EAI EndorsedTransactions
on AI and Robotics

Research Article EAI.EU

Immersive Horizons: Exploring the Transformative Power of Virtual Reality Across Economic Sectors

Abiodun Durojaye[1], Amin Kolahdooz[1,*], Abdullah Nawaz[2], Ata Jahangir Moshayedi[3]

[1]Faculty of Technology, School of Engineering and Sustainable Development, De Montfort University, Leicester, UK.

[2]Department of Electrical Engineering, University of Engineering and Technology, Peshawar, Khyber Pakhtunkhwa, Pakistan.

[3]School Of Information Engineering, Jiangxi University Of Science And Technology, No 86, Hongqi Ave, Ganzhou, Jiangxi,341000, China.

Abstract

The scholarly discourse surrounding the manifold advantages, applications, and limitations of implementing Virtual Reality (VR) in the contemporary milieu has burgeoned over time. VR holds immense potential, attracting fervent interest from governmental and private entities alike. Nevertheless, the existing body of literature pertaining to the expanding utilization of VR in diverse economic sectors remains scant. Therefore, the primary objective of this study is to furnish a comprehensive literature review encompassing VR applications across various economic domains while elucidating concerns surrounding its integration within engineering education. A total of 108 publications were extracted from prominent databases such as Scopus, Elsevier, Science Direct, and Google Scholar, with a subsequent review of 51 relevant works. These scrutinized journals were published between 2015 and 2022 and were predominantly authored in English. The reviewed publications encompassed VR applications in education, robotics, healthcare, transportation, sports, agriculture, governance, security, and media. The study's findings unveiled significant advancements in VR implementation within engineering education, medical training, cognitive augmentation, aircraft assembly, governance, and diverse other spheres. Notwithstanding these achievements, impediments to VR deployment were identified, stemming from financial exigencies, cultural and conventional norms, with scant evidence of VR's prevalence in underdeveloped nations, given that all the assessed research originated from developed economies. Additionally, the limitations of this review encompassed a small sample size and a narrowly focused demographic in the examined articles. Nevertheless, despite these constraints, the research highlights substantial progress in VR utilization over the preceding decade.

Received on 27 May 2023; accepted on 05 June 2023; published on 09 June 2023

Keywords: Virtual Reality, Economic Sectors, Robotics, Education, Health

doi:10.4108/airo.v2i1.3392

1. Introduction

Various definitions of Virtual Reality (VR) exist in the literature owing to the complexity of describing VR since interpretations are also related to the aims and methods on which it is utilised. At its most basic level, VR's fundamental purpose is to give the impression of being in another location or engaged in a different world [1]. Technological breakthroughs are bringing us closer to developing the concepts we imagine through seeing and reading a reality. In recent years, many devices such as the Oculus Quest 2, Sony PlayStation VR, HP Reverb G2, and others have made VR technologies more accessible to the entire populace [3]. Education, travel and tourism, construction, sports, and the financial environment were among the most affected human institutions during this global epidemic, as a result of crowd control and social alienation control measures implemented and regulated to prevent the virus from spreading and keeping the populace safe [3–6, 8–10]

*Corresponding author. Email: amin.kolahdooz@dmu.ac.uk

Externalities such as these resulted in immigrants being barred from leaving or entering another nation, as well as the shutdown/restrictions of educational institutions, public transportation and cross-border transit, hotels, and rental flats, public recreation and leisure spaces, and other services [3–6, 8–10]. VR technologies have been implemented in a variety of industries, ranging from aerospace [13], education [14, 16], healthcare [17, 18], music [19], and media [20] to robotics [21], and tourism [23]. From the standpoint of knowledge and skills acquisition, it has been proposed that VR may be viewed as a heuristic instrument via which users of VR technology can learn skills such as spatial socialization, exchanging ideas, data visualization, and real-time experimentation [24, 26]. Notably, when information is presented numerous times and through multiple channels, people learn more and remember it better, allowing instructors to cater to each student's "preferred" learning method [27]. Furthermore, virtual reality technology may aid in teamwork and communication, which promotes the notion of problem-based learning in the classroom [29]. VR is being implemented in a variety of instructional settings in higher learning, including languages, math, and science [30, 31]. Scholars have just begun to investigate VR design concepts for higher education, which is supported by valid learning theories that provide optimal learning outcomes. Accordingly, [32] significant VR attributes that create beneficial learning results include interactive capabilities, immersion interfaces, animation routines, movement, and simulated virtual scenarios [33].
According to statistics [36], the worldwide virtual and augmented reality technologies market is predicted to increase at a Compound Annual Growth Rate (CAGR) of 60.4 percent from $13.4 billion in 2018 to $142.4 billion in 2023. This anticipated rise emphasises the need for further research and development in VR technology to attain the optimum outcomes, since it has been recognised as a vital technology that will define the future of e-commerce and may be used by businesses to influence consumers' purchasing decisions [37]. The world's current uncertainties, such as the COVID-19, is the most recent in a string of occurrences that has kept the globe on edge for the past two decades, has emphasized the importance of continuing to adopt and utilize remote accessible and virtual technologies in all areas of human endeavour. Thus, this study aims to provide a literature review of VR application in various economic sectors, and the concerns associated with adoption in engineering education.
The research contribution can be listed as follows;

- To identify the benefits, applications, and constraints of adopting VR in different economic sectors.
- To explore the concerns associated with the integration of VR in engineering education.
- To examine the advancements and progress made in VR utilization across domains such as education, robotics, healthcare, transportation, sports, agriculture, governance, security, and media.
- To highlight the limitations inhibiting VR deployment, including financial, cultural, and conventional barriers.
- To assess the prevalence and applicability of VR in underdeveloped nations.
- To contribute to the existing body of knowledge on VR's potential impact and opportunities for innovation in economic sectors.

