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Augmented Reality Technology (ART) in Science Education and Engineering Technology: A Review

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Abstract : This paper provides a comprehensive analysis of Augmented Reality Technology (ART) in Science Education and Engineering Technology. Science Education and Engineering Technology go hand in hand as without scientific studies applications cannot exist. The term science is well known for knowledge-based society. It has a vast scope in this world. In every step of human life, the terms Science and Technology are both the two sides of one coin. The main objectives of this review are to -

1. Understand the concept of Augmented Reality Technology (ART).
2. Identify the different types of Augmented Reality Technology (ART).
3. Find out the correlation between Augmented Reality Technology (ART) and Science Education.
4. Identify the various strategies of Augmented Reality Technology (ART) for Science Education.

The rising prominence of Augmented Reality (AR) technology stems from its ability to deliver captivating and interactive experiences to users. The current landscape of AR technology is characterized by its dynamic and fast-paced evolution, with numerous applications emerging across industries like gaming, retail, education, and healthcare. By overlaying digital content onto the physical world, AR technology creates a blended reality environment that offers engaging and immersive experiences to users.

In particular, AR has the potential to revolutionize the methods through which students comprehend and interact with scientific and engineering concepts. It presents an opportunity for future research to delve deeper into exploring the extensive capabilities of this technology and unlock its full potential in educational contexts.

Keywords : Augmented Reality Technology (ART); Education; Engineering; Science Education; Technology.

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1. Introduction

Augmented Reality (AR) refers to a modified reality where computer-generated content overlays the user's real-world view, enabling the integration of digital assets into their physical environment. AR offers operational advantages across the engineering lifecycle, generating knowledge alongside technological advancements. Post World War II, the significance of science in human history became evident, leading to the emergence of development policies aligned with scientific advancements. Notably, augmented reality possesses distinct characteristics, including the fusion of real and virtual realms, real-time interaction, and precise registration of real and virtual objects in three dimensions.

Some characteristics of augmented reality are mentioned below:

1) Combination of real and virtual world

2) Real-time interaction

3) Accurate 3D registration of real and virtual objects.

Education holds a pivotal role in human development across various spheres of life. The Gurukul system marked the early stages of education, which underwent transformative changes to adapt to evolving needs. Science, in particular, witnessed significant progress, with scientists actively engaged in laboratories, striving to invent and integrate technology for societal betterment. The progress of nations and societies is now gauged by advancements in science and technology, prompting governments to prioritize policies supporting industrial development. Effective communication between scientists and engineers plays a crucial role in realizing impactful industrial growth and maximizing the potential of inventions.

While augmented reality technology presents numerous applications, it encounters challenges such as the need for high-quality hardware and software, limited content availability, and lack of standardization. Nevertheless, due to the escalating demand for immersive and interactive experiences, the future of AR appears promising, poised to shape various industries. In the realm of science education and engineering, the integration of AR technology offers several benefits. It fosters immersive and interactive learning experiences, facilitating comprehension of complex concepts. AR empowers students to explore diverse scenarios safely and systematically within controlled environments, promoting experimentation. For engineers, AR proves advantageous in identifying potential issues before investing resources and time in physical prototypes, as it enables the creation of virtual models and visualizes designs. Consequently, augmented reality has gained substantial popularity in science education and engineering, owing to its ability to deliver immersive and interactive learning experiences by utilizing cameras, sensors, and computer-generated images to overlay virtual objects onto the real world, establishing a mixed reality environment.

The 21st-century generation exhibits a strong affinity for technology, evident in the increased reliance on online teaching and learning during the COVID-19 pandemic. Traditional classroom approaches often hinder learners' perception levels, particularly in science subjects where abstract concepts can pose difficulties. Integrating technological aspects into the teaching and learning process holds the potential to enhance learners' perception and alleviate monotony in the classroom. AR technology has found practical application in science education, enabling the creation of simulations and visualizations that facilitate the exploration of intricate systems and phenomena. For instance, students can employ AR to venture into the solar system, delve into human anatomy, or simulate chemical reactions. Moreover, AR can create interactive textbooks that engage students in a more captivating manner. In the domain of engineering, AR aids in the creation of digital prototypes and visual representations, facilitating effective communication of ideas and collaboration among team members. By employing AR, engineers can construct virtual models of their designs, enabling the early detection of potential issues and enabling necessary adjustments before physical prototyping.

2. Literature Survey

A study by Cheng and Tsai (2014) looks into the benefits of augmented reality (AR) in science education. It discusses the unique benefits and promise of augmented reality technology for boosting science learning experiences. The authors stress the significance of further research on the impact of augmented reality technology on knowledge acquisition, engagement, and motivation in science education. They also recommend researching design principles and instructional strategies to maximize the usage of augmented reality in science learning. This assessment of the literature provides major insights into the possibilities of augmented reality technology in science education and suggests future research options (Cheng et al. 2013).

In 1997, Ronald Azuma published an article where Augmented reality (AR) technology was thoroughly discussed by him. Numerous facets of augmented reality, including its definition, characteristics, and applications, are covered in the survey. Azuma goes over the main components and techniques used in augmented reality systems, such as tracking, registration, and display technologies. The limitations and challenges of AR technology at the time are also covered in the essay. Because it provides an overview of the field, Azuma's study is a great resource for learning the key concepts and achievements in augmented reality. It sheds light on the potential uses of augmented reality and lays the framework for future research and development in the field (Azuma et al. 1997).

