Using Virtual Reality for an Immersive Experience in the Water Cycle

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***Abstract*—A common misconception regarding virtual reality (VR) technology is that it is simply a gaming platform. The main purpose of this project is to refute this notion and demonstrate the applications of VR beyond entertainment. One such usage for VR is in education. VR can be used to immerse the user in an environment where he or she learns through interaction with the surroundings. This concept led to the development of SplashSim, a mobile-based VR application in which the user traverses through the stages of the water cycle in the perspective of a water droplet. Through this approach, SplashSim enables the user to experience the water cycle in a unique and engaging way. Within this immersive VR environment, users are not only able to more closely observe processes such as the water cycle, but can also study other important mechanisms that are not readily observed in the real world.**

I. Introduction

The 21st century is commonly defined as the age of technological advancements. With the rise of smartphones and other digital devices, many new ideas have been developed to accompany the latest innovations. One such concept is *virtual reality (VR)*, which allows users to immerse themselves in a computer-generated environment. The objective of this project is to create a product that uses VR to improve the learning experience. The resulting application, *SplashSim*, places the user in the water cycle and allows him/her to become more engaged in the environment. This paves the way toward integrating VR in education, where students can learn through interaction and visual reference.

II. Background

A. VR Technology

In the past few years, VR has become widely used in the creation of video games. However, the practical applications of VR technology can extend much farther than gaming. VR is a platform that places the user in a virtual world with an interface that allows for realistic interaction. The user puts on a headset and can become fully engaged in a simulated environment as if they are actually existing in it, providing a unique medium of immersion. A smartphone's accelerometer and gyroscope bolster the VR experience with a sense of motion and position. The user is also able to move their head to the respective part of the scene or explore the environment as they please. There is also 3D sound that plays louder when the user is near the audio source. By inserting students into normally inaccessible areas and allowing them to experience it first hand, VR enriches problem solving and critical thinking skills. [1] There are many different types of VR such as Window on World, Immersion, and Telepresence. Window on World does not require a headset: it is simply a realistic simulation. Immersion is the Window on World system that uses a headset to further engage the user. SplashSim is an example of immersion virtual reality. Finally, Telepresence is a form of VR controlled remotely by a user. It typically involves using a drone to transmit a VR image to the operator.

VR is a viable instrument for advancing education techniques because it is capable of holding students' attention. [2] SplashSim is an example of how VR can be used as a versatile type of technology with broad applications to various fields.

B. VR History

The concept of virtual reality has been around since the 19th century. The first VR head mounted display was made in 1960 by Morton Heilig. Since then, VR has spread widely. 2016 can be considered the year of virtual reality because of the influx of new VR technology such as the *Oculus Rift* and the *HTC Vive*, both of which are high-performance headsets.

C. Visual Learning and Immersion

Some may argue that using VR for education is unnecessary since videos and shows are just as effective at explaining content. However, VR offers a level of immersion that is unparalleled by traditional mediums. With VR, users feel more connected to the content because they are able to personally interact with and manipulate it. [3] Compared with television, where the experience is from an outside point of view, VR offers a realistic first person perspective. This key aspect gives VR large potential for educational uses.

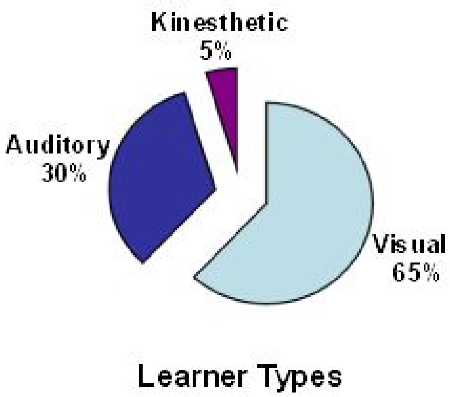

Fig. 1 Pie chart depicting distribution of learner types [4]

According to a study done at the University of Alabama School of Medicine, the majority of people are visual learners, meaning they learn best when looking at a visual representation of a concept. [5] SplashSim appeals to this wide body of visual learners by immersing them in an environment that they can see and explore.

