3D Desktop Application for Interdisciplinary STEM Education

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Figure 1: Environment for the interactive game displaying the Advanced Science Research Center Initiatives

ABSTRACT

Innovation in the field of STEM Education is just as important as innovation in academic research and scientific industries. The field of STEM is taught with an effort to provoke forward-thinking, but efficient STEM education must convey complex concepts. Visualization of complex processes and concepts is increasingly required to grasp the full scope of natural processes and phenomena along with the research tools and practices used to discover them. This need motivated this study, focusing on the question of how effective computer games can be utilized in interdisciplinary education. This tool, designed to give users freedom to explore a space and be easily accessible to the public, aimed to educate users on the various instruments used to carry out research within the CUNY Advanced Science Research Center among each of their five interdisciplinary research initiatives. This the study observed how participants interacted with the the game, which was deployed on a computer, and how well participants could recall key scientific information embedded within the game.

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CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; • **Computing methodologies** → *Perception.*

KEYWORDS

Desktop Game, Interdisciplinary STEM Education, Recall, Advanced Science Research Center, ASRC

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1 INTRODUCTION

Education in STEM is often assisted by visual aids such as pictures and videos. Visual examples help convey complex concepts in a digestible fashion. However, education can extend beyond visual stimuli. It has been proven that the addition of interactive components can help retain information and increase comprehension [2]. Interaction can come in many forms when discussing STEM education, as demonstrative approaches such as lab experiments can offer fun alternatives to reading from a textbook [7].

Many would like to capitalize on this alternative to STEM education, including the Advanced Science Research Center at The Graduate Center CUNY's (ASRC) Outreach Education Program. The ASRC's primary Outreach Programan interactive visitor center located on the first floor of the building called The Illumination Space. The space is filled with interactive, educational displays and games. These games are designed to engage youth with the philosophy of interdisciplinary research and the center's five research initiatives: nanoscience, environmental science, structural biology, photonics, and neuroscience. The space, designed in 2015 is currently undergoing a redesign process, providing an opportunity to update and innovate the interactive methods in which students can learn about the center.

This study aims to investigate the effectiveness of a STEM-based educational game implemented in the ASRC Illumination Space, which can be used as a visualization and interactive education tool. Focusing on user recall and their experience with the game, the study aims to observe how wide ranges of audiences interact and react to the educational tool. This game, coming in the form of a desktop application, allows users to explore an open lab space, and interact with three-dimensional models of various instruments used within laboratories at the ASRC. Important information about how the tool is used in research is presented through pop-up informational panels as the user interacts with objects in the space.

2 RELATED WORK

2.1 Games for STEM Education

The question is often asked where people learn academic content more effectively through traditional techniques or through games [7]. With younger audiences previously tested using a game whose purpose was to educate students on comparing decimals, several factors contributed to higher performance when it came to learning on the subject matter [5]. Mayer et al. observed that the test group, being sixth graders, has better comprehension with comparing decimals and had a higher enjoyment level when learning, suggesting they may even play the game in their free time. Other models studying a similar pattern take a different approach, using older students to test lab-based games [6]. Nedungadi et al. provided these student online labs on desktop and mobile devices to perform or replicate experiments under conditions that would be 'impractical' such a zero gravity. The simulations provided gave the students the ability to visualize how their actions affect a zero-gravity system under safe conditions. The performance of the students after use of the simulation presented an increase in conceptual understanding of the science they were studying [7].

Additional studies focused on augmented reality implementation in STEM education, observing how creating a game for young students can incentives them to learn structural biology. Created and observed in the ASRC IlluminationSpace, Chow et al. provided tablets for students and instructed to scan QR codes scattered throughout the facility [3]. These codes presented different protein models that they were able to observe. The goal was to observe if students were able to learn through this 'exergame' through a gamefied, ar-based, building-wide scavengerhunt.

2.2 Assessing Learning in STEM Education

How student learning can be measured and interpreted plays a crucial role in this study taking place. Student learning needs to be assessed, and when dealing with interdisciplinary studies, learning of the individual topics must be assessed. Given that the ASRC is an interdisciplinary facility, Reviewing Assessment of Student Learning in Interdisciplinary STEM Education presented how pulling data from user education could be approached. Assessment for interdisciplinary studies will need to be more free for the user being assessed, as presentations, written work, or multiple choice assessments were shown to be the most effective methods of gauging student learning. Many suggest active recall to present that a concept is engrained within the student [1].

3 METHODS

3.1 Overview

Based on previous succesful virtual labs as learning enviornments, the vision for the application was to create a virtual gallery of lab tools. This approach aimed to enhance students' experience and understanding of the ASRC's strength as an interdisciplinary research and state-of-the-art instrumentaion facility. The first step was to identify which tools to highlight. The ASRC's Instrument Database, accessible through the center's website, contains various tools. As the application was conceptualized as an experience navigating an open lab space or gallery it was determined to display the tools in sections consistent with the five ASRC research initiatives. Tools identified included inspection microscopes, an electroencephalogram, an Erlenmeyer flask, etc., with informational catalogs attached to each instrument so the user can learn what the tool does and how it is used.

