Literature Review of Simulating Scientific Experiments Using Virtual Reality

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Abstract

The purpose of this study is to examine and analyze an educational platform developed to support secondary school students' science learning. In particular, the focus is on how this platform is enriched with virtual reality (VR) technology and how mobile and web application platforms are integrated. Addressing the limitations of traditional methods in teaching science for secondary school students is the main motivation for this study. Virtual reality technology has the potential to present students with abstract concepts through a concrete experience, enhance visual learning, and encourage student engagement. Therefore, the study examined in detail how this technology can enrich students' science learning and improve teaching materials. This study will be an important reference source for researchers and educators on how VR technology and digital platforms can be used to improve science education in the future.

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1. Introduction

Education is a fundamental component that contributes greatly to the development of society. Science education, in particular, plays a critical role in providing students with scientific thinking, analytical skills, observation skills and problem-solving abilities. However, traditional classroom education methods face some challenges, especially for students at the secondary school level. These difficulties include difficulty understanding abstract concepts, low student engagement, and decreased interest in learning. In addition to all these, considering the ignorance and inexperience of secondary school students, the target group of this study, in the use of tools in the laboratory environment, the possibility of various injuries and accidents has become inevitable.

Virtual reality is one of the most innovative technology advancements in the world today, and their potential for improving the education system is massive. The use of Virtual Reality (VR) in education has been on the rise in recent years and provides a wealth of opportunities to leverage technology-enhanced learning.VR introduces students to immersive digital experiences that cannot be replicated through traditional teaching methods, enabling them to better engage with complex material beyond just lectures and textbooks, while enabling lecturers to customize content for individual learning styles. Not only can these technologies create a more immersive experience, but also offer the potential for educators to provide simulations and step into virtual field trips without the physical travel implications. Additionally, the use of innovative technologies such as VR can bridge the gap between traditional classroom instruction and real-world experience, providing tangible benefits for learners' professional development. On the other hand, Virtual Reality (VR) is an advanced technological innovation that has revolutionized the way we experience and interact with digital environments [1].

The focus of this study is an educational platform developed to enrich science learning for secondary school students. This platform includes VR technology as well as mobile and web applications. While VR offers students the opportunity to experience laboratory experiments in a realistic way, mobile and web applications make learning even more flexible by providing students with access at any time and from anywhere. This provides students with greater access to learning materials, a better understanding of science topics and the opportunity to improve themselves.

Additionally, various tests, quizzes and assessments offered on the platform are used to monitor and evaluate students' progress. This helps students assess their own learning and identify gaps, while providing teachers with the ability to track student progress and deliver customized learning experiences.

In conclusion, this study aims to explore the potential of the integration of VR technology and digital platforms in science education for secondary school students. This review will be an important reference source for enhancing student learning, making science teaching more effective, and highlighting the role of technology in future education. This educational platform can contribute to improving the scientific knowledge and skills of future generations by making science learning more effective and attractive.

2. Educational Aspect of the Project

This project's primary goal is to integrate virtual reality (VR) technology with teaching. Virtual reality has garnered a lot of interest in the realm of education lately and has enormous promise, particularly for teaching science. Virtual reality (VR) provides students with the ability to turn abstract ideas into tangible experiences, increasing student engagement and making learning more dynamic.

In addition, it can give students practical applications and visual experiences, which can help them comprehend abstract and difficult science subjects in particular. Through virtual reality simulations, students can witness and experience laboratory experiments in a realistic manner.

2.1. Application Examples of VR Technology in Education

Virtual reality (VR) technology is increasingly being used in education. Pupils can engage in more immersive interactions with their surroundings, which boosts engagement and helps them grasp subjects better. The future of AR and VR technology is probably going to be much more accessible as the cost of the hardware keeps going down. The use of virtual reality (VR) technology in the classroom is completely changing how students engage with and learn from their surroundings. Virtual reality presents novel prospects for learners to engage with three-dimensional objects, investigate their surroundings, and enhance their comprehension of ideas. Virtual reality has the potential to generate interactive simulations that furnish learners with a secure and captivating setting for delving into intricate ideas [2].

Science Laboratories

Science lab experiments aid in the understanding of abstract concepts by students in middle school and high school. However, for security concerns, certain experiments cannot be carried out or access to the laboratory may be restricted. Virtual reality provides students with the ability to conduct lab experiments electronically. In a secure setting, students can participate in chemical, physics, or biology experiments. This approach is less expensive because it doesn't require any test equipment or raw materials.

Historical and Cultural Simulations

VR has the potential to improve history education. Our target audience, secondary school students, typically study very old times (2.5 million years ago) in their history curricula. Furthermore, a learner of that period might find it challenging to picture the stone age, paleolithic age, or paleolithic age together with the historical events that occurred during that era.For instance, a student studying in Stavanger, Norway, might not always be able to visit the Anatolian Civilizations Museum in Ankara, Turkey, to view Stone Age tools. However, this might be feasible if a virtual museum equipped with VR technology is created. Because of this, pupils are able to virtually go to historical sites or ancient societies.

Spatial Physics and Mathematics

Virtual reality provides a means for students to make abstract mathematical and physical concepts tangible. Three-dimensional simulations and images help students learn geometry, trigonometry, and mechanical mechanics more effectively. This improves the understandability of abstract mathematical notions. For instance, using at least two or three different types of liquids with varying densities is necessary for a student to feel how the density of the liquid affects the buoyancy of water, which may not be feasible in a classroom setting. Here, the student can readily see its impact thanks to a straightforward VR simulation.

Language and Culture Learning

Students studying foreign languages can experience real-world applications and enhance their speaking abilities in the target language by utilizing virtual reality. To make this task easier and more enjoyable, two people who live in different countries and speak different languages but want to learn the same language can be brought together in a single setting. Furthermore, students can broaden their understanding of culture by virtually experiencing various cultures. For instance, there are virtual reality simulations that can be used by a student who is interested in learning about French culture but is unable to visit museums, historical sites, or squares in France.

Simulations and Skill Development

Virtual Reality provides students with the chance to learn practical skills. This feature can be very helpful, particularly for students enrolled in applied science faculties. Medical students, for instance, can practice surgery on virtual reality simulators. Students in their senior year of dental internships can use virtual reality to simulate root canal therapy. Students studying chemical engineering and pharmacy can conduct reactions in a virtual reality-prepared experimental environment that could result in an accident or injury. Students aspiring to become pilots can practice flying in flight simulators, where they can feel the same G-force vibrations that they will encounter in the air.

Special Education

Experimental research studies on people with autism spectrum disorder, intellectual disabilities, hearing impairments, physical disabilities, and neurological disorders have primarily focused on virtual reality systems. Evaluations and research findings regarding the use of virtual reality in special education are presented in the section that follows.