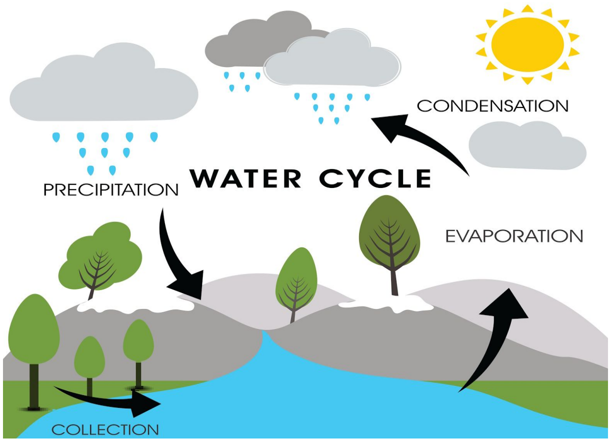

Fig. 2 Diagram of the water cycle [16]

D. The Water Cycle

The *water cycle* is the process by which water undergoes changes in states through *evaporation*, *condensation*, and *precipitation*. Evaporation is the process through which water changes from a liquid into a gaseous substance. During condensation, gaseous particles of water come together and form liquid droplets. Finally, during precipitation, the liquid droplets fall back to earth in the form of rain, hail, or snow, or sleet. Some of these processes are depicted and explained in SplashSim.

E. VR as a Platform for Education

Traditional educational methods are slowly becoming supplanted by more advanced techniques. Educators constantly seek to develop new and exciting methods to make education more interactive and effective for the students. The education experience is being reshaped for students and teachers alike through new innovative teaching methods, advancements in technology, and programs designed to make technology more readily available. [7] In particular, VR in education helps students retain information better, as it creates a unique, individualized environment that cannot be replicated in the classroom setting.

F. Unity

Unity is a development platform that is used to create 2D and 3D games. The editor allows users to design *scenes*, instances of the 3D landscape in Unity, and instantly observe the results of edits made. Unity also enables users to deploy their games to a myriad of platforms including TV, desktop, and mobile devices. Furthermore, Unity supports VR and *augmented reality (AR),* which makes virtual objects appear in the real world, and is used to create games for virtual reality headsets. Most games in Unity include features from the Unity asset store, which also allows users to access artwork, models, and *scripts*, programs that accomplish tasks in Unity. Finally, Unity allows users to share their work with others: *Unity Teams* allows for collaboration on projects while *Unity Connect* allows users to share their work with potential recruiters.