Two significant papers contribute to the overview of the literature on the effects of augmented reality (AR) in scientific education. The first study, titled "The Effects of Augmented Reality on Science Education: A Meta-Analysis," was published in the Educational Research Review in 2014 by Kim, Lee, Kang, and Kim. The total effect of augmented reality technology on scientific education is looked into in this meta-analysis. The authors review and synthesize the results of earlier studies to evaluate the impact of AR on various educational outcomes. A paper by (Dunleavy et al. 2009) analyses the benefits and drawbacks of immersive interactive augmented reality models for education. They investigate the benefits and drawbacks of implementing augmented reality technology in the educational setting. The two studies' findings shed light on the applications, benefits, and limitations of augmented reality technology in scientific education. The meta-analysis provides a broad view of the impact, whereas the second study focuses on the special affordances and restrictions of immersive participatory AR simulations (Kim et al. 2014, Dunleavy et al. 2009).

Ullah, R. et al.'s study from 2017 examines the usage of augmented reality (AR) in engineering design and production, concentrating on its uses and effects in these fields (Ullah et al. 2017).

(Cipresso et al. 2011) give a network and cluster analysis of the literature on virtual and augmented reality research, examining the history, present, and future trends in this field. When discussing the application of augmented reality (AR) in informal science education, (Salmi, Thuneberg, and Vainikainen, 2017) focus on how it can improve learning opportunities and make invisible phenomena observable (Cipresso et al. 2018, Salmi et al 2017).

According to a proposal by (Singhal, Bagga, Goyal, and Saxena 2012), 'Augmented Chemistry acts as an interactive education system that makes use of augmented reality technology to improve learning in the subject of chemistry. [Syuhendri et al. 2019] investigate student instructors' comprehension of Kepler's laws of planetary motion and clarify any misconceptions that may exist. (Yashpal Netragaonkar, 2021) analyzes the skill sets needed in higher education in the twenty-first century, noting the potential, challenges, and advantages given by twenty-first-century technologies such as AR [Singhal et al. 2012, Yashpal, Netragaonkar 2021].

(Yashpal Netragaonkar, 2022) wrote a book that investigates the use of AI in higher education and its implications. The creation of an elective course in Novosibirsk called "Supplemented Reality" was discussed by (D. Yu. Kalugin in 2017). This course is about using augmented reality in education. (J. Hawking 2017) wrote "Unity in Action," a book about multiplatform development with the C# programming language. Peter released the book in St. Petersburg. In Budapest, Halas I. wrote the book "Principicon" in 1958. The book focuses on well-known electrical engineering subjects and offers information on several different elements of the subject as well as information on cutting-edge augmentation technologies (Yashpal, Netragaonkar 2022, Halas I. 1958).

In a 2011 review article published by Deshpande, Amit A., and Samuel H. Huang, the authors provide a survey of the most recent and cutting-edge uses of simulation games in engineering education. It was determined that the effective use of simulation games in engineering education would optimize the degree to which students' academic knowledge could be used in the workplace. In a 2013 paper by [Häfner et al. 2013], a teaching methodology for a practical course in virtual reality for graduate and undergraduate students was introduced. The paper includes some project examples from the last three years and addresses the significance of the task specification, work group makeup, and course design for the course's effective implementation. (Afsharipour, Mohammadhossein, and Pooneh Maghoul 2024) investigate how to improve the presentation and communication of soil mechanics ideas through the use of Augmented Reality (AR) and Virtual Reality (VR) models as part of Education 4.0. The development of 3D illustrations for geotechnical ideas is explained in depth, step-by-step, and includes export and publishing methods, animation, UV mapping, texturing, and animation. A handbook published in 2011 by Eastman et al. provides insights on Building Information Modelling (BIM) and also application of AR in it. With AR-powered BIM, issues can be identified, shared with the appropriate team members, and resolved promptly, whether on- or off-site. It's a very visible and effective method of problem-solving (Deshpande et al. 2011, Eastman et al. 2011).

In Automation in Construction, [Yan Wei et al. 2011] published a paper that investigates the combination of Building Information Modeling (BIM) and gaming techniques to achieve real-time interactive visualization in architecture. At the IEEE Global Engineering Education Conference (EDUCON) 2011, Abulrub AG, Attrige AN, and Williams MA presented a paper that explores the application of virtual reality in the field of engineering education. In the book "Virtual Reality Aided Design," Zimmermann P. (2008) surveyed the utilization of Virtual Reality (VR) in the automotive industry. In the book "E-Learning in der Lehre: Übersicht und Beispiel Implementation mit ILIAS," Weber H. et al. (2008) delve into the subject of e-learning. The chapter provides an overview of e-learning and includes a practical demonstration using ILIAS. In the article "Advantages and challenges associated with augmented reality for education: A systematic review of the literature," published in Educational Research Review, Akçayır, M., & Akçayır, G. (2017) conduct a comprehensive review of the literature on augmented reality for education. The review critically examines the advantages and challenges associated with the implementation of augmented reality in educational settings (Yan et al. 2011, Akçayır et al. 2017).

