AN INTERACTIVE SCIENCE LAB GAME TO HELP STUDENTS LEARN MORE ABOUT SCIENCE USING UNITY

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ABSTRACT

In the evolving landscape of education, the integration of technology has become paramount, especially in adapting to the needs of digital-native students. Our paper addresses the challenge of engaging students in science, technology, engineering, and mathematics (STEM) subjects through traditional teaching methods, which often fail to capture the interest and imagination of today's learners [9]. We propose a solution through the development of an educational platform that combines gamification with virtual and simulation-based learning environments. This platform utilizes augmented reality (AR), virtual reality (VR), and adaptive learning algorithms to create immersive, interactive educational experiences that enhance student engagement and understanding of complex concepts [10][11].

The development process faced challenges, including balancing educational content with game engagement and ensuring equitable access to technology. These were addressed by integrating adaptive learning techniques to customize user experiences and forming partnerships with educational institutions to improve accessibility.

Experimental application across diverse learning scenarios revealed significant improvements in student engagement, concept retention, and practical skills application. Our findings underscore the effectiveness of combining gamification with immersive technologies in education. Ultimately, this approach promises to revolutionize STEM education by making learning more engaging, accessible, and effective, thereby preparing students for the challenges of the 21st century.

KEYWORDS

3D game for chemistry lab, Education of chemistry, STEM Education Innovation, Virtual Reality Learning

1. INTRODUCTION

This game is for middle school or high school students to let them know more about chemistry and enjoy the chemistry labs. I'm interested in chemistry labs, and I know the students in middle school and high school can also did chemistry lab in school but not all students take chemistry class and maybe the chemistry lab in school is not enough for students, there are about 12 or 13 chemistry labs for one whole semester of the chemistry lab I've taken, but there are so many elements and knowledges in chemistry that can be included in chemistry labs, I don't think the labs in school are enough for the students that really like to do labs but not just sit in class and learning. I want to make the labs as much as I can to let the students enjoy the chemistry experiments. About the virtual lab in school, the labs were developed to provide a variety of

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problem-solving activities that can be completed during class time. Students can work alone or in small groups to complete the labs and receive rapid feedback from the computer simulation [1].
Methodology A aims to enhance twenty-first-century skills through a Multiplayer Educational Gaming Application (MEGA) for high school biology students, focusing on interactive learning to improve engagement and educational outcomes [12]. Its shortcomings include potential neglect of content depth and reliance on technological infrastructure. Our project addresses these by integrating comprehensive curriculum content within the game, ensuring depth in biology understanding alongside skill development.

Methodology B utilizes virtual labs with augmented reality and virtual worlds for an immersive educational experience in science and engineering fields, overcoming traditional lab accessibility and safety issues. However, it lacks the tactile feedback of physical labs. Our enhancement involves gamification to increase student engagement and knowledge retention, offering an innovative leap beyond current virtual lab methodologies.

Methodology C reviews simulation games in engineering education, promoting active learning over traditional methods to better prepare students for industry challenges. Limitations include access barriers and the complexity of simulating real-world scenarios. Our project improves on this by introducing more nuanced simulations, making engineering scenarios more accessible and diverse, aiming for a realistic preparation for industry applications.

For those students who really like doing labs, I created this game for them. The game will be a better way to help these students. I'm also a student that like doing labs but not just learning, maybe listen to teacher and get knowledge from book might be a way to help students learning, but I believe that let students to do something is a faster and clearly way to get knowledge, they can learning better for doing lab than teacher just told them and show them videos. Just like we play a game, we play a game that has a lot of rules, some player have not played this game before, other does, the player who know how to play this game can teach them what the rules are, but the rules are too complex, maybe let the player try the game first can let them understand the game better. Another benefit of experimenting with 3D games is that it does not pose a safety hazard, experiments that involve risks in the real environment due to poisonous or unsavory gas releases can be safely performed in virtual laboratory environment / uncontrolled explosions (e.g., NI3) have no real-world consequences, etc [2]. In addition, in real chemical experiments, some experimental equipment may be damaged or lost, but in virtual experiments there will be no problems with experimental equipment. As virtual laboratory equipment is not at risk of being broken or lost, users can use virtual laboratories freely. Experiments that cannot be conducted in a real laboratory due to shortages of equipment and materials can be repeated in a virtual lab without any loss [3]. The virtual labs can also help us to see how students like it. The virtual lab can record all student interactions for analysis [4]. Carefully develop sound virtual laboratory experiences that complement or replace existing practices, reduce the need for equipment and laboratories, and provide suitable alternatives for students and professionals [5].