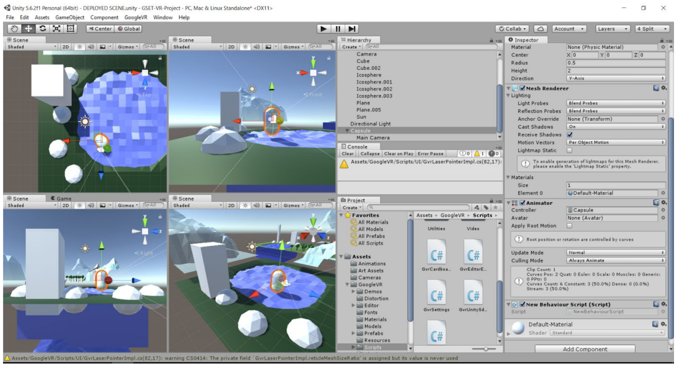

Fig. 3 The User Interface (UI) for Unity

G. Google Cardboard

Many VR devices are available to the general public, such as the *HTC Vive*, the *Playstation VR*, or the *Oculus Rift*; however, the *Google Cardboard* is one of the most affordable VR technologies on the market. It is a cardboard box with a slit that can fit Samsung and iPhones. This device is a popular alternative to other VR devices because it is cheap and simple to use. The interactive conductivity button, as seen on top of the device in figure 4, is one such piece that allows users to press a button that transfers an electrical signal and taps the screen. Due to features such as this, VR simulations are able to be more immersive. While most other VR technologies cost hundreds of dollars, the Google Cardboard is the perfect instrument to mass produce for all people to use. It is an important part of making VR an essential part of classrooms all over the world. Google estimated that about 1 million Cardboards had been distributed, and that was before the New York Times recently distributed more than a million to its subscribers. [8] The Google Cardboard was used in the development of the project, and is essential in making VR more mainstream and accessible for the general population.

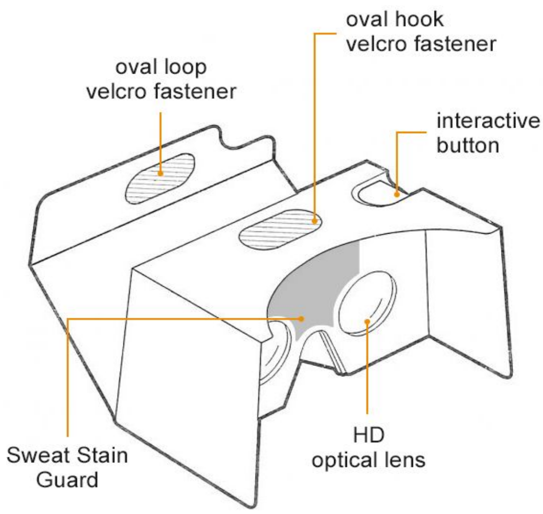

Fig. 4 The components of the Google Cardboard [19]

H. Blender and Assets

In order to build an immersive world in SplashSim, artwork and models are moved from Blender, the 3D modeling software where they are created, into Unity where the movements are created. This artwork is called *assets*. They were essentially objects that populated the simulation. The 3D art is saved as an .fbx file, which allows the assets that are published in Blender to be manipulated and changed in Unity.

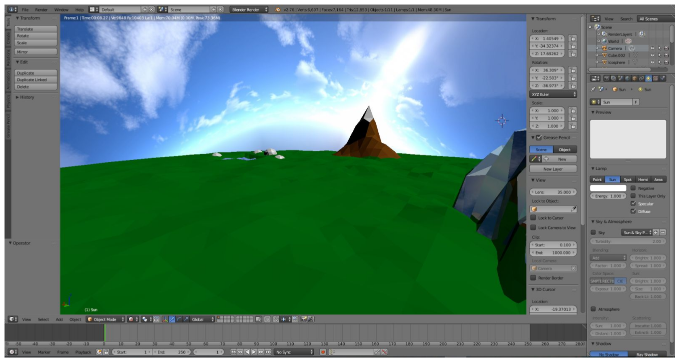

Fig. 5 Blender interface

I. Android SDK

The *Android Software Development Kit (SDK)* was integral to the development of the project as it enabled SplashSim to be deployed to a Samsung Galaxy Note 5. The Android SDK integrates Unity-based programming with Blender artwork and allows it to be viewed with the Google Cardboard. There were many settings in Unity that were configured with Android SDK in conjunction with the Java Development Kit that enabled SplashSim to be run on a Samsung Galaxy Note 5.

J. Github Repository

Github is web-based platform that allows users to collaborate on code. As a version control system, a *GitHub repository* was made and shared with all group members. GitHub desktop was used and enabled the ability to push and fetch updates and changes made by each group member almost instantly. GitHub Desktop made sharing the project simple and fast. GitHub's user interface allows the any member to see every change made by other members and revert to old versions if deemed necessary. This feature was very useful throughout the entire process.

K. Elements of Virtual Reality used in SplashSim

1) *Low Poly Environment:* Low poly is an artistic and 3D modeling style where the meshes, or framework of the models, contain a low number of polygons, hence the name "low poly".

2) *Rails:* The rail consists of the path the camera takes as it rises and falls throughout the course of the water cycle simulation.