In Educational Research Review, Lee, Kim, and Kim (2015) conducted a meta-analysis where the study aimed to explore the efficacy of augmented reality in the context of e-learning. An article by Billinghurst and Duenser (2012) discusses the potential benefits and possibilities of augmented reality in educational settings. In the Handbook of Research on Educational Communications and Technology, Dunleavy and Dede (2014) contribute to the topic of teaching and learning with augmented reality. They provide insights and lessons learned in this field. In the International Journal of Gaming and Computer-Mediated Simulations, O'Shea, Mitchell, Johnston, and Dede (2009) share their experiences and expertise in designing augmented realities. They delve into the practical aspects of creating augmented reality experiences. Arbeláez, Viganò, and Osorio-Gómez (2019) focus on haptic augmented reality (HapticAR) and its application in assembly guidance, as highlighted in the International Journal of Interactive Design and Manufacturing. Hincapié, Caponio, Rios, and Mendívil (2011) discuss augmented reality applications specifically in aeronautical maintenance, as presented at the 13th International Conference on Transparent Optical Networks. Kamarainen et al. (2013) introduce the EcoMOBILE project in Computers & Education, which integrates augmented reality and probeware to enhance environmental education field trips. Zhou and Chen (2018) conducted a meta-analysis published in Educational Research Review, investigating the effectiveness of augmented reality in science education. Lastly, in Interactive Learning Environments, Yang, Chen, and Jeng (2010) explore the integration of augmented reality and tangible interaction in the domain of astronomy education. Garcia-Ruiz and de la Torre-Díez (2018) survey the use of augmented reality in industrial maintenance, focusing on its application and impact in the journal Sensors (Lee et al. 2015, Garcia-Ruiz 2018).

A paper by Hsieh and Wu (2019) provides insight into the world of engineering design and the potential of augmented reality technology to improve student learning experiences. The study's goal is to evaluate the usefulness of augmented reality in improving student engagement, comprehension, and performance. The article discusses the advantages of incorporating augmented reality into engineering education and makes suggestions for how to do so in a way that will be successful (Hsieh et al 2019).

A comprehensive evaluation of augmented reality applications in maintenance was conducted by Palmarini, Erkoyuncu, Roy, and Torabmostaedi (2018) and published in Robotics and Computer-Integrated Manufacturing. Their research looks at the many applications of augmented reality in maintenance processes, offering light on potential benefits and practical implications. Webel et al. (2013) present an augmented reality training platform designed to improve assembly and maintenance skills. The authors focus on developing a training system that leverages augmented reality to enhance proficiency in these areas (Palmarini et al. 2018, Webel et al. 2013).

Speicher, Tenhaft, Heinen, and Handorf (2015) discuss the utilization of augmented reality applications in enabling Industry 4.0. Their study examines how augmented reality can be integrated into industrial settings to support and enhance various processes associated with Industry 4.0. In the domain of design and manufacturing, Nee, Ong, Chryssolouris, and Mourtzis (2012) explore the applications of augmented reality. Their research investigates how augmented reality can be harnessed to facilitate design and manufacturing processes, offering potential improvements in efficiency and productivity. Mario Lorenz et al. (2019) address the requirements for an augmented reality maintenance worker support system in industrial settings. Their study focuses on identifying the necessary elements and functionalities of an augmented reality system that can effectively support maintenance workers in industrial environments. S. Oh and W. Woo (2008) introduced ARGarden, an augmented edutainment system that incorporates a learning companion. The system combines augmented reality with educational and entertaining elements to provide an immersive and interactive learning experience)Speicher et al. 2015, Oh et al. 2008).

Sivapriyan et al. (2024) presented a paper that delves into the profound impact of Augmented Reality (AR) in civil engineering education and practice. The paper highlights AR's potential to revolutionize sectors, emphasizing its pivotal role in shaping future innovations by bridging the digital and physical realms seamlessly (Sivapriyan et al. 2024).

At the 2020 International Conference on Vocational Education and Training (ICOVET), Sendari, Siti, and Adim Firmansah presented a study that investigates the performance of augmented reality (AR) based on Vuforia using 3D marker detection, particularly in addressing skills gaps in engineering education. Through various scenarios involving different shooting angles, light intensities, distances, and coverage of the object's surface, the study evaluates Vuforia's performance. This research contributes to enhancing the effectiveness of AR-based learning media in addressing skills gaps in engineering education. Xu et al. proposed a study in 2024 that explores the impactful role of augmented reality (AR) features in e-commerce. Through a mixed-method approach, the research contextualizes the Stimuli-Organism-Response (S-O-R) framework within the domain of AR retailing. The study aims to identify key AR features influencing consumers' perceptions and behaviors in e-commerce, enhancing their understanding of products and fostering a playful atmosphere. In a 2024 paper, Chen et al. examine the role of augmented reality (AR) in the metaverse market, focusing on multimodal sensory interaction. They experimented and employed structural equation modeling (SEM) to analyze the data, revealing that AR's multimodal sensory interaction enhances consumers' intention to purchase in metaverse spaces. The findings offer insights for designing metaverse environments and highlight AR's potential to enhance consumer experiences beyond traditional online shopping settings (Sendari et al. 2020, Chen et al. 2024).