In the first experiment, we aimed to explore the process of oxidation by burning iron wool to produce iron oxide (Fe2O3). We measured the mass of the iron wool before and after burning it, using a timer to record the duration of combustion and an electronic scale to weigh the resultant iron oxide. The significant finding was an increase in the mass of the iron wool post-burn, which can be attributed to the iron combining with oxygen from the air, demonstrating the principle of mass increase in oxidation reactions due to the addition of oxygen atoms.

The second experiment focused on comparing the reactivity of magnesium and calcium with hydrochloric acid (HCl) to understand the reactivity series of metals. We prepared two test tubes, each containing HCl, into which we separately introduced magnesium and calcium, using a clock to measure the time taken for each metal to react. The notable observation was that calcium reacts more vigorously and faster than magnesium, concluding in shorter time spans. This outcome aligns with the reactivity series, where calcium is more reactive than magnesium, indicating that more reactive metals displace less reactive ones in acid-metal reactions.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Labs

The major component of my program is the different labs that this game have, actually I have some trouble on what kind of labs should I choose, because there's so many labs for students, so I know I can search online to know the level of different labs, I want to know which is easier and which is harder, then I can rank them in order of difficulty. Finally I came up with 3 labs. First is very easy, just make the water boil. Second is to burn the Iron and check for the substance after burning. Third is to compare the reaction time of the Mg and Ca with HCl.

2.2. 3D modeling

The second major component of my program is 3D modeling. For this part, I can find some models of the tools that are used in chemistry labs online, but some models are hard to find online, and I need to build it. I found a tool for 3D modeling and downloaded it [15]. I could use it to build anything that I need to use in my 3D game. The modeling is also a fun part of creating a 3D game.

2.3. Make the Game more Interesting

The third major component is to make the game more interesting and easier. In real life, when we do the chemistry labs, some labs are really complex and after finishing the labs, we need to fill out a lab report. I think there are too many steps to do labs in real life. I want players to enjoy the chemistry labs and I didn't add the lab report in the game. In real life, after we finish a lab, we can get grades, and in the game I can build a store system, players can get money after finishing the lab and buy the materials in the store.

3. SOLUTION

First player starts at a Hallway Scene, there are some doors in the hallway and different doors are different labs. The first door is the lab that is about boiling water. The player can click on the door and then go into the first lab scene. In the scene there is a PPE checker at the lower left corner, and a phone at the lower right corner. There are two pieces of software in the phone, one is a shop and another is a checklist. In the shop players can use money to buy the material such as Iron, there will be Hydrochloric acid, Magnesium and Calcium in the shop for the third lab. When the player finishes a lab player will get points from the lab, there are 3 points total: first one is for lab completed, second is for PPE worn, third is for clean up. If the player gets 3 points totally, then he(she) will get money. First lab is boiling water, players should wear PPE(gloves, mask, goggles) first, there will be some beakers, a burner and a iron platform on the table, there's a water station near the door, player need to use these thing to complete the lab, and clean up after finish lab. The second lab is to burn the iron and measure the weight of the substance that formed after the iron finishes burning. There will be a burner, an iron wool ball, a bowl that can contain the iron ball, an electronic scale, and a piece of paper that can write the weight of the substance. The third lab is to compare which substance is more relative with HCl(hydrochloric acid). There are two substances that are Magnesium and Calcium. There are two test tubes and a test tube rack, and there's a bottle of HCl.

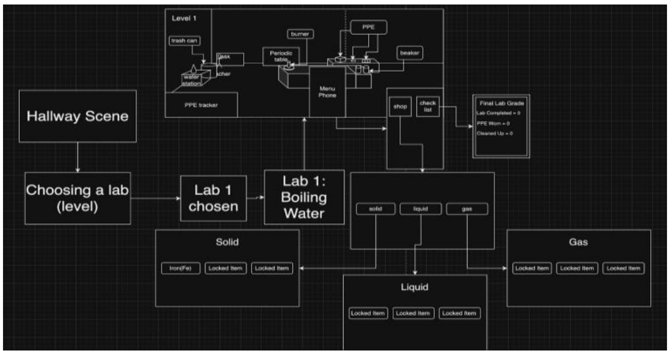


Figure 1. Overview of the solution

The first one is the lab choice. Players go near the door and click on it to get into the lab. There are three labs total, first lab is boiling water, second is burning iron and checking the weight, third is putting Mg and Ca in HCl to compare which one is more relative. The things in the lab scene are similar, the only difference between different labs is the material that is on the main table for the lab.