Studies in virtual reality created for students with autism spectrum disorders. Virtual reality applications provide appropriate learning environments for people with autism spectrum disorders (ASD) because they are compatible with a variety of situations inherent in the disorder. The effectiveness of graphic-based visual presentations in virtual reality applications is supported by Strickland, as it is widely recognized that people with ASD primarily use visual-based thought systems [3].

Because people with ASD have superior visual perception, virtual reality applications are therefore more suitable for these students. As a result, engaging in real-world learning activities can occasionally be too much for people with ASD. Students with ASD may perform poorly because they struggle to manage the high volume of different stimuli and experience confusion and anxiety as a result. Furthermore, a number of communication elements, including facial expressions, mimes, gestures, intonation, and stress, are also recognized by some students with ASD as distractions. This assessment allows for the customization of the stimulus level in virtual reality applications, as well as close monitoring of the quantity and quality of stimuli for students with ASD. Applications for virtual reality can have their content simplified to a level that each user can handle. Individual preferences can be applied to objects, structures, or virtual characters hosted in these applications (e.g., the color of buildings).

Additionally, when needed, the tactile and auditory elements of virtual environments can be turned off and substituted with other stimuli that are more in line with the pace and alignment preferences of the individual. It is simple to increase the amount of interaction and stimuli if a student requires a higher load of input (Strickland, 1997)[3]. This makes it easier for the students to focus on the desired skills .

Studies in virtual reality intended for pupils with intellectual disabilities. Two major barriers stand in the way of learning new skills for people with moderate to profound intellectual disabilities. These are barriers to learning and limitations in cognitive processing. While accessing learning refers to making appropriate use of learning resources and tools, cognitive processes are classified as reasoning, planning, sequencing, remembering/retaining, processing, and cognitive pace. This classification includes learning resources and tools that are universally designed because of their adaptable, straightforward, organic, and error-tolerant structure.

When created with universal design principles in mind, virtual reality applications can offer a plethora of opportunities for students, particularly those with profound disabilities, to try new things and improve learning at their own pace [4].

Studies using virtual reality intended for students with epilepsy and physical disabilities. Applications for virtual reality have also been used for rehabilitation and to teach students with varying needs skills. Several virtual reality applications have been developed for use by groups with neurological disorders. In addition to the basic skills needed to operate the wheelchair, one of the prerequisites for students with physical disabilities is learning spatial navigation techniques. Applications for virtual reality that are created with this in mind can greatly enhance the skills required of students with physical disabilities. According to studies by Kirshner, Weiss, and Tirosh, participants were able to master the skills they practiced in a lab setting and then apply them in real-world situations [5].

2.2. VR Related Statistics, Market Sizes

The market for virtual reality (VR) is expected to reach a valuation of USD 59.96 billion globally in 2022 and expand at a compound annual growth rate (CAGR) of 27.5% between 2023 and 2030. Users can experience a three-dimensional real-world environment through virtual reality. VR technology creates this immersive experience for users through devices like bodysuits, glasses, gloves, and headsets.

By allowing users to immerse themselves in a highly simulated environment, virtual reality technology has also revolutionized the gaming and entertainment industries. The market is expanding due in part to the growing use of virtual reality (VR) in instructional training, which includes field workers, engineers, mechanics, pilots, defense personnel, and technicians in a variety of industrial sectors.

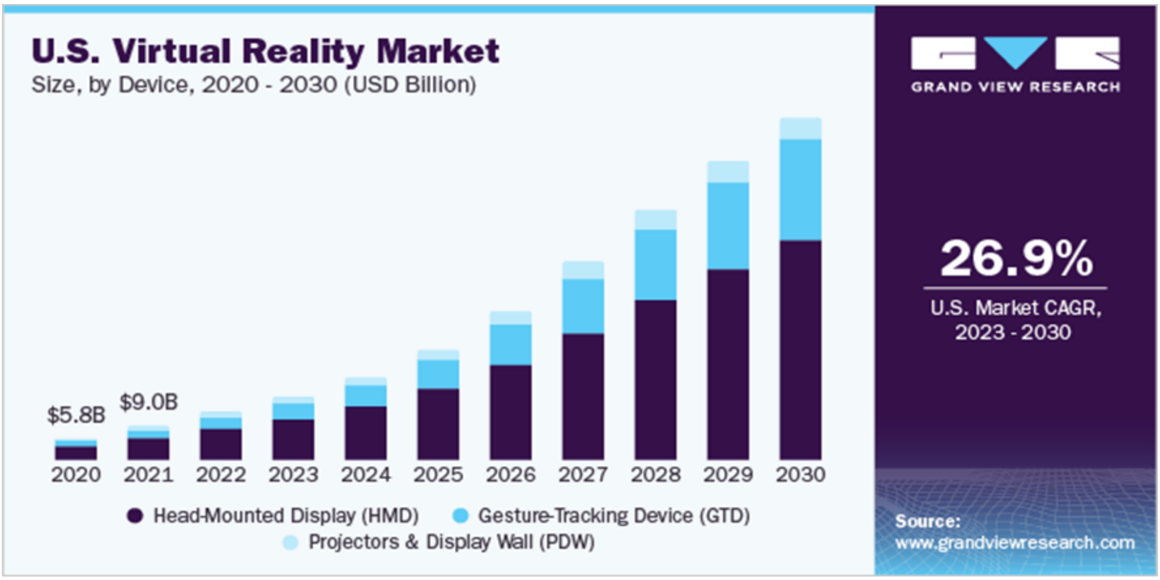

Figure 1 - Market Sizes on VR

Furthermore, because VR has many operational advantages, it is widely used in many industries, including the automotive and healthcare sectors. In the automobile industry, for example, engineers can test a vehicle's design and construction early on using virtual reality before incurring expensive production costs. BMW, for example, employs mixed reality (augmented and virtual reality) in its vehicle engineering and development processes. Furthermore, the use of cutting-edge technologies in the treatment of mental health disorders is predicted to rise with the introduction of VR exposure therapy. Travel agencies also use virtual reality (VR) technology to let prospective visitors explore landmarks, famous locations, parks, and more virtually.

Lockdowns and the temporary closure of several industries were implemented during the COVID-19 pandemic to stop the virus's spread, which had an effect on regional business operations.

On the other hand, there is now a greater need for VR due to businesses having to continue operating online. In order to carry out their business operations, including organizing meetings and creating policies and strategies, companies migrated to virtual platforms. By hosting the event on a virtual platform and making it available as a VR experience, the organizers gave attendees interesting and varied experiences. Consequently, the market is expanding due to the increasing significance of virtual events. Another element anticipated to propel market expansion is the growing usage of VR applications in the planning and architecture industries. Virtual reality (VR) technology is being used in architecture to help with decision-making and to visualize the results of proposed architectural plans and urban designs.

