Chemistry VR

P2 – Project Preliminary Paper

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INTRODUCTION

The main goal of this project is to design a VR application to help chemistry students in learning the redox titration experiment before heading to the lab. Another purpose of the project is to aid professors as this will lead to less chemical waste in the lab and more productive learning.

ABSTRACT

Our project is a VR chemistry station. When the student starts the application, they will be in an entrance room where they must first log in, and then they can choose between different kinds of labs to do at a chemistry station. To start with, this chemistry station will be capable of completing the redox titration chemical reaction. The user of our VR app will have limited control of the chemistry station, and the application will guide them through the lab. If they make some mistakes, our system will give more and more descriptive hints until they complete the lab correctly. The user should get feedback when they make mistakes as well. There will also be a notepad to record data while experimenting. Finishing the lab properly will present them with a congratulations message and the options to either reset the lab or to go back to the main menu to select a different lab to complete.

The purpose of this application is to introduce the experiment to the student before they go to complete the lab in person. Most students make mistakes when completing this lab. This VR prelab can help reduce chemical waste when they go to complete the lab in person. The student will familiarize themselves with the experiment after using our application and will hopefully be less likely to make a mistake, or as many mistakes when they complete it in person.

1 Literature Reviews

1.1 Elizabeth Dayton Review

"The JUST VR Tool: An Innovative Approach to Training Personnel for Emergency Situations Using Virtual Reality Techniques" [1]

VR tools are an incredibly successful tool for simulating real-world situations. It creates a sense of really being in the situation at hand and tests whether someone would be ready if the simulation occurs. The research paper I have chosen successfully demonstrated that a VR tool felt like a real-life situation, and users felt like they were there in a health emergency scenario. They used 20 participants and two different cases to test whether the VR simulation felt like life and could be useful in training people for high-intensity situations. Participants had to complete a survey, like other surveys created by Slater, Usoh, and Steed. The purpose of this survey was to assess the participants' feelings about their sense of presence and how close to reality the simulation felt. Comparing the results to the results of similar surveys, they found that the participants felt very strongly that the VR simulation felt real and that they felt very present in the situation. This test was conducted in 2004 when VR technology was relatively new. Since 2004, VR technology has made many advancements, and VR is much more affordable (the system had a cost between $20,000 and $80,000). I felt that this article was relevant because VR is a continuously growing technology, and there are many uses for it apart from entertainment. This study showed that VR could help in an extreme scenario like a health emergency, and I think it shows that it is beneficial for other situations that are not high intensity. I think it shows that for our purpose, a chemistry experiment VR experience, it could be helpful for both students and teachers. It can help students learn and limit chemical waste. Also, now that VR headsets are much

more affordable, students and teachers can make use of them for this learning purpose. It feels just like a real-life scenario and will benefit students who are unfamiliar with chemistry equipment or with the experiment at hand. It will help students feel more confident and give teachers a resource to aid student learning.

1.2 Cole Beck Review

"Diagnosing changes in attitude in first-year college chemistry students with a shortened version of Bauer's semantic differential" [2]

Students of chemistry are often assessed based on their pre-existing understanding of the concepts of chemistry to evaluate and develop fitting instruction for the surveyed students. The research paper I have chosen suggests that assessment of a student's attitudes toward chemistry as a subject may be just as crucial as the student's prior knowledge of the information when considering how best to develop a pedagogical approach. Naturally, one must have a successful diagnostic tool to measure such attitudes toward chemistry to effectively determine how impactful a student's temperament is on their learning outcomes. Unfortunately, these tools are sparse; however, the paper assesses the effectiveness of the semantic differential test, ASCIv2, when measuring student attitudes toward chemistry. The tool asks students to choose one of two opposing adjectives to describe the subject of chemistry in a series of questions. For example, "chemistry is easy/hard." The study conducted found that the assessment tool was adequate in measuring the attitudes of students toward chemistry as well as measuring statistically significant changes in student attitudes if assessed more than once.

The utility of this study and its findings should be of great assistance after the completion of the ChemistryVR project. Without a proper assessment, the ChemistryVR project did not prove that it could help students have a better attitude towards chemistry. Ideally, the project will reduce student anxiety in the lab setting that will improve grades. Theoretically, these improvements would result in statistically significant improvements in student attitudes toward chemistry that could be confirmed by the ASCIv2 diagnostic tool. Additionally, the diagnostic tool can assess any added feature to determine if it requires improvement or even removal in the case that it decreases student scores on the ASCIv2 diagnostic tool.