This comprehensive review aims to provide scholars with a holistic understanding of Virtual Reality (VR) in various sectors, fostering familiarity with this emerging field. By examining the breadth of VR applications across different economic sectors, this study equips researchers with a comprehensive overview, enabling them to grasp the multifaceted potential and implications of VR.
this paper is arranged as follows; In Section 2, the paper explores the application of VR in education, highlighting its various uses and benefits within this sector. Section 3, delves into the specific applications of VR in robotics, discussing how it is revolutionizing this field. Section 4, examines the impact of VR in the realm of health, discussing its potential for medical training, therapy, and patient care. In Section 5,, the paper explores the use of VR in sports, showcasing how it enhances training, performance analysis, and fan engagement. Section 6, delves into the application of VR in agriculture, governance, security, and media. These sectors have recently garnered increasing attention from scholars due to the transformative possibilities offered by VR. The paper explores the unique applications and implications of VR in these domains. Section 7, focuses on the adoption and challenges associated with VR implementation. It investigates the factors influencing the uptake of VR technologies and highlights the obstacles that need to be addressed for successful integration. Finally, the paper concludes by summarizing the key findings and discussing the implications for future research and practice.

2. Application of VR in Education

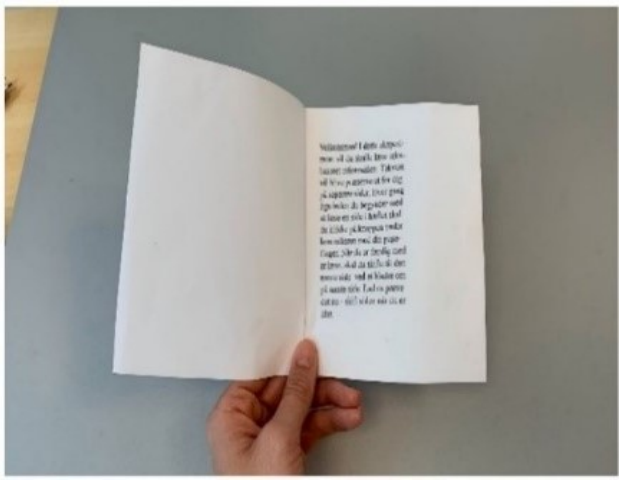
There is a growing body of literature on the applicability of VR in the education sector, most of which stressed Higher Education [14, 16, 19, 33, 38, 40, 41, 43, 44].

In the research [33], an attempt was made to examine the ability of VR technology to afford a holistic experiential learning cycle. The research methodology was premised on a design thinking workshop and focus groups with participants comprising students and lecturers from various disciplines. Findings from the workshop showed that students yearn to change from traditional teaching to a learning environment that caters to experiential learning. The group participants collectively developed three innovative VR prototypes to adequately attend to students' needs and provide a strong backing to the experiential learning process. To further validate the results of the workshop, three focus groups of students evaluated and refined the designed prototypes. The findings of the research give further credit for the practise of internet provided education learning and teaching process. An internet-enabled VR application will ensure the transfer of the real-world experience of experiential learning in higher education from field trips to an online platform or storage. Retrieval of information from an online database becomes easier and more efficient while communication is further enhanced [33]. The limitation of the study includes but is not limited to participants of the workshop and focus group being experts in subject matter and not experts in technology in the broad sense, which makes their submissions on adopting VR not to reflect the wholesome possibilities and limitations of such technology. Therefore, future studies could combine technology experts in subsequent user-oriented design activities since they will be more equipped with ideas on exploiting the uniqueness of VR for experiential learning [33].

While exploring the application of VR technology as a teaching aid to design and implement a teaching platform for multimedia music appreciation, in their research [19], expressed that the traditional method of teaching music is often restricted to being abstract in content thereby making it a heinous task to accomplish the goal of teaching. A questionnaire was designed to elicit relevant information from students and analysed descriptively. The result of the analysis revealed that students' interest in learning music was aroused as a result of applying VR technology which promotes efficiency and personal learning. Also, students in the fifth and sixth grade who used the VR platform performed better scoring 88.2 and 92.5 respectively, contrary to the control group which scored 78.5 and 84.1. Therefore, it was concluded that the application of VR technology to the teaching of music appreciation stimulates students' learning processes.

In the words of [14], students' understanding, educational experience, grade and performance was enhanced by the application of VR technology, while the institutions are presented with an avenue to spend less in term of physical laboratories and lecture halls required for the traditional teaching methods, and in the face of a similar pandemic like the COVID-19 necessitating social distancing, working from home and remote learning, students and colleges that adopt VR technology earlier than counterpart are guaranteed an edge coupled with refined educational excellence and quality assurance. These were concluded on the backdrop of a research into the application of VR technology in engineering education as it further revealed provision of levelled playing ground for students with special needs and those who cannot access the physical laboratories for practical are given equal learning experiences. In a similar perspective, the research investigated the effect of remediating content of learning from traditional non-immersive media to immersive VR on learning and cognition with specific attention to the difference between traditional learning content cognised differently in the virtual environment as a result of immersive media [38] as shown in Fig 1.

(a) Reading in VR environment



(b) Real-reading condition

Figure 1. (a) Reading in VR environment and (b) Real-reading condition [38].