It also makes it possible to identify and fix errors early on, which saves both time and money. Additionally, a number of real estate companies have started offering virtual tours of their properties via VR, which raises the possibility of a sale. For example, PropVR opened its VR center in Mumbai, India in September 2022 so that real estate developers could provide potential buyers with VR home tours. VR technology has helped the sports and entertainment sectors tremendously. It is anticipated that VR technology will become extensively used in gaming, music, theaters, and location-based entertainment. For example, Shanghai Disney Resort debuted an immersive virtual reality (VR) experience at its Disneytown shopping, dining, and entertainment complex in September 2022. It is anticipated that the growing acceptance of VR in entertainment will fuel market expansion.

Device Insights

With a 61.9% revenue share in 2022, the Head-Mounted Display (HMD) device segment led the market and is expected to continue to do so until 2030. The market demand for VR headsets is being driven by their increasing use in both consumer and commercial applications. The availability of a variety and types of HMDs, including tethered, hybrid, and wireless HMDs, is credited with the segment's growth. In addition to providing training in a variety of fields, including research, aerospace, engineering, the military, and medicine, HMD devices are used to demonstrate a broad range of use cases through interactive features. In addition, businesses frequently introduce technological advancements and enter into strategic partnerships to provide customers with an extremely immersive experience.

During the course of the forecast period, the Gesture-Tracking Device (GTD) segment is expected to grow at the fastest rate of 29.9%. Given that gesture tracing is a cutting-edge and extensively used technology that facilitates more immersive and nearly natural interaction, the growth of this market can be attributed to a shift in demand from basic gesture tracing to visually immersive gesture tracing. Virtual reality projectors, processors, sensors, large displays, and multi-screen projection systems are among the different kinds of GTD virtual reality hardware. Additionally, a number of businesses are working to increase the performance of the sensors and processors that VR systems use in order to give users a much more immersive experience.

Technology Insights

In 2022, the semi-& fully immersive segment generated the highest revenue share, amounting to 82.7%. Over the course of the projection period, the segment is also anticipated to have the highest CAGR of 28.9%.

The segment's growth can be ascribed to the ongoing increase in demand for virtual reality headgear (HMDs) for commercial and educational settings. The architecture of real environments can be replicated in a virtual platform with semi- and fully immersive technology, which is helpful for intricate tasks and planning. It involves the use of powerful personal computers, sophisticated emulators, and high-resolution screens. Virtual reality (VR) technology is also in demand for educational applications because it enables students to practice reasoning and motor skills that aren't feasible in a traditional classroom.

In 2022, the non-immersive segment's revenue share was 17.3%. Users of non-immersive VR technology can experience a virtual environment or a workstation-generated environment as opposed to an immersive, lifelike world. Due to its increased availability and increased efficiency in network management, this technology is currently in vogue.

The technology can only be used for limited purposes, such as designing, gaming, medical assistance, and more, because of its restricted 2D interaction. Furthermore, for computers and consoles to operate correctly, input devices like controllers, keyboards, mice, and displays are needed. This has a positive effect on the growth of the non-immersive system market because it eliminates the need to invest in a completely new system.

Application Insights

In 2022, the commercial segment held the highest revenue share of 54.7%. New growth potential for the market is offered by the growing use of VR headsets and VR experience rooms in the commercial sector, including real estate, car showrooms, and retail stores. Furthermore, it is anticipated that the commercial sector will use VR technologies at a faster rate due to the growing popularity of mobile and other handheld devices. In a similar vein, companies are utilizing VR to introduce new goods and draw customers in with a more engaging experience.

Over the course of the forecast period, the healthcare segment is anticipated to register the highest CAGR of 32.2%. This is related to the use of virtual reality (VR) in the healthcare industry, primarily in learning, training, operational procedures, and disease awareness. As VR tools and solutions are used by hospitals and medical colleges to train future physicians, there will likely be an increase in demand in this market. Furthermore, the trend of performing surgeries and other complicated operations remotely is anticipated to fuel the market's expansion. For example, physicians can try difficult surgeries in virtual reality to verify likelihood before performing the procedure on the real patient

Component Insights

In 2022, the hardware segment held the highest revenue share of 67%. Since developers are adding VR-based features to more devices, the high penetration and use of smartphones, tablets, and other sophisticated electronic handheld gadgets are predicted to support the segment's growth. The segment also includes consoles, input/output devices, and accessories that users can purchase for virtual reality setups. Furthermore, it is projected that Original Equipment Manufacturers (OEMs) will have more opportunity to expand into VR equipment providers as a result of the increasing use of VR headsets in commercial applications, theme and amusement parks, and other locations.

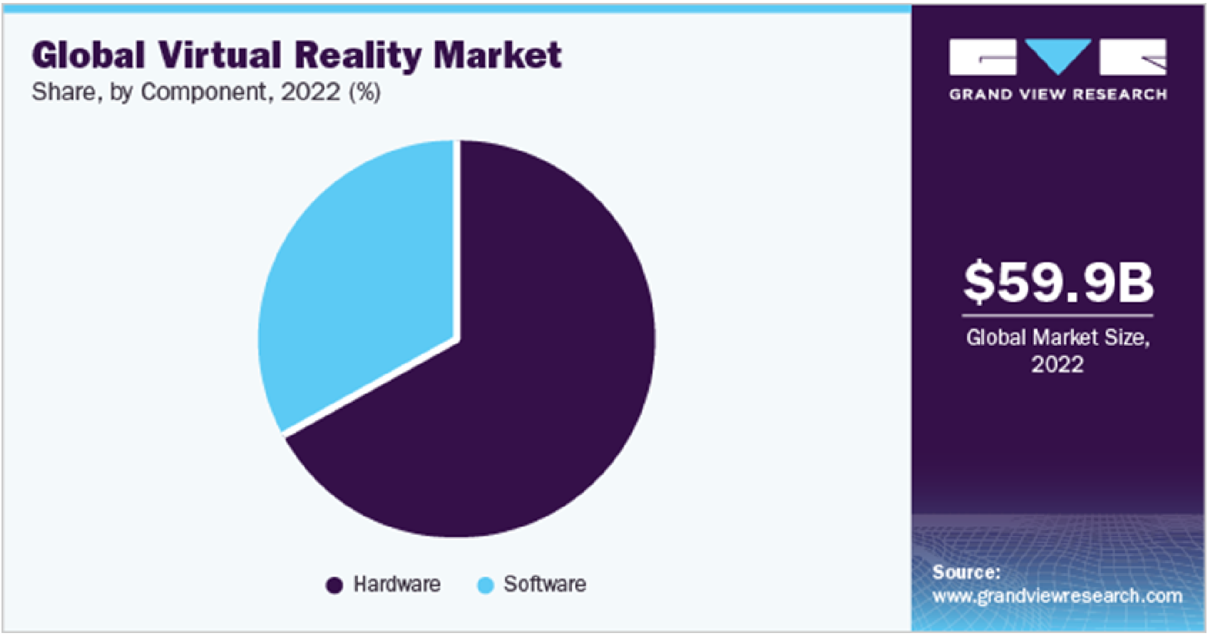

Figure 2 - Global VR Market Statistics

Over the course of the forecast period, the software segment is expected to record the highest CAGR of 29.7%. The software's ability to handle input/output sources, generate feedback, and analyze data is responsible for the segment's growth.