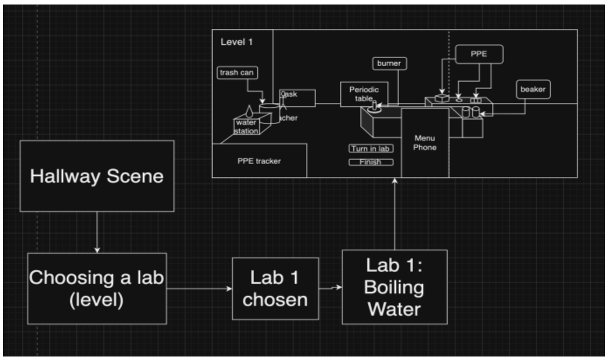


Figure 2. Screenshot of the lab

```
// assign the game to search for the player
public void Start ()
{
    player = GameObject.FindGameObjectWithTag("Player");
}

public void Update ()
{
    DistanceCalculator();
}


// Calculate the distance of the player to the door to avoid the player accidentally loading into the wrong level
void DistanceCalculator ()
{
    float distanceToPlayer = Vector3.Distance(transform.position,player.transform.position);

    if (distanceToPlayer <= range)
    {
        isInRange = true;
    }
    else
    {
        isInRange = false;
    }

}

// if the player is in range then they will be allowed to proceed through the door into the respective level
private void OnMouseDown ()
{
    if (isInRange)
    {
        SceneManager.LoadScene(levelToLoad);
    }
}
```

Figure 3. Screenshot of code 1

The code is for each door to find the distance between player and door. If the player is close enough to the door, the player can click on the door then go into the lab. I created three labs, which are three scenarios related to different experiments. Through the unity system, the three labs can be set to the numbers 1, 2, and 3. Using this code to connect these numbers allows the first door to correspond to the first lab, the second door to the second lab, and the third door to the third lab.

Second part is the shop system part. In the phone at the lower right corner, there’s a software called shop, in which the shop player can buy the substance like any liquid, solid or gas. Players can get money after finishing a lab, players can use the money to buy the substance for the next lab.

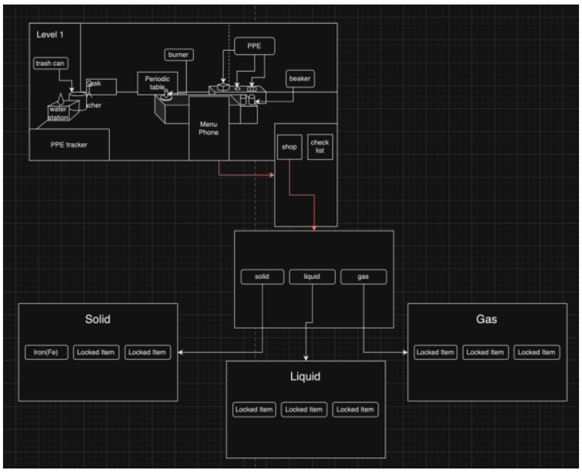
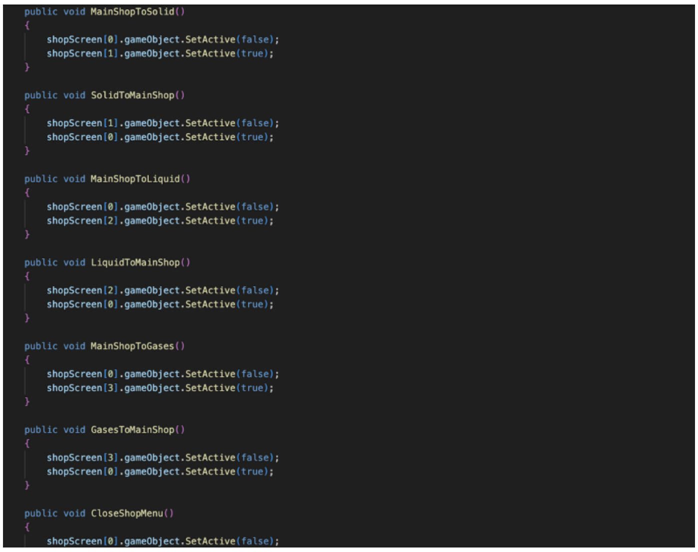


