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Design and Development of Educational Game Using Virtual Reality

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Abstract: *The lab applications, which were introduced in mid-19th century education system not only provide a new point of view but also bring about a new dimension to the lessons. At early times they were used to prove theoretical knowledge but lately they turned into environments where students freely discover knowledge as an individual or in groups. The activities that have come up with the recent form of labs substantially contributed to training ideal students for effective learning approach, who research, inquire, test, seek solutions, wear scientist shoes and deeply reason about the concept of concern. Therefore we developed a 3D interactive virtual chemistry laboratory (VCL) for chemistry experiments.* ***This paper aims at developing a 3D Interactive Virtual Chemistry laboratory simulation*** *based on advanced 3D interaction interface with simulated chemical items and to perform chemistry experiments. The main objective of paper is to provide a user friendly virtually simulated environment for effective learning among a class of people having the same goal or vision.*
Keywords: *Virtual Reality, Augmented Reality, Virtual Chemistry Lab, Three Dimensions*

I. Introduction

In the half dozen years since a previous thorough overview of intelligent tutoring and computer-based instruction the change of technologies has been breathtaking. Although we knew back then that what we were doing on expensive Lisp machines would soon be possible on ordinary personal computers, it is still unnerving to see not only that it is now possible, but that so much more is possible. The virtual reality (VR) technologies that have transformed the landscape in the intervening years offer unique new viewpoints on the core goals of training and education. What distinguishes VR from all preceding technology is the sense of immediacy and control created by immersion: the feeling of "being there" or presence that comes from a changing visual display dependent on head and eye movements.

In effective learning approach, students construct actively their knowledge by thinking, doing, and interacting with the environment. For this reason, laboratory has a great importance for chemistry teaching and learning. The laboratory has been given a central and distinctive role in science education, and science educators have suggested that there are rich benefits in learning from using laboratory activities.

However due to less availability of resources most of the practical are not performed which is a serious issue. The solution to the challenge posed in such scenario is the use of Virtual Reality technology in the field of learning and education.

Virtual Reality is implemented by a combination of technologies that are used in order to visualize and provide interaction with a virtual environment. With the ability to provide a vivid visual representation of different realities and alternate experiences, virtual reality is a great way to help people visualize scenarios. These environments often depict three-dimensional space which may be realistic or imaginary, macroscopic or microscopic and based on realistic physical laws of dynamics, or on imaginary dynamics. The multitude of scenarios that VR may be used to depict make it broadly applicable to the many areas in education.

Virtual chemistry laboratory is more flexible and helpful in chemistry practical learning. Students demonstrate active participation while doing an experiment in a virtual environment; they may carry out the experiment individually or in collaboration with colleagues. This is the most important difference that separates virtual laboratories from traditional applications. In addition, thanks to the flexibility of virtual environments, abstract concepts that inevitable for chemistry become more concrete, daily life experiences can meet lessons and students can go ahead according to their personal learning pace and needs. Virtual laboratories as a supportive factor to real laboratories enriches learning experiences of students and offers students to do experiment, to control materials and equipment, to collect data, to perform the experiment interactively, and to prepare reports for the experiment as well as developing experimenting skills.

II. Literature Survey

In [1] Laura Freina, Michela Ott proposed paper A literature survey on Immersive Virtual Reality in Education: State of The Art and Perspective shows how VR in general, and immersive VR in particular, has been used mostly for adult training in special situations or for university students. It then focuses on the possible advantages and drawbacks of its use in education with reference to different classes of users like children. It concludes outlining strategies that could be carried out to verify these ideas.

In [2] Numan Ali, Sehat Ullah, Aftab Alam, and Jamal Rafique published paper 3D Interactive Virtual Chemistry Laboratory for Simulation of High School Experiments describes the potential contribution of the VCL in students' learning improvement which is based on advanced 3D interaction interface. The aim of VCL is to provide more immersive virtual environment to users by using 3D interaction with chemical items and to simulate their chemistry experiments on high school level.

