Using Extended Reality Technology in Science Education

Iman Cumberbatch
School of Computing
Montclair State University
Montclair, NJ 07043
cumberbatci1@mail.montclair.edu

James Olatunji
School of Computing
Montclair State University
Montclair, NJ 07043
olatunjij1@mail.montclair.edu

Stefan A. Robila
School of Computing
Montclair State University
Montclair, NJ 07043
robilas@montclair.edu

2023 IEEE Long Island Systems, Applications and Technology Conference (LISAT) | 979-8-3503-1116-7/23/$31.00 ©2023 IEEE | DOI: 10.1109/LISAT58403.2023.10179579

Abstract— **Across all scientific fields, the amount of data generated continues to grow exponentially, which creates both opportunities and challenges. Increased availability allows for new insights into phenomena and stimulates discovery. While traditional ways of interacting with data have focused mostly on flat displays, Extended Reality (XR) technologies have the potential to transform the way both research and education are done. They provide an immersive and interactive experience that allows participants to visualize and interact with data while also working collaboratively. In this paper, the research and development of immersive educational 3D visualization tools aligned with several science drivers including environmental science and sustainability and life sciences is described. Specifically, the development of two XR applications is discussed with emphasis on the innovative mechanisms introduced using head-mounted display technologies. Preliminary results from the prototype applications indicate that the use of the XR technologies significantly expands the visualization ability by integrating additional data sources and improving the user's experience.**

Keywords- modeling, science education, sustainability, virtual reality

I. Introduction

Across all scientific fields, the amount of data generated continues to grow exponentially, which creates both opportunities and challenges. Increased data availability allows for new insights into phenomena and stimulates discovery. Conversely, growth in data renders many traditional processing approaches obsolete [1]. Visualization of large data through traditional means is particularly challenging, as it continues its transformation from mostly a presentation to an exploration tool [2].

Recent decades also coincide with significant efforts to engage those viewing data and captivating it in an immersive manner, especially through Cave Automatic Virtual Environment (CAVE). CAVEs are virtual environments that provide immersive stereoscopic displays using multiple projections, wraparound screens, head tracking, and shutter glasses [3]. While such systems have supported scientific advances, they also had significant limitations. The cost of creating a CAVE system was high, with the need for a space, multiple projectors, proper lighting, and tracking cameras. Once a CAVE system was set up, it was difficult to disassemble and relocate the system. There also came the issue of simultaneous users within a CAVE system because immersion was broken for anyone other than the person being tracked by the tracking cameras [4].

With the growing availability of XR devices, the chances of another breakthrough in data visualization are high [5]. Oculus technology, produced by Meta, has advanced to the point of creating standalone devices that do not require support to be a fully functional, 6 degrees-of-freedom virtual reality (VR) experience [6]. Recent results have shown that XR technology can be used to build scientific data visualization environments that integrate data and instruments [7]. From this, Oculus VR platforms were shown to be both versatile and inclusive to novice users.

While the use of VR technology continues to grow in both commercial and academic sensing, the value brought on by it for educational activities is still being evaluated. In this paper, we describe the research and development of immersive educational 3D visualization tools aligned with several science drivers including sustainability and life sciences. The paper is organized as follows: Section II describes the current XR technology, Section III describes the development and evaluation of XR applications for sustainability and environmental science, Section IV presents our preliminary work on developing XR applications for life science education, and a Discussion and Future Works section followed by references to conclude the paper.

II. Extended Reality Visualization

XR refers to a class of immersive technologies that offer users digital experiences that are either virtual or combine virtual and real components. XR can be further divided into terms Virtual Reality (VR) or Augmented Reality (AR) [8]. XR heavily relies on advances in visualization and the development of mobile displays such as tablets, phones, and, more recently, headsets. The ability of current devices to combine information display and rendering, spatial information, virtual content and tools, user and device position, and provide spatial sound leads to a Mixed Reality environment where digital and real fully converge [9].