Figure 4. Screenshot of shop system



```
public void MainShopToSolid()
{
    shopScreen[0].gameObject.SetActive(false);
    shopScreen[1].gameObject.SetActive(true);
}

public void SolidToMainShop()
{
    shopScreen[1].gameObject.SetActive(false);
    shopScreen[0].gameObject.SetActive(true);
}

public void MainShopToLiquid()
{
    shopScreen[0].gameObject.SetActive(false);
    shopScreen[2].gameObject.SetActive(true);
}

public void LiquidToMainShop()
{
    shopScreen[2].gameObject.SetActive(false);
    shopScreen[0].gameObject.SetActive(true);
}

public void MainShopToGases()
{
    shopScreen[0].gameObject.SetActive(false);
    shopScreen[3].gameObject.SetActive(true);
}

public void GasesToMainShop()
{
    shopScreen[3].gameObject.SetActive(false);
    shopScreen[0].gameObject.SetActive(true);
}

public void CloseShopMenu()
{
    shopScreen[0].gameObject.SetActive(false);
```

Figure 5. Screenshot of code 2

The code in the picture is for different pages for the store, there is the main page of the store and solid page, liquid page and gas page. These pages are for buying different kinds of elements. For example, in the solid page there are some elements such as iron, magnesium, and calcium, in the liquid page there is Hydrochloric acid, in the gas page there’s no elements provided so far [14].

Third is the grade part, after the player finishes the lab, clicking "Turn in the lab" can check the grade and clicking finish can get money. The amount of money is decided by what grade that player gets, if player gets A, then he/she will get $30, if player gets B, then he/she will get $20. If he gets an A on the first try of an experiment, he/she gets an extra $30.

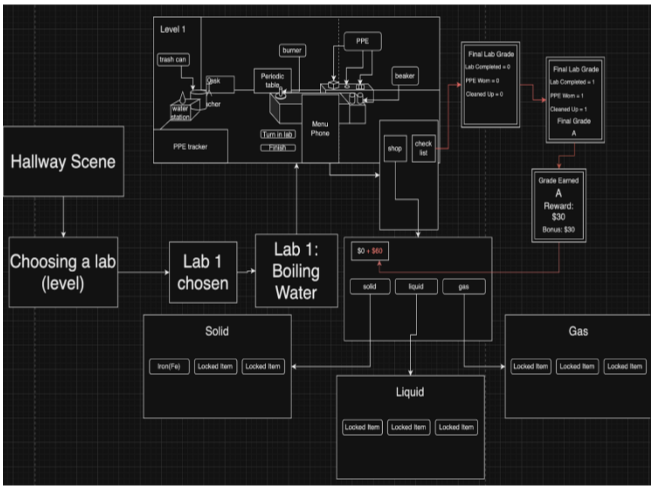


Figure 6. Screenshot of grade part

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class MoneyManager : MonoBehaviour
{
    public int playerMoney;
    private static GameObject sampleInstance;
    // Start is called before the first frame update

    private void Awake ()
    {
        if (sampleInstance != null)
        {
            Destroy(sampleInstance);
        }
        sampleInstance = gameObject;
        DontDestroyOnLoad(this);

    }


    // Update is called once per frame
    void Update()
    {
        playerMoney = Globals.playerMoney;
    }
}
```

```
void CalculateReward()
{
    switch (finalGradeScore)
    {
        case 0:
            break;
        case 1:
            Globals.playerMoney += 10;
            break;
        case 2:
            Globals.playerMoney += 20;
            break;
        case 3:
            Globals.playerMoney += 30;
            break;
    }


    if (bonusEarned)
    {
        bonusText.gameObject.SetActive(true);
        Globals.playerMoney += 30;
    }
    else
    {
        bonusText.gameObject.SetActive(false);
    }
}