3.2 Materials

Variations of the tools were either found through third-party three-dimensional model platforms(Turbosquid, Sketchfab, GrabCAD) or remodeled using SolidWorks. To further observe the instruments and lab setting, a tour through the photonics lab was provided to refine certain tool models. All additional structures(lab space, desks, chairs, bookshelves) were recreated through SolidWorks, exported as STL files, converted to OBJ files, and imported into Unity. With Unity being the platform in which the actual game-interaction aspect of the project was developed [2]. All in-game actions, interactions, and UI were programmed using C#. Trials were consistently run to ensure smooth user control and that information for each instrument was accessible.

3.3 Deployment

Following the development process for the desktop application, the Unity 'game' was deployed to a web application using WebGL. The application aims to eventually be available publicly for all to virtually explore and learn about the instruments within the ASRC. Following the deployment for WebGL, the link for the game will be available through a GitHub link and on the ASRC outreach webpage.

3.4 Participants

The application was used on two participating groups, allowing for interaction feedback from a wide range of age groups. The first group consisted of high school students participating in a field trip, and the second group consisted of those who participated in the 2024 cohort of Hunter College's VR-REU. Following the tour, they were assessed and evaluated further on their experience of the virtual lab game. The assessments were created using Google

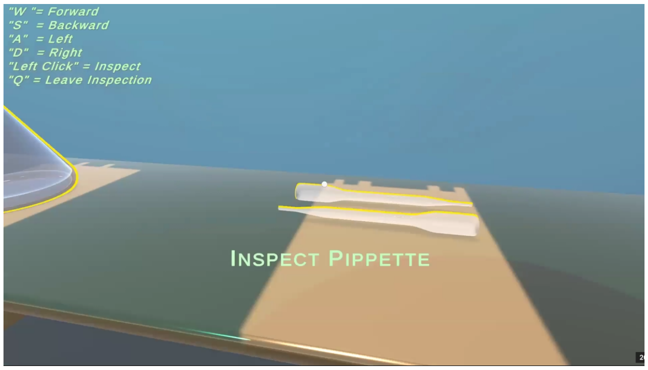

Figure 2: User interface where user presenting how users can interact with an object

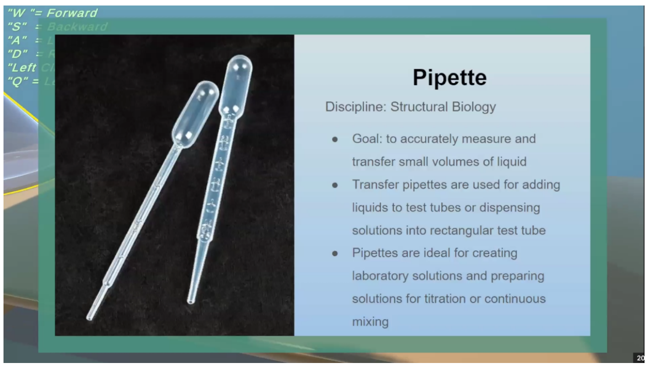

Figure 3: Informational slide that is presented upon user interaction with the object

Forms, in which the users were given the names of the tools and asked to recall how each instrument functioned [4]. The purpose of the instruments were mentioned on each slide to be recalled for each item, and whether those details were recalled accurately determined the score the user received.

4 USER STUDY

Testing the teaching effectiveness of the application required multiple groups of users, as this game was intended to be played by a variety of age groups. To do that, testing took place over multiple days, with phase one participants in high school and phase two participants in the Hunter College VR-REU 2024 cohort.

The game was designed as a desktop application, preferably intended to be used with a mouse, rendering it not readily available for mobile use. To accommodate this, a demo of the game was provided in the ASRC's Illumination Space on a screen in the Structural Biology section and on a laptop in the Environmental Science section. Before using the game, the users were given a brief explanation illustrating the overall goal of the game and were informed that they would be assessed following their trial.

After using the game's demo, the students were provided QR codes to complete the survey assessment. The only identifying factors in the questionnaire needed were the school and the level (middle school, high school, or college) they were currently in for data analysis. Following that, the users were prompted to rate their experience and the game's usability. Afterwards, the user was given a free response prompt to answer what the goal was of each instrument present in the game. At the end of the questionnaire, the user was free to make any comments or suggestions on how to improve the game.

5 RESULTS AND ANALYSIS

Following user testing, the post-game survey was provided, and fourteen responses were recorded and analyzed, four of which were from high school students and the other ten from college students. The survey asked the users how they would rate the game's usability and overall experience in a Likert scale fashion and then asked them the goal of each of the instruments provided in the game. Five students rated their experience as "Great", seven students rated their experience as "Satisfactory", and the remaining two rated theirs a "Neutral". Similarly, one student rated the game's usability "Neutral", six rated the usability "Satisfactory", and the other six rated the usability "Great".

