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Middle School Students Learn Binary Counting Using Virtual Reality

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***Abstract*—Educational fields that are abstract in nature, such as computer science (CS) and other science, technology, engineering, and mathematics (STEM) fields may find alternative teaching methods useful to maximize student opportunities to internalize and process the curriculum. When designing alternative educational tools in virtual reality (VR) technologies, the objective is to expose an academically diverse population to CS in an engaging and immersive environment. With this objective in mind, we built and tested a CS educational VR experience, CSpresso, designed to teach students to count in a binary (base-2) number system. Testing confirmed that the student group who learned to count binary in VR were just as successful as those who learned from a certified CS instructor. This shows that VR educational experiences can be used as alternative teaching tools in CS education, which can supplement traditional teaching methods enabling new learning methods for students in the classroom and at home. We believe that this is evidence to support a larger effort in adapting the current CS education system to meet the needs of a more diverse student body that may find alternative teaching tools useful in internalizing abstract concepts.**

***Index Terms*—STEM Education, Computer Science, Educational Technology, Computer Aided Instruction, Virtual Reality**

INTRODUCTION

Instructors are at the front line of education and can have a strong impact to the curriculum delivery of an education program based on their experience level in teaching methods, curriculum domain knowledge, and new technological instruction mediums. For this reason, it is useful for an educational program to have alternative teaching tools and methods available to maximize students' opportunities to internalize and process the curriculum. This issue may become more severe for educational fields that are abstract in nature, such as computer science (CS) and other science, technology, engineering, and mathematics (STEM) fields.

The traditional method of CS teaching involves lecture and textbook methods, with alternative teaching methods involving project-based learning and interactive programming tools. Modernizing education practices with interactive technology to supplement traditional teaching methods may give students additional opportunities, at school and at home, to be given the opportunity to excel in the field [1]. However, technology usage in the classroom often depends on the teacher's beliefs and their teaching philosophy [2] [1]. Professional development for educators is a common strategy to overcome barriers in the effective use of technology in the classroom [3].

Instructors' self-efficacy is one of the most significant factors that impact their use of technology in the classroom [2]. As with pedagogical factors, improvement in this area can be facilitated through professional development [4]. More effective approaches focus explicitly on improving personal mastery. In the case of integrating technology that is still a work-in-progress, there is an opportunity to involve the instructors in the design process [5]. Participatory design initiatives allow instructors to familiarize themselves with the technology in depth. Instructors, as co-designers, can also suggest modifications in the technology itself, which can help to align it with their pedagogical beliefs better [2].

This gives educational technologists an opportunity to increase the positive impact of technology in the classroom. They can increase the overall usage of such technology if they consider integration in their design. Supplementary technologies have the potential to shift the burden of integrating them into the classroom from teachers to technology designers if said technologies are properly self-contained. The newest generation of virtual reality (VR) headsets, called standalone VR, have wireless free roaming features that may be able to accomplish an engaging virtual learning environment that is a self-contained alternative teaching tool in the classroom and at home [6].

Based on this hypothesis, we co-designed an educational VR experience, *CSpresso*, with CS educators, and ran a study to test if VR as an educational technology designed with these consideration in mind would be an acceptable alternative teaching tool. CSPresso was designed to be accessible, engaging with its narrative and gameplay, and have an adjustable pace to match an individual's learning pace [7]. The aim was to use VR as an alternative teaching tool to attract a more diverse student population who may not otherwise choose to learn CS.

RELATED WORKS

Game-based learning (GBL) is an approach to education that uses games to enhance or facilitate the learning process, which encompasses VR. Unlike gamification, this approach does not limit itself to using game mechanics such as incentive systems in non-game settings [8]. The exact relationship between game complexity and learning has not been definitively confirmed by literature [9]. The effectiveness of games used purely as a

Fig. 1. Virtual reality participants receiving equipment training

Fig. 2. Virtual reality participants in an experiment session

substitute for "drill and practice" activities has not been verified by existing research [10] as well. Among the frequently cited reasons for the use of games are motivation and engagement that games enhance in their players [11]. The impact on skill and knowledge acquisition is the common measure of success in games in education settings [12] [9]. Recent reviews by Qian et al. suggest an expansion of criteria to include problem-solving and other skills, sometimes referred to as "21st-century skills" [9]. They highlight recent interest in approaches expanding beyond course material and educational outcome measures suggesting that computational thinking and problem solving skill building are currently being explored in GBL.