At the heart of XR is the head mounted display (HMD) sets (see Figure 1) [10]. At the basic level, HMDs are simply displays with limited to no sensing capability. Low cost efforts were proposed, like using off-the-shelf smartphones with a mounting device (some created from DIY kits [11]). Advanced solutions include the Oculus Quest from Meta [12] or the HoLolens from Microsoft [13]. Said devices are capable of beyond the display, eye tracking, and motion tracking sensors. In addition, hand-held input devices help users to interact with the environment from simple remotes to more complex haptic devices that can provide tactile feedback adjusted to a user's reaction. Additional sensing can be provided by devices in the environment, such as imaging or radar. The XR environment is further expanded with see-through HMDs where the virtual rendering can be over-imposed on a live image of the participant's environment. Finally, the HMDs may be tethered or untethered. Tethered HMDs take advantage of the computational and storage power available in stationary computer systems, while untethered HMDs provide increased movement autonomy at the expense of reduced compute capacity.

Design and manufacturing of XR technologies continues to evolve. A discussion of the current research directions on the VR design is beyond the scope of this paper. Such discussion can be found in [14].

III. XR FOR ENVIRONMENTAL SCIENCE EDUCATION

A. *Environmental Science Research and Education*

As society continues to evolve, we begin to see advancements in the way technology is developed to understand and retain information efficiently. Environmental data can represent a range of information like viewing current weather forecasts, census tracts for demographic and income data, and researching the number of parks nearby to identify the best walkable cities to live in. Data cleaning, which organizes and visualizes spreadsheets of emissions data that an organization can contribute to, prediction analysis, which identifies which areas may be at risk based on frequent environmental patterns, and calculating an apartment's distance from green space are all examples of environmental analytics. These analyses apply to real-world experiences and have the benefit of building off conventional methods of technology that are most ordinarily used today.

Urban vegetation encompasses the plants and trees that coexist with urban cities. Green space in urban areas is extremely important not only to the environment but to the citizens as well [15]. Trees reduce the number of air pollutants, block winds by reducing energy, and cool the atmosphere [16]. As environmental disasters and occurrences tend to increase, the more you see a pattern in the way trees let go of their health, and growth and make themselves more susceptible to stress. Extreme environmental occurrences not only leave an effect on tree growth but can also have an impact on the way residents within the areas reach green space [17].

Figure 1. VR Head Mounted Display (Photo: Sergeant Rupert Frere RLC/MOD, OGL v1.0) [18].

While environmental data can be displayed in a static form, with the connection of interactivity, users can be guided to persuasively read and understand extreme disasters.

XR technologies allow traditional data visualizations; which are traditionally displayed in [14]charts and graphs, to connect environmental data in an increased interactive fashion. In education, a student's method in which they apply what they're learning can vary. Currently, there are 4 main learning styles; Visual, Auditory/Aural, Read/Write, and Kinesthetic [19]. Although many students may have a clear concept of the methods, they use to retain information, understanding your specific learning style can be an important way to improve the navigation information efficiently. Integrating technology into various learning styles can help promote efficient understanding of different course materials effectively.

Visual learners typically learn through the sense of sight, and data visualization tools such as graphs, maps, and diagrams are essential ways to translate information for visual learners. Auditory/Aural learners usually learn by listening to lectures, video tutorials, and people speaking the information out loud. Learners of Read/Write frequently learn by reading and taking notes. Lastly, kinesthetic learners typically acquire knowledge through interactive learning and physical activity. For an individual, understanding your particular learning style can be fundamental in any case, it doesn't need to be obliged to the one of their enjoying.

Learning styles can vary in XR. It is a method where users can virtually interact, read, write, and even communicate. There are a lot of environmental terms and systems that students of environmental science must understand in an educational setting, especially in environmental science. These systems can have the space to become more interactive with communication, the ability to adjust and switch between data sets and environments, and the tools necessary for students to closely connect with real-world environmental issues with the environmental XR tool.

The XR environmental tool can incorporate capabilities for multiple users with the help of these factors. The tool can encourage interactive labs and lectures, fostering a sense of community and enabling students to converse during lectures. In addition, students will have the advantage of navigating and exploring locations like New Jersey, where certain areas are affected by deforestation and extreme heat and that they may not have access to in real life when learning about environmental issues in particular locations. Additionally, this may support the student's need to act and comprehend significant environmental science issues.

