Work-in-Progress—Specific Heat of Water Experiment: Augmented Reality Chemistry Lab

Ryan Wirjadi
Arizona State University
Tempe, Arizona
rwirjadi@asu.edu

Alex Vuong
Arizona State University
Tempe, Arizona
avuong3@asu.edu

Frank Liu
Arizona State University
Tempe, Arizona
fwliu1@asu.edu

Robert LiKamWa
Arizona State University
Tempe, Arizona
likamwa@asu.edu

***Abstract*—Augmented Reality (AR) is becoming readily more available as the number of AR capable smartphones and tablets increase in popularity. With its exponential development, augmented reality offers an oppurtunity to facilitate education in online chemistry. In hopes of furthering the advancement of augmented reality in online chemistry education, we developed a boiling water experiment to show the effects of heat capacity and to create an interactive lab experiment for online learning. Our work-in-progress paper explores how the utilization of augmented reality can improve the learning process and better exhibit chemistry lab concepts.**

***Index Terms*—augmented reality, chemistry, heat capacity**

I. Introduction

Augmented Reality creates a 3D world with an augmented layer added upon the real world allowing for virtual interactions and information to be displayed at the user's discretion [1]. Our AR experiment can simulate a life-like experience for students similar to when being in a physical chemistry lab. Furthermore, AR could allow students to perform chemistry labs remotely in an affordable and accessible manner. With its ease of use and its already common availability, AR education via smartphones and tablets can become a core learning tool in virtual learning.

We developed a boiling water experience to demonstrate the key chemistry concept of heat capacity, which shows the boiling of water and the temperature change over time. Students will then be able to study the concept of specific heat of water through the specific heat equation and observe the temperature transition into a plateau as the temperature reaches 100°C. The augmented lab provides a virtual beaker with a set amount of water being heated over a bunsen burner and displays the value of each unit necessary to the specific heat formula. Students will also have the ability to pause the lab experiment, to allow the data collection of the temperature to be more leisurely. A research team in Australia conducted a similar experimentiment, where they developed an AR titration lab and performed user studies to test their application [8]. In their lab experiment, users simulated a real-life titration lab and determined the lab was similar to an actual titration experiment. From their user studies, they found that their AR titration lab has improved confidence in handeling chemicals commonly found in titration labs and has given the users a better understanding about titration.

Our goal, with the help of AR, is to create a more immersive experience which can help teach core chemistry concepts, as well as bring chemistry lab experiments to online students. The physical boiling water experiment is commonly conducted by middle school and high school students in physical labs. Our AR experiment also targets the same group of students. The boiling water experiment with its AR integration will help achieve the immersive experience and showcase a new learning method for students.

II. Related Works

The utilization of AR in online chemistry education can be seen in its availability and ease of use. To best understand the benefits of AR in chemistry education compared to traditional remote learning, we reviewed past studies on the use of AR in learning outcomes.

Systematic reviews of research articles and studies on the use of AR in education has been shown to increase academic performance. In a 2020 study done by a team of researchers, they took a hundred 7th graders where half were given AR supplemented learning resources and found that middle school academic performance had a significant increase, while also improving the educational attitude towards the subject with the use of AR [2]. Furthermore, when AR is used in chemistry teaching it gives students the opportunity to practice using simulated laboratory equipment with less risk [8]. The simplicity of AR-based application means that it can be used in both formal and informal education which can help foster curiosity in students when they don't have access to an in-person lab experience [3], [9]. Unlike traditional online learning methods with a mouse and keyboard, AR provides a natural interaction between the user and the simulation, which is more related to actual chemistry labs [4]. Although displayed in a 3D augmented world, the developed chemical tools and equipment are based on real chemistry tools and behave in a similar fashion. Futhermore, similar to real world experiments, AR-based applications can be made with object manipulation and a tangible UI in mind, allowing students to feel as if they are in an in-person chemistry lab environment.

Online chemistry education has the potential to develop further with the use of AR and can grow into an immersive and interactive experience that can facilitate students with academic achievement and attitude towards the course [2], [5].

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Research suggests that augmented reality benefits and in some cases out-performs normal learning standards with increased positivity towards AR-based applications. We continue this exploration of AR education through the development of a specific heat boiling water experiment.

III. Design And Implementation

The goal of the experiment is to create an interactable and immersive experience that can accurately display how the temperature of water behaves after reaching a certain threshold to demonstrate the effects of heat capacity. The lab experiment includes a virtual burner, glassware, and fluid simulation.

A. *Virtual Lab Experience*

Through the use of Unity 2020.2, we developed an augmented reality lab. With the Vuforia Augmented Reality SDK, we were able to take advantage of image targeting to display the augmented reality scene onto a smartphone screen. Realistic fluids were generated with the Obi Fluid Asset. Obi fluid is a dynamic fluid simulation that gives realistic fluid interactions that allows the developer to change the appearance and physics of the liquid. Furthermore, all virtual chemistry equipment was created with the onShape web browser software. The augmented scene includes a beaker on top of a beaker stand where both directly stand above a bunsen burner.