Studies examining the impact of game-based learning approaches in mathematics have shown improvement in self-efficacy and increased learning motivation in addition to improved learning achievement [13]. Applications that depend on GBL to encourage students to self-study have also shown a positive impact on math scores [14]. To better understand different student populations, Ku et al. investigated the effect of GBL on confidence and performance by separating participants into low and high ability groups. While students in both groups improved in performance, the low-ability students have shown improved confidence in the GBL group only [15]. These findings helped direct our design efforts when building CSpresso for binary counting. When designed well, VR experiences can immerse the user in the virtual environment causing them to be less aware of their surroundings which may increase their confidence of performing binary math equations in front of their peers.

GBL also shows promise in CS education at the K-12 level. Comparing game and non-game versions of otherwise identical educational material demonstrated better results in the game version, effectively isolating gameplay as a significant factor [16]. Recent interest in computational thinking education promotes novel designs and approaches. Researchers have explored a multistage game-based system for fostering computational thinking skills in a 2019 study, with positive results on student engagement. The project also included a successful integration of VR as a visualization tool [17]. Weintrop et al. make a case for a novel approach to designing video games, rooted in constructionism learning theory. Using qualitative data to analyze computational thinking strategies, the researchers have found games in this genre to support multiple play styles [18]. We found similar parallels when designing CSpresso around an open exploration space with interaction elements meant for open-ended tinkering. We designed the experience to account for multiple play styles by having interaction elements display the results of their actions, and show how multiple actions stack together for a final answer that the student may change at any time during the task based on reviewing any of the easy to view feedback areas.

METHOD

The goal of our study was to examine if a VR educational experience could have the same benefits as live lecture in the classroom for teaching binary (base-2) counting. In addition, we wanted to conduct a pilot study to test standalone VR technology, designed with the teacher and student considerations in mind, as a CS educational technology in school settings. To address these goals, we conducted a controlled experiment comparing a teacher-led lecture (our control) and a virtual reality experience (using CSpresso; our treatment) introducing binary counting. We compared the learning outcomes between the conditions and interviewed the VR group participants to understand how to improve the experience with CSpresso.

Environment

We ran the study with a group of middle school students attending a CS camp at a local high school. For our study, we used the gymnasium (for the VR activity), and two classrooms (one for the teacher to lecture about binary counting; and one for interviewing VR participants after completing their activity). The gymnasium was split into five 20ft x 20ft quadrants, one for each VR station (see Figure 2). Due to this configuration, we were able to run a maximum of five VR sessions concurrently.

Participants

The participants were 34 middle school students (19 girls and 15 boys), from 5th to 8th grade (median 6th grade), participating in a 9 session Saturday CS camp. These students were randomly dividing into two classrooms at the beginning

