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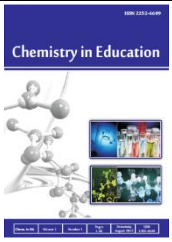

Designing, Modeling and Application of Virtual Reality experiment for Biochemistry

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Abstract

Virtual Reality (VR) is a relatively new addition to the education system, poised to become an effective complementary learning medium alongside traditional methods. VR offers an interactive experience, particularly valuable in the realm of science education, such as chemistry, where many concepts are abstract and challenging to visualize with the naked eye. Moreover, VR systems typically require relatively technical hardware, thus limiting the risk of students becoming overly reliant on them and ensuring their primary use in educational contexts . In response to an analysis of the current trends in VR applications for chemistry education, we have proposed a novel VR system known as 'Biomolecule-VR.' This system is designed to support chemistry education by facilitating the study of biomolecules, including their conformation, structure, and function in a student-friendly way. Biomolecule-VR offers a valuable tool for educators to impart intricate knowledge about biomolecules to students, making chemistry more engaging, fostering logical thinking, and providing students with a virtual realm to explore and immerse themselves in. The primary aim of this research is to create a tool that simplifies and enhances the teaching a nd learning of challenging aspects of chemistry, which are often difficult to convey through traditional teaching methods.

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INTRODUCTION

We all know that teaching aids will increase the teaching-learning process easy as they involve more senses of a child in the process. Practical exercises increase the involvement of more senses in learning. These practical applications can often be likened to games, engaging students actively while imparting new knowledge (Chan et al., 2023). Virtual reality (VR) has gained prominence in education, serving multiple purposes, including facilitating students' acquisition, comprehension, and retention of information (Mandal et al., 2013). By leveraging the visual channel, VR makes the learning process more engaging and user-friendly. VR-based learning fosters a multimodal human-computer interaction environment that appeals to users. The ultimate goal is to construct an educational tool using a chemistry learning scenario so we created Biomolecule-VR (Cassidy et al.,2020). This application is an interactive educational tool based on VR can provide valuable solutions. It caters to the curiosity of individuals eager to learn chemistry, develop logical thinking, and explore the world through a smart device, such as oculus rift. This application has the potential for expansion and allowing students to visualize the biomolecules. Furthermore, it opens doors to the development of similar applications for other subjects like physics, biology, and geography. The Biomolecule-VR learning application ignites interest in the educational domain, seamlessly merging learning and enjoyment through virtual reality

Since 1994, virtual reality (VR) has garnered significant attention, evolving into a spectrum that includes augmented reality (AR). While VR replaces the real world with virtual elements, AR supplements it, creating adaptable, student-centric spaces. Despite the widespread availability of smart devices, even during the COVID-19 pandemic, and the pr evalence of VR in engaging games, its potential in chemical sciences remains underutilized (Abumalloh et al., 2021).

In chemistry education, VR has the capacity to address both theoretical and practical aspects. Theoretical concepts, such as the behavior of atoms and molecules, are often challenging to convey through traditional 2D methods. VR technology, which promotes "Active and Student-Centred Learning" (ASCL), engages students interactively, yet its full potential is yet to be realized. Various VR applications have been developed for chemical education. For instance, Molecular AR/VR provides information about organic molecules through a gaming format, available on the Play Store. Other VR applications, like Molecular Rift and UnityMol, offer desktop experiences for exploring molecules and biomolecules, while web tools like VRmol and ProteinVR focus on molecular studies.

VR also supports the study of crystal structures through Virtual Reality Learning Environments (VRLE), simulating museum-like environments where users can explore Bravais lattices (Extremera et., 2020). Practical laboratory experiments, essential in chemistry, can be conducted in virtual laboratories like Second Life, overcoming barriers such as equipment costs and pandemic restrictions. These virtual labs provide realistic environments for students to perform experiments, enhancing their learning experience.