Because virtual reality technology allows users to interact with applications and tasks in a three-dimensional environment, it is widely used in product prototyping. In addition, the market for this segment is expanding due to its potential applications in learning experience platforms, virtual reality, training, simulation, and the development of virtual tools and applications.

Regional Insights

In 2022, Asia Pacific had the highest revenue share, coming in at over 39%. The expansion of the regional market can be ascribed to nations like China, which are significant manufacturers and suppliers of gear related to virtual reality. Additionally, because of the automation trend, the region is home to a large number of factories and industries that use VR in various processes. Furthermore, it is anticipated that Asia Pacific's growth will be driven by the increasing ubiquity of handheld devices that support virtual reality.

Figure 3 - VR Market Statistics on Asia Pacific

With a CAGR of more than 29.3% over the course of the forecast period, Europe is anticipated to emerge as the regional market with the fastest rate of growth. This is because VR technology has been widely used in many different applications across a number of industry sectors, especially the gaming and automotive industries. Modern VR headsets are becoming more and more popular in Europe thanks to the continent's large gaming population. The growth of the regional market has been accelerated by the quick development and sale of powerful VR hardware targeted at the gaming community in European countries.

Key Companies & Market Share Insights

The major players use tactics like joint ventures, acquisitions, partnerships, R&D, and geographic expansions to strengthen their positions within the industry. In order to remain competitive and better meet the evolving needs of users, businesses are also concentrating on enhancing their product offerings. For example, Meta Platforms Inc. acquired Within Unlimited, Inc. in February 2023 due to its expertise in virtual reality (VR) and its well-known VR application, Supernatural.

Important businesses are also diversifying their offerings by introducing new products or greatly enhancing those that already exist. Since the VR industry is experiencing rapid technological advancements, new features and tools are frequently added to current products. For example, HTC Corporation introduced the Vive XR Elite, a new virtual reality and augmented reality headset, in January 2023. The product has a high-resolution display for an immersive experience, the company claims. Some of the prominent players in the global virtual reality (VR) market include:

> Alphabet Inc., Barco NV, CyberGlove Systems, Inc., Meta Platforms Inc., HTC Corporation, Microsoft Corporation, Samsung Electronics Co., Ltd., Sensics, Inc., Sixense Enterprises, Inc. (Penumbra, Inc.), Ultraleap Ltd.

Table 1. Virtual Reality (VR) Market Report Scope [6].

Virtual Reality (VR) Market Report Scope	
Report Attribute	**Details**
Market size value in 2023	**USD 79.36 billion**
Revenue forecast in 2030	**USD 435.36 billion**
Growth rate	**CAGR of 27.5% from 2023 to 2030**
Base year for estimation	**2022**
Historical data	2018 – 2021
Forecast period	2023 – 2030
Quantitative units	Revenue in USD million/billion and CAGR from 2023 to 2030
Report coverage	Revenue forecast, company ranking, competitive landscape, growth factors, and trends
Segments covered	Device, technology, component, application, region
Regional scope	North America; Europe; Asia Pacific; South America; MEA
Country scope	U.S.; Canada; Mexico; UK; Germany; France; Italy; China; Japan; India; South Korea; Brazil; Argentina; South Africa; Saudi Arabia
Key companies profiled	Alphabet Inc.; Barco NV; CyberGlove Systems, Inc.; Meta Platforms Inc.; HTC Corp.; Microsoft Corp.; Samsung Electronics Co., Ltd.; Sensics, Inc.; Sixense Enterprises, Inc. (Penumbra, Inc.); Ultraleap Ltd.
Customization scope	Free report customization (equivalent to up to 8 analyst working days) with purchase. Addition or alteration to country, regional & segment scope
Pricing and purchase options	Avail customized purchase options to meet your exact research needs.

2.3. Educational Applications Using VR Technology for Secondary School Students

2.3.1. “Sınıfta Ben de Varım” Project

The Avcılar District National Education Directorate launched the "Sınıfta Ben de Varım" Project with the goal of preventing loneliness among 12 Avcılar students who are socially and physically isolated from school and receive their education at home. In the classroom, this method makes use of cameras, the internet, and VR (virtual reality) goggles.Students receiving instruction at home can experience the classroom setting, hear and see their teacher and classmates, and use 360-degree cameras and mobile phone technology with VR goggles, making it possible for them to feel less alone. The Turkish Avcılar Ambarlı Primary School was the first to implement this project.

The following succinctly describes the practice session observations made regarding the project's implementation: The instructor tells the class to "take your seats, get ready, let our friends at home watch and learn" before the live broadcast begins. All of the students in the classroom wave and say "good morning" to their friends who are receiving instruction at home as soon as the live broadcast starts. When asked if they are prepared to start going over the material, the students say, "Always, always, always." Additionally, the students in the classroom read aloud the content on the board for their friends who are receiving education at home because it may not be clearly visible through the camera.

Following the teacher's instructions, the students in the classroom say "see you later" and wave to their friends who are taking part in virtual reality goggles when the lesson comes to an end.

Students who receive their education from home and are unable to interact in person with their peers benefit from the encouragement and morale this teaching approach offers. Project Objective: Education and Socialization (Communication with Friends) Advantages: Contribution to Education, Motivation, and MoraleDisadvantages: Lack of Face-to-Face Communication, Limited Active Participation, Internet Connectivity (Data Limitation) [7].

