Virtual Reality (VR) Simulation of Chemistry Lab Using Blender and Unity

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Abstract
The new age of coping with change has driven us to employ all the technology to make everything in our day-to-day work and study life available remotely. In the time of virtual education and virtual meetings, this project intends to add to virtual education. Modern times have made us realize that lessons may be held online and do not require a physical presence in the institution of education, but the same cannot be said for laboratory-integrated disciplines. Our answer to having access to laboratories that would necessitate physical participation is to recreate the laboratory and its exercises to deliver an analogous interactive experience through a Virtual Reality (VR)-rendered 3D simulation. In this project, we are replicating a chemical laboratory with 3D animation. This allows the user to do experiments in the same manner as they would in a chemistry laboratory. The simulation is rendered in VR so that the user can interact with the objects in the 3D world. The elements are generated with Blender and the interactions are managed with Unity. Thus, universities and institutions that have chemistry laboratory integration into their curricula can benefit tremendously from this project.

Keywords: Virtual Reality, Blender, Unity, 3D Simulation

1. Introduction

The Covid-19 pandemic forced everyone to isolation from the public. However, the processes of society could not stay idle for long. A solution had to be discovered to make everything function again. Mutunhu-Ndlovu et.al (2022) notes that educational institutions had to switch blindly from physical classes to online classes whilst having inadequate resources to do so. Thus during this era classes and meetings moved to virtual meeting platforms. All conceivable systems that could run virtually did so and are still doing so as a contingency plan, especially for low to middle-income countries (Zheng,2021; Vincent-Lancrin,2022). For the education sector with laboratory experiments, Virtual Reality seemed to be the inevitable next step for the advancement of education (Lampropoulos ,2022).

Virtual Reality (VR) is a computer-generated simulated experience where the user may interact with an artificial world or an environment that mimics an actual one with the use of electronic equipment such as a VR headset or a keyboard and a mouse Ip (2022). With the use of VR, we build or develop an artificial, interactive, computer-made environment or simply a "world" (which might look fairly real to an existent area) inside which the user can immerse themselves (Lege,2020). Interactions in the virtual world might range from gazing left, right, or any other direction, as if they were genuinely there in that reality It can also entail interactions of the elements existing in the world to create a more real-time experience of a particular job. With education at the cornerstone of a successful community and the transfer of information being humanity's number one priority since the dawn of civilization, humans have been exploring ways to communicate information more readily, promptly, and efficiently (Akuma and Callaghan,2018; Keiner and Graulich,2021). In the digital era, we now can employ technology to improve the technique of learning.

Not only are there very few systems that exist for VR laboratories but there are hardly any institutions implementing them. This project aims to be friendly for the institution and the courses it will supplement using Virtual Reality. A virtual environment in which any chemical interaction is possible, can lead to unaccounted possibilities and affect the accurate learning process. Hence limiting the experiments to a set of allowed possibilities allows for precise learning. Rarely can a university support a fleet of pricy and cutting-edge research instruments exclusively for pedagogical purposes. As a result, rather than keeping up with the newest discoveries, the design of the analytical chemistry curriculum is bound by the access and availability of scientific instruments. How can we get past the dilemma of restricted access to scientific knowledge and the desire for sophisticated content that demands the usage of scientific equipment? In this paper, we address this issue by inventing a virtual reality (VR) chemistry education platform that leverages VR connectivity to connect scientific equipment to a huge classroom.

This project will enable one more system to the virtual world, the laboratories. Creating the laboratory setting, where a given set of experiments have to be done could comprise the set of experiments needed completion by a course. The laboratory is displayed in VR output so that the user may interact with the elements as he would in a real-world chemical laboratory. The created environment, if offered to every person who is required to complete the experiments, can permit remote access and completion of the course without needing to be present physically in the laboratory. We propose a small-scale 3D environment where the experiments are performed as per the course that an institution requires. The deviation from the experiments will be very less as, in a simulated environment, if it’s not coded it’s not possible. This controls the degree of freedom that a student or a user has in the environment.

2. Objectives

1. To develop a web application that simulates a chemistry laboratory
2. To simulate a chemistry practical experiment
3. To set up chemistry apparatus in a virtual environment

3. Existing Systems

Agbonifo et al. (2020) developed a Virtual Chemistry lab for acid–base titration experiments. Their virtual lab is an alternative to physical laboratories with inadequate reagents. Their lab provides students with real-life experiences of practical labs thus enabling adaptive learning.