A total of 48 of 51 undergraduates from European universities were provided with written learning material for a specially designed subject, and the result analysed with Electroencephalography (EEG) measurement techniques, learning tests, and cognitive load measures to compare conditions. The students were divided into two distinct groups, with one group made to read about sarcoma cancer on a printed pamphlet, and for the other group, a special hospital room was designed, and identical text on sarcoma cancer was read on a virtual pamphlet embedded within an immersive VR environment. A special spatial application of VR was designed with the aid of Unity 3D for the HTC Vive VR system coupled with the design of a virtual environment in the semblance of a hospital room environment to ease the attainment of environmental propping, which prevents learners from having contact with external objects and characters from the environment.

The study revealed that VR greatly enhances knowledge transfer as sampled participants perform better with higher scores in comparison with their counterparts who applied traditional reading and learning methods. More so, it was observed that learners applying VR find learning less demanding, unlike the other group, while the EEG measure predicted more cognitive effort and less time efficiency in VR learners when compared to the real reading condition [38, 67]. Results show that the VR group performed significantly better on a knowledge transfer post-test. However, reading in VR was found to be more cognitively efficient with lesser stress and timely. The limitation of the study is such that there is uncertainty in the translation and application of the results to other VR enhanced learning interface since the interface used for this study is that likened to a real-world device like a book. Therefore, future studies should focus on the effects or environmental embeddedness on lesser embodied reading mechanisms associated with VR. Being among the first study applying EEG to determine environmental embeddedness on cognitive actions during repeated reading, the study left out the distribution of learner's cognitive demands between additional processing stimulation resulting from the external environment and construction of internal mental representations. Hence, future studies should incorporate eye-tracking techniques with an ability to monitor visual attention during a learning process. Similarly, the effectiveness of a VR based task on undergraduate students' presentation skills in a virtual environment was investigated by measuring students' performance with a pre-and post-test multiple-choice test alongside self-evaluation instruments [40]. The research sample consists of thirty-six students from the department of life sciences in a Dutch University, of which seventeen of the students were subjected to VR conditions, and the remaining nineteen were subjected to the face-to-face condition [40]; validation of data was founded by adopting on principal component analysis (PCA). Results revealed that students exposed to the VR were appreciative of the comprehensive analytical feedback received, with a significant improvement from pre-test to post-test for the three presentations. However, a larger sample should be considered in future studies as limited sample size is a limitation to the application and generalisation of findings.

In the same vein, the efficacy of VR technology in education was examined by a study which focused more on the application of VR to business class so as to have a better understanding of its relevance to improved communication skills, participation in public events and effective presentations by students with a sample size of 71 students at the private North Eastern University [16]. Upon familiarising with the VR technology, students were admitted into an Ovation virtual classroom after putting on an Oculus rift headset in preparation for their maiden presentation, after which they are provided with feedbacks and return for another set of presentation. Generally, the study demonstrates that the adoption of VR can be extremely beneficial to business educators in helping students enhance their presentation skills by improving their engagement attributes such as gaze, voice, and gestures. The result of the study showed that the overall score of participants was significantly improved for their second presentation in the VR environment with a mean of 0.685 compared to the initial presentation with mean score of 0.579 ($p<0.01$). Findings of the study revealed that business education could be enhanced by adopting VR technology as students' presentation skill is honed by practising with a VR aided technology [16]. Future studies should therefore explore the performance of students' presentations to a live audience upon rehearsing and practising with the VR software. Another research [41] explored learning media based on VR for teaching business ethics, a learning media technique which is made of five steps, namely, analysis, designing, development, implementation, and evaluation developed by the Research & Development Institute of Yogyakarta State University and Centre for Accounting Education Faculty of Economics and Business, Universitas Gadjah Mada, Indonesia. All participants were provided an ethics theory, and those in the treatment group received it using VR-based learning media that included behaviour simulation situations with ethical dilemmas. The scenario is based on ethical difficulties that auditors may face, such as whether to choose being a detector or to remain ignorant of profit tampering by the audit client. Participants performed as auditors in this study which was targeted at appraising cognitive and non-cognitive outcomes. Results from the study include but not limited to revealing that a

Table 1. Summary of Reviewed Articles for Application of VR in Education

Year	Focus	Findings	Novelty	Ref
2021	Ability of VR technology to afford a holistic experiential learning cycle	An internet-enabled VR application will ensure the transfer of the real-world experience of experiential learning in higher education from field trips to online platform or storage	HTC Vive	[33]
2021	Application of VR technology as a teaching aid to design and implement a teaching platform for multimedia music appreciation	The interest of students in learning music was aroused as a result of applying VR technology which promotes efficiency and personal learning	MVC design pattern, VRML language, Java, CSS, JS and other technologies	[19]
2022	Application of VR technology in engineering education	Students understanding, educational experience, grade and performance was enhanced by application of VR technology while the institutions are presented with an avenue to spend less in term of physical laboratories and lecture halls required for the traditional teaching methods	Application of constructivist and variation learning theory,	[14]
2020	Construct of a modular teaching resources based on the quest 3D methods of VR with a design of measurable, visual, balanced and interactive resources	The constructed VR learning resources enhanced theoretical and experimental teaching alongside independent learning by students	Quest3D, Auxiliary software like Javascript, database MySQL, AutoCAD, 3D Coat, Tekla Structures, and BIM technology	[45]
2016	An exploration of other VR technologies that can be applied with Google Cardboard head mounted displays (HMDs) in teaching of geography	Expedition and other VR related applications of Google cardboard is capable of enhancing teaching and understanding of geography alongside improving the obvious willingness on the side of students to learn geography	Google Cardboard head mounted displays (HMDs)	[43]
2020	The efficacy of VR technology in education	Business education can be enhanced by adopting VR technology as students' presentation skill is honed by practicing with a VR aided technologyOvation VR software, Oculus Rift, adopting t-test inferential statistics, online survey on sampled population.	Ovation VR software, Oculus Rift, adopting t-test inferential statistics, online survey on sampled population.	[16]
2021	The effect of remediating content of learning from traditional non-immersive media to immersive VR on learning and cognition	VR greatly enhances knowledge transfer as sampled participants perform better with higher scores in comparison with their counterpart who applied traditional reading and learning methods	Advanced EEG measurement techniques, learning tests, and cognitive load measures	[38]
2019	The effectiveness of a VR based task on undergraduate student's presentation skills in a virtual environment	Students exposed to the VR were appreciative of the comprehensive analytical feedback received with a significant improvement from pre-test to post-test for the three presentations	Unity, Mixamo, C#, Microsoft Kinect, ActiveMQ	[40]
2020	Learning media based on virtual reality (VR) for teaching business ethics	A media based on VR ensures a motivating and interesting learning process which enhances perception of learning efficiency which equally increases the rate of individual's ethic and self-efficacy	semi-immersive VR, descriptive and inferential statistics (standard deviation, ANOVA, MANOVA)	[41]