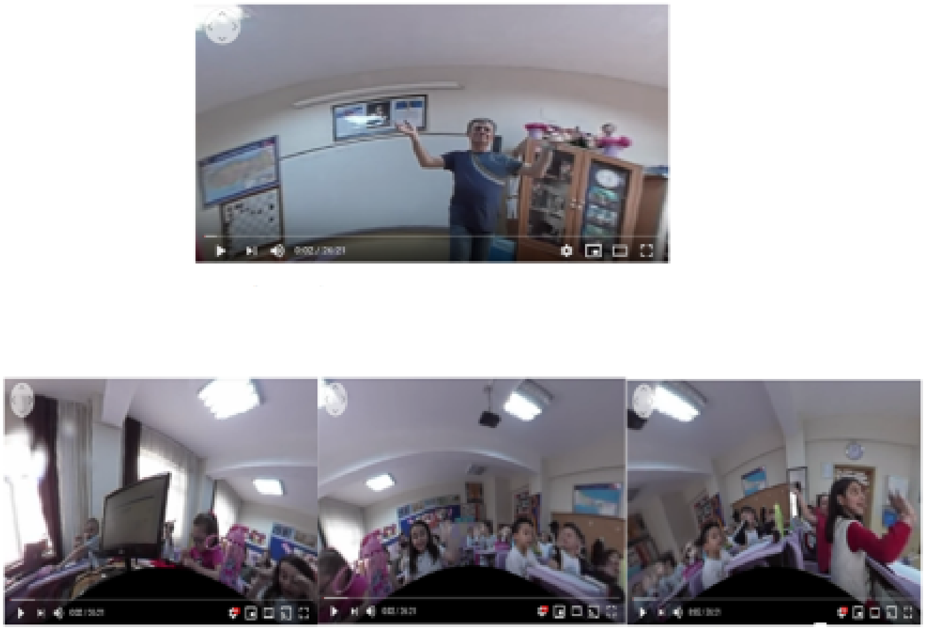

Figure 4 - Some Photos from "Sınıfta Ben de Varım"

2.3.2. ClassVR

A company called ClassVR advocates for the use of virtual reality technology in education with the goal of improving the educational process. It gives educators and educational institutions the chance to give students VR experiences. The company provides VR goggles and associated tech equipment so that teachers can give students 360-degree experiences and content. This enables students to participate in a more productive learning environment, experience visual learning, and obtain a deeper understanding of the material.

ClassVR actively participates in project implementation as well. It helps educators and educational institutions use virtual reality (VR) to improve student experiences and raise standards. For instance, it lets Nagel Middle School use ClassVR goggles to involve students in projects and make science lessons more engaging. Students get the chance to learn through practical applications through these kinds of projects.

Bringing Science Lessons to Life with Virtual Reality: The Nagel Middle School Experience

As more demands for student-focused content emerge, 360-degree content development gets underway in response to teacher requests as students are introduced to experience-specific content. The school also purchases its own 360-degree cameras to record and upload staff and student-generated content to the ClassVR website.

Student Projects:

Students work on a project at one point in the project process that uses Class VR goggles to advance 21st-century learning. In order to enhance instruction within the school, students are expected to recognize an issue, present it, and offer potential solutions. When they present this project to a group of community representatives, they do so with Class VR goggles.

Science Lessons and Green Roofs:

Students are tasked with creating a city that lowers carbon emissions in one example scenario. Students design the city within a budget by incorporating solar panels, wind turbines, colorful roof coverings, and other eco-friendly products using a digital simulation. They compute things like reduced carbon emissions, enhanced albedo effect, and historical significance. Using green roofs with plant coverings that act as carbon filters is one of the simulation's options for lowering carbon emissions [8].

Figure 5 - VR Usage Example from a class

2.3.3. Mondly – Learn Languages in VR

Mondly is a mobile application that offers an innovative approach to language learning. The app distinguishes itself by promising to give users authentic dialogues in thirty different languages. But what sets Mondly apart is how it uses virtual reality (VR) technology to give students the opportunity to participate in these conversations. Unlike conventional language learning approaches, this application highlights how important it is to use the language in everyday contexts.

Students can practice speaking the language in addition to listening to it through Mondly's virtual reality experience. This bolsters scientific studies that conclude that learning a language is best accomplished through use in authentic situations. By immersing users in a virtual language learning environment, virtual reality creates a realistic experience [9].

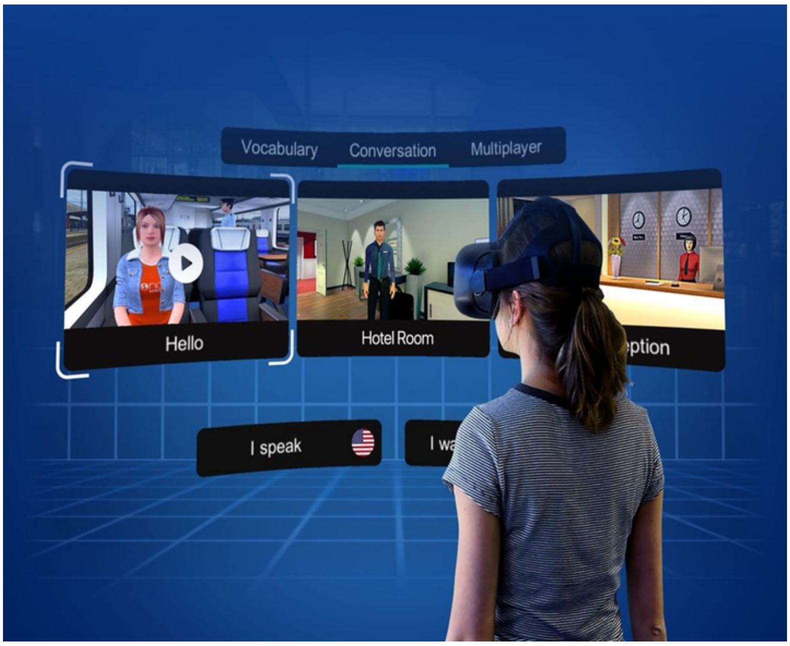

Figure 6 - Sample VR Screen

2.3.4. Math in Virtual Reality

Students are presented with abstract mathematical concepts in a 3D environment through the use of this application.This application aims to increase accessibility to the field of mathematics, particularly for those who learn best visually. It simplifies abstract mathematical ideas through the use of highly visual representations, giving students a better understanding. Students can use the application to help make abstract ideas more understandable and tangible [10] .