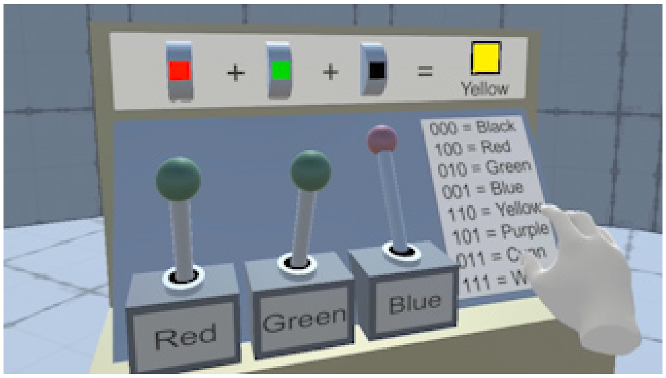


Fig. 3. User interacting with the color station in the VR activity

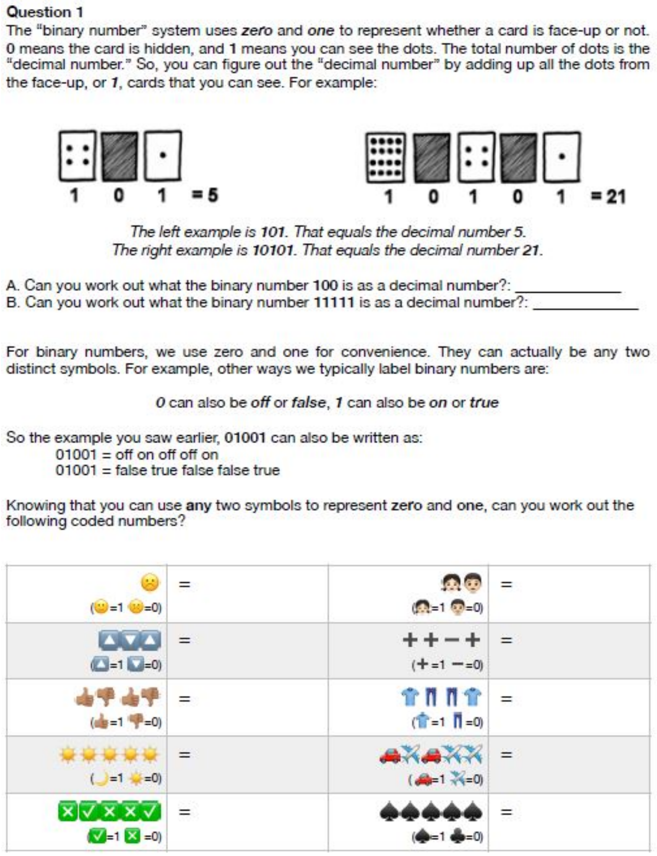
of the camp, and we held the binary counting session during their 7th Saturday. We randomly assigned students in one room to be the control group, and the other room's students as the VR group. Neither room's students were aware of the other room's assigned activity. This was done to minimize distractions, as recruiting only a subset of students from each room to participate in the VR group might cause non-VR participants to complain that they could not partake in the novel activity. After we completed our data collection for the day, we informed the non-VR room participants about the activity, and allowed them to try out the VR activity as well.

Implementation

We developed the activity for our study by reviewing CS Unplugged—activities designed to introduce computational thinking concepts to students without the use of computers [19]. We chose to teach a binary counting lesson, which was a topic that was not covered in the CS camp. For the control condition, the teacher used the binary counting lesson from CS Unplugged. For the VR condition, we adapted the lesson and created a VR environment to demonstrate the concept using the Oculus Quest VR headset, a standalone, wireless system which does not need an accompanying phone or computer.

The control group had 15 participants (8 girls and 7 boys). Individuals from this group participated in a 45-minute session, which included taking a pre-assessment, a 20-minute learning activity, and a post-assessment. The learning activity was led by one of the researchers (i.e., the activity teacher), and was an adaptation of the CS Unplugged binary counting card lesson. The teacher was an experienced educator, with over a decade of practice teaching introductory computer science materials.

The VR group had 19 participants (11 girls, 8 boys) divided into three groups of five and one group of four (as we were only able to have five concurrent VR sessions). These groups participated in a one-hour session, which included taking a pre-assessment, a 5 minute VR equipment training session (see Figure 1), a 20-minute VR learning activity (see Figure 2), a post-assessment, and a 10-minute focus group interview. We designed CSpresso to be a virtual learning environment able to teach the basic CS concept of binary counting.



Question 1
The "binary number" system uses ***zero*** and ***one*** to represent whether a card is face-up or not. **0** means the card is hidden, and **1** means you can see the dots. The total number of dots is the "decimal number." So, you can figure out the "decimal number" by adding up all the dots from the face-up, or ***1***, cards that you can see. For example:

1 0 1 = 5

1 0 1 0 1 = 21

*The left example is **101**. That equals the decimal number **5**.*
*The right example is **10101**. That equals the decimal number **21**.*

A. Can you work out what the binary number **100** is as a decimal number?: ____________
B. Can you work out what the binary number **11111** is as a decimal number?: ____________

For binary numbers, we use zero and one for convenience. They can actually be any two distinct symbols. For example, other ways we typically label binary numbers are:

0 can also be ***off*** or ***false***, ***1*** can also be ***on*** or ***true***

So the example you saw earlier, **01001** can also be written as:
01001 = off on off off on
01001 = false true false false true

Knowing that you can use **any** two symbols to represent **zero** and **one**, can you work out the following coded numbers?

