Proceedings of The National Conference
On Undergraduate Research (NCUR) 2018
University of Central Oklahoma
Edmond, Oklahoma
April 5-7, 2018

Undergraduate Research: Chemistry Education Through Augmented Reality

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Abstract

Three teams, comprised of chemistry, graphics design and programming, worked together to develop an augmented reality (AR) chemistry lesson plan. The plan included an atom builder, molecule builder and various lab simulations of chemical reactions. A demo of the completed sample plan was then presented to a variety of community K-12 partners and colleagues at several conferences. The feedback received from the groups suggests the efficacy of this project warrants further research and upscaling potential.

Keywords: Augmented reality, Chemistry education research, computer-based learning.

1. Introduction

Many students take chemistry and are unsuccessful at their first attempt (Sirhan, 2007). The reason is that a chemistry course requires students to have multiple levels of thinking simultaneously (Narayan, 1970). The students not only need to memorize and comprehend the information, but most importantly visualize the concept. At Utah Valley University, organic chemistry was a frequently failed course ("Most Failed Courses"). In situations like this, most students decide to change their major (Hoyt, 2014). We believe that by creating a collaborative chemistry lesson with augmented reality, more students will continue their projected path due to increased success in STEM courses.

Augmented reality has become a popular pedagogical tool within the STEM fields and will continue to be so as technology advances. Companies such as Microsoft, Google and Snapchat use augmented reality. The concept of augmented reality is derived from virtual reality and uses a simulation of the three-dimensional environment that allows interactions to seem real. Virtual reality displays a full immersive visual image while augmented reality places an image or model over the existing environment.

In 1992, a researcher of heads-up-displays, Tom Caudell, is accredited for creating the term Augmented Reality (Kangdon Lee, 2012). Caudell and his colleague David Mizell define augmented reality as an overlay of computer-present material on top of the real-world material and discuss the advantages of AR. Comeau and Bryan, engineers of Philco Corporation, developed the first precursor to the head-mounted display (HMD). This HUD has a video screen for each eye and a motion tracking system, but it lacked the integration of computer graphics and image generators (Varga, 2017). In 1968, Ivan Sutherland and his student Bob Sproull created the augmented reality system named Sword of Damocles, though was too big for the wearers to use. During 1975-1992 a few devices were created that lead to the design of augmented reality. For instance, in 1975, the first ever augmented reality laboratory called the Videoplace was invented by a scientist named Myron Krueger and demonstrated limited potential. In 1980, the first wearable computer was made by Steve Mann, called the Eye-Tap, which was a wearable device that had a camera and a computer that serves as a display screen to separate objects with its processor. Similarly, the Minolta glasses had cameras projecting an image and the lenses served as display screens. The Minolta glasses design has been a consistent design for augment reality throughout the early years of computers (Azuma, Baillot, Behringer, Feiner, Julier, & MacIntyre 2001). Although the glasses are improving, developers are facing limitations, such as display screen resolution, view angle restrictions, graphics processing limitations, motion tracking accuracy and accessibility (Van, & Poelman 2007).

As technology advances, AR continues to improve simulation experiences and developers want to use AR for educational purposes (Billinghurst 2002). With AR technology, students can interact with textbooks by providing illustrations of the chapters (Lee, 2012). Such technology has helped students take better notes, improve their grades and retain a longer attention span through its use (Pasaréti et al. 2011). AR has increased spatial skills, is easy to learn and is very engaging (Kaufmann 2003). However, teachers are asking developers to make the system more flexible (Kerawalla et al. 2006).

The effectiveness of having a flexible system has been emphasized in more recent work. A study conducted by the Kocaeli University-Umuttepe Campus located in Turkey was to design an augmented reality environment for students to better understand the periodic table and atomic structures. This environment produced an effective social and collaborative learning environment, which in turn supports real world collaboration. Due to the hand motion manipulation that the AR environment demands from students, it increased curiosity, interest and willingness to learn (TAÇGIN et al. 2016). This work motivated our team to develop a more robust chemistry AR with a focus on pedagogical advances.

2. Methodology

The collaborative chemistry lesson plan consists of a lab simulation and a molecule builder subsystem. To create the lesson, the students have been divided in-to three teams. The three teams are the chemistry team, graphics design team and the programming team. The goal of the chemistry team is to select a lab experiment and create a step-by-step guide of how to do the lab experiment and the reactions that happen during the experiment. The step-by-step guide is created for the graphic design and programming teams to help replicate the lab experiment as an AR lab simulation. The graphics design team is to create these scenes, materials and reactions that happen during the experiment and the shapes of molecules in the simulation. The programming team's focus is to program the graphics while following the step-by-step guide to create the lab simulation.