Despite the potential, numerous bibliometric analyses and student response surveys indicate that VR applications in chemical education are not yet fully embraced. Applications such as UCSF ChimeraX, VMD, Nanosimbox Research, BlendMol, RealityConvert, AltPDB, Samson Connect, Nanome, Autodesk Molecular Viewer, and iview are available but not widely integrated into curricula. Additionally, smartphone apps like PROteinVR and Corona VRus Coaster offer portable VR experiences, yet their use in education is limited. In the context of practical laboratory experiments, VR applications provide a promising solution to the challenges of limited access to well-equipped laboratories and physical presence, but their adoption is still in its early stages.

METHODS

For developing a robust virtual reality (VR) system, several high-performance hardware components are essential. These include powerful computers with advanced CPUs such as Intel Core i7-i9 or AMD Ryzen 9, and GPUs like NVIDIA GeForce RTX 30 series or AMD Radeon RX 6000 series. High RAM (DDR4 or DDR5) ensures efficient processing, while VR headsets with high resolution and wide field of view (FOV), such as the Oculus Rift, provide an immersive visual experience (figure 1). Precise motion tracking devices and high-quality immersive audio systems further enhance the VR environment. Broadband connections are crucial for collaborative VR development, ensuring seamless integration and interaction across different setups. Software tools play a pivotal role, with Unity serving as the primary development platform . Unity offers optimized camera rigs, physics, and profiling tools for performance optimization. Microsoft Visual Studio, with its C# scripting support, provides a robust IDE for real-time debugging and UI customization. Additional tools like Blender and 3ds Max enable the creation of detailed 3D models, while Adobe Premiere Pro and Final Cut Pro X are used for video editing to enhance visual storytelling in VR applications.

Figure 1. Computer setup with oculus rift for VR software development

The methodology employs a Design -Based Research (DBR) approach, chosen for its iterative nature, which integrates design, development, evaluation, and reflection phases (figure-2). This approach ensures the development of effective VR learning solutions grounded in theoretical frameworks and real-world contexts. The design and development phase utilizes Unity and Oculus Rift, focusing on user-centric principles to enhance interaction and engagement. Iterative testing cycles are conducted to identify and addr ess usability issues, with performance optimization using Unity's profiling tools. User feedback is implemented to refine the VR environments. The deployment phase ensures the optimized VR applications are compatible across various hardware and systems, maximizing accessibility. This iterative DBR methodology aims to create immersive VR educational experiences that adapt to technological advancements and meet the diverse needs of learners.