In [3] Aryabrata Basu, Kyle Johnsen proposed paper Ubiquitous virtual reality 'To-Go' demonstrate a ubiquitous immersive virtual reality system that is highly scalable and accessible to a larger audience. It also presents a practical design of such a system that offers the core affordances of immersive virtual reality in a portable and untethered configuration.

In [4] Kangdon Lee published paper Augmented Reality in Education and Training describes Augmented Reality (AR), how it applies to education and training, and the potential impact on the future of education.

The above literature review stated that the previous virtual chemistry laboratories were developed in a way that the interactions with these laboratories were limited and could not provide full exposure of a laboratory. Due to these limitation in interaction interface there was no immersion for users to take more interest.

Hence there is need for more interactive and immersive virtual chemistry lab for targeted students so that they can take full advantage and learn this subject with a whole new learning perspective and with more interest.

III. Requirement And Specification

The traditional approach to education hasn't changed much over the years. Students are expected to learn through assimilation without much scope for an immersive or experiential learning. With Virtual reality, things are going to change in the way education is being imparted. For instance in Virtual Chemistry laboratory students can now look forward to learning about the chemical reaction and in a three dimensional environment and even physically engage with the atoms molecules salts formed from reaction in chemistry lab. VR's ability to introduce practical knowledge to students without having to leave the room is an invaluable contribution to education.

Hardware Requirements

1. VR device

It is difficult to implement virtual chemistry laboratory with traditional output window. VR gear which will help students to immerse themselves in the virtual environment and explore every little details of the concerned subject without any hesitation. When using virtual chemistry laboratory every risk involved while performing real world chemical reaction for study purpose in laboratory are eradicated and wastage of chemicals while learning will also be reduced to none.

2. Leap Motion

This device tracks hand and finger gestures. The gestures are then converted into input with the help of Leap Motion Interaction Engine. The specialized Unity modules make these interactions more accurate and dependable.

3. Smart Phone Device

To make the experience more affordable, a smart phone device can be used as VR simulator with the help of cheap VR gear options like Google Cardboard. The smart phone device either needs to be an Android Device with an Android OS version of 5.0 or higher; if it's an IOS device then it needs compatible VR gear.

Software Requirements

1. Unity Engine

The Unity game engine is developed by Unity Technologies in Denmark. Unity integrates a custom rendering engine with the nVidia PhysX physics engine and Mono, the open source implementation of Microsoft's .NET libraries. The benefits of using Unity are many when compared to the other similar engines.

3.1 Documentation

The Unity User Manual helps you learn how to use the Unity Editor and its associated services. You can read it from start to finish, or use it as a reference.

3.2 Developer Community

Unity has a strong developer community (Unity Answers or Unity Forums) where developers can post queries/questions which then are answered by fellow developers or Unity staff.

3.3 Physics

Unity supports physics by using nVidia PhysX as a base. This allows developer to provide properties of real life physics to the game objects.

3.4 Rendering

In Unity, Shader programs are written in a variant of HLSL language. Shader is a type of computer program that was originally used for shading (the production of appropriate levels of light, darkness, and color within an image) but which now performs a variety of specialized functions in various fields of computer graphics special effects

Various lighting options are available in unity to enhance a scene which implements Global Illumination (GI) in either Real Time format or Baked GI, allowing developers to choose from Real time lighting or pre-processed lighting.

3.5 Materials

They define how a surface should be rendered, by including references to the Textures it uses, tiling information, Color tints and more. The available options for a Material depend on which Shader the Material is using.

3.6 Textures

These are bitmap images. A Material can contain references to textures, so that the Material's Shader can use the textures while calculating the surface color of a Game Object. In addition to basic Color (Albedo) of a Game Object's surface, Textures can represent many other aspects of a Material's surface such as its reflectivity or roughness.

3.7 Multiplatform Distribution.

Unity enables developers to deploy finished products on multiple platforms ranging from Windows, Linux, IOS, Android, etc. This saves developers the hassle of rewriting code for specific platforms. Complete binaries can simply be distributed as the developer wishes.