B. Methods

An XR environmental tool was developed as a mechanism to study how data is currently visualized and work to introduce and design ways to understand data and environmental issues with enhanced user participation. The goal of this activity was to fully simulate the appearance of deforestation in urban environments by making use of geospatial data from open data websites in urban cities like Jersey City, New Jersey, and New York City, New York, and a suburban city in New Jersey, Montclair. Utilizing geospatial data from New Jersey and New York's open data websites the study was able to fully execute a simulation of what vegetation and deforestation could look like in urban environments and compare the lack or abundance of vegetation to suburban areas.

To build the geospatial environment in Unity the data needed to be locationally accurate. ArcGIS Maps SDK for Unity is an API that provides the tool to visualize 3D maps and view them in Unity to execute the implementation effectively [20]. Each location and 3D model was developed in ArcGIS Pro and uploaded into the High-Definition Render Pipeline (HDRP) Unity with the C# API [21]. To successfully display vegetation city-wide, the system needed stability to display high-end graphics. HDRP holds large datasets with strong lighting and graphic techniques and to use this, a PC system that can strongly work with these graphics and the software that it holds is imperative to have. Additionally, the ArcGIS with Unity API uses draw calls to build a 2-D base map, this is placed as a reference to build 3D models. (See Figure 2).

The HDRP 3-D models of trees developed in ArcGIS Pro is a data visualization derived from existing data sets. To view the dataset in a 3D form, the dataset needed to be transformed to view the tree's actual height. With the Extrude Features tool in ArcGIS Pro, it was possible to create objects from the depth and dimension features of the tree datasets. This allowed the project to be versatile when it comes to different shapes and identifying the most realistic model to mimic the shape of a city tree (see Figure 3).

The datasets for green space were obtained from Jersey City and New York City Open Data websites [22]–[25]. Regions that were not found on the datasheet were identified as missing data. The missing datasets needed to be visualized in other green space parks, football fields, gardens, and public yards with grass to complete the environment.

To replicate the downloaded spaces, these were traced manually using the Digitizing Tool in ArcGIS Pro (see Figure 3). After each dataset was created, it was transferred to the Oculus Quest 2 headset for viewing.

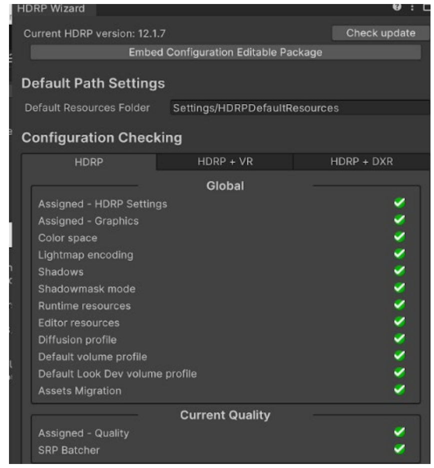

Figure 2. HDRP Wizard Displaying Available Tools for Lighting in Unity

Figure 3. Displaying Jersey City Green Space Identified with Given Dataset and Missing Data not Identified with Given Dataset

Figure 4. 3-D Model of Trees in Jersey City from a Birds Eye View

C. Results

When displaying the results, the primary focus was to build an interactive simulation that could emulate Jersey City, the Borough of Harlem in New York City, and Montclair's current worldview while bringing attention to deforestation-related environmental issues. The study identified both urban and suburban areas to understand data and also transform the way users view conventional methods of data visualization that might be attached to static graphs.