2.1 Chemistry

The chemistry team narrowed down the lab experiments based on two concepts that chemistry students where students often struggle. The lab experiments are the copper cycle and flame test, both of which cover concepts in thermodynamics. Figure 1 shows the Pugh matrix for the selection of the lab experiment. The Pugh matrix has been selected because it allows the team to set requirements and set a score scale that helps to sufficiently decide what fits the requirements best, using a 0 for 'does not meet requirements', 1 for 'meets requirement' and 2 for 'exceeds requirement'.

Requirements	Flame Test Lab	Copper Cycle
Is the lab applicable for high school, college, and university students?	1	2
Can the lab be made visual?	2	2
Is the lab difficult?	0	2
Can logic be implemented in the lab?	1	2
Total	**4**	**8**

Figure 1: The Pugh matrix that the chemistry team used.

Based on the score the copper cycle was chosen, because the lab met the requirements, particularly for difficulty. The next step is to create a step-by-step guide of the lab experiment. Figure 2 below shows a sample of the guide that is created. The guide contained a list of materials, procedures on how to do the lab experiment, along with the reactions process that took place during the experiment.

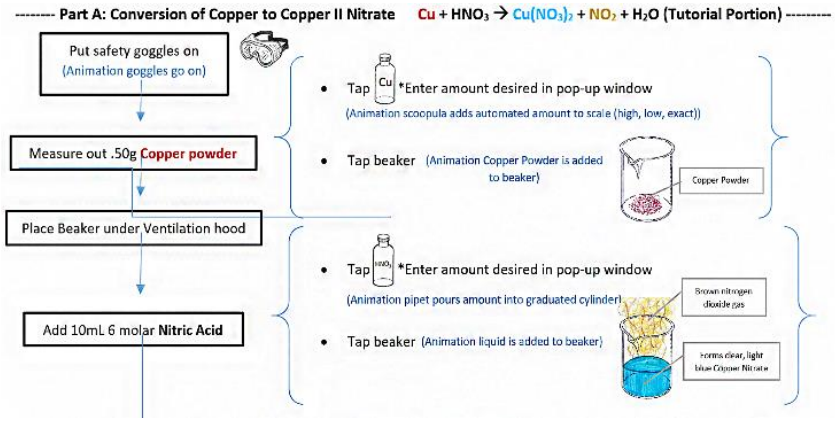


Figure 2: The diagram is a sample of the flow chart that was created as a guide for the programmers to follow so that the lab simulation can be demonstrated sufficiently.

2.2 Graphic Design

After the chemistry team has outlined the process, the next step is for the graphics design team to create all materials and reactions that the lab experiment requires. The team is to work together to finish all the graphics within the time frame and so collaborative sharing of assets is done. Figure 3a shows the 2D design sketch in Solidworks. The sketch is then rendered and imported Blender for meshing, as shown in Figure 3b. After being meshed in Blender, the model is then saved and imported to Unity. Figure 3c shows a graphic imported into Unity while Figure 3d shows a model created completely in Unity itself, which works well for less complicated shapes.

a) b) c) d)

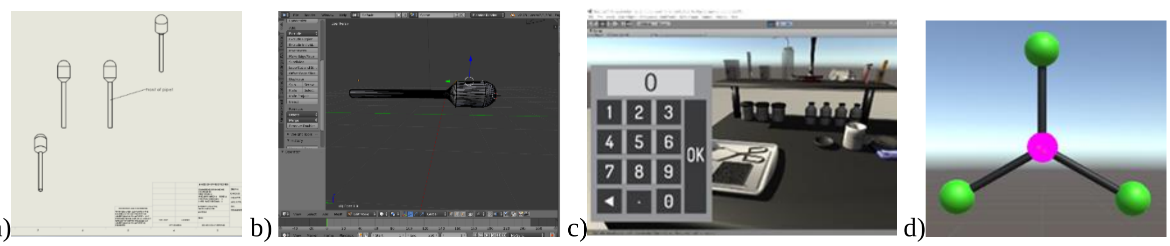


Figure 3: a) Sample sketch of one of the materials used in the lad simulation, b) the software blender, c) rendered image are imported to the Unity software, d) a sample of a molecule used in the lesson.