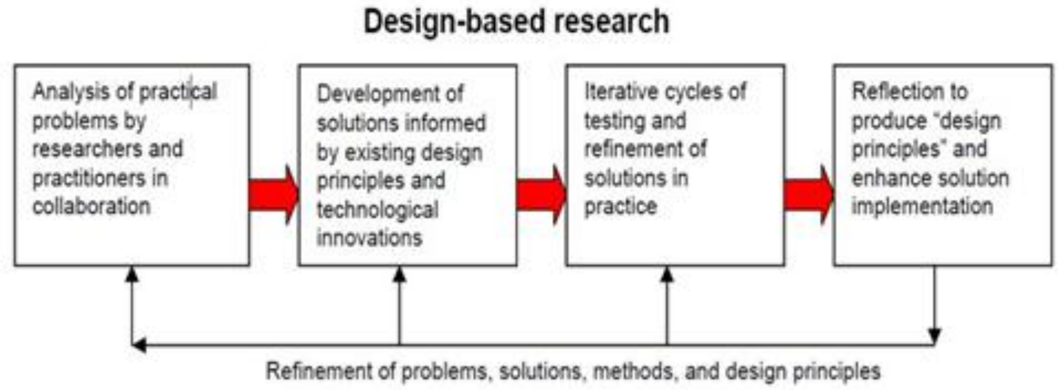

Figure 2. Design-based research

RESULT AND DISCUSSION

Experimental

This educational application is designed to facilitate chemistry learning for individuals of all ages who are interested in mastering the subject, named as Biomolecule-VR. Chemistry classes begin at the age of 14, and certain concepts can prove challenging to comprehend. The Biomolecule-VR app is crafted with vivid, explanatory visuals to enhance the learning experience. At its core, the application is powered by virtual reality (VR) and incorporates the E-learning concept. VR enables interaction with virtual objects , specifically molecules portrayed in distinct colours and volumes. These virtual molecules are viewable through oculus rift. The application utilizes Unity for seamless functionality (Kumar et al.,2021).

Figure 3. Logo of Biomolecule-VR software

The application comprises various features, one of which is Biomolecule conformation recognition. Users can also view the active site of the biomolecule. Another crucial aspect involves learning, users can learn the function and general information of the biomolecule.

Step 1 : Creation

In the first step, Unity takes the reins as the central platform for constructing the VR application, playing a crucial role in fine-tuning the immersive qualities of the virtual environment. By judiciously configuring Unity settings, we ensure optimal performance, seamless user interaction, and a visually compelling experience. We created a virtual classroom setup in Unity for the presentation of biomolecules, utilizing Unity's capabilities such as lighting effects, textures, and interactive elements, all of which contribute to the realism and engagement factor of the VR application (Radianti et al.,2020).

For this application, a specialized classroom has been crafted using Unity technology. The virtual classroom includes a board that displays the names of biomolecules, which function as interactive tabs utilizing Unity features. Clicking on these tabs navigates users to respective description sections, where 3D molecular structures are integrated for a comprehensive learning experience. This setup allows students to interact with the virtual environment, enhancing their understanding of biomolecules through visual and tactile means. The fusion of advanced technology and educational content creates an effective and interactive platform for chemistry learning, making complex concepts more accessible and engaging. This approach leverages the strengths of VR to provide an immersive educational experience that is both informative and enjoyable (Suri et al., 2023).

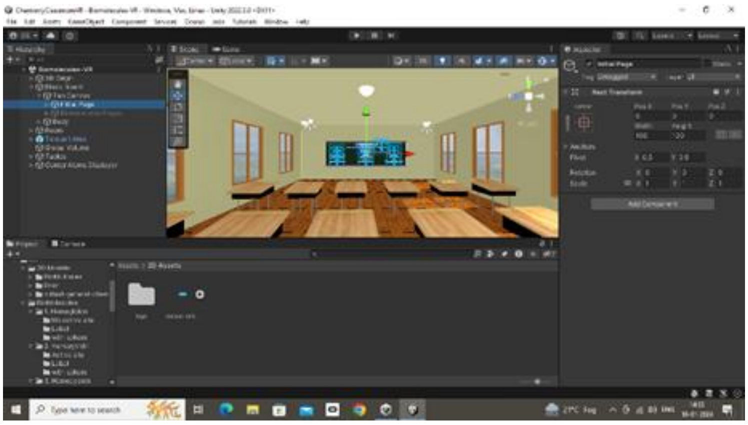

Figure 4. Step 1 to create a classroom using unity

Step 2: 3D Modelling

The second step in creating this VR application involves meticulously crafting the foundational 3D model components. Blender and 3ds Max are invaluable tools in this phase, enabling the generation of highly detailed and spatially accurate representations of molecular structures. These 3D models serve as the bedrock for an immersive and educational virtual experience. The integration of 3ds Max adds sophistication to the 3D models, enriching the visual appeal of the molecular structures and enhancing the overall quality of the VR experience (Viitaharju et al., 2023). The seamless synergy between Unity's settings and 3ds Max ensures a cohesive and captivating user journey, providing advanced features essential for the meticulous creation of intricate 3D models. This includes the dynamic representation and exploration of the globular structure of biomolecules and active sites, ensuring high precision and intricate detailing in the modeling process.