In our augmented reality boiling water experiment, the user is prompted with an on-screen UI that provides necessary information and buttons. After the printed image target is found, the user is able to add 500 grams of virtual water to the beaker with a liquid dispense button and turn on the Bunsen burner via a fire button which burns at 1000 joules per second (Fig. 1 and Fig. 2). The bunsen burner flame is simulated with a particle system which has been altered to appear and act like a bunsen burner flame. The longer the virtual bunsen burner is one, the higher the temperature of the virtual liquid increases over time. The user has the ability to pause and play the simulation via a pause/play button at any time to note the temperature value and later plot the value to see the effects of heat capacity to determine water's specific heat (Fig. 3).

In real water boiling experiments, water is added to a beaker and heated via a bunsen burner or hotplate. Students then note the temperature values over time and observe the change in temperature as it gradually increases to a constant temperature. To simulate the effect of boiling water, our simulation produces steam when the virtual water reaches its boiling point (Fig. 4). After the simulation has ended, the students are then able to plot their points and calculate the specific heat of water through the values given (Fig. 5).

To calculate the specific heat of water, we use the constant 1000 joules per second and the total time of 210 seconds to reach boiling point to solve for total energy required, Q, which equals around 210,000 joules. Then using the specific heat of water equation: $c = Q/(m * \Delta T)$, we plug in 210,000 joules for Q and divide it by mass times change in temperature, 500 grams * 100.33 °C, so our final value equals 4.2 J/ g °C, which is the heat capacity of water.

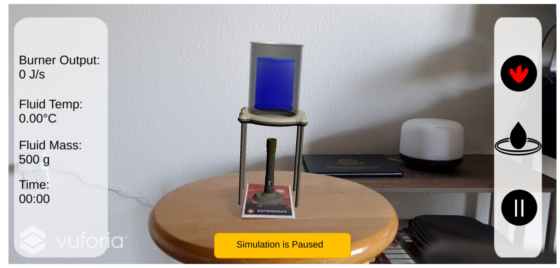

Fig. 1. Simulation Paused.

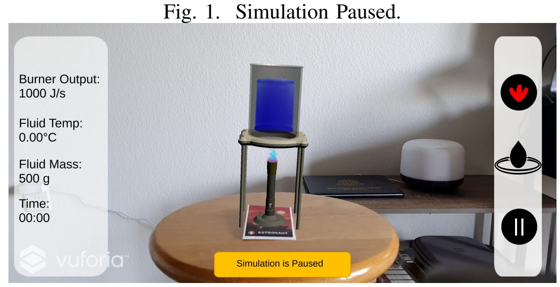

Fig. 2. Bunsen Burner On.

Fig. 3. Simulation Running at Halfway Point.

Fig. 4. Water steaming.

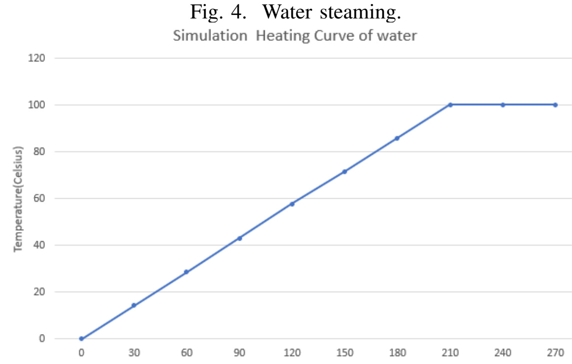

Fig. 5. AR simulation graph.

B. Smartphone Implementation

Our experiment was deployed on an android phone running Android 11. Given that this experience was developed using Unity, we can deploy this experiment over any iOS or Android device. The UI of our AR application scales accordingly to the smartphone screen size.

IV. Future Work

Our ultimate goal is to produce a finalized version of the experiment and have it used by students of all backgrounds. We will continue to develop our experiment by improving the UI and develop working versions on newer and older-generation smartphones and tablets, allowing more students with a variety of smart devices to utilize our app. To direct the students, we plan on developing a procedural screen that can direct the student though the experiment and provide warnings if the student does not use proper precautions. Also, we plan on developing a more interactive experience with the use of gesture control [6] and cylindrical targets to make the experience more immersive and consequently induce better memory retention of key chemistry concepts [1], [2]. To diversify our experiment, we aim to add more liquids other than simulated virtual water. For developing with different liquids, we can easily simulate other liquids by simply changing the color and the specific heat of the liquid to get a different heating curve. We intend on performing user studies with high school students to study the effect of AR-based liquid boiling experiments on learning outcomes.

V. Conclusion

From this work-in-progress paper, we discussed the development of an immersive water boiling experiment with image targeting and fluid interactions. The benefits of AR-based learning have the potential to improve online education and create an experience that standard browser-based online learning can not achieve. Our goal is to create rich and engaging online chemistry curriculum with the use of augmented reality.

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