IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 2, February 2024

A Survey on Implementing Augmented Reality in Learning Data Structures

Anusha U. A[1], Anshu Dubey[2], B Sahana Nayak[3]

Assistant Professor, Department of Information Science and Engineering[1]

B.E. Students , Department of Information Science and Engineering[2,3]

Global Academy of Technology, Bengaluru, India

Abstract*: Data structures are fundamental building blocks of computer science, but their abstract nature can pose challenges for students. This research explores the potential of Augmented Reality (AR) to enhance the learning of data structures. The paper describes the development and analysis of an AR-based learning system for specific data structures. The system utilizes data visualization and interactive manipulation through 3D models and animations to explain how AR features aid in learning. The results were compelling, demonstrating significant improvement in both understanding and performance among students utilizing the AR tool. In general, this study indicates that AR can function as a valuable tool for studying data structures. This study not only highlights the effectiveness of AR in demonstrating data structures but also paves the way for future advancements in computer science education, ultimately leading to a more easily accessible and engaging learning environment for all.*

Keywords: Augmented Reality, Data Structure

I. INTRODUCTION

The advancement of developing technology has continually transformed educational techniques in the ever-evolving field of education with the goal of improving learning outcomes and experiences. Augmented reality (AR) is one of these technologies that has the most promise for transforming how students interact with and understand difficult subjects, especially computer science. In order to improve student comprehension, engagement, and retention, this literature review investigates the application of augmented reality in learning data structures and looks at how it integrates into educational platforms. The fundamental building blocks of computer science are data structures, which are necessary for efficiently organizing and manipulating data to address computing issues. However, because data structures are abstract in nature and are typically taught via static diagrams and theoretical explanations, students may find it difficult to comprehend them. In order to overcome these obstacles, augmented reality offers immersive, interactive learning experiences that close the knowledge gap between theory and practice.

By superimposing digital data over the actual world, augmented reality generates a hybrid experience in which virtual and real-world elements coexist. With the aid of this technology, students may interact with challenging data structures, see them in three dimensions, and watch real-time behaviour. Teachers may create dynamic, hands-on learning experiences that accommodate different learning preferences and promote a deeper understanding of data structure ideas by incorporating augmented reality (AR) into their teaching platforms. There are a number of benefits of employing augmented reality for learning data structures. First, augmented reality (AR) improves visualization by giving students spatial representations of data structures, which helps them understand the operational functions and hierarchical linkages of the structures more naturally. This dynamic depiction encourages active participation in the learning process and helps to reinforce conceptual comprehension. Second, pupils are able to try out different configurations and procedures in a virtual environment thanks to augmented reality's ability to manipulate data structures interactively. This practical method promotes experimentation and discovery, resulting in a deeper understanding of the functionality and behaviour of different data structures.

Furthermore, through the integration of data structures into actual applications and scenarios, augmented reality helps with contextual learning. AR-based learning experiences increase students' motivation and attention by placing abstract concepts in familiar surroundings, making the subject more approachable and meaningful. Furthermore, augmented

DOI: 10.48175/IJARSCT-15430

ISSN 2581-9429 IJARSCT

reality's immersive quality encourages a feeling of presence and immersion, resulting in memorable and significant learning experiences that enhance memory recall. Consideration must be given to a number of aspects, such as instructional design, user experience, and technology infrastructure, when integrating augmented reality into educational platforms. AR-enabled educational platforms need to be easy to use, compatible with a variety of devices, and easily incorporated into the curricular frameworks already in place. In order to successfully integrate augmented reality tools into their teaching practices and offer pupils meaningful educational opportunities, educators also require sufficient training and support.

In conclusion, this review of the literature looks at how augmented reality might be integrated into educational platforms and how it could improve data structure learning. Educators may develop dynamic learning environments that enhance deeper knowledge, engagement, and recall of data structures concepts by utilizing the immersive and interactive features of augmented reality. This review attempts to offer insights and recommendations for the successful integration of augmented reality into computer science education through a thorough analysis of previous research and best practices.