😟 (🙂=1 😟=0)	=	👧👦 (👧=1 👦=0)	=
🔼🔽🔼 (🔼=1 🔽=0)	=	++−+ (+=1 −=0)	=
👍👎👍👎 (👍=1 👎=0)	=	👕👖👖👕 (👕=1 👖=0)	=
☀☀☀☀☀ (🌙=1 ☀=0)	=	🚗✈🚗✈✈ (🚗=1 ✈=0)	=
❎✅❎❎✅ (✅=1 ❎=0)	=	♠♠♠♠♠ (♠=1 ♣=0)	=

Fig. 4. Pre/post assessment questions

Learning Assessments

The design goal of CSpresso was to take full advantage of the VR headset's free roaming feature, which would allow the user to move through virtual space without entanglement by physical wires in the real world. CSpresso's virtual environment included stations with interactive consoles organized into a concentric circle, all sequentially placed in a clockwise direction. This design follows the order of interaction from start to finish, in one circular loop. Each station must be visited and interacted on by the user to complete a task, with the entire experience requiring the completion of seven progressive harder tasks involving solving binary counting problems.

There are five stations (task station, number station, color station, shape station, and output station) to interact with during a task, each with a set of levers that the user pulls to set binary values of either 0 or 1 disguised in various forms such as on or off, 0 or 2, red or green, and cube or sphere. Each task starts with the user receiving directions to perform at the task station, which involves recreating the correct binary value to represent a number, color, or shape. To do so, the user must travel to several other, specialized stations to create the correct output and return it to the task station. For example, one task is to bring 5 yellow spheres back to the task station. The user must go to the number, color, and shape stations, respectively, pull on the correct levers, and create the correct number of

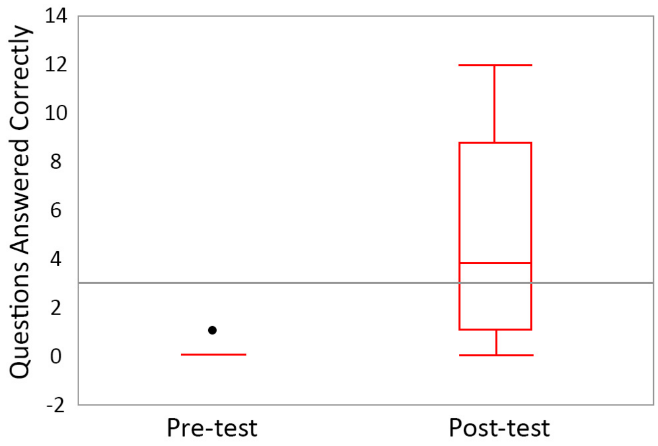


Fig. 5. Control pre and post scores show knowledge difference

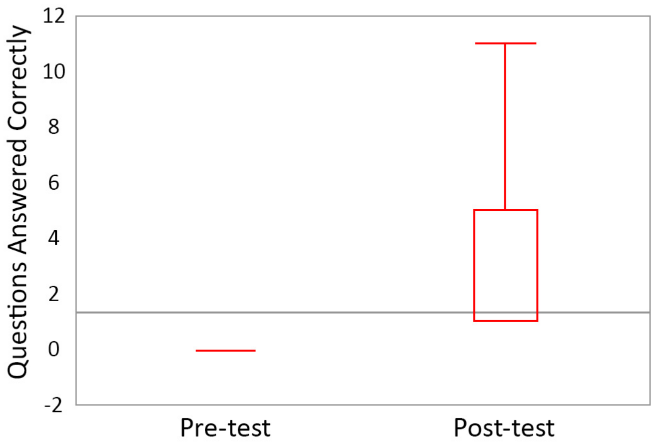


Fig. 6. VR pre and post scores show knowledge difference

required colored shapes (see Figure 3).

Before starting the sessions, participants filled out a pre-test learning assessment with 12 fill-in-the-blank questions (see Figure 4. We used questions from the CS Unplugged binary card material, and it took about 15 minutes for students to complete [19]. After learning about binary math session, participants were given the same questionnaire as the post-assessment. Changes in the participants' pre and post assessments were used to understand the differences in the learning impact of the control and VR conditions.