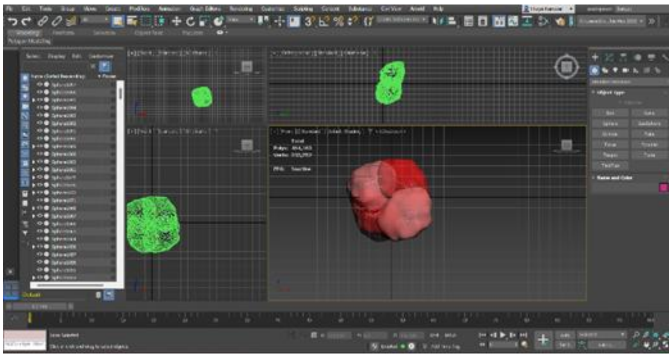

Figure 5. Step 2 to create 3D models of biomolecules

Step 3: Scripting

In the third major step, Microsoft Visual Studio contributes to the application's development by providing a robust programming environment. This enables the implementation of intricate functionalities and interactive elements within the VR app, adding depth and educational value to the overall experience. Visual Studio is used to create C# scripts for the movement and connectivity of 3D model screens. These scripts govern essential functionalities like molecule rotation, hand gestures, and click navigation, ensuring a seamless and immersive experience. Molecule rotation, empowered by C# scripts, allows users to explore the 3D structure of biomolecules from various perspectives, enhancing engagement. Hand gestures introduce an interactive element, allowing users to employ natural movements to interact with the virtual environment, adding realism and user engagement. Click navigation offers a straightforward method to explore different aspects of biomolecules or transition between sections, contributing to a user-friendly and efficient exploration process. This integration of Unity, Blender, 3ds Max, and Microsoft Visual Studio exemplifies a harmonious blend of creativity and technical prowess, promising an engaging and educational journey into the intricate world of molecular structures.

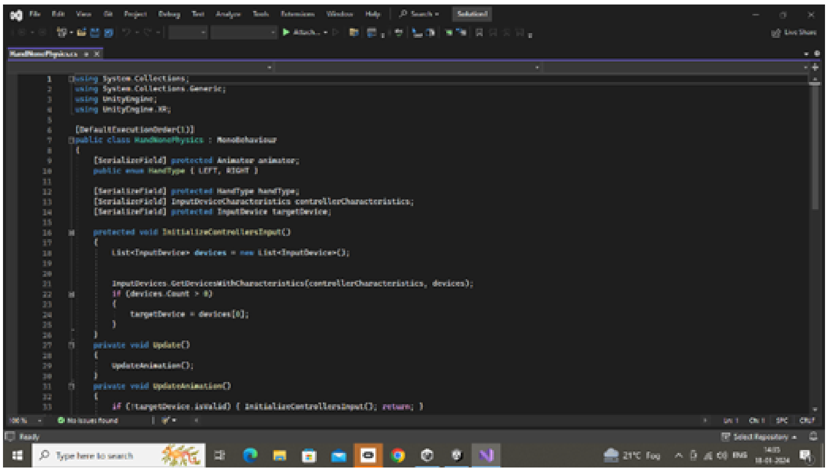

Figure 6. step 3 to create script to compile unity and 3D models in appropriate manner

Functionality

Upon launching the app, users are prompted to wear the Oculus Rift headset and hand controllers. Once equipped, users find themselves immersed in a captivating virtual classroom environment. In play mode, the classroom comes to life with various biomolecules displayed on the board. Navigation through the virtual space is facilitated by the hand controllers, allowing users to walk freely within the classroom, explore the environment, and interact with the displayed biomolecules, thereby enhancing the immersive experience (Winkelmann et al., 2017). Selecting a specific biomolecule by clicking on its name on the board using the trigger button on the hand controller triggers a wealth of information to unfold. General details and functions related to the selected biomolecule are projected onto the board, offering users a comprehensive understanding of its characteristics. Simultaneously, a three-dimensional representation of the biomolecule appears on the right side of the board, rotating to provide users with a nuanced and visually enriching perspective. This dynamic visualization enhances the learning experience by allowing users to grasp the structure and form of biomolecules intuitively.

