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Next-Generation Learning: VR Chemical Lab for Safe and Interactive Science Experiments

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***Abstract*—*Chemistry labs traditionally face a lot of issues such as lack of physical space, availability of resources and a lot of safety concerns.In this study we aim to solve all these problems with the help of Virtual Reality Chemistry labs which can provide students with interactive and immersive experiences which can enable students to perform chemistry lab experiments.. We have used platforms like blender and Unreal Engine 5 for modeling and Designing of the Virtual Lab. Our software can be useful for the educational organizations that face the problems listed above and can receive interactive, immersive and most importantly safe experience through our Virtual Chemistry Lab.*

***Keywords*—** *Virtual Reality, Blender, Unreal Engine5.*

I. INTRODUCTION

In the continuously evolving field of education, innovation is the fundamental principle of growth. With swift developments in technology, teaching techniques are undergoing a huge transition that enables students to get immersive learning experiences that are far better than the traditional teaching techniques. Leading this educational innovation is our project of Virtual Reality (VR) Chemistry Lab, which was precisely designed to fulfill the demands of 10th grade CBSE students.

This VR Chemistry lab is more than just a simulation, it's a world where the periodic table is brought to life and chemical reactions unfold vividly in front of your eyes. The experiments in the VR Chemistry Lab are like a journey that changes how students connect and learn about the topic.

Along with immersive learning experience and Innovative technology the VR lab also provides a safe and dynamic environment.

As we enter the new era in education, the VR Lab pimples the change in the methods of learning and teaching. By using the power of technology we can break the limitations of the traditional classroom teaching techniques and promote students to actively participate in technologies like VR. With all immersive simulations, interactive features the VR Lab guarantees to light up love and passion for science. chemistry and curiosity in the young minds.

By virtue of its technology-driven nature, the VR Chemistry Lab marks the start of a new level in education where creativity and imagination are the driving forces behind all learning. In the process of exploring and becoming knowledgeable, we must embrace the transformative power of technology and the boundless possibilities of education. Why? It not only makes learning more enjoyable but prepares students for the complex and interconnected world of tomorrow.

II. LITERATURE REVIEW

In paper [1], the authors talk about the advancements and trends of Augmented Reality (AR) and Virtual Reality (VR) technologies in education over the past twelve years. Techniques such as text mining and topic analysis are used to analyze 1536 articles sourced from the Scopus database. A significant surge in the adoption of AR and VR in education is observed, particularly affirming the growing importance of wearable devices in this domain. Despite the growing interest and a rapid growth the study highlights a significant gap in the swift implementation and customization of the relevant technologies within educational institutions.

In paper [2], the study shows the evolving prospect of Virtual Reality (VR) and Augmented Reality (AR) technologies in education, by studying metadata from IEEE databases spanning from 1990 to 2021. With over 700 publications analyzed, the study reveals a significant uptick in interest and exploration of AR/VR applications surrounding the education sector over the past decade. Although VR research is dominating already, AR papers are also increasing steadily in frequency. The study also points out that the authorship is currently in disparity as less developed nations tend to produce less papers as more developed nations.

In Paper [3], the authors propose the use of smartphones to address the limited availability of learning equipment/tools in low-income schools. The study highlights that even low-income households with financial constraints have a smartphone, which can be beneficial and used as a tool for education purposes. The study suggests that the adoption of AR visualizations in textbooks will provide a fully immersive and

interactive learning experience and make the concepts more interesting and clearer. The important point is that there is no extra overhead in terms of setup costs for students or schools and can be done at low-budget schools. The AR experiences can be further scaled to cover every subject across the curriculum.

In Paper [4], the authors address the challenge of preparing future teachers to create psychologically safe environments for students by utilizing virtual reality (VR) technology. It focuses on developing a VR application based on scenario methods to train pre-service teachers in handling pedagogically complex conflict situations. The research employs the ADDIE model instructional design methodology to create scenarios reflecting real teacher-student interactions and diverse instructor responses to disagreements. Moreover, expert analysis of the cases shows great scores in all aspects: relevance, realism, fulfillment of learning objectives, and effectiveness. Still, students in master's degree programs in pedagogical conflict management are worried about the fact that learning and applying VR technologies is pretty time-consuming and not very effective since it is perceived ineffective itself. The results of the study can point to a shift in adverse attitudes with growing penetration of VR development tools. The institution may, however, still face an issue because the participant's confidence in their VR skills is now put to the waters of perceived barriers in technology adoption.

In Paper [5], the authors show that user characteristics such as preference for using an interface can result in effective use of the interface. The authors have also suggested that there is a relationship between learner preference and creativity. The authors use the VARK learning styles (Visual, Aural, Read/write, and Kinesthetic) to assess students' learning styles and study how this learning preference affects the use of Augmented Reality (AR) and Virtual Reality (VR) in the creative design process.