public void CloseRewardScreen()
{
    moneyPointsCanvas.gameObject.SetActive(false);
}
```

Figure 7. Screenshot of code 3

The code in the first picture shows how much money the player has, and the code in the second picture is the money the player gets after completing the experiment, which is connected to the level system code. A player will receive $30 and an additional $30 if they get an A rating, only $20 if they get a B, and $10 if they get a C. If the score is lower than C, then the player will not get any money.

4. EXPERIMENT

4.1. Experiment 1

In my game, there's a lab that is burning the iron. For this lab, I need to test the time that it will spend burning iron, and in the game, the player should measure the production's mass, so I need to find data or the equation to measure the mass of it.

I will take a piece of iron wool and measure the mass of it. I will use the timer to measure the time that it will spend burning the iron. After the iron finishes burning, I will take the production and put it on the electronic scale to measure the mass of it. This is the way to get accurate data. I will prepare the tools like burner, crucible, electronic scale, some iron wools and a lab report on the table. When I am doing the lab, I will record the mass of the iron wool that I need and I record the mass of the production on the lab report. For example, I burned a 10g iron wool, I will get 14.292g Fe2O3, then I will write down these data on the lab report The data is the mass of Fe2O3 that can be calculated, it is a kind of average value. In this lab for real life, I can do three times to make sure my answer is correct.

4.2. Experiment 2

There's another lab that is to compare Magnesium and Calcium, to check which one is more reactive with Hydrochloric acid. We need to pour hydrochloric acid into each test tube, there're 2 test tubes and we need to take a piece of Magnesium and Calcium then put them in each tube then measure the speed at which two elements react inside.

First I need to prepare to get two test tube, hydrochloric acid, magnesium and calcium, clock, test tube rack, put the two test tube on it and pour some HCL in it, then prepare to throw the magnesium and calcium into each test tube and use clock to measure the time, if one element disappear quickly then it is relative.

The data I can get in this lab is just the time that Magnesium and Calcium disappear. The time that these two element react with HCl depends in the size of them so I can't give a specific data, because I know the Calcium is more reactive than Magnesium, so I just set the time that Calcium reacts with HCl is 5s, and the time that Magnesium react with HCl is 8s, sometimes the time that they will spend are several minute and I don't want player to wait for a long time.

5. RELATED WORK

The methodology A focuses on the creation and assessment of a Multiplayer Educational Gaming Application (MEGA) for enhancing twenty-first-century skills among high school biology students. This approach integrates technology with education to foster digital literacy, inventive thinking, productivity, and effective communication. Its effectiveness lies in promoting engagement and educational outcomes through interactive learning and gaming. However, it might overlook the depth of content understanding compared to traditional learning methods. Limitations could include reliance on technological infrastructure and potential disparities in access. Our project builds on this by possibly offering a more comprehensive integration of curriculum content within the game, ensuring that while students develop essential twenty-first-century skills, they also gain a deep understanding of biology, addressing any gaps in content knowledge that methodology A might overlook [6].

Methodology B explores the use of virtual labs in education, highlighting the advantages of utilizing technologies like augmented reality and virtual worlds for science, technology, and engineering education. This approach addresses the accessibility and safety challenges of traditional labs, offering an interactive and immersive learning experience. However, it may lack the tactile feedback and unpredictability of physical labs. Our project builds upon this by incorporating gamification to further engage students, aiming to enhance motivation and the retention of scientific knowledge, thus presenting a novel improvement over existing virtual lab methodologies [7].

Methodology C, which presents a state-of-the-art review of simulation games in engineering education. This methodology emphasizes the transition from traditional lecture-based methods to active, multi-sensory experiential learning through simulation games. It argues that proper application of simulation games maximizes students' transferability of academic knowledge to industry applications. The solution is effective in enhancing engagement, understanding, and retention of engineering concepts. However, its limitations include potential access issues, the requirement for significant initial development resources, and the challenge of accurately simulating complex real-world engineering problems. Our project improves on this by potentially integrating more nuanced simulations that address these limitations, offering a more accessible and diverse range of engineering scenarios to better prepare students for real-world challenges [8].

6. CONCLUSIONS

Our project, while innovative in its integration of gamification and comprehensive curriculum content, faces several limitations [13]. One key challenge is ensuring the balance between educational depth and game engagement without overwhelming or under-stimulating students. Another limitation is the technological accessibility, as not all students may have equal access to the required devices or internet connectivity. Furthermore, accurately measuring learning outcomes and ensuring the transferability of skills from the virtual to the real world remains a complex challenge.

To address these issues, given more time, we would implement adaptive learning algorithms to tailor the difficulty and content to individual learner profiles, enhancing personalization and inclusivity. We would also explore partnerships with educational institutions to facilitate access to necessary technology. Additionally, developing robust assessment tools integrated within the game to track progress and skill acquisition in real-time would be crucial. These steps would ensure our project not only engages but also effectively educates and equips students with relevant skills and knowledge.

Our project represents a forward-thinking approach to education, blending gamification with rigorous academic content to prepare students for the 21st century. While challenges remain, ongoing refinement and innovation promise to overcome these hurdles, making learning more engaging, accessible, and effective for a diverse student population.

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