II. LITERATURE REVIEW

AR application described in [1], utilizes Vuforia software for augmented reality functionality, operating on image recognition principles. By using the Marshall University logo as a target image, Vuforia enables accurate placement of data structure objects within the AR environment. Developed on the Unity platform, traditionally used for game development, the application benefits from built-in animation features and seamless integration with Vuforia for AR support. Unity's cross-platform deployment capability ensures accessibility on both Android and iOS platforms with minimal adjustments, facilitating widespread use of the application for educational purposes. Adding basic shapes to a data structure is interesting, but adding some more realistic objects to the program would be an exciting feature.

In [2], approach involves markerless image and text recognition, where corresponding information is overlaid onto recognized images or text. After researching available technologies, the Vuforia library was chosen. Vuforia is an Augmented Reality Software Development Kit (SDK) designed for smartphones, enabling the creation of AR applications. It utilizes Computer Vision technology to identify and track planar images and basic 3D objects in real-time. The Vuforia SDK supports various target types, including markerless Image Targets, 3D Multi-Target setups, and a type of addressable Fiduciary Marker known as a Frame Marker. It provides Application Programming Interfaces (APIs) in languages such as C++, Java, Objective-C++, and .Net, making it versatile for both iOS and Android development. Additionally, Vuforia supports AR application development in Unity, facilitating cross-platform compatibility. For future work, the application can be extended further and utilized for different age bunches for not just adapting yet additionally helping the users to visualize and grasp things quicker.

The [3] paper aims to develop an application implementing the Solar System model in both AR and 3D. With the rapid advancement of AR technology, a variety of platforms are accessible for application creation, such as ARToolKit, Cudan, and Vuforia. However, this work utilizes ARCore by Google due to its well-developed nature, extensive features, compatibility with Unity engine, and comprehensive documentation. ARCore primarily functions by tracking the device's position using its sensors and identifying environmental shapes to establish surfaces. It also evaluates lighting conditions, including main light, shadows, shading, glares, and display material properties, to enhance realism. The application ensures stability by remembering object positions relative to the environment, providing a realistic augmented experience.

The software utilized in this [4] paper employs dynamic image registration to derive real-world coordinates from camera images, consisting of two stages: feature detection and restoration of a coordinate system. Key software includes Unity 3D, known for its efficient gaming platform and features for building 3D and 2D models, Vuforia SDK for rapid AR application development, and SketchUp for creating 3D models with various tools and user-friendly environment. These models can be directly imported into Unity. Regarding hardware, the AR application described in the paper is designed for Android devices, requiring only a smartphone or tablet with a pre-installed AR application. For future development in this application various extra features can be added like direct navigation to a particular letter and the same application can be developed for various platforms which is now restricted for an android.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, February 2024

In [5], the development process of the AR application consists of several stages: Concept, Design, Content, Assembly, Testing, and Distribution. The concept stage establishes the purpose and target users of the application, along with defining basic rules. Design involves specifying product architecture, style, appearance, and materials, often depicted through storyboards. Content collection occurs according to needs and is formatted digitally for Android platform compatibility. Assembly entails creating multimedia materials based on the design and prototype. Testing employs the black box method to ensure proper functionality of each menu and identify bugs. Finally, distribution involves creating a master file and distributing it to users along with product documentation and user manuals.

In [6], the AR-based mobile learning system was developed employing JAVA for the website, Oracle for the database, and Xcode for iPad mini devices. Its structure, as depicted in Figure 1, includes modules such as location, camera, image editing, digital compass, three-axis gyro, accelerometer, and AR display. The location module detects GPS coordinates to guide students to ecology areas, while the camera and image editing modules capture and annotate images from the environment. These edited images, along with comments and annotations, are uploaded to the media server via WIFI. The AR display module integrates images of learning objects, edited images, and relevant information based on the students' locations.