Liao et al. in 2024 conducted a comparative study to explore the impact of the augmented-reality game-based learning application "StemUp" on English language learning and motivation among elementary school EFL students in rural and urban areas. The study concludes that "StemUp" with its 3D AR features effectively enhances language gains and motivation, creating an engaging learning environment for EFL learners in both rural and urban settings (Liao et al.2024).

Mokmin, Nur Azlina Mohamed, and Regania Pasca Rassy's review article in Education and Information Technologies (2024) examines the trends in augmented reality (AR) technology usage for students with disabilities in physical education (PE). The review provides a comprehensive analysis of AR applications, technology types, and target learning disability groups in PE. By offering insights into AR's development and its potential benefits in PE for students with disabilities, the study contributes to advancing research in this field and provides opportunities for further exploration. Drljević et al. (2024) published a research paper where it investigates observational frameworks for student involvement during the usage of augmented reality (AR) in early elementary education. Present observational models to assess interaction are examined in terms of their compatibility with AR learning opportunities, with an emphasis on both real-world and theoretical challenges related to student engagement monitoring. The Augmented Reality Lessons involvement Observation framework, or ARLEO, is a methodology for observing student involvement in AR that is unique to this setting and is based on pre-existing framework approaches. It is predicated on the constant comparative time coding of lesson videos captured with ARLEs on tablet PCs. Finally, recorded actions from elementary school students in the first and second grades during the use of ARLE are utilized to offer examples of application (Mokmin et al. 2024, Drljević et al. 2024).

The research proposed by Hsu et al. in 2024 investigates how important elements of augmented reality (AR) applications affect impulsive purchasing intentions. The results provide valuable data for AR application developers seeking to optimize AR programs for the best user experience, as well as shed light on the link between AR attributes and customers' impulse buying preferences. Liu et al. in 2024 present a study about a user-friendly robot teaching system based on augmented reality-assisted interaction, deep reinforcement learning, and cloud edge orchestration. Comparative numerical tests are carried out in an actual machining workplace, and the findings show that the suggested robot teaching method is both efficient and feasible due to deep reinforcement learning and cloud-edge orchestration. In 2024, Gutiérrez et al. presented a quasi-experimental research methodology that was applied to 107 first-year engineering students divided into two groups: control and experimental. Based on the experimental results, it can be concluded that the experimental group outperformed the control group in the post-test and received better academic scores. AR intervention has a significant favorable impact on student learning attitudes. Students who learned using AR technology showed a more positive attitude toward the electronics subject and AR technology (Hsu et al. 2024, Gutiérrez et al. 2014).

A paper published by Dini et al. (2015) offers a thorough analysis by examining a few recent applications in a variety of fields, including aerospace, railroads, industrial plants, machine tools, military equipment, subterranean pipelines, civil constructions, etc. Potential benefits, limitations, and disadvantages are highlighted, along with unresolved problems that may pose new difficulties in the future. An article by Bazarov et al. (2017) presents an Augmented Reality application for educating electrical and technology engineering students. A questionnaire was created and made available to students after an analysis of the state of higher education was conducted. The study comprised 24 students and looked at the learning objectives of the participants, their level of interest in studying, and their satisfaction with the educational process (Dini et al. 2015, Bazarov et al. 2017).

A paper by Badyorina et al. (2022) explores how a theoretically sound knowledge-processing methodology can generate and extract valuable new information through advanced technology. Powar et al. (2022) published a work where 3D printing technology and project-based learning were used for third-year undergraduates to 3D print internal combustion engine components, enhancing comprehension and resulting in a 5.15% improvement in CO attainment and over 10% improvement in written exams. This approach also promoted professional skill development, multidisciplinary learning opportunities, and lifelong learning. A study published by Buhari et al. in 2022 seeks to evaluate the continuous assessment performance of students in both Google Meet-based virtual classes and conventional in-person classroom settings. In a paper published in 2021, the authors present experiments with the undergraduate DBMS course using tools like crosswords, word scrambles, findword, and Kahoot, concluding with a class survey to gather feedback on these technologies. Naik et al. published a paper in 2021 where they outline their 7-point methodology, design, evaluation process, and the challenges encountered by both students and faculty, illustrated through representative projects (Badyorina et al. 2022, Naik et al. 2021).

A paper by Lokare et al. (2020) demonstrates the application of two pedagogic paradigms, Project-Based Learning, and Collaborative Learning, to the Internet Technology Laboratory course, showcasing how these approaches enable students to achieve superior course outcomes compared to traditional laboratory teaching methods. A paper published by Kannan et al. in 2018 explores the opportunities and challenges encountered by both new and experienced faculty in teaching "Computer Programming in C," based on a study with collected responses that highlight key areas for addressing challenges and leveraging opportunities. A paper by Deepika et al. (2021) describes the process undertaken by the faculty to align technological tools with the various pedagogies identified for the courses. A study (2021) by Bhamre et al. explores the intentional use of spaced questioning to maximize the benefits of feedback in the classroom. Meti et al. in 2021 published a paper that aims to enhance course content, delivery, and evaluation through an OBE framework and validate the effectiveness of the Manufacturing Technology laboratory course using a PBL approach (Lokare et al. 2020, Meti, et al. 2021).