In each category, the average college user scores varied from significantly higher to slightly higher than the high school students. The most significant disparity lay between the scores of the questions requiring the user to recall the goal of each instrument. Many factors could have led to this disparity between the scores of the two groups. Due to the number of responses recorded from each group, the variation between scores and the potential for an outlier to affect the mean was much higher in the high school group. Of the high school students, one of the four answered that they did not know the goal of any of the instruments, making their score zero. This resulted in the average being reduced by thirteen percent. In addition, the high school group's testing period was limited by the time the session had to be for the field trip, whereas the college group's time was more flexible. In addition, the ability for users to engage with the game was more prevalent in the college group due to a secondary computer running the game, allowing two students to test the game at a time.

The higher scores recorded from the college students could also be explained by the level to which each group was engaged. The second group consisted of college students conducting studies of their own involving research in gaming, virtual reality, or augmented reality, and due to that, many of the college students might have been more encouraged to explore the game.

6 DISCUSSION

6.1 Limitations

The development of this tool came with the challenges of creating with no prior knowledge. Being a prototype, the project required learning Unity from the beginning, meaning it took time to overcome the hurdles of program errors and incorrect asset assignments. From the beginning of the project's conception, the goal was to create an accessible, three-dimensional interactive educational tool. While the final product met the goal, decisions had to be made on how the user learned about each of the instruments. Those decisions potentially affected the results, as such limitations invoked simplification of the game.

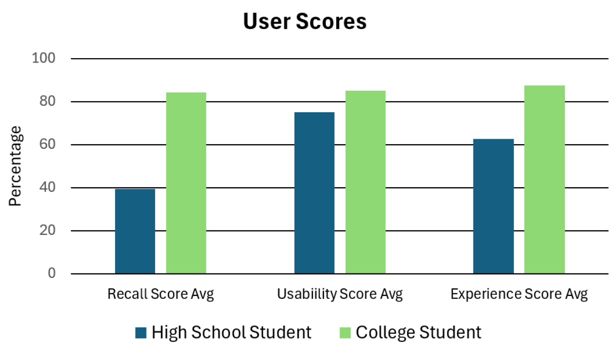

Figure 4: Graphs comparing the averages of the high school and college students separated by category

As seen in Figure 4, there is a consistent disparity between the high school group and the college group. Only four of the dozen high schoolers who attended the ASRC on the day of testing completed the survey. On the contrary, the ten college students who tested the game filled out the study, which could partially explain the disparity between the average scores of the high school students and college students.

In addition, both groups were provided a brief explanation of the game's premise and were able to test it within the Illumination Space. However, unlike the high school group, which was tested first, the college group was provided an additional computer to test the game on. This additional computer allowed the group to be split into two, raising the engagement level as more people could test the game in the limited time the groups had on their respective field trips.

6.2 Recommendations

At the end of the survey, users were encouraged to provide feedback and suggestions for improving the game to increase engagement. One of the most anticipated suggestions was to reduce the sensitivity of the "player looking" function, as users found the game hard to control, especially when attempting to interact with smaller objects such as the pipette.

One commonly recommended suggestion was to give the game more immersion and a more engaging entertainment factor. Given that the application primarily told the user information on each instrument in a straightforward piece of text, this method of conveying information can be evolved. Functions such as interacting more by even picking it up and looking at it closer or being able to perform a simple action such as pouring liquid out of the Erlenmeyer flask could be added. Gamification would be a key factor in raising the engagement factor, specifically for younger students. In addition to in-game immersion, a matching game was suggested. In the matching game, students would be able to see the instruments and try to associate which instrument fell under each of the five disciplines at the ASRC.

6.3 Future Improvements

Considering the users' feedback, plans have been considered to elevate the user experience for the game. The idea of gamification requires the user to be incentivized to complete a certain task. In the game that led the study, there was no incentive other than purely learning, meaning nothing was stopping the user from quickly clicking on each of the items and then leaving the game, having not learned anything. To prevent this, the game's second version would have a more elaborate space to explore, similar to the architecture of the Illumination Space, giving the user more to look at and a better time exploring. Starting with one of the initiatives, for example, photonics, the user would have access to a space where they would only be able to explore the next space once they pass through a gate. To get through the gate, they must correctly answer a question regarding the instrument provided in the room. One by one, they would be able to unlock more rooms, and a greater incentive would be to deduce their score in the game by relating how many times it took for them to get through each level to the time it took them. This way, the game could be a fun and competitive educational module that still educates students on the instruments in the labs of the ASRC.

The goal of this application was to be widely accessible, other than implementation in the ASRC for educational use. The prototype, only programmed for desktop use, remained a limited method of exploring the space in the game. The application could be extended to mobile devices and potentially virtual reality for greater immersion.

7 CONCLUSION

This study explored three-dimensional gaming's use in interdisciplinary STEM education and its effect on different audiences. The ASRC study presented how educational methods can resonate with different audiences. The game created for the facility was tested on a small assortment of students. Still, the responses and feedback gave insight into how different students respond to a specific learning method. With future improvements to accommodate more learning types and different attention spans while increasing accessibility across various platforms, this application could be a new addition to the ASRC's Outreach Program.

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