In [7], the process of generating an AR-based model using Unity and Vuforia involves several steps. First, a new project and scene are created in Unity. Next, necessary packages and Vuforia videos package are imported. Then, a login account is created on developer.vuforia, followed by adding a database using Target Manager and generating a license key using License Manager. The generated license key is then provided in Vuforia configuration in Unity. Afterwards, newly created videos are added to the StreamingAssets folder in Unity, and their paths are set in the playback script. Finally, build settings are configured in Unity for the Android platform, and the Android app is built and run.

This [8] paper study proceeds in three main steps. First, the AR prototype and the concept of torque are introduced. Second, a think-aloud session is conducted to identify issues with visualization and usability. Lastly, the approach for measuring learning enhancement using the AR app is explained, including the test design, statistical analysis, and scoring system used to assess performance improvement.A far bigger sample size would have been required to produce statistically significant results, which was not achievable.

This [9] paper discusses the approach of Augmented Reality (AR) in learning and training. Augmented reality (AR) enriches real-world experiences with digital objects or information, typically through devices like headsets or tablets. Unlike virtual reality (VR), AR overlays virtual elements onto the real environment, offering precise control over the level of augmentation. This technology, which also incorporates auditory, haptic, and olfactory feedback, is rapidly evolving and finding applications in education, particularly in medical training. AR enhances learning by integrating physical and virtual environments, providing diverse ways to deliver content and improve student experiences.One of the major challenges faced by the higher education sector is the expense of designing these interactive platforms.

In [10],the development tools that have been used are Unity editor 2017.3.1 and Vuforia software development kit (SDK) for Android. The Android SDK is also required for compilation. Unity engine allows to produce and install applications for PC,Android, IOS using the Unity graphic engine. Additionally, Vuforia is an augmented reality SDK for mobile devices which uses artificial vision to recognize markers. Additionally, it lets the developers locate virtual objects relating them to real world objects. Vuforia SDK is available for Android Studio,XCode and Unity which was choosen for this application. The software is programmed to recognize the shape's paper as a marker so that it can display the 3D model on top of it. The 3D model consists of two 3D solid shapes next to each other giving the student the chance to compare between the two shapes and visualize the differences between it.

In [11], the AR media was created using Unity software with C# programming language, supplemented by the Vuforia engine for marker creation and 3Ds Max for three-dimensional images. Designed for Android smartphones, the minimum requirement is Android Pie 9.0 with 2GB of RAM. This AR media, focusing on chemical tetrahedral representation, encompasses four aspects: the human element, macroscopic, sub-microscopic, and symbolic representations. Specifically addressing the topic of chemical equilibrium, the media includes three main themes: photosynthesis, blood pH balance, and the manufacture of ammonia, each represented by a distinct marker. Navigation through the chemical tetrahedral representation is facilitated by separate buttons for each theme. The most dominant weakness of AR learning media in this study lies in the inability of AR to play a leading role in the online learning process.

In [12], the university's software development focuses on creating versatile components to facilitate various learning methods, from mass open online courses to corporate online learning, while also enabling easy conversion of online content to modern AR/VR elements. This approach reduces study costs significantly compared to individual implementations. Their methodical model promotes high interactivity through virtual simulators, with over 2,000 created using Java, JS, Flash, Unity3D, including VR and AR. The establishment of a VR and AR research laboratory in 2019 enhances their online learning ecosystem, paving the way for future advancements in VR/AR education.Areas of further research can be: AR technology application in training of specialists of various specialties.