In Paper [6], the authors explore the potential of multiple inter-marker interactions in marker-based Augmented Reality (AR) mobile applications. The study introduces and explores five primary inter-marker interactions: proximity of markers, stacking markers, flipping markers, using markers as toggles, and markers as controllers. These five different interactions are designed to correlate to various application needs and the demos for these are available through prototypes, with lattice structures in Chemistry serving as an example. The paper discusses the pros and cons of these interaction methods based on initial evaluations and identifies opportunities for using and extending these ideas outside the domain of Chemistry in a wide range of other applications.

III. MOTIVATION

The motivation behind developing this is that the limitations of traditional chemistry labs are numerous. Setting up and maintaining a physical lab is expensive, requiring a constant supply of chemicals, specialized equipment, and proper ventilation. Safety concerns are paramount, with certain experiments posing real risks that necessitate supervision and protective gear. Accessibility is another hurdle, as not all schools have the resources to equip well-developed labs, limiting students opportunities for practical learning. Additionally, traditional lab experiences can struggle to fully capture student interest and often fail to effectively convey abstract chemical concepts in a visually engaging way.

This virtual environment eliminates the cost barriers associated with physical labs, making high-quality chemistry education accessible to anyone with a compatible device. Gone are the safety hazards, replaced by a safe and controlled space for experimentation.

IV. PROBLEM DEFINITION

The current methods of teaching chemistry to CBSE 10th standard students mostly depend on the student's ability to grasp complex concepts and develop practical skills. VR Chemistry Lab can revolutionize this learning process, students can use a virtual environment to perform laboratory experiments without the costs associated with setting up a physical lab. This VR chemistry lab provides a virtual environment for students to perform experiments without exposure to harmful chemicals safely. In this virtual environment, students can perform experiments interactively. Implementing the VR Chemistry Lab can significantly help students interactively get a learning environment. improve student engagement with subject, knowledge and overall performance in chemistry. This project aims to inspire the new generation with new technologies and help them in their future careers. This technology not only addresses the limitations of traditional teaching methods but can also open doors for new possibilities for interactive and making chemistry more engaging and fun for students.

V. METHODOLOGY

The project titled "VR Chemical Laboratory" aims to provide a virtual and interactive science experience for students. Traditional science laboratories are costly and difficult to access, especially for schools which are located in underprivileged areas. While physical labs can also pose safety risks due to the handling of real chemicals. This VR-based virtual lab allows students to do experiments while thinking about safety and freedom.

Unreal Engine's Blueprint visual scripting is used for building the chemistry lab along with plugins of Niagara Particles for real smoke and fire effects. Unreal Engine Motion Controller Components allow for precise control of the tools like the tongs, test tube and beakers. Unreal Engine Physics Simulation for overlapping events to trigger the visuals of Niagara effects while real life objects falling and holding objects. The "VR Chemical Laboratory" provides Dynamic Reaction using blueprints such as adding metal to an acid triggers the Niagara particle effect and emits sounds.

Project Overview

This project is a VR environment specifically designed for secondary school students (Class 10th SSC). Students can perform various experiments from their curriculum.

The VR laboratory will feature a level that closely resembles a real laboratory in VR. The students can enjoy real time graphics encouraging them to perform experiments while making learning more engaging and enjoyable.

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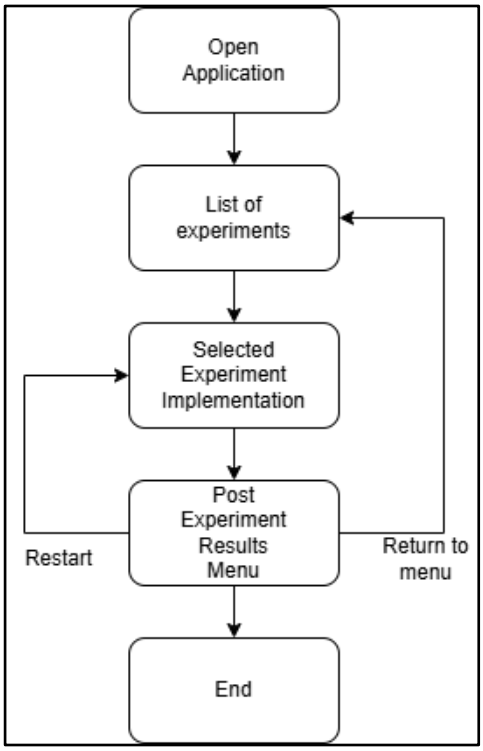

Fig. 1. Workflow Diagram

In figure 1, we can see the workflow diagram of the entire Lab with how experiments are executed and how students can dynamically select and restart any experiment according to their choice and curriculum.