3) *Animation:* The rain was animated using particle

effects which allowed for the manipulation of properties such as size and amount. The stream animations were included in the purchased asset. Cloud animations were made by using *keyframes*, which are the start and end points of major actions.

4) *Subtitles:* The text in SplashSim appears at a specific time so that it corresponds to a particular stage of the water cycle. It is also attached to the camera so that it follows the user's head movement.

5) *Sound:* SplashSim utilizes objects that contain spatialized sound, allowing the user to experience different sound effects as they progress through different regions of the virtual environment.

6) *360° Movement:* SplashSim incorporates the ability for the user to look around their surroundings by employing the phone's *accelerometer*, a device that determines the motion of the phone, and *gyroscope*, a device that measures the user's tilting and orientation.

III. Methods and Experimental Design

A. Simulation Design in SplashSim

First, a storyboard was created, delineating the visuals and effects needed for each stage of the water cycle. Afterwards, the art assets and *rail*, which is a set path that the user would travel along, was created to transport the user through the stages of the water cycle and provide scientific information at the key steps. After that, additional art assets were brought into the environment. More trees, water, and mountains were added, as well as the sound of rain.

The simulation opens at the water's surface, where information is displayed explaining evaporation.

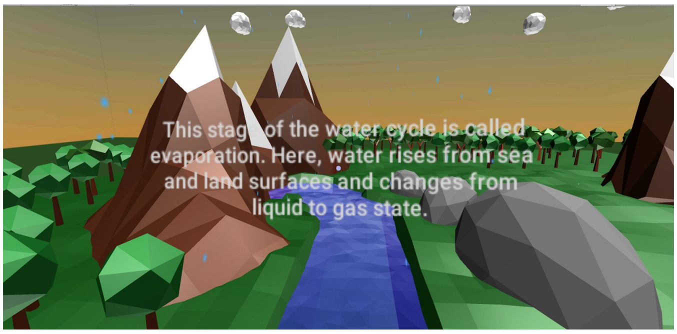

Fig. 6 This scene from SplashSim depicts the evaporation stage of the water cycle

The viewer is given time to look around the scene, where they see trees, a mountain, a sunset, and water flowing all around them. Then the camera rises to the clouds, where condensation is explained.

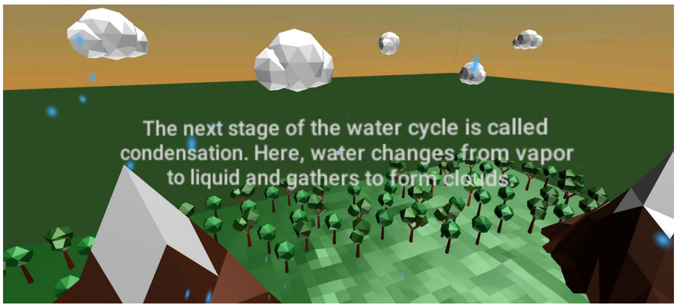

Fig. 7 This scene depicts condensation in SplashSim.

Once the user arrives far up in the sky, they watch as clouds form around them and see the information about condensation. Lastly they fall back to Earth along with rain droplets while reading information about precipitation.

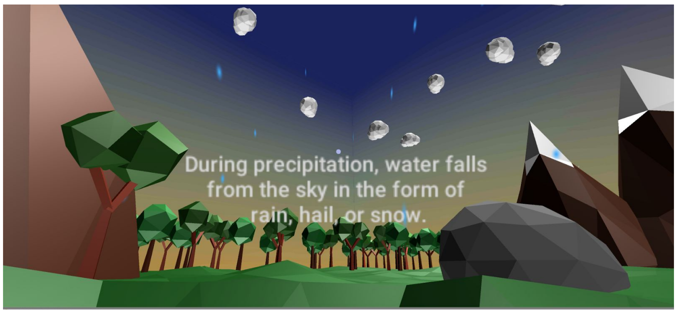

Fig. 8 This picture shows the precipitation stage as depicted in SplashSim.