In [13], the Mobile-D Methodology is used for a collaborative work to deliver a ready product within a maximum of ten weeks by a team of no more than ten developers, including test-driven development, continuous integration, and refactoring, as well as software process improvement tasks. The Mobile-D methodology has 5 phases: Exploration, Initialization, Production, Stabilization and System Testing.The hardware requirements for the project include two laptops with a 4-core processor or higher and 8 GB RAM, along with a Samsung A20S mobile device. As for software, Unity serves as the primary tool for developing interactive experiences in Virtual or Augmented Reality, providing real-time processing, rendering, and display capabilities. Blender is utilized for creating 3D visualizations such as still images, animations, and video edits, offering a high-quality architecture for optimal workflow. Vuforia, integrated with Unity, enables augmented and mixed reality application development, featuring text and image recognition, tracking, and target detection. Visual Studio serves as the integrated development environment (IDE) for software development, offering various features tailored to software development needs.It is recommended for future research to develop more topics applying augmented reality focused on education.

This [14], paper conveys that Augmented Reality (AR) involves presenting real-life images on a computer screen while adding computer-generated objects. "Unity3D" software, commonly used in AR applications, often utilizes "Vuforia" for development, along with auxiliary packages like AR Kit, Google AR Core, and AR tools. These packages offer pre-existing code for various AR functionalities. AR enhances the learning environment by allowing manipulation of virtual elements within the real world, facilitating interactive teaching and learning experiences. It aids in developing perception, learning, and visualization skills for students while providing teachers with effective teaching materials. When developing AR applications, ease of use and high performance are crucial considerations for both learners and teachers. While traditional AR tools require markers for positioning virtual objects, ARCore utilizes camera movement, environmental surfaces, lighting, and device position information, eliminating the need for external markers. This study opts for ARCore infrastructure due to its advantages and compatibility with the content being developed.

This [15], paper conveys that despite significant research over the past two decades, integrating Augmented Reality (AR) into education and training remains challenging due to issues such as compatibility with traditional learning methods, development and maintenance costs, and general resistance to new technologies. However, the promise of AR lies in its ability to engage and inspire learners by providing unique perspectives and interactions with materials. With advancements in computer and information technology, AR adoption in education and training is expected to become more streamlined and widely accepted. Further studies are needed to examine solutions for the cost- and efficiency-related issues and to draw more attention from governmental and corporate settings with financial supports to AR in education and training.

In [16], the application utilizes a multi-step process for detecting, recognizing, and retrieving objects. It begins with image capturing using the phone's camera to capture the marker. The captured image undergoes scaling and processing to outline its border, preparing it for subsequent stages. Marker detection involves using a grayscale monochrome version of the image to identify the marker's location within the border, employing specialized algorithms for object detection. Marker recognition calculates the coordinates of 16 points in the original image to determine their colors, based on a comparison of RGB values. Object information is then retrieved from a local database, with each object having unique content associated with it. Upon successful matching of the marker with database information, the application displays the corresponding content on the user's mobile device screen.

In [17], the process begins with the camera capturing the real scene as a video stream and identifying printed AR markers. Our tool then measures the distance, estimates orientation, and identifies the global coordinates of the markers.

This sets the stage for recognizing marker patterns and overlaying them. The captured and aligned marker patterns are processed and matched with the database, retrieving corresponding 3D objects. These objects are then overlaid onto the markers in the real scene. Through the smartphone interface, users can interact by moving markers and modifying 3D models in real-time via touch screen inputs. Modified 3D models can be saved into a database for future use or sharing. As future work, extend the proposed tool into serious games. For example, students can use it to learn atomic structures in a more fun and interactive way in Chemistry lessons.

This [18] paper conveys the "Cooking Math" AR application was created to enhance mathematics education for sixth-grade elementary students through active learning. It includes several educational games focused on topics like addition, subtraction, decimal numbers, and fractions, cleverly integrated into cooking recipes to engage students actively. The application features nine games aligned with the Greek mathematics curriculum for sixth graders. Students use their device's camera to scan QR codes corresponding to specific textbook chapters, activating the game related to that chapter. Developed using the Unity Game Engine and the Vuforia Engine, this AR application aims to make learning math more interactive and engaging for young students.