Interviews

We conducted focus group interviews will all participants in the VR group after they completed their post-assessments. We decided to interview students in groups of 5 participants in a focus group as this was the size of a session group and it is an appropriate size for children focus groups [20], [21]. Our research team has more than 15 years of experience in HCI (Human Computer Interface) research and a certified teacher conducted the interviews, while the participants were accompanied by their CS teacher who they have known from the program. Although the literature suggests hosting individual interviews or with 2 students at a time, we opted for a larger group for two reasons [22] [23]. First, we wanted the students to feel more comfortable with their peers and also we did not have time and resources to interview 2 students at a time. Each group that we interviewed took 10 to 15 minutes to discuss the key questions outlined in the script below. All interviews were recorded and transcribed for further analysis.

Interview question script to probe participant understanding of their user experience within VR:

- What did you like? What was fun? Did you feel engaged?
- What did you dislike? What was challenging about VR?
- Did you learn anything while playing VR?
- Did this exceed your expectations?
- Would you hope to see or do something different?
- How easy/hard it was to use the controller?
- Was it easy/hard to select/manipulate objects?
- Were you dizzy? Did you feel uncomfortable? Sick?
- Did you find the tutorials helpful? Why? Or why not?
- Could you figure things out without a tutorial?
- Did you like physical movements?
- Did you like walking while learning/playing?
- Did you need to stop early?
- Where you comfortable for a whole time?
- Did you want to stay longer or less?
- Did you experience any blurriness?
- Would you like to play on a computer or a headset?

We used the three-stage coding process described by Cambell et al., for the measurement of intercoder reliability for semi-structured interviews [24]. The interview lead read through all interviews and generated a list of codes. A group of three researchers reviewed 10% of the transcripts and reached a minimum of 87% intercoder reliability. Once this was complete, the three researchers coded the remaining transcripts and counted code occurrences.

After consolidation, we identified 13 codes grouped into 3 themes as shown below. Since we conducted focus group interviews, we counted the frequency of each code as it appeared in each group's transcript, totaled up all group's code frequencies and ordered the codes within each themes as to their frequency totals. This gave us an understanding to the dominant trends reported by our focus groups in each theme. As the resulting data are nominal/categorical, we report on the frequencies of the different codes; shown as total frequency per code for all participants from the VR group.

Codes grouped into their themes:

1) User Emotions of the VR Experience:
   Enjoying Immersion, Enjoying Physical Activity, Enjoying Learning, Feeling Bored, Feeling Distracted
2) Usability Suggestions for the VR Experience:
   Adjustable Difficulty, More Content, Clearer Directions, Improve Interactions, Fix Broken Objects
3) Platform Issues of the VR Experience:
   Blurry Vision, Disorientation, Headset Discomfort