1.3 ByeongHyeon Choi Review

"How VR In Education Will Change How We Learn And Teach" [3]

As we evolved, education became imperative in our society, and it is still more important than ever. Society pressures us to produce solutions to many global problems such as global warming, trash, food, water, and the economy. With all these problems to solve, and with the rise in advanced technology for education, we need to produce an efficient way to make students learn about the topic instead of just memorizing it. However, many would agree that the education system in the U.S. has not been the best, and some would go further and say that the U.S. education system has deterred. According to the article, current education relies on the same old practice that is fact retention, and sometimes too much information will harm the students. However, with all these advancements in technology, there are many ways to improve education. One of the best long-term and cost-efficient solutions is through VR. This article I read talks about VR in education environments and how it will change the way we learn and teach. The argument that the author makes builds off these five key points: Immersive, easy to use, meaningful, adaptable, measurable.

When using VR in an educational scenario, we are trying to create an image of life. If the user drops an object, it should have physics. If a glass falls, it should shatter. If a mixture is wrong, then there should correct reaction. This way, the user feels like this is what to expect in life, but all this challenging work of making VR immersive is useless without making VR easy to use. The user should not have a tough time starting up the application as that will cut the frequency of the visit to the application, and with ease of use, it will increase the frequency, and the application gains meaning. In the article, it talks about what meaningful means: "Meaning is important for students. You can't create a good VR learning experience without a good story." By this, the author is trying to say that the lesson should have meaning or point that students learn from because without it will just be another lesson that will lead to memorization. The article is pushing the idea of learning and not memorization, which is what our current education is. As well as having meaningful experience, it should have adaptability. Assuming so far that students have an immersive experience that is easy to use but also a purposeful impact, then we can suppose that the students have learned the material. Hence, the application should allow itself to adjust the level of difficulty when it comes to labs. Although this may seem unnecessary in our case since it is just a tutorial of how to use lab equipment, we can change the difficulty as the user progress to further advance in their learning about lab equipment. Of course, this would mean nothing if the developer and the educator cannot track measurable success and failure.

Having a VR tool to teach in education can and will bring benefits that will benefit society. In the article, it talks about many aspects of VR than the five key points, but I wanted to point those five important points as that is what we will be using in our development of Chemistry VR. Overall, the article I read gives us good key points to focus on VR for educational use. We can use the writing to look at these same points and build on them to create a functional VR Chemistry Lab.

1.4 Nick Arnold Review

"Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons" [4]

Virtual reality is something that has been around since the 1960s to 1970s. Since its invention in 1962, it had gained a lot of traction over the past decade because of its rise in popularity. It is now easily acquired for the average household if they have the money for the headset device. There has also been an increase in

the number of people who are trying to find new uses for it. Some of the applications include gaming, training, and education. While people are trying to use it for education, there are just as many people trying to verify and prove whether it is useful to students or is it just a waste of time. In the scholarly article, the authors set out to verify that the use of virtual reality does have some beneficial outcomes for the students involved in using it to learn.

First, they talk about what VR is. They describe VR as a technology that emphasizes the sense of presence in the computer-generated simulation of a three-dimensional image or environment. There have been many studies to look at how VR can help students learn various subjects including, ecosystems science, geography, geometry, and history. These studies have all yielded positive results. The writers dive into why this is. First, it is because using VR gives the students a sense of excitement that might not have been there before because it exposes them to a new form of technology that is more interactive.

There has been a multitude of experiments that have to do with whether there are benefits in using VR to teach, but this study takes a look at trying to use VR as the method of teaching for a common classroom. The VR that this study looks at is a form of immersive virtual reality (IVR) called a Head-Mounted Display (HMD), and how this form a VR can help the students of two 6th grade classes better comprehend and learn the material that they are learning.

They set up the classroom so that there would be 10 HMD for students that are all connected to a mobile tablet. The tablet would allow the teacher to control the lessons, make sure that the students were keeping on track, and help the students out if they need it. The VR system would then allow the students to go through four different lessons on various topics. Before they went to a topic, they would take a pretest that would measure their prior knowledge of that topic. After they finished learning a topic, they could complete it by going through a VR quiz/wrap-up test.