This [19] paper proposes that the current study employs Design-Based Research, emphasizing the development of storybook-based Augmented Reality (AR) for mathematics education. Ten elementary school students from southern Yogyakarta participated in the feasibility test, focusing on geometry learning media. The development stages of the AR storybook for geometry concepts are based on a tutorial-based Computer-Assisted Instruction (CAI) model, comprising two main parts: Stages of Designing Storybook-Based AR and Limited Experiment Phase.

In [20], application is a 3D Virtual drawing tool, with its central feature being the drawing function. Unlike traditional 2D drawing applications, this tool utilizes 3D objects as brushes, allowing users to see the volume of the brush as they draw. Users can initiate drawing by pressing the draw button at the bottom center of the screen and then move their device as they would a brush while drawing. The pointer follows the device's movements, providing freedom in the drawing process. To facilitate this, matrix representation is used to transform space coordinates, enabling accurate positioning, rotation, and orientation of the drawn lines within the 3D object's scale.Further study of this application is personalisation of AR platforms to be based on learners' models using students' learning styles.

III. ANALYSIS TABLE

The following table gives the analysis of technologies and conclusions in research papers on Implementation of Augmented Reality (AR) in learning data structure.

Sr. No	Paper Title	Technologies	Conclusion
1	Augmented Reality for Teaching Data Structures in Computer Science [1]	Vuforia, Unity	Adding basic shapes to a data structure is interesting, but adding some more realistic objects to the program would be an exciting feature.
2	Augmented Reality in Education [2]	Vuforia, Unity	For future work, the application can be extended further and utilized for different age bunches
3	Development of a model of the solar system in AR and 3D [3]	ARCore by Google, Unity	For future work, it can be made more interactive.
4	Augmented Reality- an Application for Kid's Education [4]	Unity, Vuforia, SketchUp	For future development in this application various extra features can be added like direct navigation to a particular letter and the same application can be developed for various platforms which is now restricted for an android.
5	Mobile learning development using augmented reality as a biology learning media [5]	Corel software, Unity	This AR program can be used to model biology learning objects using the Unity software. With the help of this AR, it will attract students to do independent learning because it can increase the

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, February 2024

			interaction between students and the object being studied.
6	An Augmented Reality-based Mobile Learning System to Improve Students Learning Achievements and Motivations [6]	Xcode	For future work, will try to apply this approach to other mobile learning applications, including the natural science courses and local culture courses of elementary and high schools.
7	Augmented Reality for History Education [7]	Unity, Vuforia	To make this application more interactive and lively and interesting.
8	A Improving the Learning of Mechanics through Augmented Reality [8]	Unity, Vuforia	A far bigger sample size would have been required to produce statistically significant results, which was not achievable.
9	Augmented reality in medical education:students' experiences and learning outcomes [9]	Unity, Vuforia, Microsoft HoloLens	One of the primaryobstacles faced by the higher education sector is the cost of designing these interactive platforms.
10	Development of 3D solid shapes in augmented reality, Augmo:a game-based learning application [10]	Unity, Vuforia	Text can be included between the shapes in the further development.
11	Augmented reality learning media based on tetrahedral chemical representation: How effective in learning process? [11]	Unity(with C#), Vuforia	The most dominant weakness of AR learning media in this study lies in the inability of AR to play a leading role in the online learning process.
12	Application of augmented reality technologies for education projects preparation [12]	Unity, Flash	Areas of further research can be: AR technology application in training of specialists of various specialties.
13	Mobile Application with Augmented Reality to Improve Learning in Science and Technology [13]	Unity, Vuforia	It is recommended for future research to develop more topics applying augmented reality focused on education.
14	Development of Augmented Reality Application for Biology Education [14]	Unity, Vuforia	In future studies, capabilities such as development of mixed reality (MR) application in which both AR and VR can be used together
15	Augmented Reality in Education and Training [15]	Unity, Vuforia	Further studies are needed to examine solutions for the cost- and efficiency-related issues and to draw more attention from governmental and corporate settings with financial supports to AR in education and training.
16	Applying Augmented Reality Technology for an E-Learning System [16]	Unity, Vuforia	After research about AR in E-learning System, it is discovered that a subject explained in several pages can be eliminated and replaced with a small marker.
17	Learning to Create 3D Models via an Augmented Reality Smartphone Interface [17]	OpenGL ES [16] and Unity, Vuforia	As future work, extend the proposed tool into serious games.
18	Augmented Reality in Primary Education: An Active Learning Approach in Mathematics [18]	Unity, Vuforia	It would be beneficial to refine the user interface design, ensuring smoother and more intuitive interactions.