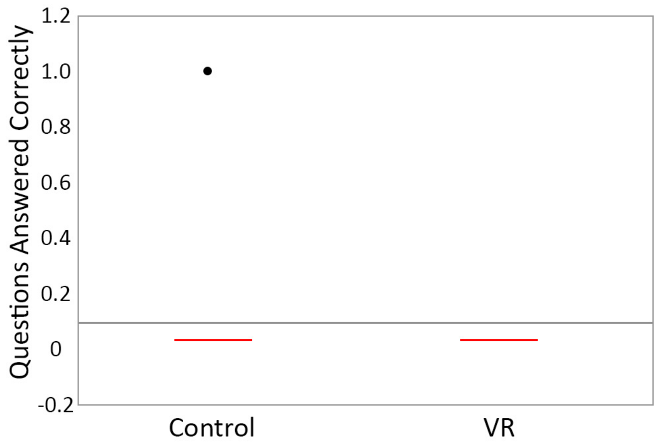


Fig. 7. Control and VR pre-test scores show no knowledge difference

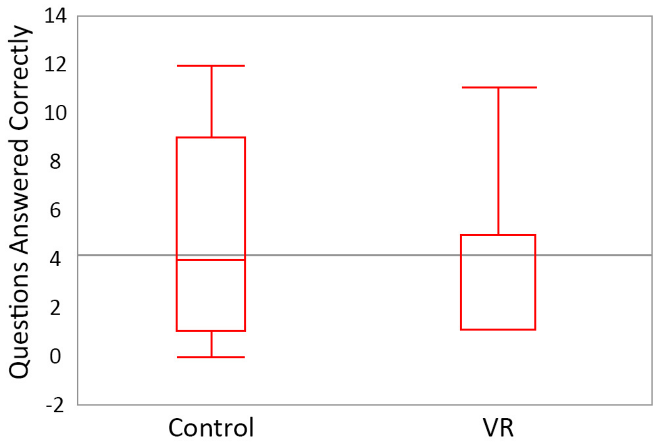


Fig. 8. Control and VR post-test scores show no knowledge difference

RESULTS

Pre and Post Learning Assessment Difference per Condition

We wanted to check if there was a difference within each condition (e.g., control pre-test vs. control post-test), to see if there was any affect by the interventions. The first intervention, in the control group, was a professor teaching a class of middle school students (n=15) how to count in binary up to 3 digits. The second intervention, in the experimental group, was a VR activity teaching middle school students (n=19) how to count in binary up to 3 digits. Students were given a pre-test and post-test with 12 questions each involving counting in binary up to 5 digits. Here, "Questions Answered Correctly" (in Figures 4-7) all refer to the total number of questions a student got correct on either the pre-test of post-test. The minimum score is 0, and the maximum score is 12. For all learning assessment analysis, we used Wilcoxon Rank Sum test with $\alpha = 0.01$ confidence, as our data was not normally distributed.

The control group participants did not do well in the pre-test, which is to be expected for participants with no prior knowledge in binary counting, but showed a statistically significant increase in their post-test scores ($W = 108, Z = -3.895, p < 0.01$), suggesting that the lecture helped them understand how to count in binary, up to 5 digits (see Figure 5).

The VR group participants also did not do well in the pre-test, but showed a statistically significant increase in their post-test scores ($W = 493, Z = 5.6786, p < 0.01$), suggesting that the VR activity helped them understand how to count in binary, up to 5 digits (see Figure 6).

Learning Assessment Differences between Conditions

We also wanted to see if there was a difference between condition (e.g., control pre-test vs experimental pre-test), to see if there were any differences between the classrooms. The control and experimental condition participants both started off the same, without any statistically significant difference in their pre-test scores ($W = 241, Z = 1.7376, p = n.s.$). This means that these students all started off the same inexperience with counting in binary (see Figure 7).

After the learning activity (either a lecture or VR), there were no statistically significant difference in participants post-test scores ($W = 286.5, Z = 1.4875, p = n.s.$). This demonstrates that both the lecture and the VR activity were both effectiveness teaching their respective students how to count in binary. Examining the boxplot (see Figure 8)suggests that the control condition students did a little bit better overall in the post-test compared to the experimental condition, but not enough to make a statistically significant difference.

Interview Codifications of Control and VR Groups

Analysis of the interview data revealed three major themes to report on: user emotions of the VR experience, usability suggestions for the VR experience, and platform issues with the VR experience. For user emotions of the VR experience, five codes appeared in the focus group interviews for a total count of 36 appearances in the interviews (see Figure 9). Of the fives codes for the user emotions of the VR experience theme, three were positive of the experience (enjoying of immersion, physical activity and learning of the experience) and two were negative of the experience (feeling bored and distracted). All three positive emotions about the experience were reported at higher rates (33.33%, 30.55%, 25%) than than the negative emotions about the experience (5.6%). For usability suggestions for the VR experience, five codes appeared in the focus group interviews for a total count of 38 appearances in the interviews (see Figure 10). For platform issues with the VR experience, three codes appeared in the focus group interviews for a total count of 13 appearances in the interviews.

Participants reported feeling enjoyed by the immersion of the experience 12 times, which is 33.33% of the total reported counted codes for the user emotions of the VR experience theme. Enjoyment of immersion covers topics of enjoying physically moving around the virtual space, and observing objects and performing the tasks in a passive manner that gave them the feeling of actually being in the experience.

Participants reported feeling enjoyed by the physical activity of the experience 11 times, which is 30.55% of the total