2.3 Programming

Once the graphics are imported into Unity, the programming team can create the lab simulation. Figure 4a shows the programmers using the animation tool Mecanim within Unity for a timeline of keyframes to indicate and track changes of the Game Object’s properties, such as its position, color and scale. Figure 4b shows a sample of the code to further animate elements within Mecanim beyond the basic transformations. The same objects can create multiple types of simulations. Basic atom builders and molecule builders allow students to study naming and atomic structure. The reaction setup allows students to create reactions and interact with the assets to simulate the copper reaction. Additional lessons can be created from the same models, as shown in Figure 4c, where students are able to find molecules of a specific name.

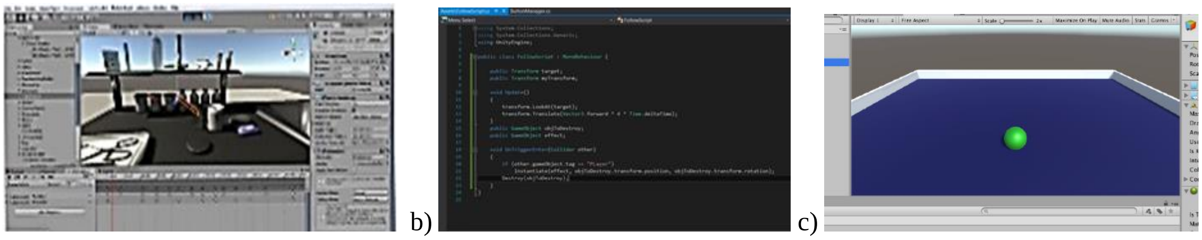
a) b) c)


Figure 4: a) Copper reaction simulation with interactive experiment table, b) sample of a code that the team used to animate the lab c) additional lecture with naming activity.

After the graphics and programming are complete, deployment to the Microsoft Hololens can be done. Unity has an output setting for the Hololens and framework available for programming alignment. A sponsor provides access to the Hololens equipment for students and community to engage in the lessons.

3. Community Feedback

The collaborative chemistry lesson plan has been demonstrated to the community and multiple service-learning environments. The purpose of these activities is to engage novice students with augmented reality concepts and provide them an opportunity to interact with the system. One significant result is that a survey conducted with 100 middle-school students at MindTrekkers had 98 respond positively when asked if they would like augmented reality integrated in their education. The community groups of outreach activities include elementary students at a STEM Expo, middle school students at a community event called MindTrekkers, and college students at regional and national conferences. The activities and information have been adjusted appropriately for each audience. A summary of outreach events is shown in **Error! Reference source not found.**.

Table 1: Service-learning outreach table

Events	**Location**	**Date**
Great Plains Honors Conference	Lamar University	March 24, 2017
SJC Honors Showcase	San Jacinto College North	April 27, 2017
Houston Robotics Day	University of Houston - Clear Lake	July 21, 2017
Gulf Coast Intercollegiate Council Honors Conference	San Jacinto College Central	November 3, 2017
Stem Expo North Campus	San Jacinto College North	November 9, 2017
MindTrekkers	San Jacinto College Central	March 8-9. 2018
Great Plains Honors Conference	Oklahoma State University	March 23-25, 2018
National Council on Undergraduate Research	Oklahoma State University	April 4-7, 2018
SJC Honors Showcase	San Jacinto College North	April 23, 2018
SJC URG Symposium	San Jacinto College Central	April 27, 2018

The outreach has been conducted to the Houston metro area and allows college students on the team to interact with more than 7,000 students and parents during the research period. Regional and national conferences extend this opportunity and bring professional development to the members and knowledge dissemination to the community. Elements of the research are integrated as elements of engineering courses while others are purely outreach to cover and enhance learning outcomes.

4. Conclusion

The research presents a starting point for further development in the augmented reality development of chemistry. The feedback received from our presentation indicate a high level of interest in augmented reality approaches for science classes. Future research should include pilots of other subjects and a more complete development of chemistry itself. Standardizing of grades into a learning management system would allow for the deployment to occur so that the grades can be transferred into the school grading systems. Struggling students have new opportunities in chemistry classes with augmented reality and the research contributes a process.

5. Acknowledgements

Special Thanks to SerL.IO, Sheer Industries, Microsoft, NSF, BSC DUE 1317386, NASA C2 STEM, and San Jacinto College Honors Program, and San Jacinto College AI-Tech Lab, Professor Karen Hattaway Ph. D, Professor Edwin Aiman M.S.

Contributors: Richard Woodward, Justin Tarwater, Hector Zaragoza Saldana, Pablo Garza, Bruno Esquivel, Jubayer Moyen, Jorge Montoya, Juan Maya, Aldec Saniel, Tai Tran.

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