2020	Cloud-to-end rendering and storage management for virtual reality in experimental education	The rendered system was found to have the capability to enhance 3D experimental academic scene with high image quality and reduced latency than all other rendering system	Cloud-to-end rendering and storage system, Interactive 3D models, transmission-control protocol /internet protocol (TCP/IP), 3D-warping algorithm.	[47]

media based on VR ensures a motivating and interesting learning process which enhances the perception of learning efficiency which equally increases the rate of individual's ethics and self-efficacy.

The result of the study revealed a mild contribution to persuasive technology theory with VR as an interactive technology developed to intentionally change attitudes. This finding further lays credence to the notion that ethical learning hinged on VR has more benefits by increasing individual self-efficacy [41]. More so, comparing VR with other learning media was not considered, which opens a room for future studies to compare the potency of VR with other media of learning like Augmented Reality (AR) or 3-Dimensional video.

VR aides three-dimensional scenarios comprising hardware and software to provide an enhanced experience and the possibility of interaction to the end-users. This perspective of VR spurred the research [43] to explore other VR technologies that can be applied with Google Cardboard Head Mounted Displays (HMDs) in the teaching of geography in furtherance of the merits and demerits of immersive VR to teaching and learning. It was revealed by this research that Expedition and other VR related applications of Google cardboard are capable of enhancing teaching and understanding of geography alongside improving the obvious willingness on the side of students to learn geography. The application of this new technology will assist teachers who are more facilitators in recent times than lecturers in their new role. The submission of the study agrees with the findings of Hussein & Nätterdal [44] that virtual environments and 3D objects better explain some educational issues which cannot be efficiently illustrated and understood with plain text.

Furthermore, Wang [45] applied VR techniques to construct modular teaching resources based on the Quest-3D methods of VR with a design of measurable, visual, balanced, and interactive resources. The constructed VR learning resources enhanced theoretical and experimental teaching alongside independent learning by students. The research results open a novel path to modular teaching and provide a good reference for course teaching in architectural studies, which enables the combination of the two modules into a successful application of a virtual simulation system in real engineering. Thus, giving it a strong simulation effect on actual engineering applications and providing revolutionary and creative teaching resources and means for construction engineering, which is in line with the guiding ideas of modular teaching.

Similarly, a cloud-to-end rendering and storage management system for virtual reality in experimental education was explored, with the designed system consisting of two models namely, background and interactive models, as the methodology [47]. This design is coupled with an enhanced warping of 3D and a hole-filling algorithm meant to improve the quality of the image due to a variation in the viewpoint of users. The rendered system was found to have the capability to enhance the 3D experimental academic scene with high image quality and reduced latency than all other rendering systems. The result further showed that the rendered system presents a good experience without going beyond the costs of computation [47]. The first study to adopt the cloud and lightweight rendering for VR experimental education; it is generic and can be adapted to other application domains, including mixed reality. Its major shortcoming is the inability to apply the tool for arbitrary 3D scenes since manual and interactive models are to be separated manually ahead of time. Therefore, further study should focus on the application of algorithm to automatically identify and separate background and model images, allowing users to conduct more interactive operations. summary of reviewed articles for application of VR in education shown in table 1

3. Application of VR in Robotics

There is, interestingly, an expanding collection of literature on the application of VR technology in the field of robotics .Notably, [21, 22] conducted a study on VR-based framework to simulate control algorithms for robotic assistance and rehabilitation tasks through a standing wheelchair. The dynamic and kinematic model of a Virtual Standing Human–Wheelchair System simulator (VSWHS) formed the basis for the developed VR environment to create scenarios based on routine chores in a human's life that enables individuals with motor impairments to undertake independent rehabilitative and support tasks. The hardware in the Loop and Full Stimulation enables the implementation and autonomous control of the designed standing robotic wheelchair. The designed robotic standing

wheelchair is made of a differential drive mobile robot (DDMR) capable of rotating around its vertical axis without hindrances [7, 21]. The study concluded that the framework of the robotic standing wheelchair designed is capable of stimulating motor rehabilitation exercises when applied to people suffering from motor disabilities.