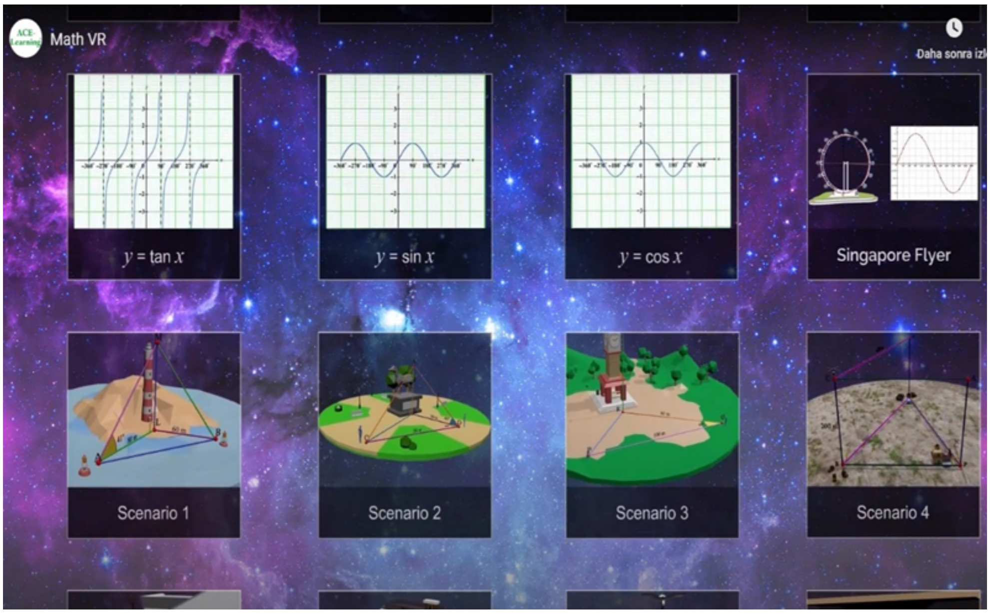

Figure 7 - Sample VR App UI

2.3.5. IXR Labs: The Future of Science Laboratories with Virtual Reality

Among the companies that are leading the way in creating products for science labs to use virtual reality (VR) technology is IXR Labs. Science education could undergo a major revolution thanks to virtual reality. With the help of products from IXR Labs, students can perform scientific experiments in a virtual setting. Students are able to apply their theoretical knowledge and actively participate in laboratory experiments as a result. Virtual reality technology provides students with a more tangible understanding of abstract scientific concepts.

VR equipment specifically designed for science labs is available from IXR Labs. Students can conduct virtual laboratory experiments with these products. The capacity to conduct experiments in a variety of scientific domains, including engineering, chemistry, physics, biology, and more, is acquired by students. In order to improve learning outcomes, these products also give teachers the ability to monitor student progress and produce specialized content as needed.

The virtual reality products from IXR Labs have the potential to improve the efficacy and appeal of science education. Learning becomes more profound and enduring when students experience a sense of having carried out the experiments themselves. They also get to conduct experiments without having to worry about making mistakes, which is especially beneficial when safety is a major concern [11].

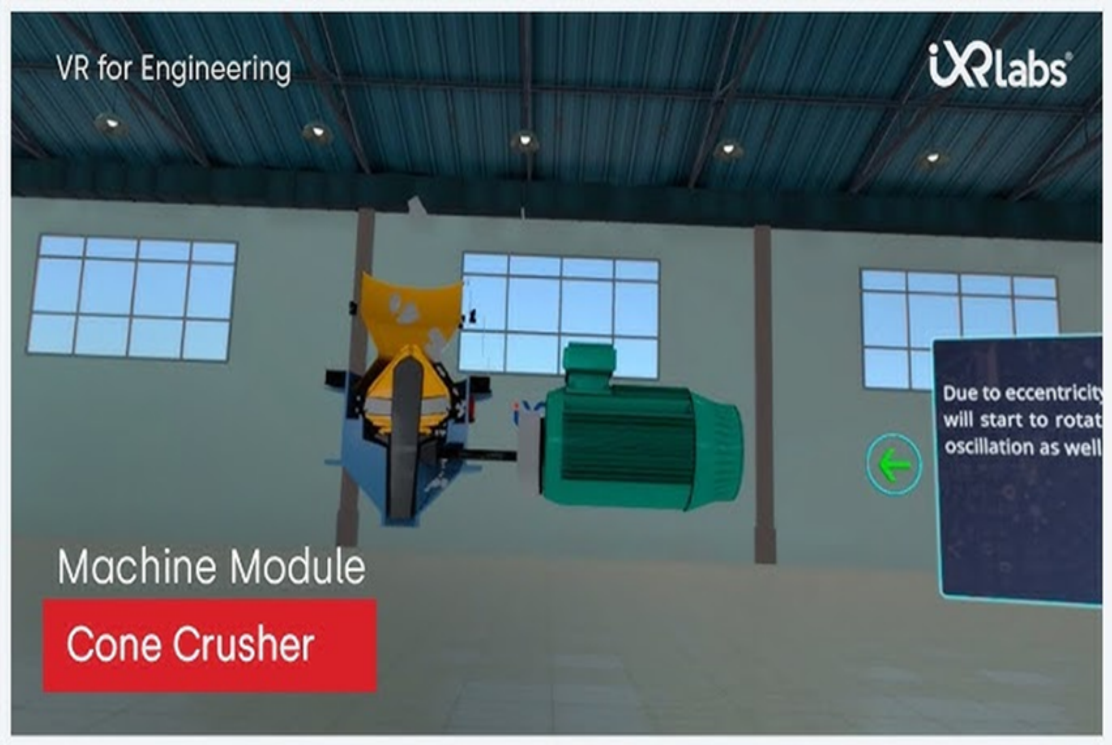

Figure 8 - A VR App from iXRLabs Company

3. Technological Dimension

In essence, this educational platform uses three primary technologies. VR, mobile, and the web are these. While the mobile and web portions primarily consist of tests and quizzes and carry the platform's promotional mission, the VR portion is the platform where simulations are conducted.

3.1. VR (Virtual Reality)

3.1.1. What is Virtual Reality?

Virtual reality, or VR as it is commonly known, is a term with many different meanings. Some people associate virtual reality (VR) with a particular set of technologies, usually related to immersive audio systems, glove input devices, and head-mounted displays (HMDs). Through the use of these technologies, users can immerse themselves in remarkably lifelike computer-generated simulations.

On the other hand, a broader definition of virtual reality encompasses not only the expensive hardware but also traditional media, such as books, movies, and the domain of pure fantasy and imagination. When interpreted in this wider context, virtual reality (VR) comes to refer to any media that immerses viewers in a different reality or ignites their imagination in a way that gives them the impression that they are in a different place.

However, one of the most precise and encompassing definitions of VR is articulated in the book "The Silicon Mirage," where it is described as: "Virtual Reality is a means for humans to visualize, manipulate, and interact with computers and exceedingly intricate data [12]."

The essential role of virtual reality as a bridge connecting the real and digital worlds is emphasized by this definition. Virtual reality (VR) provides an immersive means for users to interact with and perceive data and computer-generated environments. Users can interact with their surroundings, move objects around, and enter virtual environments while still feeling present and immersed, making it difficult to tell the difference between virtual and real-world experiences.