Bortnik (2017) developed a chemistry laboratory platform enhanced with virtual reality. The experiments carried out in their Virtual lab is a titration. This enables students to do pre-lab experiments virtually before accessing the chemistry wet lab. This enables autonomous learning. Georgiou (2007) developed an integrated web-based learning environment for the simulation of chemical experiments. Their application presents institutions with low resources and inadequate infrastructure with an opportunity to familiarize themselves with a real chemical laboratory using cost-effective measures. Hu-Au and Okita (2020) did a comparison study between Virtual Reality and Real Life chemistry laboratories. Their study shows that there are differences in learning experiences in terms of laboratory skills, safety standards, and knowledge content.

In all these systems noted, several programming engines were used in the study of virtual environments which included Unreal Engine, Panda 3D, and libGDX.

Despite the recognition of these existing systems we identified limitations faced by these systems which include the following:

1. Simulation as it is not tailored to a course.
2. The endless possibilities under a sequence of actions are not accounted for and are inaccurate.
3. Expensive simulation as the mixing up of solutions and salts is not limited.
4. Redundant complex interactions in the perspective of a course.

To overcome the above limitations we propose a new system to counter some of these limitations. This system we propose, has tailored experiments to a particular course. The aim is to allow four experiments from the twelfth-grade state syllabus of the Karnataka government.

4. Research Methodology

For the research, a Build methodology is being used. A build methodology is used considering this as a new piece of technology and the research aims to test whether the approach of building this software will influence one's understanding. The hardware requirements for this project are a VR headset and controllers for an immersive experience. This application also runs on the student’s personal computer where the application is interactive with an available mouse. The chemistry laboratory should have experiments that can be performed.

In this project, we have simulated four experiments:

1. CuCO3 heat CuO + CO2
2. CuSO4.5H2O heat CuSO4 + 5H2O
3. 2Pb3O4 heat 6PbO +O2
4. 2HgO heat 2Hg + O2

In the figures below we can see the color change as part of experiment number three where the orange Pb3O4 changes its color to reddish brown when heated and yellow when it is cooled.

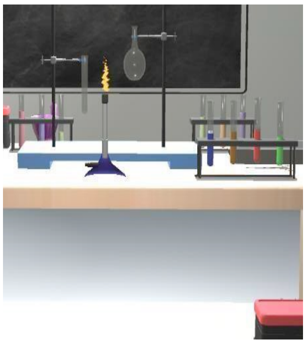

Fig 1: Orange solution of lead oxide in the second test tube from left

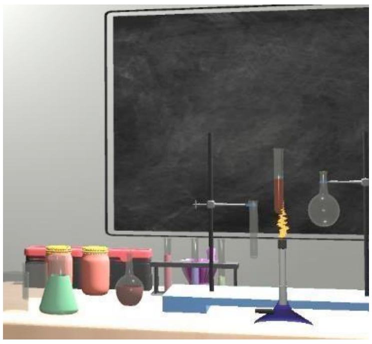

Fig 2: Solution changes color to reddish brown on heating

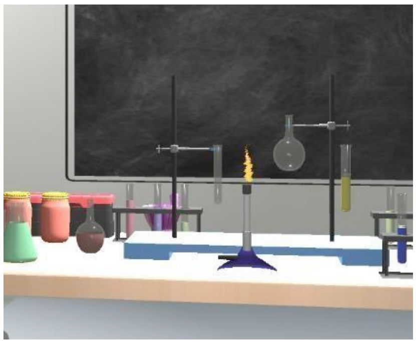

Fig 3: Solution turns color again to yellow on cooling

i Light green copper carbonate turns black on heating along with carbon dioxide gas
ii Blue copper sulphate solution turns white on heating
iii Orange lead oxide solution turns reddish brown on heating and yellow on cooling releasing oxygen gas
iv Red solid mercuric oxide turns to silver droplets near the mouth of the test tube on heating along with oxygen

The experiments have been selected due to visible inference. The experiments show a change in the color of compounds when heated. The color changes for the experiments are as such.

4.1 Different Modules of the Project

1. Camera Control

The VR simulation can be experienced only through a VR headset and hence for that experience, there must be a camera system that translates the users viewing position from which they see into the simulation. The camera control module takes care of the camera movement.

2. Collision

In a 3D world, the interaction of elements can also be called collisions. For an environment that is built in the 3D workspace, the interactions make the environment an active one.