At this stage, the view turns to a stream where the user flows back to their starting point.

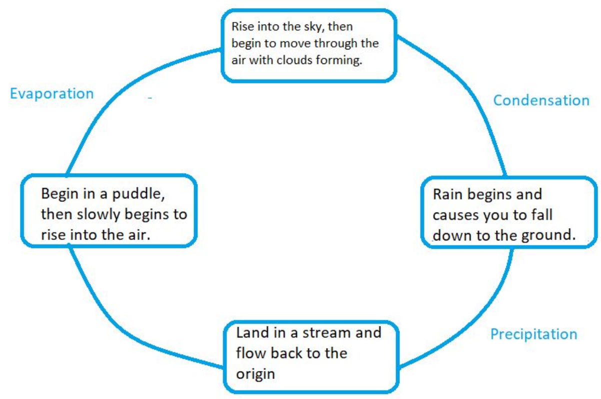

Fig. 9 Flowchart of simulation

B. Hardware Methodology

Google Cardboard was the hardware device used for the project. It allows the user to experience VR by placing a smartphone in its compartment. The two lenses in the Cardboard merge the left and right images that are displayed on the screen of the smartphone in order to perceive the depth of the 3D environment. The Google Cardboard is an effective platform for the deployment of SplashSim because of its low manufacturing cost, which makes it a popular and affordable VR head mounted display.

The *Samsung Galaxy Note 5* is a smartphone than runs the Android operating system, a mobile operating system developed by Google. Using this smartphone for development made building and testing fast and simple because of its compatibility with Unity.

C. 3D Art

The app required all the art assets to be made in Blender. Models that were made include mountains, rivers, rocks, lakes, trees, and glaciers. A *skybox*, which is an infinite cube around the simulation that contains the sky texture, was also made using textures in Unity's built-in editor. Another major aspect of the program was animations, which were done in Unity. All the assets were rendered in low poly. The *shaders* are adjustable properties that manipulated how the lighting affected the materials and textures of the assets.

Fig. 10 Example of a mountain asset

Fig. 11 Example of tree asset

D. Programming

All programming for this project was done in Unity using *C#,* a programming language and *Microsoft Visual Studio,* a program that runs and organizes code. The *GoogleVR asset* was found on the Google developer website and contained the scripts and assets necessary for creating a VR environment in Unity. The GoogleVR asset came with scripts for 360° head movement and a *reticle pointer*, which is a small dot in the center of the screen through which the user can focus on a specific part of the simulation. The Unity built-in animator was used to move the player through the simulation.

Inheritance was used for *objects*, elements that characteristics can be attributed to within a game, that needed to be animated. Inheritance allows objects take on the properties of other objects. Animated objects were made *children* of other objects, meaning they inherited the attributes of their parent object. Animations were added to the parent object and automatically applied to all of the children objects.

E. Minimum Viable Product

SplashSim was tested throughout the development process. A *minimum viable product (MVP)*, a basic skeleton of the environment needed for the simulation to function, was created as a way to test all of the mechanics of the VR simulation. Through multiple tests, it was determined that the speed of camera animations had to be slowed down to reduce the chance of the user experiencing motion sickness. The art assets and lighting were adjusted based on feedback from testers. There were many occasions where SplashSim encountered errors, but through rigorous testing, the final application runs smoothly.