2 Visual Studio

The system was developed by using C# as the main language. Microsoft's visual studio provides a sophisticated C# development environment. Think smart auto completion, computer-assisted changes to source files, smart syntax highlighting and more.

Unity's Visual Studio integration allows you to create and maintain Visual Studio project files automatically. Also, Visual Studio will open when you double click on a script or on an error message in the Unity console.

3 Leap Motion Interaction Engine

Leap motion interaction engine is a customizable layer that exists between the Unity game engine and real-world hand physics. It uses the Interaction Engine to create natural object interactions and user interfaces. Leap motion interaction engine supports both hands and PC controllers. It cuts the number of draw calls for a huge rendering boost and tightly pairs with the Interaction Engine to create user-friendly curved interfaces. It provides a range of optimized rigged hand models, plus the power to design your own with an auto rigging pipeline.

IV. Methodology

1. Development:

For the system to replicate a real world chemical laboratory specialized modules were developed to simulate a virtual chemical lab. These modules are as follows:

4.1 Liquid Simulation

This module was developed to replicate a liquid's physical properties such as viscosity, density and its ability to take shape of the container containing it. This enables system to simulate different liquids by adjusting the inherit physical property. The rate at which the liquid flows from a container will depend on the angle of pouring i.e. at what angle the container is held will directly result the pouring of the liquid from the container. The volume of liquid in the container Depending on the viscosity the rate will be different for different liquids. This module also determines where the liquid was poured by using ray casting methods, which means the system is capable to determine whether the liquid was poured on the floor or in a specified target container. The module makes use of specialized Shaders which are computed to mimic a liquid's physical properties such as whether the liquid was transparent or not, which color it had, and it's shape and volume in the container holding it.

4.2 Organic Structure Simulator (OSS):

The game let's user to explore the atomic structure of chemicals in the experiment. This is done by generating 3D models of organic chemicals. To generate the model the covalence of each atom is considered by the system and based on it the dynamic models are generated for the given organic compounds chemical formula. The user can interact with these models to learn about the structures. The user can scale, rotate and move the structures around in a 3D space. Interacting with the structure let's user develop keen interest in organic chemistry and helps in understanding the complex structures. Specialized Shaders are used to create materials of the models mimic a holographic effect, to give off a futuristic, sci-fi feeling to the models.

4.3 Virtual Periodic Table:

The users can interact with a virtual periodic table. It informs the user with the selected element / atom's properties such as name, atomic number, general description and interesting facts. It is easily accessible to the player throughout the game. It also gives useful hints to players to be used in the quiz mode of the game.

4.4 Game play :

The player is greeted with a main menu screen upon starting the game/application. The player can then choose whether to start the game, make changes in settings or select game modes.

4.5 Overview:

Players can select the experiment of their choice to perform in the game or follow the set order of experiments predefined in the game. The set of experiments are arranged in the order of increasing difficulty which helps player to learn the basics first and then gradually move towards the advanced concepts.

4.6 Evaluation:

Each experiment is divided into a number of steps. With each step the player is given instructions to follow which guides the player to complete the said step. The step also provides key points, tricks or warnings to players that they can remember while attempting the experiments in real-world. The completion of a step depends on whether the player successfully completed the given task. For example, let's say the player was asked to pour the contents from a test tube to the beaker, then the system will determine whether the player poured the contents of the test tube in the beaker or not. If the player passes the evaluation then the task/step is flagged as "successfully completed". Upon completion of such a step the player is provided with the next step.

4.7 Conclusion:

After all the steps are completed successfully the experiment is concluded and the player is given their score. The score helps player keep track of their progress in an experiment. The player can re-attempt the experiment to get a better score. The player is then asked whether they wish to proceed to another experiment, answer quizzes related to the experiment or return back to main menu.

V. Quizzes

"Quizzes" is a game mode accessible from the main menu or after an experiment is over. The player is given multiple choice questions (MCQ), where they have to select the right answer to score points. Two types of quizzes are available in this game mode.