The collision module states the rules of the interactions like when one particular element will change interaction depending on how far away it is from the element that it interacts with.

3. Materials

Just like everything in the real world has its appearance. The virtual world elements must also have their appearance and attributes like gloss, grading, and transparency. The materials are fine-tuned to mimic the real-life inspired elements.

4. Particle Color

The flame element is a type of element that uses a particle flow system since it is not a rigid entity. The particles of the flame simulation allow for an unpredictable movement of the flame that mimics the uncertainty of a real-world flame.

4.2 Code Snippet of Particle Colors

```
Particle Colors
using System.Collections; using System.Collections.Generic; using UnityEngine;
public class ParticleColor: MonoBehaviour
{ public GameObject particle;
// The new material you want to apply to the particle system
public Material new material;
private void Start() {
// Access the 'ParticleSystemRenderer' component,
and change the material to 'new material'.
Particle.GetComponent<ParticleSystemRenderer>().material = newMaterial; } }
```

The application when launched finds the 3D elements within its camera frame. These 3D elements have properties that allow them to be dragged and dropped along the axes. The active elements in the environment when interacting with each other, like the test tubes and the flame, a change in the color of the content of the test-tube occurs. Until this change is noticed the elements have to be brought near each other. The change in the color of the elements is not spontaneous and is only triggered when it comes in contact with the flame.

5. Experimental results

3D environment:

Fig 4: Frontside

Fig 5: Backside

Fig 6: Camera View

From this angle, the simulation can be viewed. This is a fixed camera position. The experiments can be performed and viewed from this angle.

The following is a demonstration of one of the experiments conducted.

5.1 Experiment on $CuSO4.H2O$

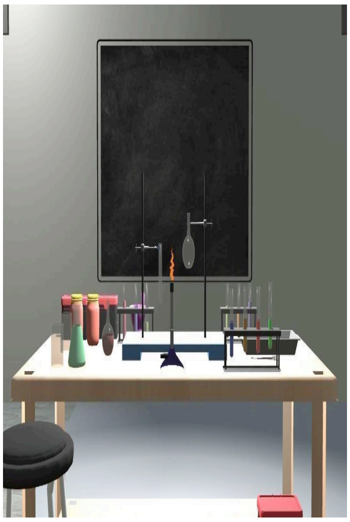

Fig 7: Initial position Test tube containing CuSO4.H2O is in the test-tube tray.

Fig 8: When brought near flame element

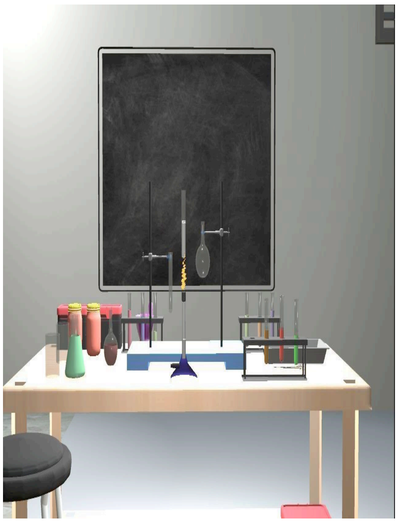

Fig 9: Near the flame for some time

The color change of the solution is visible as it changes from blue to white.

6. Conclusion and Future Enhancement

We believe that this project will be instrumental in a time when access to laboratories is limited. In 2019 when the pandemic got the whole world, the quick response and solutions to shifting education and work to virtual platforms was one way to have everything moving. In such a time, laboratories were the hardest to implement, in terms of education. This project is also for those who would like to access the laboratories but are not able to because of distance and inaccessibility physically or various other reasons. The project was created with animation in 3D not only to provide for learning but also to provide a safe space where the deviations from the experiment and its consequences are minimum. The 3D immersive experience can be out of the ordinary, capturing the attention of its users more than regular labs attended physically. The project allows for a reality where the resources are never exhausted. The chemicals that are used in the real-world laboratory can be expensive and hard to maintain. A virtual reality where you can do something, restart and everything is back to the same as it was, in the beginning, offers the best cost-cutting solution to this problem. The virtual platform has a fixed number of possible actions. In a real-world laboratory, however, the resources could be misused. This project offers a solution to all misuse of resources in a chemistry laboratory. The project can work as a hybrid learning platform. This flexibility can inspire the education field to make use of such platforms. This project could also be seen as a game, providing an immersive experience to its users and keeping them interested.

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