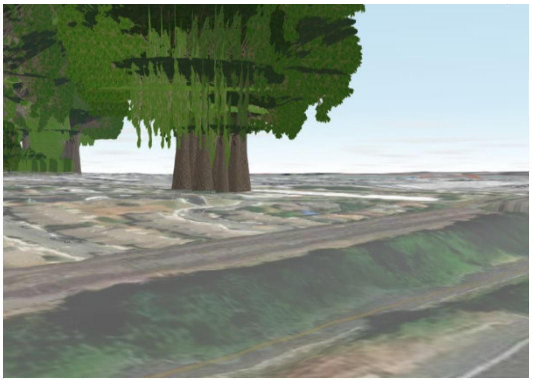

Figure 5. Close Up View of Public Trees in Jersey City with Satellite BaseMap

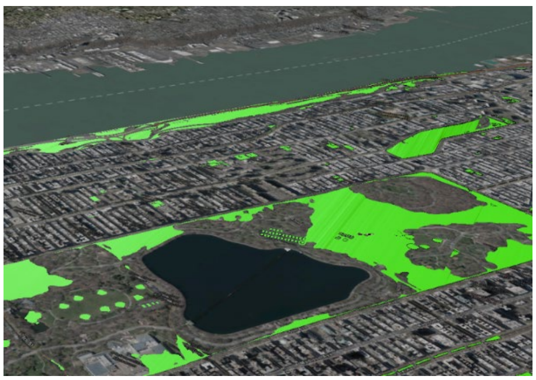

Figure 6. Birds Eye View of New York City's Green Space and Trees

The development demonstrated that it indeed is possible to create an immersive experience where data is reconstructed into objects (see Figure 4). This opens doors for different ways to spread awareness about environmental issues and obtain information kinesthetically. Within the headset, a user will be able to view 3-Dimensional data at a large scale from a bird's eye view or eye level (see Figures 5 and 6).

Additionally, students studying environmental issues can use this interactive tool to engage their visual and kinesthetic learning styles through environmental science. The student will be able to tangibly work with the dataset by manually evaluating each column and row that stores the data when a green space or tree is selected, thereby familiarizing themselves with real-world spatial locations and kinesthetic and visual learning. With this, students will be able to examine large and small amounts of vegetation to discover connections between lack of vegetation, abundance, and the overall health of trees. With extended reality, this study will also offer an interdisciplinary approach to the way students can collaborate in the use of technology and environmental systems to obtain information. The suburban and urban focus areas offer a different perspective on how the community is built and cared for. To effectively concentrate on each component in the XR, each environment can be viewed separately.

IV. XR USE IN LIFE SCIENCE EDUCATION

A. Life Science Research and Education

XR technologies have the potential to transform how students learn in the field of life sciences. Traditional methods of learning such as lectures and textbooks can often be abstract and difficult to understand for students, especially when dealing with complex structures and processes. However, XR technologies provide an immersive and interactive experience that allows students to visualize and interact with these structures in a way that is not possible with traditional methods of learning. As an example, in a recent study, an AR application focused on Physics topics and skills was shown to significantly improve the student's understanding of the concepts [26].

One of the ways XR technologies are being implemented in life science education is through visual simulations and modeling of various concepts such as cells, compounds, tissues, muscles, or skeletal structures. These simulations provide an immersive experience that allows students and professionals to visualize and manipulate complex biological structures and processes. AR also allows students to practice complex procedures without needing access to real-life environments: In a recent study, the retrospective engagement survey, psychological tests, and composite neuroimaging did not reveal any significant differences between pre-service teachers that learned topics in real-life situations vs VR simulations [27]. Similarly, most surgical planning tools offer 3D renderings made from image data. This enables the doctors to comprehend intricate interior architecture, identify concern areas, and boost their confidence. The use of virtual reality (VR) has developed in recent years, to the point that it can now be utilized to provide visuals and interactivity for planning sophisticated medical cases more effectively and quickly than desktop-based methods. Studies have shown that doctors who used the VR simulation had a better understanding of the structure and function of the liver compared to those who learned through traditional methods [28].

Furthermore, XR technologies are used as a tool in life science education with augmented reality. By superimposing digital information over the physical world, augmented reality gives students a more engaged and interesting learning experience. [29]. VR was also used to teach students about the human skeletal system. An application was developed to provide students with an interactive experience where they could scan their bodies and view the skeletal system overlaid onto their bodies. The study found that the use of the augmented reality app improved student engagement and knowledge retention [30].

Mixed reality is also being used in life science education to provide students with an interactive and immersive learning experience. To make learning more realistic and interesting, mixed reality integrates features of both virtual and augmented reality. According to a recent study, using immersive virtual reality laboratory simulations in students' science classes, enhanced their engagement and sense of efficacy. [31].

