real world and in the world presented via the Oculus Rift headset. In addition, to further ensure your safety, I will be present in the room for the duration

of the testing.

Take your time using the module. Any difficulties you encounter is the fault of the module, not you. Your results will be kept confidential. No personal identifying information will be used. Data will be aggregated in statistics only. You can stop at any time. Do you have an questions?

D.2 Consent Form: Video

Hello and thank you participating in my virtual reality and gamification study. My name is Shinell Manwaring and I will be administering this study. In this study you will be watching a video which explains the behavior and ideology of Lists, you will also answer a short survey, and take short test before and after watching the video. I will be present in the room for the duration of the testing and will try to answer any questions or concerns that may arise. I will do my best to answer, but if I cannot answer during the study, I will answer them after. The aim of today's study is to test how well a video can teach an Intro to Computer Science topic. During the study I will be asking you to complete a series questions relating to the video you have watched. Your results will be kept confidential. No personal identifying information will be used. Data will be aggregated in statistics only. You can stop at any time. Do you have an questions?

D.3 Survey Form

Administrator: Shinell Manwaring **Subject Study Title:** Combining VR and Gamification to Improve Academic Performance

Thank you for taking the time to participate in my subject study. Before we begin, please answer this brief survey. This will solely be used to gather background information on the participants that have agreed to take part in my study. No personal identifying information will be used when reporting on my findings. Participant results will be kept confidential and data will be aggregated in statistics only. If at anytime you no longer want to participate in the study, please notify me. You can stop at anytime.

Directions: Please answer the following questions to the best of your ability. If you have any concerns, please don?t hesitate to ask.

1. What is your class year? (e.g. Freshman)

2. What is your projected graduation date? (e.g. Class 2022)

3. What is your currently declared major/minor?

4. Which introductory Computer Science course are you currently enrolled in?

5. Have you taken Computer Science courses before entering college? (e.g. at high school or at a separate program)

6. Do you have family members whose occupation requires them to work with/understand Computer Science topics?

7. If you answered yes to previous question, what is their occupation?

8. Do you know what Lists/Arrays are? Briefly explain?

D.4   Test Form

Administrator: Shinell Manwaring

Subject Study Title: Combining VR and Gamification to Improve Academic Performance

Directions: Please answer the following 4 questions to the best of your ability. If you have any concerns, such as clarification on the phrasing of a question, please don't hesitate to ask.

1) I just bought a bunch of groceries. Can you tell me how many items I have in my bag?

Bag =

"Bread"	"Tomato"	"Pear"	"Broccoli"

2) My bag is a mess, can you sort what I have based on price? If two items have the same price, please determine their order based on the first letter of their name. Please fill in the list below.

Bread.price = $5

Tomato.price = $1

Pear.price = $3

Broccoli.price = $3

Bag =

Use list A to answer questions 3 - 4:

A =

"Apple"	"Lemon"	"Avocado"	"Tomato"

3) What item is in index A[-1]?

4) If any, what item is in A[4] and why?

D.5   Module Instructions

In a few minutes, you will be provided with the Oculus Rift and begin using the module. Please follow all directions provided to the best of your ability. As previously stated in the permission slip you signed earlier, the module will prompt you to complete various tasks relating to Lists and will teach you the controls that should be used. I ask that you please think aloud, that is narrate what you are doing and why you are doing it. As well as anything regarding your thoughts, feelings, and confusions about this module. Take your time using the module. If you have any questions, do not hesitate to ask. If you begin to feel ill and can no longer continue using the module, please notify me immediately. I will be sitting in the corner of the room for the duration of the testing. Now, let's begin.

Prior to jumping into using the Oculus Rift, we're going to step through a few activities to get yo comfortable with using the controllers. First, use the joystick on the right controller to rotate your point of view. Next use the joystick on the left controller to move within the scene. Now I want you to approach an object on any of the three counters. Once in front of the object, extend your arm and try to touch the object. Grasp the controller and press the "grip" button with your middle finger. This will allow you to grab the object. Release the "grip" button and the object will fall. If you release the "grip" button while simulating a throwing motion, you will throw the object. Finally, I want you to step forward in real life and notice the blue wall that appears. This is the boundary box, which signifies you have stepped out of bounds. Try your best to remain within this boundary box. Once the game begins, use the "A" button to press any and all dialogue buttons that appear. Look at the controller and try to memorize it's layout. All other relevant controls will be mentioned through the procession of the module. Tell me when you're comfortable with the controls and ready to move on.

We are now going to jump into the opening scene for Level 1. You are an employee of a store called "Fruit Stands" and will be greeted by your manager, which is a blue block. Please follow all of his prompts and remember i'm here to answer any questions/concerns that arise.

D.6   Video Instructions

In a few minutes, you will be shown a short video explanation on the implementation used in Lists. As previously stated in the permission slip you signed earlier, the aim of today's study is to test how well a video can teach an Intro to Computer Science topic. If you have any questions, do not hesitate to ask. I will

be sitting in the corner of the room for the duration of the testing. Now, let's begin.

D.7   Debriefing of Module and Video

Thank you for completing my subject study. Your participation was greatly appreciated. Before leaving, here is a debriefing of the goal of my study.

Virtual reality (VR) and gamification are growing trends that have resulted in the increase of college student motivation, engagement, and educational performance. To examine this claim, I created of a module, a self-contained unit of an Introductory Computer Science topic, which combined the use of gamification and VR. Virtual Reality (VR) is a computer-generated simulation that can be interacted with using special electronic equipment. "Gamification" is the application of game-like elements to non-gaming activities which can help to encourage people to participate and achieve specific goals. The module I created used distinct programming concepts of Lists and translated them into a gamified VR application.

The purpose of this module is to test whether implementing it can improve the academic performance of Union College Introductory Computer Science students. Since I wanted to ensure that my findings were entirely due to VR?s interactive component, I split participants into groups that were allowed to use my VR module and those that watched a video about Lists. By comparing the results of each group, I will be able to verify whether using VR produces different/better findings when compared to a simple video approach. Your participation has provided me with statistical data that will allow me to verify this assumption.