3. Augmented Reality Technology

To enhance the user's perception and interaction with their surroundings, augmented reality involves superimposing computer-generated material over the real world. Using cameras, sensors, and other input devices, augmented reality (AR) systems gather data about the user's surroundings and then add virtual elements like 3D models, animations, or educational displays to enhance it.

One of the key aspects of AR is its ability to blend digital content seamlessly into the real world, creating a mixed-reality experience. This integration allows users to perceive and interact with virtual objects as if they were part of their physical environment. Real-time interaction is another important feature of AR. Users can engage with the augmented content in real time, manipulating and responding to it as it dynamically adapts to changes in the real world. This interactivity enhances user engagement and opens up numerous possibilities for applications across various fields, including gaming, education, design, healthcare, and more.

Accurate three-dimensional alignment of virtual and real objects is crucial for creating a convincing AR experience. By utilizing techniques like computer vision, object tracking, and spatial mapping, AR systems can precisely anchor virtual objects to specific points or surfaces in the real world. This alignment ensures that the digital elements maintain their position relative to the physical environment, regardless of the user's movements. Overall, augmented reality technology offers exciting opportunities for innovation and creativity, enabling users to perceive and interact with their surroundings in new and enhanced ways.

Fig. 1 : Types of ARTs which are based on their differences.

1. Location-based AR: This sort of AR uses augmented reality GPS to determine the user's external location. It supports a variety of location-based applications, including Waze, Google Maps, Lyft, Uber, GasBuddy, and WhatsApp by identifying a person's whereabouts globally. However, it consumes a large amount of energy, making it better to use Android or iOS's location services.

2. Projection-based AR: To create three-dimensional images, projection-based augmented reality (AR) throws immersive light onto a flat surface. It detects human interaction with augmented content using Simultaneous Localization and Mapping (SLAM). By permitting the fabrication of holograms, this technology can be used for both professional and leisurely pursuits.

3. Overlay-based AR: By overlaying a virtual image of an object that has been upgraded, overlay markerless AR provides several views of the same object that are not now available. The Nextech Configurator, which enables customers to alter the color and configuration of a 3D product model, is an illustration of this technology. By placing it in their room, customers can picture how the customized item would appear in their setting.

4. Contour-based AR: By using SLAM to outline item silhouettes, contour-based AR, sometimes referred to as outlining AR, can imitate natural human contact. This form of AR can be especially beneficial in designing applications for safe driving in difficult settings such as poorly lighted roads, severe rains, or low visibility situations.

By categorizing ARTs based on their unique features, we can better understand and explore the diverse applications and capabilities of augmented reality technology.

3.1. ART and Science Education

"Education is not preparation for life; education is life itself." – John Dewey

Education plays a crucial role in the development of human life across all aspects. It begins with the Gurukul system, and as time progresses, the concept of education undergoes various transformations. Traditional tools like chalk and blackboards have been replaced by smart boards and smart pens as technology enters the education sector. In the 1980s and 1990s, educational technology, television, and audiovisual aids emerged, while today, computers, laptops, tablets, and educational apps, along with advancements like machine learning, blended learning, computer-assisted learning, flipped classrooms, artificial intelligence, and augmented reality, are transforming education even further. The global market and society are immersed in scientific knowledge and the derived concepts from science and technology. Science and technology are interdependent, with science exploring knowledge and technology facilitating its practical application for the betterment of human life. The recent knowledge explosion has led to the creation of technologies such as artificial intelligence, cloud computing, machine learning, flipped classrooms, blended learning, computer-mediated technologies, and augmented reality, all of which enhance learners' perception and contribute to effective teaching. The fundamental aim of science education is to increase understanding of science, promote the construction of knowledge, and foster scientific literacy and responsible citizenship. Science's success is measured by its truthfulness, as stated by J.W.N. Sullivan, while Henri Poincare compares science to a house built with stones, emphasizing that an accumulation of facts alone does not constitute science. Mahatma Gandhi defines true education as one that stimulates the spiritual, intellectual, and physical faculties of children, highlighting the holistic nature of education.

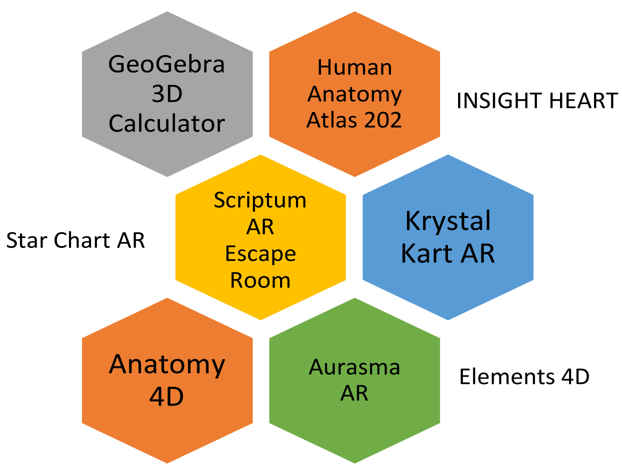

Fig. 2 : ART Apps

3.2. ART and Present Classroom Strategies

In the current era, classrooms have become increasingly technologically advanced, incorporating cutting-edge techniques such as smart boards that are as advanced as Android devices available in the market. Augmented reality presents a valuable opportunity to enhance classroom experiences by creating interactive assignments that involve navigating through the school campus or nearby locations. Here are some potential applications of augmented reality in the classroom.