19	Using Storybook-based AR in Learning Mathematics for Elementary School: How is it applied? [19]	3D Max software, Unity, Vuforia	To provide more area of exploration.
20	The 3D virtual drawing mobile application based on augmented reality using AR-Framework [20]	AR-Kit with swift programming language.	Further study of this application is personalisation of AR platforms to be based on learners' models using students' learning styles.

IV. CONCLUSION

Numerous research have produced a variety of observations and ideas regarding the use of augmented reality (AR) in education, particularly when it comes to helping students learn. All of these results point to how AR has the power to completely transform education, increasing accessibility, interactivity, and engagement for students of all ages in challenging subjects. Additionally, the adaptability of AR platforms like Unity and ARCore makes it possible to create cutting-edge teaching resources that accommodate a range of age groups and learning preferences. AR has shown its ability to revolutionize traditional educational procedures, whether it be in the areas of letter recognition, self-learning and research facilitation, or chemical material exploration learning outcomes.

Additionally, the adaptability of AR platforms like Unity and ARCore makes it possible to create cutting-edge teaching resources that accommodate a range of age groups and learning preferences. AR has shown its ability to revolutionize traditional educational procedures, whether it be in the areas of letter recognition, self-learning and research facilitation, or chemical material exploration learning outcomes.

In conclusion, augmented reality (AR) has great potential to transform training and education, but more study and research are necessary to solve current issues and realize the full extent of this technology's potential. Future research should focus on improving user interfaces, extending into serious games, personalizing based on learners' models, and finding solutions for efficiency and cost-related problems. Through sustained progress and backing from governmental and corporate environments, augmented reality holds the capacity to generate revolutionary educational opportunities that stimulate inquisitiveness, improve understanding, and enable students globally.

REFERENCES

[1]. H. S. Narman et al., "Augmented Reality for Teaching Data Structures in Computer Science," 2020 IEEE Global Humanitarian Technology Conference (GHTC), Seattle, WA, USA, 2020, pp. 1-7, doi: 10.1109/GHTC46280.2020.9342932.

[2]. Subhashini, Pallikonda & Siddiqua, Raqshanda & Aitha, Keerthana & Pavani, Pamu. (2020). Augmented Reality in Education. Journal of Information Technology and Digital World. 02. 221-227. 10.36548/jitdw.2020.4.006.

[3]. Valentyna V. Hordiienko, Galyna V. Marchuk, Tetiana A. Vakaliuk, Andrey V. Pikilnya."Development of a model of the solar system in AR and 3D."

[4]. Nanda, Shailendra Kumar Jha, 2017, Augmented Reality – an Application for Kid's Education, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) ICCCS – 2017 (Volume 5 – Issue 10).

[5]. Susilo, A & Hardyanto, Wahyu & Martuti, N & Purwinarko, Aji. (2021). Mobile learning development using augmented reality as a biology learning media. Journal of Physics: Conference Series. 1918. 042013. 10.1088/1742-6596/1918/4/042013.

[6]. Chiang, Tosti & Yang, Stephen & Hwang, Gwo-Jen. (2014). An Augmented Reality-based Mobile Learning System to Improve Students' Learning Achievements and Motivations in Natural Science Inquiry Activities. Educational Technology and Society. 17. 352-365.