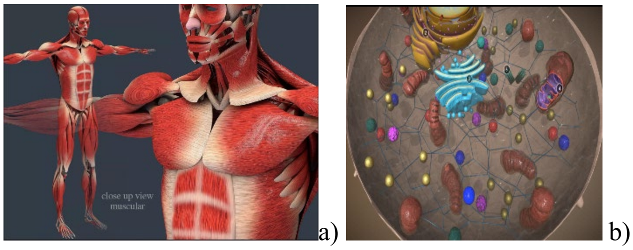

Figure 7. Assets available for Life Science Education within the Unity store a) Human anatomy [32] b) plant cell [33]

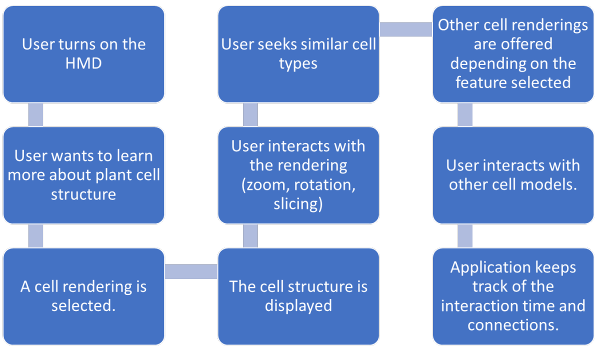

Figure 8. Scenario for user interaction with an XR application in life sciences

B. Methods

Unity and the C# programming language are currently being used to develop a prototype for the use of XR in life science education. The application would present the data from the virtual point of view of the user. Users were able to learn about anatomy and the human body in this educational setting. Users could effectively digest information and retain it for longer periods by doing this.

The application uses assets available at the Unity store (see Figure 7). Figure 8 provides a use-case scenario for the application. In the first step, the user turns on the HMD (in this case, an Oculus Quest system). They would then select a specific concept to investigate (say a cell structure). The XR environment allows the user to interact with the cell model by zooming, rotating, and slicing. In subsequent steps, the user would be able to select a specific component of the cell model and search for other types of cells that share similar components. To better assist the learner, the application will keep track of the time spent and also of the connections made by the user among the various cell models. This data can also be used to infer the best learning strategies as they allow the application to construct a learner model specific to the user.

C. Results

By providing students with a three-dimensional learning environment, XR technologies offer a more comprehensive understanding of the subject matter. With the ability to interact with virtual models and manipulate them in real-time, students can gain a deeper understanding of how biological systems function. It has been demonstrated that students are more engaged and better able to remember information when they have a hands-on learning experience like this one, which can help them perform better and gain a deeper understanding of the material.

The potential for XR technologies to change the area is obvious, even though their use in life science education is still in its early phases. As the technologies continue to evolve and become more accessible, they will likely become an increasingly important part of the life science education landscape. The use of XR technologies has the potential to transform how students learn and to enhance the overall quality of life science education. It is an exciting time to be a student in this field, as the possibilities for learning and discovery are endless.

V. Discussion and Future Work

Interest in XR continues to grow in both the commercial world and the broader society. Head-mounted displays and other XR technologies are essential to the immersive experience offered by current Metaverse systems. [34], or Roblox [35]. Beyond its commercial appeal, XR can also play a significant role in revolutionizing education by providing real-life environments otherwise not accessible to learners as well as facilitating interaction among participants that are not in physical proximity.

To support the rising need for accessible learning in STEM, the study carried out a range of simulations that are immersive and engaging to the educational experience using XR. It focused on data visualization and developing a spatial and healthy environment to allow users to understand urban deforestation, human anatomy, and cells. With the continued development of XR technology, these tools can become an essential part of education with the way curriculums are formed as technology continues to grow. The tools have already demonstrated the value of XR technologies for education, even though they are still in the prototype stage. Testing in the classroom and validation through interviews with educational and domain experts will be part of future work. Additionally, technological advancements will be made, with an emphasis on increasing resolution and including additional Unity assets.

The XR tools used in environmental science and life science both emphasize integrative learning practices in various fields to create a tool that can be used in any field. The incorporation of XR technologies in education has opened a new realm of possibilities for students across various disciplines, and the field of life and environmental sciences.

Environmental science and life science can work together with technology to focus on combining visual and kinesthetic learning with extended reality to create a new and innovative learning experience. By identifying each model in front of them, students can connect with what they are learning and apply it to the way they retain information. Both tools can be used as a guided example to replicate the way data visualization is generally displayed. In an immersive and interactive setting, students can learn about intricate processes and structures of reality efficiently. Therefore, there are numerous advantages to incorporating XR technologies into life and environmental science education.