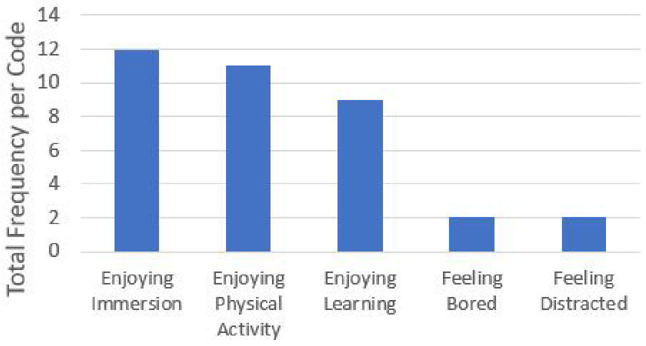


Fig. 9. User Emotions of the VR Experience

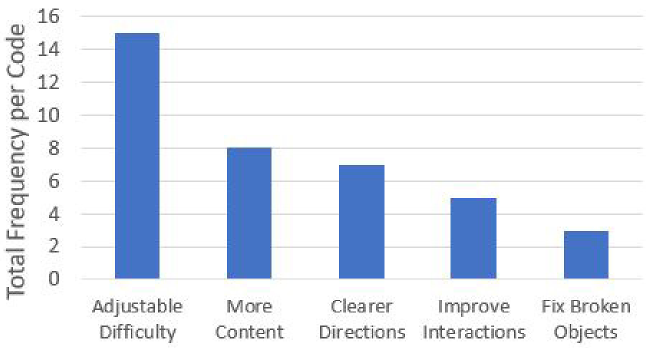


Fig. 10. Usability Suggestions for the VR Experience

reported counted codes for the user emotions of the VR experience theme. Enjoyment of physical activity covers topics of enjoying actively interacting with objects and the environment, such as throwing objects, pulling levers, picking up and moving objects with VR hands.

Participants reported feeling enjoyed by the learning of the experience 9 times, which is 25% of the total reported counted codes for the user emotions of the VR experience theme. Enjoyment of learning covers topics of problem solving without any guidance, while in experience and/or retaining knowledge from tutorial or experience.

Participants reported feeling bored by the experience 2 times, which is 5.6% of the total reported counted codes for the user emotions of the VR experience theme. Feeling bored covers topics of expressing a frustration of not being challenged enough or the activities becoming too tedious.

Participants reported feeling distracted by the experience 2 times, which is 5.6% of the total reported counted codes for the user emotions of the VR experience theme. Feeling distracted covers topics of being afraid of bumping into things, while trying to concentrate on tasks in the experience. Hearing classmates talking while in the experience.

Participants reported wanting adjustable difficulty for the experience 15 times, which is 39.5% of the total reported counted codes for the usability suggestions of the VR experience theme. Adjustable difficulty covers topics of complaints about too difficult or too easy tasks, and expressing the need for more guidance in the experience.

Participants reported wanting more content for the experience 8 times, which is 21.1% of the total reported counted codes for the usability suggestions of the VR experience theme. More content covers topics of suggesting or asking for more levels, different activities, characters, or scenarios.

Participants reported wanting clearer directions for the experience 7 times, which is 18.4% of the total reported counted codes for the usability suggestions of the VR experience theme. clearer directions covers topics of walking out of the boundary, pressing buttons that are instructed not to press, not following along with either in-game or pre-game tutorials.

Participants reported wanting improved interactions for the experience 5 times, which is 13.2% of the total reported counted codes for the usability suggestions of the VR experience theme. Improved interactions covers topics of not liking how something works or looks in the experience.

Participants reported wanting to fix broken objects in the experience 3 times, which is 7.9% of the total reported counted codes for the usability suggestions of the VR experience theme. Fixing broken objects covers topics of functions of different objects in experience not working correctly.

Participants reported blurry vision in the experience 7 times, which is 53.8% of the total reported counted codes for the platform issues of the VR experience theme. Blurry vision covers vision issues or trouble with fitting glasses into headset.

Participants reported disorientation in the experience 4 times, which is 30.8% of the total reported counted codes for platform issues of the VR experience theme. Disorientation covers topics of disoriented during or after experience, complaints about no visible feet or legs, and jittering of the VR hands.

Participants reported discomfort from the headset in the experience 2 times, which is 15.4% of the total reported counted codes for the platform issues of the VR experience theme. Discomfort from the headset covers topics of uncomfortable, heavy feeling on the face from headset.

DISCUSSION

The outcome of this user study was highly rewarding with a majority of participants not wanting to leave VR at their maximum play time of 20 minutes and a few students opting to play a second time. The overall impression received from observing the students was that CSpresso, even in its rough state, was engaging and fun. Students made full use of the Quest's untethered feature, breaking out into victory dances and freely moving about in their 20 by 20 foot space. A very small number of students did not seem to enjoy the experience, but after talking to them, it was unclear if the negative feedback was due to the platform of VR, or the design of CSpresso, with one participant describing motion sickness and eye strain.