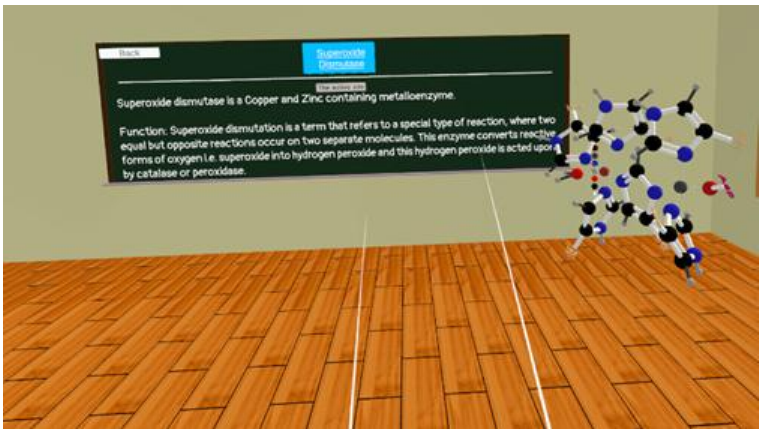

Figure 7. Screenshot of classroom showing active site of biomolecule

The application also incorporates a dedicated tab showcasing the active site of the biomolecule for in-depth exploration. Selecting this tab immerses users in a dynamic presentation of the active site's conformation, offering valuable insights into molecular interactions and detailed structures. The active site conformation is designed to rotate, providing users with a comprehensive view from different angles. The use of the ball-and-stick model enhances the visual representation, allowing users to observe the spatial arrangement of atoms and bonds within the active site. In addition, the right side of the molecule is adorned with informative symbols, serving as key indicators that offer contextual information and enhance the user's understanding of the biomolecule content. In essence, the active site tab, combined with a rotating ball-and-stick model and informative symbols, elevates the app's capabilities for molecular exploration. This thoughtful design enhances user engagement and educational value, fostering a more profound understanding of biomolecular structures in an interactive and dynamic virtual environment. Navigation through the application is seamless and user-friendly, ensuring a smooth and customizable learning journey.

The Biomolecule-VR learning application encourages active engagement and exploration, offering users the flexibility to choose and visualize different biomolecules in an interactive manner. This immersive approach facilitates a deeper understanding of biomolecular structures and transforms the learning process into an enjoyable and dynamic virtual experience.

Participant Feedback and Performance Analysis of Biomolecule-VR

The usability test conducted for the Biomolecule-VR learning application yielded overwhelmingly positive results among a diverse group of participants, primarily college students pursuing graduate and postgraduate degrees. Participants, many of whom were novices to VR technology, swiftly adapted to the application's interface and functionalities, showcasing its intuitive design and seamless operation. The comprehensive feedback collected through questionnaires highlighted a notable shift in participants' understanding and appreciation of VR concepts and applications following their engagement with the app.

Figure 8. Students using *Biomolecule-VR* application

Initial findings revealed a significant majority, 85%, had never previously interacted with VR applications, emphasizing the novelty and educational impact of the Biomolecule-VR app in introducing virtual reality experiences to users. Post-test feedback was unanimously positive, with all participants praising the app's functionality, operational efficiency, and educational value. The app received outstanding ratings for response speed and overall performance, underscoring its ability to meet users' expectations for immersive and effective learning tools in biomolecular studies.

CONCLUSION

In conclusion, the Biomolecule -VR app not only met but exceeded expectations in providing a compelling and educational virtual reality experience. Its success in engaging users and enhancing their understanding of biomolecular structures highlights its potential as a valuable tool in educational settings, paving the way for future innovations in VR-based learning applications.

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