The two classes of 6th graders randomly split into two groups, with one learning with the VR system, and the other learning from traditional classroom methods. On the pretest of the topics, the control group had a higher score with a mean of .56, while the experiment VR group had a mean score of .50. However, the results of the posttest show that the experimental VR group showed better results with their mean score jumping to .713 while the control group only moved up to a .563. The experiment also tested the engagement of students in different categories, but in all the criteria, the experimental VR showed better results.

Overall, the purpose of this study was to prove that there were benefits to having students learn different subjects using IVR as the method of teaching, and I think that it did that. The results showed that the students who used the VR not only learned more but also had a more enjoyable time while doing so.

1.5 Joshua Gatlin Review

"Virtual Reality and the Transformation of Medical Education" [5]

VR technology can drastically shift the field of medical education. For several years now, medical education has recognized that skilled medical practitioners can gain experience through simulation of real-world conditions and not through memorization and head knowledge. The thing is physical simulations are expensive and do not truly simulate real-world conditions. VR can change this. Situations created inside a virtual environment can reproduce the real world to a higher degree. A virtual world can convey the stress and chaos of an emergency, and each action can occur without risking the safety of a real patient. There are a few drawbacks, an example of which would be that VR does nothing to help a doctor break the bad news to the patient. Using VR for medical training has become popular with surgeons, though it is still catching on in other medical fields. However, VR's potential cannot be underestimated, and even the way it is now, it could be used to save a great deal of money in medical training.

This article relates to our Chemistry VR project because it lends context and provides an example of how and why students use VR in another field of learning. It shows that it makes sense for students to use VR to learn about a subject before trying something with greater risk or a higher price tag. In the case of the medical profession, VR replaces expensive training equipment and gives the student knowledge about what to do in a real medical situation without any of the risks involved. For chemistry, the reasons to use VR are very similar. Practicing an experiment in a virtual space before trying it in the real-world may conserve money and increase safety. Chemicals are not free, and if improperly used during the experiment then they must get thrown out and replaced by new chemicals. Chemicals can also be dangerous. Having students practice handling them in VR may prevent injuries. Considering the relatively low price tag of VR, it just makes sense to take the extra step to give students the extra practice they need before stepping into a laboratory.

1.6 Ben Dempsey Review

"10 Ways Virtual Reality Is Already Being Used In Education" [6]

Educational settings can use VR for many purposes. The immersive experience is a helpful learning tool. For example, students studying foreign languages can use virtual reality to simulate visiting a foreign country to practice the language. VR creates an opportunity for students that are not able to afford an international trip. Virtual reality can also be useful for topics like architecture and design. Being able to view building designs in an immersive three-dimensional plane is much more realistic than using schematics alone.

A chemistry virtual reality program would similarly allow students to become familiar with the tools that are common in a lab and could let students remotely get a similar experience that would otherwise be in person. Many students are not familiar with the tools in a common lab, and so being exposed to those for the first time may create anxiety for some. With a virtual reality

lab test, students can get to know the lab environment without worrying about breaking glassware or any of the other possible things that could go wrong.

1.7 Jay Cieutat Review

"The Data-Driven Case for Virtual Reality Learning" [7]

Virtual reality programs are an effective way to deliver necessary information to students. Academic studies have shown that virtual reality is incredibly effective at making students absorb the information given. These studies also show that students utilizing high-level virtual reality simulations in the classroom have an increased rate of learning retention. There are a few theories about why this is the case. Perhaps adding multiple senses (sight, sound, etc.) increases the learning retention of these subjects. Another reason this might be the case is that virtual reality is fun. In many situations, a virtual reality simulation is more fun than a typical classroom experiment. These simulations may also be perceived as games, which are a great way to capture the full attention of students.

This article is relevant to our project because it gives us academic results to show that virtual reality is an improvement when it comes to information retention of students. While virtual reality labs are being used during the COVID pandemic lockdown, it can also greatly benefit students outside of this situation. It is also worth mentioning from an accessibility standpoint that virtual reality labs might be more accessible to those with disabilities than traditional labs. As we have learned in this class, accessibility is an important part of designing useful software. The idea that virtual reality labs could be more effective in teaching students than traditional labs gives the ChemistyVR project longevity.