Similarly, another research [12, 13] explored the simulation of VR Human-Robot Coexistence (HRC) for the final assembling of an aircraft to increase productivity and identify key issues during the process while also evaluating Key Performance Indicators (KPIs) of the processes employed in new automated and semi-automated cargo and cabin assembling scenarios. Five workers were selected as the sample for the study. The results showed that the developed VR environment is at least 20% better and more beneficial than the traditional assembly process in terms of worker cost, and in terms of overall KPIs such as assembly time, worker costs, and ergonomics, the sequential and parallel scenarios are 13% and 79% better than the traditional process, respectively. Hence, the proposed VR processes is capable and dynamic enough to enable multifaceted scenarios made of HRC, assist in decision-making in the early stages of assembling, and facilitate an improved all-encompassing productivity [13, 28]. When compared to the process of the traditional Final Assembly Line, the new VR simulation environment for assembling aircraft can sustainably improve productivity and reduce time spent at work and assembly hours while also improving the return on investment (ROI) time to 1-2 years for investment of 100K – 200K euros. The limitation of the proposed VR simulation environment is its inability to adopt the HRC safety requirements, which will be an interesting and important field to explore in subsequent studies.

In the same vein, in a bid to enhance better efficiency and neglect musculoskeletal related strain in assembling mechanical products and machinery Dimitrokalli, [48, 55] focused on the collaboration between human and robot in a modern assembly plant using VR to assemble prototype robotic filament winding head. A Unity 3DTM was enlisted in constructing the virtual environment while Leap MotionTM enabled tracking of the user's hands, and a Head-Mounted Display was used for navigation and immersion purposes. Twelve graduating students of mechanical engineering students certified in Manufacturing Automation and Robotics Engineering were drafted to participate in the experiment aimed to determine the level of risk each activity exposes a worker to, of which a modified ergonomic scoring method was adopted [42, 85]. Two different experiments were carried out on the same assembly plant, with one being a robotic arm assistant for participants and the other one without assistance from a robotic arm with the aid of a real onscreen projector display or virtual projected screen mounted before the participants. Results showed that enlisting the service of a robot in mechanical assembly is advantageous, while a serious drop in measured strain to the wrist was evident with simple robotic arm assistance. Timely completion of assembling was equally enabled with greater efficiency while engaging with a robot [46, 50]. VR tools were concluded to be valuable for future assessments of assembly plants. More so, while assessing the design and implementation of a teleoperation-based system that utilizes VR to provide the user with a good understanding of the shop floor environment for path planning and control of industrial robots with the goal of minimizing effort and time during execution, the teleoperation-based method integrated with a VR interface was adopted by [39, 49, 50] to examine the VR environment. This is geared towards enhancing the dynamism of an installed robotic cell to enable cost-effectiveness with minimal alterations in its hardware [49]. To enable a remotely processed offline simulation, the implementation of a VR interface becomes important. The proposed enhanced VR environment users are equipped with a hands-on and clear grasp of the situation in a remote workplace, enabling a renewed stance in naturally intuitive way while defining and detailing the task [15, 57].

In another attempt, [34, 52] investigated the application of VR training for vesicourethral anastomosis during robot-assisted radical prostatectomy. A total of twenty-four (24) participants made of eighteen (18) patients and three (3) certified robotic urologists, and three (3) urologists without training in robotics were enlisted for the study. The results of the 20 virtual anastomosis training sessions indicated that the economy of motion improved from 459.0±59.2cm to 239.3±33.9cm, and the cumulative rating improved from 65.0±10.8 to 92.7±3.5 ($p = 0.014$). Consequently, the study confirmed that trainees' skills effectively improved through VR training, with the average time of anastomosis decreasing from 279.0±48.0s to 119.3±12.5s, a 57.2% decrease, and interestingly, surgical skills of the trainee enhanced, with the average duration of anastomosis during actual surgical operations also decreasing significantly from 40.0±12.4 min to 25.1±7.1 min ($p = 0.015$). The study concludes that VR training ensures surgeons are timely made aware of manipulating robotic systems, enhancing their vesicourethral anastomosis skills while reducing the learning curve, hence aiding surgical operation with improved efficiency.

Furthermore, [2, 53] investigated the design, application, and evaluation of a social robot and immersive VR platforms for use in cognitive training

Table 2. Summary of Reviewed Articles for Application of VR in Robotics

Year	Focus	Findings	Novelty	Ref
2021	VR-based framework to simulate control algorithms for robotic assistance and rehabilitation tasks through a standing wheelchair	Robotic standing wheelchair designed is capable of stimulating motor rehabilitation exercises when applied on people suffering from motor disabilities	Kinematic and dynamic model of the standing human–wheelchair system, Full Simulation (FS) and Hardware in the Loop (HIL) techniques and Virtual stroboscopic movement.	[21]
2022	The design, implementation, and comparison of a social robot and immersive virtual reality platforms for use in cognitive training	Participants viewed the robot as an emphatic social entity with qualities synonymous to human which excited the users. However, a VR platform on short term interpersonal variation was preferred for training by users	Socially Assistive Robots (SARs), immersive Virtual Reality (iVR), Cognitive Training (CT), C# programming language and EZ-Robot SDK.	[53]
2020	Collaboration between human and robot in a VR modern assembly plant	Enlisting the service of a robot in mechanical assembly is advantageous while a serious drop in measured strain to the wrist was evident with simple robotic arm assistance	Unity 3D^{TM}, Leap Motion^{TM}, Head Mounted Display, virtual Avatar, Virtual scene, Oculus Rift DK2TM and Ergonomic assessment.	[48]
2021	Virtual reality environment for industrial robot control and path design	The proposed enhanced VR environment users are equipped with hands on and clear grasp of situation in a remote workplace	Head Mounted Display (HMD), Open Motion Planning Library (OMPL), Massively Multiplayer Online (MMO), and CAD designs.	[49]
2021	Application of virtual reality training for anastomosis during robot-assisted radical prostatectomy	VR training ensures surgeons are timely made aware of manipulating robotic system enhances their vesicourethral anastomosis skills while reducing learning curve	Mean standard deviation, r Pearson's Chi-square test, Virtual anastomosis, and training of participants.	[52]
2021	Simulation of VR human-robot coexistence (HRC) for the final assembling of an aircraft	The developed VR environment is capable and dynamic enough to enable multifaceted scenarios made of HRC and enable an improved and all-encompassing productivity	Key Performance Indicators (KPI), Ergonomics analysis.	[13]
2021	Teleoperation and remotely manipulation of resources and sensors combining VR elements with simulated environment	Simulation and VR scenarios are potent educating tools which enhances effectiveness of a course and reduces the cost and risks involved	Android OS.	[54]
2019	The control and stimulation of industrial robot in a VR environment connected with IR camera sensor	Integration of a VR tool into certain control system enhances the procedures and enables an interactive user experience alongside a remote access to operation preferred in some endeavour	Unity3D, HTC VIVE headset, Leapmotion sensor, KUKA KR10, , Matlab, SteamVR and Autodesk MAYA.	[56]