Virtual reality (VR) essentially provides a means for people to interact with intricate, data-driven scenarios while overcoming the constraints of conventional two-dimensional interfaces. This opens up possibilities for a variety of applications, including gaming, entertainment, education, training, and healthcare. Virtual reality technology is a game-changer for both personal and professional use because it allows users to actively participate in computer-generated experiences rather than just observe them.

3.1.2. History of Virtual Reality

Virtual reality technologies of today are based on concepts that stretch back nearly to the invention of practical photography in the 1800s. The first stereoscope was invented in 1838 and projected a single image using two mirrors. Eventually, that evolved into the View-Master, which is still in production today and was patented in 1939.

However, Jaron Lanier, the founder of VPL Research, coined the term "virtual reality" in the middle of the 1980s when he started creating the necessary equipment, such as gloves and goggles, to experience what he called "virtual reality."

But even before then, technologists were creating virtual worlds. The Sensorama in 1956 was one significant event. The motion picture business in Hollywood was Morton Heilig's previous career. His goal was to see if viewers could actually experience being "in" the film. You "rode" a motorcycle through a realistic urban environment as part of the Sensorama experience. In the created "world," multisensory stimulation allows you to see the road, hear the engine, feel the vibration, and smell the exhaust from the motor. In 1960, Heilig also received a patent for the Telesphere Mask, a head-mounted display device. His pioneering work would serve as a basis for many inventors. In 1965, Ivan Sutherland, an additional inventor, proposed "the Ultimate Display," a head-mounted gadget that he claimed would function as a "window into a virtual world." In the field, the 1970s and 1980s were a very exciting time. Developments in optics coincided with efforts to create haptic feedback systems and other tools for virtual reality navigation. For instance, the Virtual Interface Environment Workstation (VIEW) system at NASA Ames Research Center enabled haptic interaction in the mid-1980s by combining gloves and a head-mounted device[13]. The science fiction tale Pygmalion's Spectacles was published by Stanley Weinbaum in 1935. The protagonist of the story dons goggles that take him to a made-up world with holographic recordings and appropriate sensory stimulation. Some people believe that this story is where the idea of virtual reality (VR) first emerged because it accurately foresaw the goals and accomplishments of the future.Nonetheless, our timeline begins in 1838 because the first technological advancements for VR occurred in the 1830s.

In addition to being the first to describe stereopsis in 1838, Sir Charles Wheatstone received the Royal Medal of the Royal Society in 1840 for his research on binocular vision, which eventually led to the creation of the stereoscope.

The findings showed that the brain combines two images (one eye viewing each) of the same object taken at different angles to create the illusion of three dimensions and depth in the image.Wheatstone was able to develop the first kind of stereoscope thanks to this technology. It employed two mirrors, angled 45 degrees from the user's eyes, to reflect a picture that was situated off to the side.

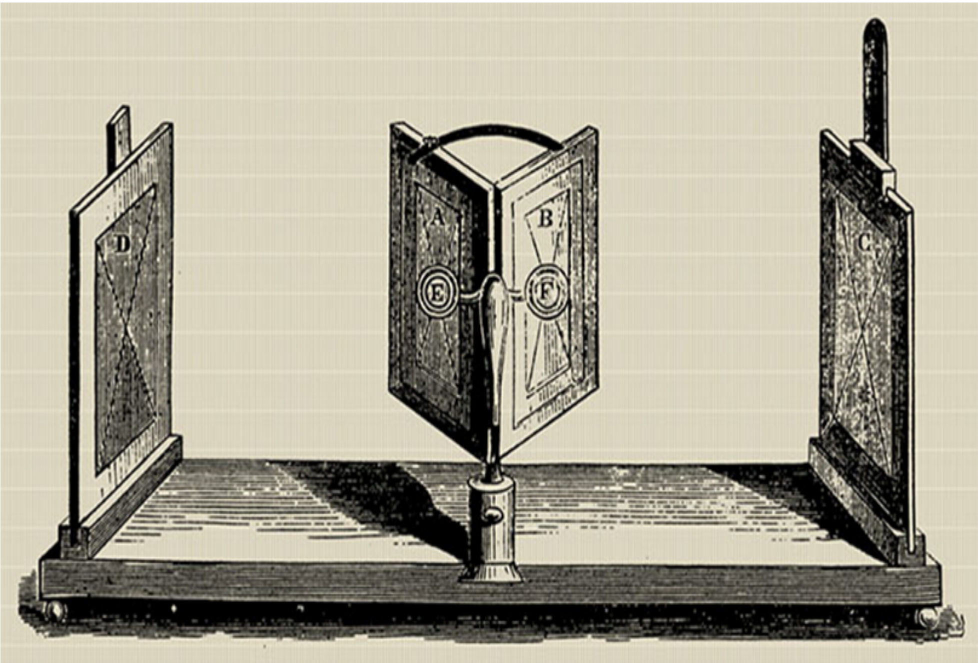

Figure 9 - The Wheatstone mirror stereoscope.

The first VR device, Sensorama, was invented in 1956 by cinematographer Morton Heilig and was patented in 1962. Up to four people could fit in the spacious booth at once. It employed a variety of technologies to arouse the senses, including full-color 3D video, sound, vibrations, scent, and atmospheric effects like wind.

Scent generators, a vibrating chair, stereo speakers, and a stereoscopic 3D screen were used for this. Heilig wished to completely submerge viewers in their films because he believed that the Sensorama was the "cinema of the future". For it, six short films were created.

Figure 10 - The Sensorama VR machine

Sutherland and his pupil Bob Sproull invented The Sword of Damocles, the first virtual reality headgear, in 1968. This head-mount was very basic, only able to display basic virtual wire-frame shapes, and it was connected to a computer instead of a camera.Because of the tracking system, these 3D models altered perspective when the user moved their head.

Because it was too heavy for users to wear comfortably and had to be strapped in because it was suspended from the ceiling, it was never developed further than a lab project.

Figure 11 - First VR Applications from History

For military use, McDonnell-Douglas Corporation incorporated virtual reality (VR) into its headgear, the VITAL helmet, in 1979. The HMD's head tracker tracked the pilot's eye movements to correspond with images created by the computer.

Figure 12 - Another Usage of VR from the history

After being awarded a contract by NASA to create the audio component of the Virtual Environment Workstation Project (VIEW), an astronaut training virtual reality simulator, Scott Foster established Crystal River Engineering Inc. in 1989. Real-time binaural 3D audio processing was developed through this company.Based on VPL's DataGlove, Mattel, Inc. introduced the Power Glove. Due to its difficulty of use, the Power Glove, a controller accessory for the Nintendo Entertainment System, was never very popular.