1.8 Everett Clemons Review

"Reasons to Use Virtual Reality in Education and Training Courses and a Model to Determine When to Use Virtual Reality" [8]

An example of the evolution of computers and technology is VR. VR has been one of the most expected and anticipated technologies. It has appeared in many Sci-Fi movies as a technology seen hundreds of years in the future. This type of computer technology has always integrated itself into education, and VR is no different. This immersive VR tech can fully immerse students in an experience that "are specifically designed to help students learn the material." This type of immersive experience cannot be obtained through traditional means of instruction. Immersive and hands-on experiences educate better and faster than just formal teaching. Virtual reality can create these hands-on experiences for students that classroom education cannot. VR also gives new methods of "visualization" and helps students visualize the instruction they got. This type of teaching can provide students with a face to the material they are learning. VR has also proved to motivate students. It is an exciting new technology.

VR is a technology that motivates students to interact, not just passively learn. This motivation is the most vital part of VR in the classrooms. Instead of passively learning material, students can now be active in their learning and interact and collaborate with technology. Our project aims to show that this is true. VR can benefit millions of students, and, during these times of quarantine, many institutions are already relying on VR to offer distance learning to students. The benefits can already be seen. This project would give students an experience outside of the classroom that would allow them to get used to the chemistry lab environment, outside of the classroom, instead of a passive video. A VR experience would create a mental construction of the lab before students even step foot in the lab. This would allow students to practice safety rules without being in danger. VR experiences would be very beneficial to students and our project aims to show that.

SPECIFICATION/REQUIREMENTS

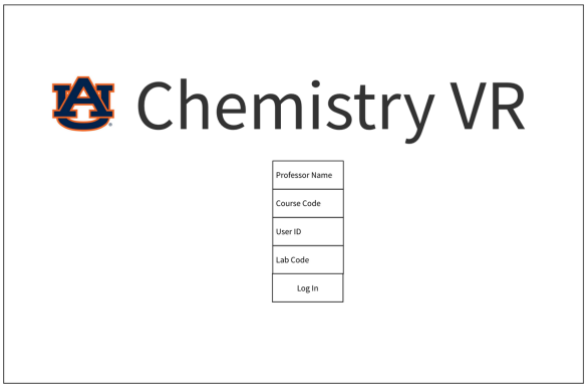

Figure 1: Wireframe showing the envisioned login/welcome screen of the application.

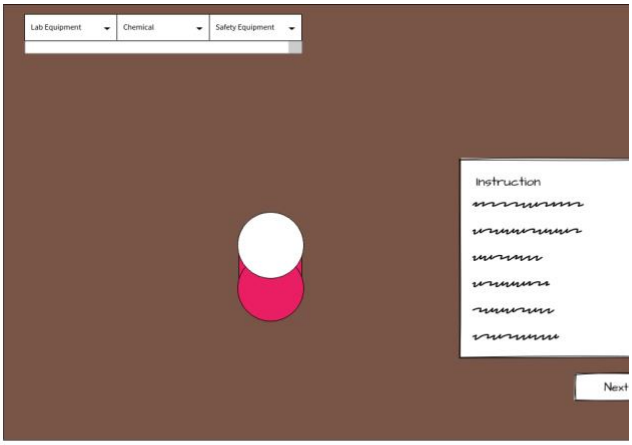

Figure 2: Wireframe showing the beginning setup of the redox titration experiment.

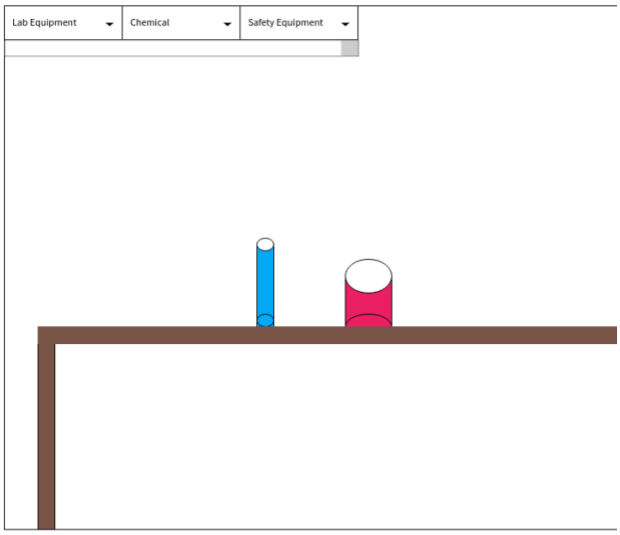

Figure 3: Wireframe showing another step of the redox titration experiment.