Learning Assessment Interpretations

The analysis of the learning assessments indicated the VR group participants learned binary math just as well as the control group participants that were taught by the summer camp's instructor. This suggests that CSpresso can be as effective as an instructor-led lecture without the restrictions on instructor availability and locality. These results revealed that the CSpresso experience is educational, and suggests that it may have some benefits over traditional teaching methods.

The control and experimental condition participants both started off the same score that is close to zero. In other words, they did not know how to count in binary. After either a lecture or using CSpresso, students' post-test scores were significantly higher. However, there was no statistically significant difference between these groups' post-test scores, meaning that both the lecture and CSpresso activities led to similar outcomes when teaching the students how to count in binary.

The results of the learning assessments shows that the participants who learned binary math through the VR educational experience were just as successful as those who learned from a certified CS instructor. This indicates that VR educational experiences can be used as alternative teaching tools in CS education which can supplement traditional teaching methods enabling new learning methods for students in the classroom and at home.

Interview Interpretations & Observations

Of the fives codes for the user emotions of the VR experience theme, the three positive emotions about the experience were reported 5-6 times more frequently than the two negative emotions about the experience. Since all three positive emotions are reported at 33.33%, 30.55%, and 25% frequency and both negative experiences are reported at 5.6% frequency, we can point to the experience being an engaging, immersive, and impactful learning experience, which is a successful accomplishment for this study of the VR educational experience.

Of the five codes for the usability suggestions of the VR experience theme, the most frequent was to make the experience more customizable for the user. This involves adjusting task difficulty and training time during the tutorial, and offering help during tasks if users get stuck. Of all usability codes, this was requested 39.5% of the frequencies. The second most frequent request was for more content, which is a reasonable request since this version of the experience had no high quality graphics and only focused on the interactions and progression of the experience needed for learning the binary math material. Since then, we have put extensive work into the graphics quality of the experience, which can be seen at artncoding.com. The remaining codes dealt with refining the current experience by making the directions clearer, improving interactions, and fixing broken objects.

Of the three codes for the platform issues of the VR experience theme, the most frequent issue was blurry vision, followed by user disorientation and discomfort of the headset. Since these are issues with the current hardware implementation, we will not focus on discussing them and assume that these issues will be fixed with future hardware iterations. Some additional observations from listening to the participants were:

Effortless and intuitive interaction: Participants felt that learning was natural and easy. They liked to see their hand motions and the natural interaction through hand gestures. Most of all, they liked the ability to physically walk around in VR.

Request for more content: Participants liked the provided activities and wanted to participate in more similar activities as they felt the task got redundant toward the end when they grasped the main concept taught by the activity.

Gender-specific feedback: Male participants requested action-based and exciting events such as explosions while the female participants were happy with a calm and quiet virtual environment allowing them to take their time to solve the tasks.

Other Requests: Participants wished to have a guide or a friendly helper during an experience and wanted to see more of their virtual body parts besides their hands. One student found the found the headset to be heavy.

Future Work

In future studies, we would like to look at the student's recall of the lesson learned over a period of time. We believe this is where we will see a significant difference between a standard lesson and hands-on VR technology. We already developed the second level of CSpresso, which teaches bubble sort, a CS sorting algorithm. We also developed an augmented reality (AR) alternative teaching tool for the binary counting concept that works with a textbook supplemental section designed to work with the AR educational experience. We would like to test both educational experiences on the same student demographic, and we are currently testing the VR binary counting activity with different virtual environment features to see the effects on undergraduate students.

CONCLUSION

This paper presented a study on a CS educational VR experience called CSpresso. We found that by presenting binary counting in gamified, engaging, and private manner, students were not only able to learn how to count in binary, but were comfortable with the learning process. We observed students verbally walking themselves through binary counting tasks, expressing frustration when trying to solve a problem, and breaking out into victory dances when eventually solving that problem. All the while, these students knew that they were in the company of their peers but did not seem to mind taking their time to learn or have much concern as to what their peers might think of them. Testing confirmed that the student group who learned binary counting through this VR educational experience were just as successful as those who learned from a certified CS instructor. This suggests that VR educational experiences can be used as alternative teaching tools in CS education which can supplement traditional teaching methods enabling new learning methods for students in the classroom and at home.

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