(CT) aimed at encouraging patients to stick to therapy regimens. The CT was administered using Socially Assistive Robots (SARs) and immersive VR Fig. 2 by incorporating recognised cognitive tasks in gamified situations that provide a strong sensation of presence. The study was hinged on a tripod principle of gamification, modularity, and presence of immersive VR and social robot system, with the study's findings affirming that participants viewed the robot as an emphatic social entity with qualities synonymous

with humans, which excited the users. However, an immersive VR platform was favoured for short-term interpersonal variation as users indicated that the platform provides spatial awareness and a rich multi-sensory experience that immerses participants in a simulated space. Additional robots and virtual environments should be considered in a differing social and social environment.

Figure 2. VR scenarios in a cognitive-training game [53].

Adopting the simulation and VR tools to describe the application of digital technologies in educating operators in a secured and safe environment was investigated in this research [54]; the study specifically focused on teleoperation and remote manipulation of resources and sensors combining VR elements with the simulated environment. The study is further streamlined to train operatives and workers while bringing them close to Industry 4.0 technologies. Findings revealed that the simulation and VR scenarios are potent educating tools which enhances effectiveness of a course and reduces the cost and risks involved [54, 80]. Efficient interaction is further enhanced by a safe environment from simulation when combined with the possibility of an improved immersive and intuitive technology of the VR. However, future research should apply more sensors, like laser scanners or 3D cameras, in the simulated environment, displaying information and variables to the VR application, improving the perception capabilities of the workers and enabling a stress-free remote manipulation of the resources.
In the same vein, [56, 63] conducted a study on the control and stimulation of industrial robots in a VR environment connected with an IR camera sensor. The various research approaches required to manipulate and direct KUKA KR10 industrial arm manipulator using VR technology, followed by establishing the relationship between the user and manipulator 3D Modelling by adopting a Unity3D game engine as well as the HTC VIVE Pro headset for enhanced virtual visualisation as the method alongside an Autodesk MAYA software and LeapMotion sensor. Findings revealed that the exported application from the Unity 3D environment enabled the user to easily connect with HTC VIVE which is a virtual version of KUKA KR10 and LeapMotion sensor enabling both offline and online route and plan the movement of the KUKA robot [56, 72]. Therefore, it was concluded that the integration of a VR tool into a certain control system enhances the procedures while also enabling an interactive user experience alongside remote access to operation preferred in some endeavour. Summary of Reviewed Articles for Application of VR in Robotics shown in Fig 2.

4. Application of VR in Health

Several studies have conducted research into the application of VR technology to healthcare ranging from the application of VR technology to the treatment of burn [17], adaptive nature of VR in mental health [18], functional motor lateralization [58], application of VR technology to inpatients rehabilitation from COVID-19 [59], including numerous studies incorporating VR technology to various health-related issue in the society [58–62, 64]. Considering the global pandemic, a research work [59] endeavoured to descriptively understand the satisfaction of patients and their felt benefit of VR on COVID-19 recovery. The study was conducted in the COVID-19 Recovery Unit (CRU) of New York Presbyterian / Weill Cornell Medical Center, located in New York City, USA. Thirteen patients and eleven staff were selected as samples for the study with questionnaires and interviews adopted as the instrument of data collection. The soothe VR technology; a pre-programmed headset, was the adopted methodology for this study. The headset comes along with varieties of categories like the guided meditation in realistic, immersive natural scenery as well as games that stimulates patient cognitive attitude and host of others which are more of a three-dimensional soothing natural setting [51, 59].
It was concluded by the research that the application and implementation of VR technology on patients at the COVID-19 rehabilitation units was potent as it positively enhances the treatment of patients and caters for the wellbeing of healthcare workers. The interest of staff in the evolution and expansion of VR application for inpatient treatment was enhanced while patients established more interest in its application [59]. Negating a formal, thematic analysis of patients' and staff's opinions is one of the major limitations of this study.

Therefore, future studies should focus more on determining the effects of a VR oriented treatment on the rehabilitation of patients via a thematic analysis of unstructured comments from respondents. Fig. 3 show VR modules sample backgrounds.
In the same vein, Sokołowska [58] explored the application of VR technology in functional motor lateralization by applying the algorithms offered by the innovative computer system of (neuro) rehabilitation of NEUROFORMA which is an innovative hybrid of VR tele-platform. Twenty-five right-handed healthy adults were sampled for the study with structured interviews adopted as data collection instrument, and the collected data was analysed with STATISTICA 9.0 PL coupled with Friedman (ANOVA) test. At the same time, the Bonferroni correction was used to determine the differences in results. Results from the findings [58] agree with other studies revealing that a VR-based cognitive training with the Wii Balance Board (WBB) platform is an important tool for determining the right-left side of the body functional asymmetries in disturbed lateralization as well as educating and training healthy subjects.