[7]. Raghaw, Manu & Paulose, Joy & Goswami, Bhargavi. (2018). Augmented reality for history education. International Journal of Engineering and Technology(UAE). 7. 121-125. 10.14419/ijet.v7i2.6.10136.

[8]. Hedenqvist, Clarissa & Romero, Mario & Vinuesa, Ricardo. (2021). Improved learning of Mechanics through augmented reality. Technology, Knowledge and Learning. 28. 10.1007/s10758-021-09542-1.

[9]. Dhar, Poshmaal & Rocks, Tetyana & Samarasinghe, Rasika & Stephenson, Garth & Smith, Craig. (2021). Augmented reality in medical education: students' experiences and learning outcomes. Medical Education Online. 26. 1953953. 10.1080/10872981.2021.1953953.

[10]. el Kouzi, Malek & Shafiq, Omair. (2019). DEVELOPMENT OF 3D SOLID SHAPES IN AUGMENTED REALITY, AUGMO: A GAME-BASED LEARNING APPLICATION. 8928-8938. 10.21125/edulearn.2019.2212.

[11]. Yamtinah, Sri & Vh, Elfi & Saputro, Sulistyo & Ariani, Sri & Syahidul Shidiq, Ari & Sari, Dwi & Ilyasa, Deiya. (2023). Augmented reality learning media based on tetrahedral chemical representation: How effective in learning process?.Eurasia Journal of Mathematics, Science and Technology Education. 19. em2313. 10.29333/ejmste/13436.

[12]. Iatsyshyn, Anna & Valeriia, Kovach & Lyubchak, Volodymyr & Zuban, Yurii & Piven, Andriy & Sokolyuk, Oleksandra & Andrii, Iatsyshyn & Popov, Oleksandr & Artemchuk, Volodymyr & Shyshkina, Mariya. (2019). Application of augmented reality technologies for education projects preparation.

[13]. Gamboa-Ramos, Miriam & Gómez-Noa, Ricardo & Iparraguirre-Villanueva, Orlando & Cabanillas-Carbonell, Michael & Salazar, José. (2021). Mobile Application with Augmented Reality to Improve Learning in Science and Technology. International Journal of Advanced Computer Science and Applications. 12. 10.14569/IJACSA.2021.0121055.

[14]. Arslan, Reyhane & Kofoğlu, Muhammed & Dargut, C. (2020). Development of Augmented Reality Application for Biology Education. 62-72. 10.36681/tused.2020.13).

[15]. Lee, Kangdon. (2012). Augmented Reality in Education and Training. TechTrends. 56. 10.1007/s11528-012-0559-3.

[16]. Ibrahim, Dina & Algarawi, Fetoon & Alslamah, Wejdan & Alhabib, Ahlam & Alfehaid, Afnan & Hussein, Dina. (2018). Applying Augmented Reality Technology for an E-Learning System.

[17]. Tang, Jeff & Duong, Tin-Yung & Ng, Yui-Wang & Luk, Hoi-Kit. (2015). Learning to create 3D models via an augmented reality smartphone interface. 236-241. 10.1109/TALE.2015.7386050.

[18]. Christina, Volioti & Orovas, Christos & Sapounidis, T. & Trachanas, George & Keramopoulos, Euclid. (2023). Augmented Reality in Primary Education: An Active Learning Approach in Mathematics. Computers. 12. 207. 10.3390/computers12100207.

[19]. Nur Rahman, Habib & Nur Wangid, Muhammad. (2019). Using Storybook-based AR in Learning Mathematics for Elementary School: How is it applied?. 10.2991/iccie-18.2019.39.

[20]. Safrodin, Mohamad & Zikky, Moh & Ghozi, Saiful & Wicaksono, M. (2020). The 3D virtual drawing mobile application based on augmented reality using AR-Framework. Journal of Physics: Conference Series. 1450. 012078. 10.1088/1742-6596/1450/1/012078