Below is a curated list of augmented reality apps that can be effectively utilized in educational settings:

1) GeoGebra 3D Calculator
2) Civilizations AR
3) Human Anatomy Atlas 2021: Complete 3D Human Body
4) INSIGHT HEART
5) Scriptum AR Escape Room
6) Krystal Kart AR
7) AR Flashcards
8) Star Chart AR
9) Just a Line - Draw Anywhere, with AR
10) Chromville Science - A Beginner's Guide for Anatomy
11) Anatomy 4D - Your "On the Go" Anatomy Teaching Tool
12) Unravel the "Under Water" Secrets through the Barcy AR App
13) Elements 4D - An Easy Way To Master Chemistry
14) Arloon Geometry - An AR App
15) Butterfly AR
16) Aurasma AR

Furthermore, the AR Media Player app allows students to explore three-dimensional models from various angles, providing the ability to pinch, rotate, and zoom the models from any perspective. This app is also compatible with Google SketchUp models, expanding its versatility and potential applications in the classroom.

3.3. ART In Engineering & Technology

The use of AR in engineering and technology is being used gradually as the technology becomes more advanced. As an illustration, researchers developed an AR application that allowed students to investigate the effects of magnetic fields to explain the fundamental principles of electromagnetism. The advantages of augmented reality have been demonstrated in numerous studies to include greater authenticity, increased animation, raised interactivity, improved student engagement, and decreased costs. The phrase "augmented reality" (AR) has become more well-known in recent years. With applications in the fields of architecture, commerce, sports, the military, and geographic information systems (GIS), augmented reality has grown to be a highly versatile technology. Given this, engineering can benefit greatly from the use of augmented reality. These are the six augmented reality engineering applications that are currently in use: CAD, gaming, assembly, upkeep, instruction, and quality assurance.

I. Gaming - The gaming business was one of the first to embrace augmented reality technology and is now one of the most active areas in terms of AR development. The debut of the Pokemon GO game in 2016 was a watershed event that showcased the possibilities of AR in the gaming industry. The game immediately became a global hit, with millions of people playing it on their cell phones. The success of the initial AR mobile games has reignited the gaming industry's interest in AR technology. Several big gaming companies, including Nintendo, Microsoft, and Sony, are aggressively investing in AR technology.

II. CAD - The ability of AR to depict a design that is present in the CAD program as it would appear in the real world is one of the major benefits it offers over CAD. This will be accomplished by utilizing two interfaces: the visual target and the software. Assume you're working on an IC engine or any component of a car's interior. Designers may view the design via the physical surroundings by superimposing the digital data of design elements. This has essentially propelled designers and engineers into embracing AR technology to see various sets of prototypes and hypotheses.

III. Assembly - Assembly is a critical step in the manufacturing process. The total cost of a product, the time required to complete it, and its quality are all determined by the efficiency and precision with which the various assembly phases are carried out. These processes can sometimes be difficult and need minute modifications to get a satisfactory outcome. A complex series of many elements must be assembled in a specific order to guarantee that the product will function as it should. Augmented Reality (AR) technology may be particularly well-suited to overcoming these challenges. To connect the user's eyes with the actual scene in front of them, an AR system must first create virtual elements in their optical path. To do this, the following steps must be taken: With the aid of a video camera, real-world images are captured, and tracking is necessary to identify and keep track of the location and orientation of objects in the environment for the virtual image to be correctly aligned. Vision-based tracking technologies, such as virtual image and composite image production, as well as markerless and fiducial marker identification (which use properties of the object rather than artificial markers to locate components in space), are also widely used.

IV. Maintenance - For the upkeep and repair of equipment, augmented reality is employed in several industries. When a technician directs the camera at a machine, electrical wiring, or plumbing, the device displays relevant comments on the screen. Arrows on the screen indicate what the notes are referring to. Using this technology, an expert can discover the source of the problem more quickly. He or she knows where each pipe or cable is, the drive that powers each motor, and other data. He or she could receive information from the device regarding the replacement parts that are required and whether or not they are available in the warehouse. AR can direct the technician in the desired order. For example, it might begin by removing covers and guards before going on to filter replacement and drain port inspection.

V. Training - In several work training scenarios across numerous disciplines, augmented reality-based teaching is already being implemented. According to Deloitte research, about 90% of medium-sized businesses are currently utilizing AR in various capacities. Walmart, which has always been forwardthinking, has opted to go with AR-based staff training and has purchased several thousand Oculus Go headsets for the purpose. Numerous multinational firms and huge enterprises have begun to hire developers to create AR apps for their training programmers.

VI. Quality Control - Manufacturing businesses will be able to prevent flaws throughout the production process by using AR (Augmented Reality) for quality assurance, thus assisting them in providing consumers with the best goods. AR can be useful for training untrained staff to conduct an inspection. The system may show the inspection procedure recommendations on the AR screen. This will help technical professionals at every step of the process. As a consequence, there will be no issue with forgetting to include certain product components.