Figure 13 - A glass developed by NASA

In 2012, Luckey launched a Kickstarter campaign for the Oculus Rift which raised $2.4 million.

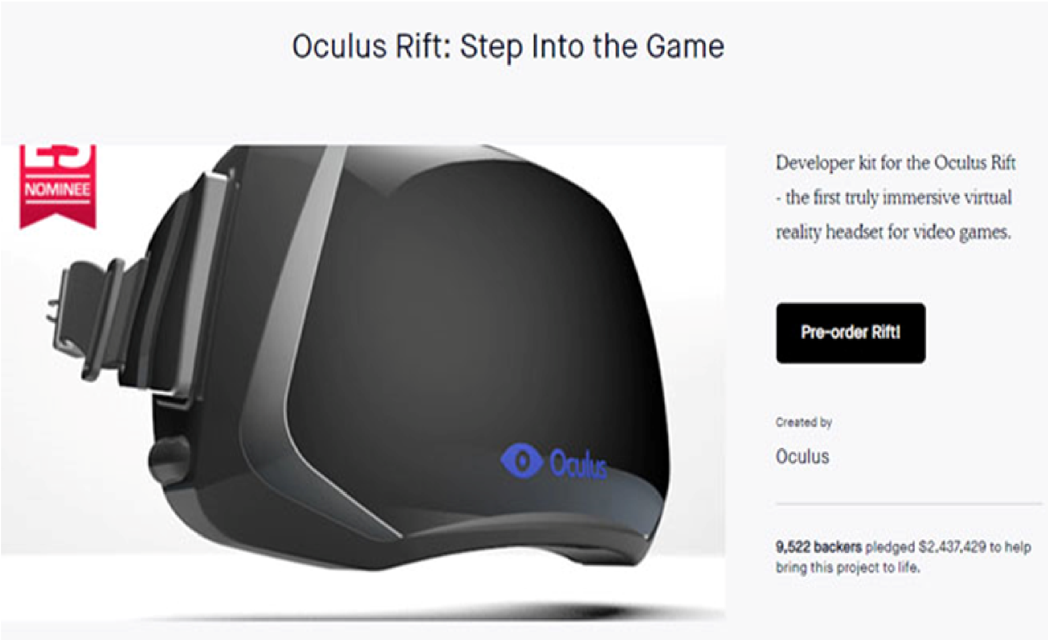

Figure 14 - Oculus VR Glass

Facebook paid $2 billion to acquire the Oculus VR company in 2014 (see Figure 14). This was a pivotal point in the history of virtual reality because it quickly took off. Sony revealed that they were developing a virtual reality headset for the PlayStation 4 (PS4) called Project Morpheus. Google introduced Cardboard, an inexpensive, DIY stereoscopic smartphone viewer. Samsung unveiled the Samsung Gear VR, a headgear that displays content through a Samsung Galaxy smartphone. As more people became interested in VR, they began experimenting with its potential and adding cutting-edge accessories. One such developer, Cratesmith, combined the Oculus Rift with a Wii balance board to recreate a scene from Back to the Future involving hoverboards.

2019 is The Year Virtual Reality Gets Real, according to Forbes. Facebook's standalone headset, Oculus Quest, generated a lot of buzz and interest, selling out in several stores and bringing in $5 million in revenue from the sale of content. Since standalone VR headsets are far more user-friendly for the typical consumer, the transition from tethered to standalone headsets signified a change within the immersive ecosystem. According to Road to VR, more than one million VR headsets are now connected to Steam each month, a first for the platform. On April 12, Nintendo introduced the Labo: VR kit for Nintendo Switch to the VR market. Beat Saber made history in March by being the first app to sell one million or more copies in less than a year.

Figure 15 - Nintendo VR Glasses

With the release of the Apple Vision Pro, a forthcoming mixed-reality headset, at its 2023 Worldwide Developers Conference (WWDC) on June 5, 2023, Apple announced its entry into the VR market in 2023. The headset will sell for $3,499.

Figure 16 - Meta announced the Meta Quest 3 on June 1, 2023. The headset will sell for $499 [14]

3.1.3. VR Development Environments

Unity Engine

Unity is a versatile and widely used game engine and development platform for creating VR applications. It provides comprehensive support for VR development, with built-in tools, assets, and plugins. Unity is known for its user-friendly interface, a large community, and cross-platform compatibility, making it a popular choice among VR developers.

Unreal Engine

Unreal Engine is a powerful and widely used game engine for VR app development. It is known for its advanced graphics capabilities, making it a popular choice for creating visually stunning VR content. Unreal Engine offers a range of VR-specific features and plugins and is suitable for developing VR experiences with high-quality visuals. It has gained popularity in the gaming, architectural visualization, and training industries.

CryEngine

CryEngine is another game engine that supports VR app development. It offers advanced graphics capabilities and is well-suited for creating visually impressive VR content. CryEngine is favored for its high-quality visuals and is suitable for developing VR games and simulations.

4. Conclusion

This project aims to explore the integration of education and virtual reality (VR) technology. VR holds significant potential, especially in science education, as it allows abstract concepts to be transformed into tangible experiences, making learning interactive and engaging for students. Here are some examples of how VR technology can be applied in education:

Science Laboratories: VR enables students to conduct laboratory experiments virtually, providing a safe and cost-effective way to explore concepts in subjects like chemistry, physics, and biology.

Historical and Cultural Simulations: VR can make history lessons more effective by allowing students to virtually visit historical events and ancient cultures, enhancing their understanding of the past.

Spatial Physics and Mathematics: VR helps students grasp abstract mathematical and physical concepts through three-dimensional graphics and simulations, making complex subjects more understandable.

Language and Culture Learning: VR supports foreign language learning by offering real-world applications and cultural experiences, helping students develop language skills and cultural understanding.

Simulations and Skill Development: VR provides opportunities for students to develop real-world skills, such as medical procedures, engineering tasks, and more, in a safe and controlled environment.

Special Education: VR can create customized learning environments for individuals with special education needs, including autism spectrum disorder, intellectual disabilities, and physical disabilities.

The examples stated above illustrate how VR technology can transform education, making it more interactive and enriching for students. The global Virtual Reality (VR) market was estimated to be worth $59.96 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 27.5% from 2023 to 2030. VR technology offers users a three-dimensional immersive experience in the real world. It has transformed both the entertainment and education sectors and found applications in industrial training, healthcare, and automotive industries. The demand for VR increased during the pandemic as online activities surged.

Furthermore, VR usage in architecture, real estate, entertainment, and sports industries continues to grow. The Asia-Pacific region dominates a significant portion of the market, with Europe rapidly expanding. Key players are staying competitive through partnerships, innovations, and product development. In summary, the VR market is rapidly expanding and finding diverse applications.

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