ACKNOWLEDGMENT

James Olatunji's work was supported by the Garden State – LSAMP Program. Iman Cumberbatch's work was supported through a PRELS supplement by the same program. Both components were funded by the National Science Foundation. Stefan Robila acknowledges support by the Montclair State University's Faculty Scholarship Program. Compute access was provided with funding from Montclair State University's College of Science and Mathematics. The authors also thank Dr. Amy Ferdinand, Dr. Dirk Vanderklein, and MSU Biology Students that have built and shared the tree data set for Montclair (used in this study).

REFERENCES

[1] P. Fox and J. Hendler, "Changing the equation on scientific data visualization," *Science*, vol. 331, no. 6018, pp. 705–708, 2011.

[2] G. J. McInerny *et al.*, "Information visualisation for science and policy: engaging users and avoiding bias," *Trends Ecol. Evol.*, vol. 29, no. 3, pp. 148–157, 2014.

[3] S. Manjrekar, S. Sandilya, D. Bhosale, S. Kanchi, A. Pitkar, and M. Gondhalekar, "CAVE: an emerging immersive technology--a review," in *2014 uksim-amss 16th international conference on computer modelling and simulation*, IEEE, 2014, pp. 131–136.

[4] T. W. Kuhlen and B. Hentschel, "Quo vadis CAVE: does immersive visualization still matter?," *IEEE Comput. Graph. Appl.*, vol. 34, no. 5, pp. 14–21, 2014.

[5] G. Atanasov, "Head-Mounted AR/VR For Human Realistic 3-D Data Visualization," *Telerik AR VR*, Dec. 07, 2018. https://medium.com/telerik-ar-vr/head-mounted-ar-vr-for-human-realistic-3-d-data-visualization-40f570a8a363 (accessed Mar. 04, 2023).

[6] J. W. Kelly, T. A. Doty, M. Ambourn, and L. A. Cherep, "Distance perception in the oculus quest and oculus quest 2," *Front. Virtual Real.*, vol. 3, p. 27, 2022.

[7] J. L. Kline and P. L. Volegov, "Toward 3D data visualization using virtual reality tools," *Rev. Sci. Instrum.*, vol. 92, no. 3, p. 033528, 2021.

[8] B. Marr, "What Is Extended Reality Technology? A Simple Explanation For Anyone," *Forbes*. https://www.forbes.com/sites/bernardmarr/2019/08/12/what-is-extended-reality-technology-a-simple-explanation-for-anyone/ (accessed Mar. 04, 2023).

[9] qianw211, "What is mixed reality? - Mixed Reality," Jan. 25, 2023. https://learn.microsoft.com/en-us/windows/mixed-reality/discover/mixed-reality (accessed Mar. 05, 2023).

[10] S.-M. Park and Y.-G. Kim, "A metaverse: taxonomy, components, applications, and open challenges," *IEEE Access*, vol. 10, pp. 4209–4251, 2022.

[11] "Google Cardboard – Google VR." https://arvr.google.com/cardboard/ (accessed Mar. 05, 2023).

[12] "Meta Quest 2: Immersive All-In-One VR Headset | Meta Store." https://www.meta.com/quest/products/quest-2/ (accessed Mar. 05, 2023).

[13] "Microsoft HoloLens | Mixed Reality Technology for Business." https://www.microsoft.com/en-us/hololens (accessed Mar. 05, 2023).

[14] V. Angelov, E. Petkov, G. Shipkovenski, and T. Kalushkov, "Modern virtual reality headsets," in *2020 International congress on human-computer interaction, optimization and robotic applications (HORA)*, IEEE, 2020, pp. 1–5.

[15] A. Arnberger and R. Eder, "The influence of green space on community attachment of urban and suburban residents," *Urban For. Urban Green.*, vol. 11, no. 1, pp. 41–49, 2012.

[16] D. J. Nowak, P. J. McHale, M. Ibarra, D. Crane, J. C. Stevens, and C. J. Luley, "Modeling the effects of urban vegetation on air pollution," *Air Pollut. Model. Its Appl. XII*, pp. 399–407, 1998.