3.4. AR Importance in various engineering technologies

1) Applications of Augmented Reality in Electrical Engineering - You can accurately replicate equipment and processes using 3D visuals. Only the computer's processing power and capacity to faithfully reproduce the simulated object can limit the simulation's accuracy. The developed augmented reality application is meant to be used in the learning process for subjects like "Introduction to Professional Activity" and "Electrical Machines" for "Power Engineering and Electrical Engineering." The "Electrical Engineering" course might cover engineering specialties outside of electrical engineering.

2) The Use of Augmented Reality Technologies in Civil Engineering - AR has several helpful applications and provides productivity benefits. It serves as an auxiliary tool that makes it easier to compare the main applications. Real-time comparisons with the existing structure may be made using the models, which would also aid in the field coordination of subcontractors. AR might also determine the overall positions of existing systems to avoid any unintended damage that may occur when cutting through concrete slabs or walls. Despite the relatively high initial expenses, the productivity value and advantages surpassed them. Because AR did not meet the criteria for simplifying construction, only the consulting firm thought it was not yet worth using.

3) The Application of Technologies for Augmented Reality in Computer Engineering - A fast-developing technique in computer engineering is augmented reality (AR). User interfaces, visualization, maintenance and repair, training, and product design are just a few of the uses it can be put to. The capacity to design more creative and highly engaging user interfaces is one of the main advantages of augmented reality in computer engineering. Virtual keyboards or control panels can be added to physical devices using augmented reality to make it easier for users to interact with them. To generate virtual prototypes and test designs in a simulated setting, AR can be utilized in product design. This enables designers to see how a new product will look and function in the real world without the need for costly and time-consuming.

4) The Use of Augmented Reality Technologies in Biotech Engineering - Augmented Reality (AR) technology has the potential to greatly benefit the field of biotech engineering. AR can change the way scientists and researchers work in the laboratory and has several applications in the field. Drug discovery is one of the most promising applications of AR in biotech engineering. Researchers can gain a better understanding of how different molecules interact by using AR to visualize and manipulate 3D molecular structures. Allowing researchers to simulate and test new compounds in a virtual environment, can speed up the drug discovery process. Medical imaging, such as MRI or CT scans, can also benefit from AR. AR can be used to superimpose a medical image onto the patient's body, allowing doctors to visualize the internal structure more imaginatively and accurately. This can result in more accurate diagnoses and treatments. AR can help researchers navigate complex laboratory procedures by providing real-time feedback and instruction. This can reduce errors and boost laboratory efficiency. AR can be used in education and training. Students and researchers can gain a better understanding of complex biotech concepts and techniques by using AR to create interactive training materials. This can result in a more skilled workforce and faster advancement in the field.

5) The Use of Augmented Reality Technologies in Marine Engineering - Augmented Reality (AR) is an innovative technology with the potential to revolutionize the field of marine engineering. Ship

design and simulation is a key application of AR in this field. Engineers can use AR to visualize ship designs in 3D and identify potential design flaws such as structural weaknesses or equipment placement issues. This allows them to make necessary adjustments and improvements before the ship's construction, lowering the risk of costly mistakes and delays. AR can also be used to simulate ship operations, allowing engineers to test various scenarios and optimize ship performance. Furthermore, AR can help with ship maintenance and repair by providing technicians with real-time data and instructions on how to complete tasks, improving efficiency and accuracy.

4. Ar Need And Significance

A. Improved Visualization: AR technology enables engineers and designers to visualize their designs more realistically and interactively, which can assist in identifying design flaws and improving overall product quality. This can result in improved efficiency and cost savings.

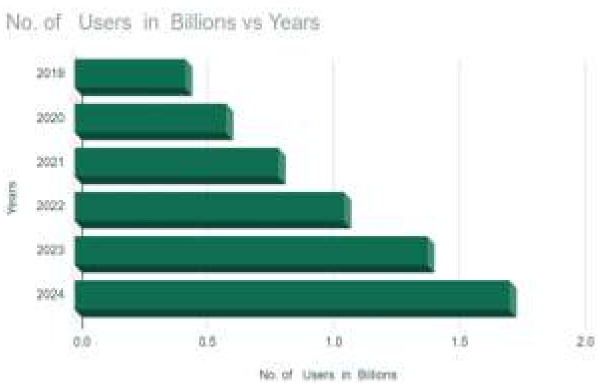

Fig. 3 : Comparison of increasing users of ART since 2019.

https://www.statista.com/statistics/1098630/global-mobile-augmented-reality-ar-users/

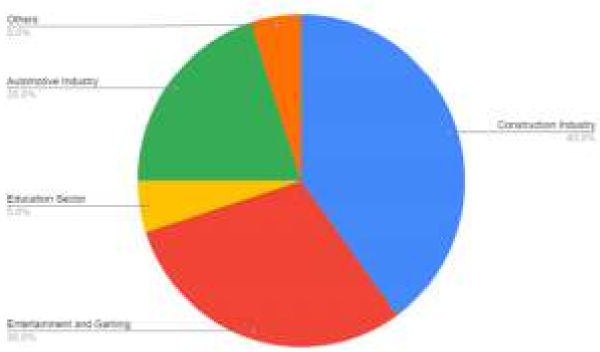

Fig. 4 : Use of ART in different sectors or Industries.