5.1 Experiment specific quiz:

These are the quizzes which are based on a particular experiment selected by the player. They are also available to player upon successful completion of an experiment.

5.2 General quiz:

The questions in this quiz are selected randomly and cover the entire spectrum of available experiments in the game.

The player score is evaluated after the completion of a quiz and the player is presented the options to either see the correct answers to all questions or reattempt the quiz.

VI. Free Roam

This game mode let's player explore the virtual laboratory at their own pace and allows them to interact with various chemicals at their own leisure. The players are warned about consequences of a lethal reaction if they attempt to mix random chemicals. Upon completion of a reaction the system provides player with the conclusion the reaction i.e. which compound was created in the process, what is it's chemical formula and in some cases the nature of the reactions (exothermic or endothermic). The player can also interact with the aforementioned virtual periodic table to learn more about the elements.

VII. Organic Structure Visualizer

The player can enter an Organic Compounds formula in the tab provided via a virtual keyboard to generate a 3D model of the said compound. This is done with the help of Organic Structure Simulator (OSS) module. The OSS generates a model only if the entered formula is valid. The players can then move around the structure or rotate and scale the structure to experience the atoms in a 3D virtual space.

VIII. Figures

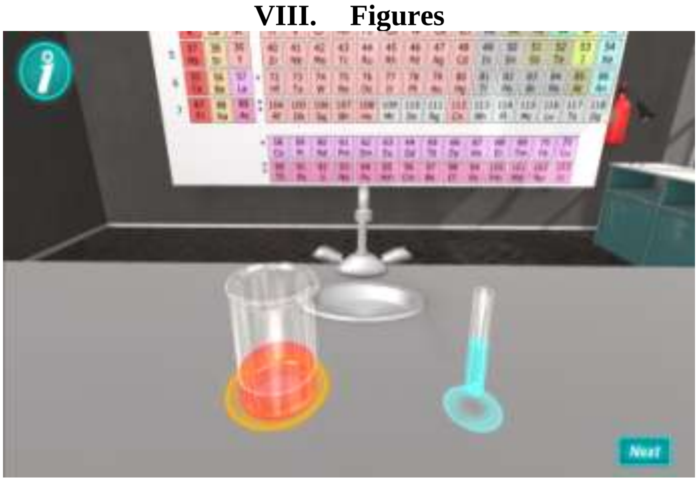

Fig. 1. Screen capture of selected chemicals in the virtual lab.

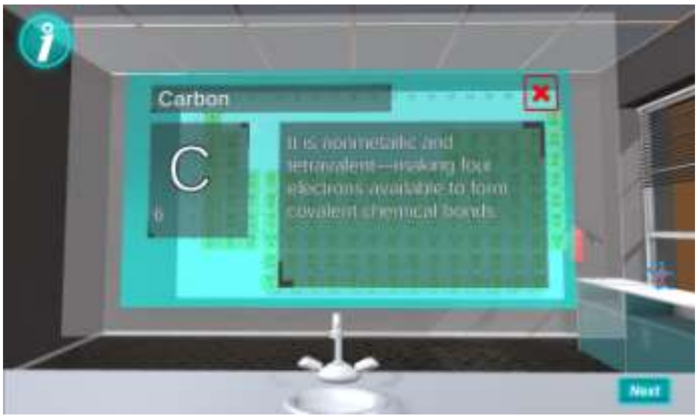

Fig. 2. Screen capture of an element from Virtual Periodic Table.