[17] R. Juknys *et al.*, "Dynamic response of tree growth to changing environmental pollution," *Eur. J. For. Res.*, vol. 133, pp. 713–724, 2014.

[18] S. R. F. RLC, *English: A Reservist soldier demonstrating a virtual reality headset.* 2015. Accessed: Mar. 05, 2023. [Online]. Available: https://commons.wikimedia.org/wiki/File:Soldier_Using_Virtual_Reality_Headset_MOD_45158483.jpg

[19] N. A. Chaudhry, A. Ashar, and S. A. Ahmad, "Association of Visual, Aural, Read/Wite, And Kinesthetic (VARK) learning styles and academic performances of dental students," *Pak. Armed Forces Med. J.*, vol. 70, no. Suppl-1, pp. S58-63, 2020.

[20] "ArcGIS Maps SDK for Unity | ArcGIS Developers," *ArcGIS Maps SDK for Unity*. https://developers.arcgis.com/unity/ (accessed Mar. 05, 2023).

[21] "High Definition Render Pipeline overview | High Definition RP | 16.0.0." https://docs.unity3d.com/Packages/com.unity.render-pipelines.high-definition@16.0/manual/index.html (accessed Mar. 05, 2023).

[22] "2015 Street Tree Census - Tree Data," *NYC Open Data*. https://data.cityofnewyork.us/Environment/2015-Street-Tree-Census-Tree-Data/pi5s-9p35 (accessed Mar. 05, 2023).

[23] "2021 Tree Inventory." https://data.jerseycitynj.gov/explore/dataset/2021-tree-inventory/information/ (accessed Mar. 05, 2023).

[24] "Jersey City Parks." https://data.jerseycitynj.gov/explore/dataset/jersey-city-parks-map/api/?disjunctive.park (accessed Mar. 05, 2023).

[25] "Green Spaces," *NYC Open Data*. https://data.cityofnewyork.us/Recreation/Green-Spaces/mwfu-376i (accessed Mar. 05, 2023).

[26] F. C. Wibowo, "Effects of Augmented Reality Integration (ARI) based Model Physics Independent Learning (MPIL) for facilitating 21st-century skills (21-CS)," *JOTSE*, vol. 13, no. 1, pp. 178–192, 2023.

[27] R. Lamb and E. A. Etopio, "Virtual reality: A tool for preservice science teachers to put theory into practice," *J. Sci. Educ. Technol.*, vol. 29, pp. 573–585, 2020.

[28] D. Wang, D. Ma, M. L. Wong, and Y. X. J. Wáng, "Recent advances in surgical planning & navigation for tumor biopsy and resection," *Quant. Imaging Med. Surg.*, vol. 5, no. 5, p. 640, 2015.

[29] M. Akçayır and G. Akçayır, "Advantages and challenges associated with augmented reality for education: A systematic review of the literature," *Educ. Res. Rev.*, vol. 20, pp. 1–11, 2017.

[30] M. El Kouzi, A. Mao, and D. Zambrano, "An educational augmented reality application for elementary school students focusing on the human skeletal system," in *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, IEEE, 2019, pp. 1594–1599.

[31] G. Makransky, G. B. Petersen, and S. Klingenberg, "Can an immersive virtual reality simulation increase students' interest and career aspirations in science?," *Br. J. Educ. Technol.*, vol. 51, no. 6, pp. 2079–2097, 2020.

[32] "Human Male Anatomy | Characters | Unity Asset Store." https://assetstore.unity.com/packages/3d/characters/humanoids/humans/human-male-anatomy-195418 (accessed Mar. 05, 2023).

[33] "Biology Cells Pack | 3D | Unity Asset Store." https://assetstore.unity.com/packages/3d/biology-cells-pack-97118 (accessed Mar. 05, 2023).

[34] "The Metaverse is the Future of Digital Connection | Meta." https://about.meta.com/metaverse/ (accessed Mar. 05, 2023).

[35] "The role of Roblox in the metaverse," *Internet Matters*, Aug. 05, 2022. https://www.internetmatters.org/hub/news-blogs/the-role-of-roblox-in-the-metaverse/ (accessed Mar. 05, 2023).