Table 1: Comparison of Art in Science Education And Engineering Technology

Aspect	Science Education	Engineering Technology
Goal	To teach scientific concepts and theories through immersive experiences	To facilitate learning of engineering design and construction processes
Applications	Biology, Chemistry, Physics, Geology, Astronomy, Ecology	Architecture, Civil Engineering, Mechanical Engineering, Aerospace Engineering
Benefits	Enhances understanding of abstract concepts, improves engagement, and retention	Enhances design visualization, improves construction and assembly accuracy, improves worker training
Examples of AR tools	Anatomy 4D, Elements 4D, Augmented Reality Sandbox	ARchitect, ARWeld, AR - Inspect, AR-Assist
Challenges	Limited availability of AR resources, high development costs, technical barriers	Limited availability of AR tools, difficulty in replicating real-world situations, limited accuracy in detecting changes in real-world environments

B. Enhanced Learning Experience: By providing interactive and immersive simulations, AR can improve the learning experience for engineering and technology students. This can assist students in comprehending complex concepts and improving their problem-solving abilities.

C. Increased Safety: In the manufacturing and construction industries, AR can be used to provide workers with real-time information and guidance, which can help prevent accidents and injuries.

D. Technology Advancement: Researching AR can help improve and advance technology. Developers and engineers can identify technology limitations and develop solutions to address these limitations by conducting research.

AR has the potential to generate new business opportunities in a variety of industries. By researching augmented reality, entrepreneurs can identify market gaps and create new products or services that make use of the technology.

5. Discussion and Conclusion

Augmented reality (AR) is revolutionizing the engineering industry and holds immense potential in various other sectors. Its ability to generate precise data on design, components, and machinery translates into significant time and cost savings. Additionally, AR enables users to visualize 3D designs in different configurations, providing a realistic experience similar to real-life interactions.

AR technology has experienced rapid advancements in Augmented reality (AR) is revolutionizing the engineering industry and holds immense potential in various other sectors. Its ability to generate precise data on design, components, and machinery translates into significant time and cost savings. Additionally, AR enables users to visualize 3D designs in different configurations, providing a realistic experience similar to real-life interactions.

AR technology has experienced rapid advancements in recent years, gaining popularity across diverse industries like entertainment, gaming, education, and healthcare. With ongoing technological advancements, the possibilities for AR applications are virtually limitless. Shortly, AR is projected to become more commonplace as devices and platforms increasingly incorporate AR features. In the realm of science education, AR is expected to become an indispensable tool for both learning and teaching. By offering students a more engaging and interactive learning environment, AR enhances their understanding of complex concepts intuitively. It also enables the simulation of real-world scenarios, facilitating the development of practical skills among students. The use of ART has increased significantly since the last decade as new techniques are introduced for better understanding for elementary-level school students.

Augmented Reality Lessons Engagement Observation framework (ARLEO), an innovative methodology in the education sector, revolutionizes student engagement assessment by leveraging ART. It involves systematic observation and analysis of classroom interactions during AR learning experiences using tablet computers. ARLEO facilitates a comprehensive understanding of individual student engagement levels across various learning scenarios, enabling comparative research and optimization of AR-based teaching strategies.

AR is moving toward deep learning, multimodal sensory interaction, robots, building information modeling, and much more these days. The benefits of technology for shopping in metaverse places and the distinctive character of interaction are becoming better-understood thanks to augmented reality. Increased multisensory experience and spatial presence via multimodal sensory contact can help to effectively reduce product ambiguity and information overload. Only in the set task environment may operators handle and pre-program robots due to a lack of easily understood and practical education methods. While some 3D planning suites can simulate offline programming, there is still a lack of interaction with the actual environment and impediments. A method for augmented reality-assisted interaction that uses deep reinforcement learning and cloud-edge orchestration for user-friendly robots is being developed to address research gaps. AR provides valuable insights for application developments as well by enhancing user experience through immersive features. One common and important consumer behavior that has a big impact on organizations is impulse buying. Numerous studies have conclusively shown that customers regularly give in to impulse buying, motivated by a variety of factors such as enticing promotional commercials and eye-catching product designs. The relationship between AR characteristics and consumers' impulse buying intentions is improving as per commercial growth is concerned. Cutting-edge AR technology for BIM seamlessly merges advanced augmented reality with BIM software, offering real-time visualization and interaction with 3D models on-site via AR glasses or wearables. This integration provides instant access to vital data like design plans and equipment locations, fostering collaborative decision-making and enhancing project efficiency, accuracy, and safety.

As augmented reality (AR) technology develops, it will more and more seamlessly integrate with other cutting-edge technologies, such as artificial intelligence and the Internet of Things. This integration will increase AR's potential, creating new opportunities for innovation and promoting development. As AR becomes more advanced in engineering, it has the potential to change several industries, including education and civil engineering.

AR stands at the forefront of technological advancements, reshaping the way we perceive and interact with our environment.

Overall, the integration of AR technology in science education and engineering has the potential to revolutionize the learning and working experiences of students. As AR evolves further and becomes more accessible, its role in these fields is expected to become increasingly prominent.

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