Figure 3. VR modules sample backgrounds [59].

The Sokołowska study further revealed that performing a virtual task performed with the two hands is synonymous to the usual one with the possibility of applying the usual hand more often, thereby, making the feeling of fatigue more in the usual hand when the exercise requires intense physical effort and lastly showed that VR tasks are undertaken willingly in a bid to ensure better outcome and success by combining different cognitive elements. The study concludes that evaluating the effectiveness and performance of various human anatomies in relation to health and disease is enhanced and improved by adopting VR technology. This study particularly indicates the usefulness and effectiveness of VR methods as a tool for the research and assessment of functional lateralization.
Furthermore, a study on the adaptive nature of VR in mental health was conducted by designing a validation exercise of a multi-faceted architecture for affective-driven procedural content generation in VR application to mental and health wellbeing [18]. The intensity of certain motions based on a 9-point Likert scale was quantified for twenty participants who took part in data collection with the aid of Visual Analogue Scales (VAS) while the general overall mood was analysed with the help of Self-Assessment Manikin (SAM) as questionnaire served as data collection instrument, and MATLAB R2017a was adopted for the final analysis of all collected data.
The Emotional Labyrinth was understood to have a general pleasant enabling the proposed procedural content generation to induce unique psycho-physiological patterns, which often supports the meaning of the metaphors used in the labyrinth design [18]. Furthermore, the collected psycho- physiological responses enabled the generation of computational models of users' reported experience enhancing the future execution of the closed-loop mechanism to adapt the Labyrinth procedurally to the affective state of users. The study concluded that the designed physiological sensing technologies are capable of being applied in immersive and non-immersive VR systems, which comes in handy for application in a clinical context.
The emergence of therapeutic VR is becoming more prominent in the health sector, prompting the research [60] to develop a methodological framework collaborating with an international group to conceive a design, analysis and eventual implementation alongside trials for testing VR treatments. VR treatment was applied to enhance clinical trials. The twenty-one (21) VR Committee of Outcomes Research Experts (VR-CORE) came up with three clinical VR designs, which was concluded to be influential in treatment. The design was understood to aid in facilitating an improved, high quality and safe treatment of patients from VR to enhance the rehabilitation period [60].

In the same vein, over the years, the procedures for treating burns give a significant painful experience to patients, which eventually results in poor physical and psychological outcomes. This prompted research [17] to evaluate the perception of stakeholders (patients and healthcare providers) on the feasibility, effectiveness,

Table 3. Summary of Reviewed Articles for Application of VR in Health

Year	Focus	Findings	Novelty	Ref
2018	Perception of stakeholders on feasibility, effectiveness and applicability of low-cost VR technology in treating incidence of burn in adults	The quantitative and qualitative analysis of response from participants backed the feasibility and application as well as efficacy of low-cost VR technology in clinics burn patients	Mixed method research design, participants from various cultural background, fifth generation iPod Touch, Sunnypeak VR headset, Sentey Flow LS 422 headphones.	[17]
2019	Adaptive nature of VR in mental healthThe application of VR technology in functional motor lateralization by applying the algorithms offered by the innovative computer system of (neuro) rehabilitation of NEUROFORMA	The developed physiological sensing technologies are capable of being applied in immersive and non-immersive VR systems which comes in handy for application in a clinical context	Emotional Labyrinth, VRTK library, Unity3D, HTC Vive, BioSignalsPLUX, PhysioLab toolbox, One-sample Kolmogorov-Smirnov test, Findings presented in tables and charts.	[18]
2021	The application of VR technology in functional motor lateralization by applying the algorithms offered by the innovative computer system of (neuro) rehabilitation of NEUROFORMA	VR-based cognitive training with WBB platform is an important tool for determining the right-left side of the body functional asymmetries in a disturbed lateralization	Wii Balance Board (WBB), virtual BALLS and virtual BUTTERFLY, VR NEUROFORMA environment, Virtual Reality Lateralized Attention Test (VRLAT).	[58]
2021	Satisfaction of patients and their felt benefit of VR on COVID-19 recovery	Application and implementation of VR technology on patients at the COVID-19 rehabilitation units was potent as it positively enhances treatment of patients and caters for the wellbeing of healthcare workers	Conducted in an hospital, Questionnaire, VR headset.	[59]
2019	Exploratory study of a social learning theory infused with Spherical Video-based Virtual Reality (SVVR) to educate nursing students on signs and symptoms of childbirth	Students who are subjected to the SVVR witnessed an improved satisfaction and achievement in learning which revealed that a 360o inferred VR enable student diffuse the world and improves learning efficiency	Spherical Video-based Virtual Reality (SVVR), Likert scale, ADDIE instructional design model, social learning theory (SLT).	[62]
2021	Application of virtual 3D-model to surgical planning with a focus on its adoption in liver surgery	The application of immersive VR for preoperative planning of 3D liver surgery giving it an advantage over the known 3D PDF an 3D print in planning preoperative liver surgery	3D-printed liver models, VR headsets, System Usability Scale (SUS), semi-automatic segmentation software, stereolithography (STL) files, OpenVR compatible VR headsets.	[65]
2018	Applicability of VR to control preoperative anxiety of patients in ambulatory surgery	Management of preoperative anxiety is enhanced by the innovative strategy offered by VR which efficiently manage the preoperative anxiety of patients while having no negative externalities of the healthcare team	Twenty Participants, Visual Analog Scale (VAS), Salivette® swab (Sarstedt™), Oculus®, Oculus Rift®, Prism®, high-performance NVIDIA® GeForce GTX 1060 6 GB graphics card.	[68]