When the user launches the application he will be directed to the main menu which will have three buttons Start, Controls and Exit. On starting, users will be directed to the screen with a list of experiments to choose from and perform. The list of experiments contains all of the experiments from the 10th SSC chemistry syllabus. Mentioned below is the list of experiments:-

1 Identification of Halide IONS (Cl-, Br-, I- ions)

2.Identify the type of Reactions by studying the reaction and recording the observations,

(i) Combustion of Magnesium in Air

(ii)Action of dilute sulphuric acid on zinc

(iii)To heat Lead Nitrate

3. Classify the reaction into type (i)Combination (ii)Decomposition (iii)Displacement (iv) Double Displacement

4. To arrange the metals according to the decreasing order of their reactivity.

5. To study the oxidation and addition reaction of carbon compounds

VI. Results and Output

We designed the Virtual Laboratory in Unreal Engine 5. On the AR/VR side of our project our main objective was to enhance the learning experience of students and provide a single solution to the safety risks posed by physical chemical laboratories.

Given that 10th graders are curious about new ways to study and relate to the concepts, the VR world offers an immersive and highly engaging setting. Students can carry out chemical reactions in a safe environment of virtual reality (VR) without having to deal with real-world issues including handling dangerous chemicals, difficult processes, and equipment upkeep. Real-world problems including cost management, simulation and modification of experiments, accessibility, and flexibility will be successfully addressed by VR.

Fig. 2. Virtual Lab Exp 1

Fig. 3. Virtual Lab Exp 2

Fig. 4. Virtual Lab Exp 3

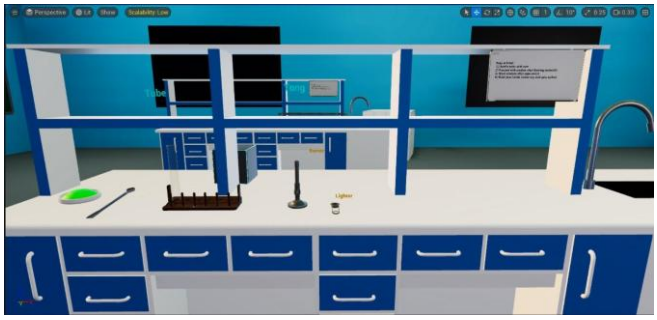
Fig. 5. Virtual Exp 4

Figure 2, 3, 4, 5 show the virtual lab environments that we

have designed for the students to conduct and perform experiments. It is simple to understand and very safe and easy to implement.

VII. ADVANTAGES

VR chemistry experiments can work with any room that has an internet and VR gear like the Oculus.

Virtual labs remove the hazards of using risky substances and tools in chemistry classes. Students can try different experiments with no special safety equipment or teacher watching, which might lead to injuries or contact with dangerous substances.

Setting up and maintaining chemistry labs costs much money due to equipment and chemical needs. Virtual labs provide a budget-friendly alternative by eliminating the need for financial investment in equipment and chemicals. Virtual labs are a budget-friendly alternative that avoids the need for investing in equipment and chemicals.

VR chemistry lab provides instructors with the flexibility to tailor experiments to match particular learning goals.

VIII. APPLICATIONS

Before lab activities, virtual labs can help prepare students for hands-on experiments. Students should familiarize themselves with lab techniques, handling, and safety guidelines before joining the science lab.

Online chemistry labs offer interactive games and visual aids to help students grasp complex chemical ideas.

Virtual chemistry labs let people check out how to do experiments online before actually doing them in real life.

Advanced Equipment Lessons: Online chemistry labs teach how to use complex tools and methods like light measuring, substance separation, and materials checking.

IX. SOFTWARE AND HARDWARE

The Development of VR chemistry lab involved use of several software tools which helped create the 3D environments, immersive and interactive experience.

Unreal Engine 5 was used as core software for the development of this project. It was primarily used for creating 3D environments, interactive elements, and applying physics on the simulations.

Blender, an open-source 3D computer graphics software was used to create 3D objects and assets that were required for the VR chemistry lab. thE objects and the assets included containers for chemicals, laboratory glassware, tables, boards, and other equipment. The models created in blender were then exported to UE5 in the form of static meshes with proper texture and material.

In terms of hardware the simulations were created on PC of the following specifications: Graphics card used was Nvidia RTX 4060 mobile of 6 GB VRAM, 16 GB of DDR5 memory.

VR headset, Oculus Quest 2 was used as a primary device for simulating the VR chemistry lab. The oculus touch controllers were for the interactions such as grabbing, pouring, manipulating substances in experiments and also for the purpose of movement of the character.

X. CONCLUSION

The VR chemistry teacher's helper offers new possibilities in the field of chemistry making it possible to get rid of the classic laboratory constraints. By relating more playful, safe and interactive experience it is quite clear this project will change how chemistry education is imparted in the near future.

Coming advancements in the way of visual technology and large language models can make it even more powerful as a learning unit without much effort. With the changing dynamics of the world, it is almost apparent that VR chemistry will most probably be used in the future of chemistry education.

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