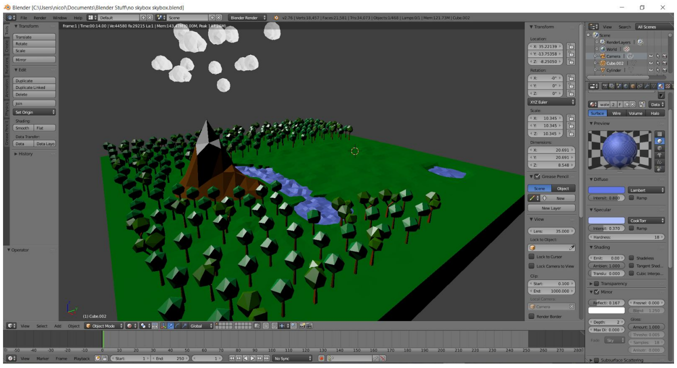

Fig. 12 The MVP in Blender

F. Deployment and Final Product

Over the course of the project, as various elements of the SplashSim environment were created, it became necessary for it to be seen through a VR device. These elements were deployed onto the Samsung Galaxy Note 5, which allowed it to be seen in VR through the use of the Google Cardboard. SplashSim was deployed onto an Android phone and turned into an app by building the scene as an *Android Package Kit* file (.apk), an executable file for Android phones.

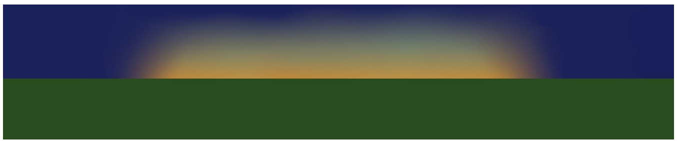

Fig. 13 The sunset hue of the skybox followed by the landscape

IV. Results and Discussion

A. Immersion in SplashSim

VR has long been criticized for being a niche technology. The most useful aspect of this technology is its immersive capability, as it allows users to step into a simulation. VR is designed to keep its users invested in the simulation before they take off the headset and continue about their day. Not only do these simulations allow the users to experience environments that are very difficult to reach otherwise, but they can also be used to help students visualize difficult concepts. VR adds a level of personal input which is hard to be recreated elsewhere. In SplashSim the immersion of being in the water cycle is what differentiates it from other mediums for education such as charts and diagrams. It is much easier to learn about something while actually experiencing it.

B. Improving the Learning Experience

VR is an effective education tool for youths in particular because its strengths lie where traditional education is lacking. VR in education can connect with students and help them retain information better, as it creates a unique, individualized environment that cannot be replicated in the classroom setting. VR also demonstrates the applications of the content in the real world. Instead of showing a picture or a video or describing an event, teachers can instantly bring their students on a virtual field trip so they can interact with the content firsthand and in full detail. By creating a more engaging and stimulating environment, VR will improve the learning experience. In SplashSim, learning about the water cycle is enhanced by the more immersive experience that comes with using VR. Further applications may include allowing students to virtually perform experiments that are not suitable for the classroom, give presentations to overcome their fear of public speaking, or participate in stories as their favorite characters.

Fig. 14 Picture of a child amazed by VR [17]

C. Mobile Application Benefits

SplashSim is an educational mobile app that can be used in and outside of the classroom. It effectively introduces students to the water cycle through a memorable and immersive experience. In the future, many apps similar to SplashSim can be created to target students of all ages. Difficult school subjects such as physics and chemistry can be taught through the use of VR simulations. The best part of using a mobile application is that it is very easy for students to download and learn. They do not have to go through a long process to download, and do not have to watch tutorials to understand. The applications themselves are very user friendly.

V. Conclusion

A. Summary

In the past few years, VR has mainly been used as an additional platform for playing games, from the HTC Vive to the Playstation VR. However, VR can be used in so many other ways. For example, it can be used in education to create a more immersive environment. The goal of SplashSim is to have the user feel immersed in the water cycle. They are in the point of view of a droplet of water as it goes through all the stages of the cycle. Rather than using videos or charts that are typically used to explain the water cycle, using VR allows the user to feel more personally connected with their surroundings and helps them learn more effectively. As educators begin to look for more interactive methods to help their students learn, SplashSim aims to spread the benefits of VR technology to provide students with the proper amount of immersion and learning that they need to prepare for the future.