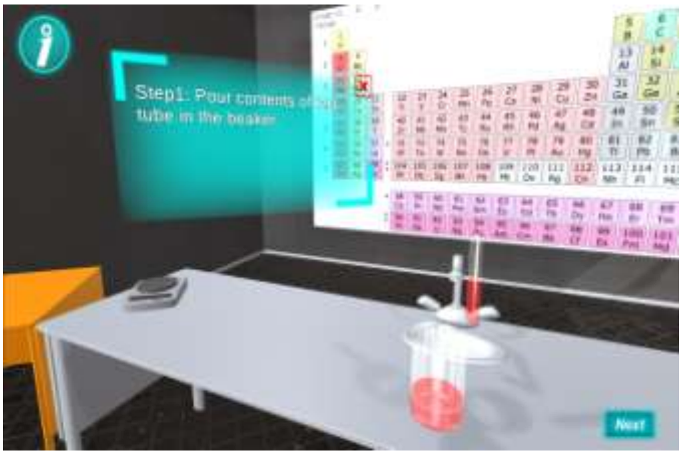

Fig. 3. Screen capture of an experiment with instructions.

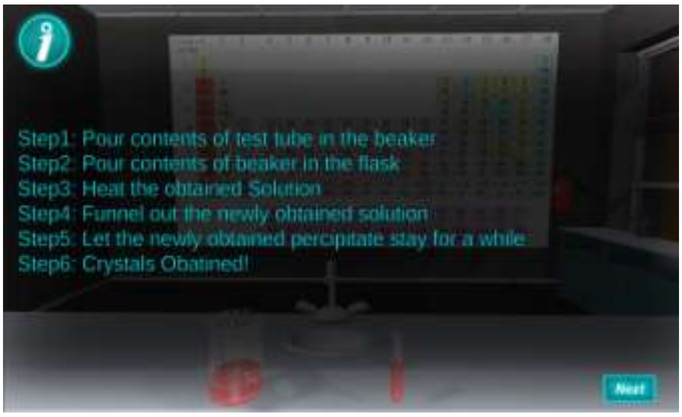

Fig. 4. Screen capture of steps for an experiment.

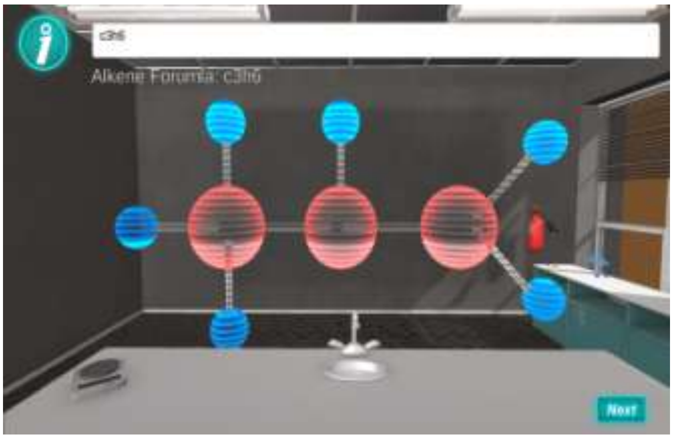

Fig. 5. Screen capture of formula structure generated for C3H6.

IX. Conclusion

VR is here and it is here to stay, with this system aim to bring the concepts of virtual learning in classroom one step closer, and help student learn and interact in a non-daunting fashion.

The application aims on motivating students to interact with chemical components and visualize how interesting chemical experiments are performed without facing pungent/corrosive smell of lab's chemical or danger of spilling chemicals.

With intuitive graphical user interface design, student will find them comfortable with application VR environment in no time.

The GUI will guide user through the experiment and mention key points that user can remember while performing experiments themselves in real life. Students can revisit old experiments or perform new one to their heart's content to enable them to grasp the concepts, develop a scientific attitude and enjoy the learning experience from the comfort of their home or classroom.

This system also aims to provide quizzes related to experiments to help student prepare for exam or viva by assimilating the theoretical and practical concepts.

The use of computer technology is important in development of activities that are appropriate to implement constructivist teaching in the schools. Another study's finding supports this idea that "virtual learning environments have positive effect on independent and cooperative learning". Other virtual laboratory applications examined in the literature was also seen to support the learning environments appropriate for constructivist approach.

On concluding lines we would like to say that this application focuses on creating a fun learning platform where students can have an unlimited access to their own personal virtual lab where they can explore different experiments at their own place.

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