CONCEPTUAL MODEL

The functional requirements we have for our application to be successful are as follows:

- The system shall support a student in that they will feel comfortable with the redox titration experiment and be familiar with how to complete each of the steps.
- The system shall support a student using the Chemistry VR application in learning the redox titration experiment so that they may complete it with little to no errors in a real-world lab.
- The system shall support a student in that if they are struggling to understand or complete any of the steps, they will be met with helpful hints and suggestions until they can complete the step.

SOFTWARE REQUIREMENTS

The software requirements are as follows and are based on the VR technology that exists as of the completion of this paper:

Hardware (if it is a VR headset that requires a PC):

- Graphics card: GTX 1060/AMD RX 470/570 or greater
- CPU: Intel Core i5-4590/AMD Ryzen 5 1400 or greater
- Memory: 8GB but recommend 16GB
- AIO: HDMI 2.0, DisplayPort 1.2, USB 3.0, USB c,
- OS: Windows
- VR Headset: Valve Index, Oculus Rift, Oculus Quest, HTC, and more
- Controller: VR controller

Software:

- Chemistry VR application (that will be completed in Unity using C#)

SOFTWARE DEVELOPMENT PROCESS

The type of software development process that we will be using is the XP (EXTREME PROGRAMMING) methodology.

Using XP we will be able to manage our client's rapid introduction of ideas into the system.

XP is also the right choice in terms of the development process because it allows the team to work closely together. We will complete the process through means such as pair programming. Since we have a limited timeframe to complete the application it would be wise to combine our efforts.

All the advantages of XP, such as the ability to continuously evaluate our specifications regarding the demands of our client, will benefit our productivity greatly. The disadvantages of XP programming also will not affect us in this instance. Issues such as requiring a closely-knit team and geographic location will not be a problem for our development team.

LEXICON

The user will need to aware of jargon included in the chemistry experiment itself. Familiarity with chemistry lab equipment as well as the chemicals are required to complete the experiment. These include, but are not limited to, potassium permanganate solution, beaker, molarity, burette, KMnO4,

Erlenmeyer flask, hydrogen peroxide, graduated cylinder, and meniscus.

Potassium permanganate solution, or KMnO4, is a chemical compound that combines manganese oxide ore with potassium hydroxide. It was originally used as a disinfectant and is still used to treat skin conditions like fungal infections.

A beaker is a lipped cylindrical glass container for laboratory use.

Molarity is the number of moles of solute per liter of solution, which is calculated using the following equation: molarity = mol of solute/liters of solution. A mole is a standard scientific unit for measuring large quantities of small entities such as atoms, molecules, or other specified particles.

A burette is a graduated glass tube with a tap at one end for delivering known volumes of a liquid, especially in titrations.

An Erlenmeyer flask is a conical flat-bottomed laboratory flask with a narrow neck.

Hydrogen peroxide is a colorless, viscous, unstable liquid with strong oxidizing properties, commonly used in diluted form in disinfectants and bleaches.

A graduated cylinder, also known as a measuring cylinder or mixing cylinder, is a piece of laboratory equipment used to measure the volume of a liquid. It has a narrow cylindrical shape. Each marked line on the graduated cylinder represents the amount of liquid measured.

A meniscus is the curved upper surface of a liquid in a tube.

EVALUATION/RESULTS

We will evaluate our project success and useability based on user testing of our application. This user testing will consist of us, the designers/developers, using the application and verifying that our functional requirements are met and that the application performs as expected. We will also use both Xin Wei and Qi Cui's feedback about our project to determine its success. We will receive their feedback periodically throughout the process and will make changes and adjustments accordingly. As the clients, their responses are ultimately what will determine our project's level of success.

The think-aloud protocol that we will use will evaluate the effectiveness of the program. The questions from the protocol will include two parts, with one occurring before the participation in the application. The other section will be given after the participant has used the application. We will ask the participants about how comfortable they are and their knowledge level on the experiment. The two sections will then have their answers compared, and we can evaluate how much benefit the program has provided to the participants.

DISCUSSION/CONCLUSIONS

We have spoken to Dr. Seals, Xin Wei, and Qi Cui about our project and received a lot of help and valuable information from them. Their vision is something we keep at the forefront of our minds while designing our project and will continue to be our main focus when we go into development. We anticipate that upon completion of this project, other developers in the future may take what we've done and add on other reactions and labs for students to complete.

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