B. Errors / Issues that Occurred

Throughout the course of the project, many technical problems occurred. For example, Unity's user interface had a high learning curve, and it took several days to get familiar with it. There were many times when additional Unity tutorials had to be watched. The Android SDK had problems integrating with Unity as well. Another problem was importing the Unity app onto an Android phone. Due to the fact that there is no ability to deploy a Unity project on iOS using PC, there was no other option but to use Android which only one group member had access to. There were also issues with the GoogleVR asset and deploying the scene with the art assets that were designed in Blender. All of these problems were solved by troubleshooting and testing, as well as using the demo scene that was included with the GoogleVR asset. These issues that occurred slowed down the process of creating the app because it was difficult to test and debug the simulation. The project had to be broken down into several components that would be easily tested separately, and through the use of GitHub, the numerous components had to be assembled together to create SplashSim. The problems that arose distinctively shaped the way SplashSim had to be created.

C. Future Improvements

In the future as the application continues to be developed, further sections can be added to make SplashSim more interactive and immersive for the user. For example, additional paths could be created which lead to other kinds of precipitation, such as hail and snow. This would allow the user to choose a path that could lead to different results. Another way to make SplashSim more interactive would be to implement buttons that could be clicked by the user through the conductivity button and could allow the player to move or make text appear.

Additionally, improvements could be made in adding detail to the environment of SplashSim. Small animals and sounds could be added into the simulation as well as higher quality graphics. Additionally, the interactive conductivity button can have more usages with a pause and start button as well as a menu. Adding a user interface into SplashSim would also make the application more welcoming to users. Lastly, incorporating narration into SplashSim would add an additional way to help users learn.

D. Future Applications and Discussion

In the future, the implementation of virtual technologies will continue to expand. An additional example of this can be seen through AR. It can be used as an extension to VR by creating a more immersive experience by incorporating the real world in simulations. As seen in figure 11, the *Microsoft Hololens,* which are AR glasses, adds an extra layer into the world through which additional information can be shown. SplashSim may be further developed by expanding its social impact and addressing important environmental issues concerning water. The simulation can discuss the implications of water pollution and teach people how to conserve water, thus expanding the target audience to adults as well. SplashSim already focuses on water, so incorporating pollution into the simulation could be simple to do, yet create a powerful message.

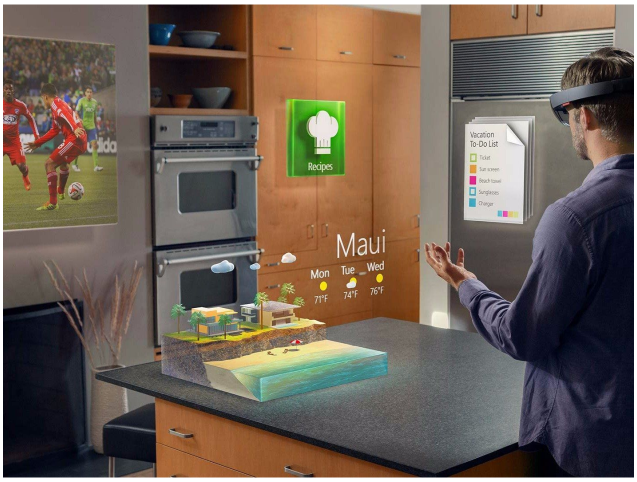

Fig. 15 Simulation of AR using Microsoft Hololens [11]

In addition to illustrating the water cycle, more simulations can be added, to demonstrate other uses for VR in education. For example, a simulation can be created that allows users to perform science experiments virtually. This would be helpful for students who do not have access to necessary laboratory materials, as they would no longer have to watch someone else perform a lab. Additionally, it would allow them to perform important but dangerous experiments that are not suitable for the classroom setting.

In addition to science, VR can also be extended to childhood literacy. A simulation could be created to insert the user in his/her favorite children's story, allowing him/her to interact with the characters and affect the outcome of the story. This simulation would not only be more interesting and immersive than reading a book, but it would still retain the education value of teaching a child basic language skills.

VI. Acknowledgements

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