2018	Methodological framework collaborating with international group to conceive a design, analysis and eventual implementation alongside trials for testing VR treatments	The design was understood to aid in facilitating an improved, high quality and safe treatment of patients from VR to enhance rehabilitation period	Virtual Reality Committee of Outcomes Research Experts (VR-CORE), Food and Drug Administration (FDA) Phase I-III pharmacotherapy model.	[60]
2021	A collaborative VR environment to aid and enhances liver related surgeries	A collaborative VR environment ensures that surgeons are well equipped with the requisite data on safety and critical areas around a faulty tumor in liver operations with the assistance of VR technology	Collaborative virtual reality (VR) environment, 3D surfaces and 2D image slices, d different colour maps, NVIDIA GeForce GTX 1070 graphics.	[79]
2018	Adoption of VR exposure (VRE) as a preparatory tool for selected day care surgery in children known with reduced anxiety level	Children subjected to the VRE group required lesser analgesic which is clinically relevant resulting from the externalities associated with analgesic drugs	modified Yale Pre-operative Anxiety Scale (mYPAS), CONSORT guidelines, randomised controlled trial (RCT), HTC Vive, Mann–Whitney U test, tables and charts.	[70]
2020	the impact of EyeSi surgical VR simulators on posterior capsule rupture (PCR) in cataract surgery	A significant drop in the unadjusted PCR rate of trainee surgeons was experienced which is quite beneficial to cataract surgery patients	RCOphth NOD, seven years long, tables and charts, EyeSi surgical simulator (VR Magic).	[71]

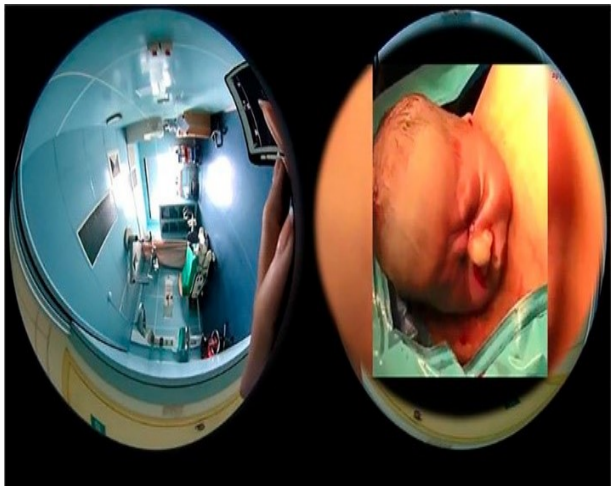
and applicability of low-cost VR technology in treating the incidence of burn in adults. The VR treating mechanism was adopted to serve as a distraction to patients undergoing treatment to ensure the pains during treatment are not really felt while they concentrate fully on the VR technologically provided therapeutic distractions like games, videos, and a host of others. Ten participants admitted for burn treatment at the West Penn Burn Center Clinic in Pittsburgh were drawn and adopted as the sample for this study alongside eight medical practitioners. Findings from the study revealed almost 100% positive responses from patients, with 60% achieving significant related pain reduction while undergoing treatment from various grades of burn. The majority submitted that the technology competes for their attention and successfully distracted them from concentrating on the treatment procedures, which are often painful and challenging [17]. Similarly, the health officers were of the opinion that the VR technology enables them to work efficiently and effectively as they had little or nothing to do in pacifying the patients whose attention had been drawn by the VR technology, hence, making treatment easier task. Finally, the result from the quantitative and qualitative analysis of responses from participants backed the feasibility and application as well as efficacy of low-cost VR technology in clinic for burn patients [17].

To further entrench the efficacy of VR technology in burn care. Future qualitative studies should be comprehensively extended to various health providers like nurses, physicians, lab assistants and others. Also, there will be an addition to the growing body of literature if future research focuses on other aspects of treatment like paediatric patients; determining the actual procedure that enhances optimal distraction; addressing the technology application and implementation in clinics to determine the adequacy of reception by patents and providers and equally ascertain the relationship with psychological strategies to further improve analgesic, anxiety reduction and general coping [17, 35]. The exciting and wide application range of the VR technology prompted [61] to present the application of VR as an emerging tool for training healthcare professionals and inducing behavioural shifts in patients. The study was conducted by twenty-one experts certified in the field of VR at the 3rd Annual Conference held at the centre for behavioural change at the University College London (UCL). A panel discussion was conducted and centred on the adoption of a short immersive VR environment to reshape doctors' prescribing behaviour, shortcomings and potential application and implementation of the technology generally in medical education [61].

The experts involved in the panel discussion include but not limited to medical education and training, health practitioners, general practices, management, ethics, philosophy, and virtual reality. It was concluded

by the panel that; VR is an important tool in medical training that is capable of succeeding in situations where other initiatives had failed to enhance and induce behavioural change. By consulting a VR, a doctor is equipped with improved self-awareness to dictate future actions in more informed and improved therapeutic way. However, the study is restricted and limited in the smaller number of data, hence the need for more data. More so, the technology was not applied in a physical training environment. Fig. 4 illustrates the SVVR-based learning system applied by [62].

(a) Caesarean childbirth with SVVR



(b) Natural Childbirth with SVVR

Figure 4. (a) Caesarean childbirth with SVVR, (b) Natural Childbirth with SVVR [62]

More so, [62] presented an exploratory study of a social learning theory infused with Spherical Video-based Virtual Reality (SVVR) to educate nursing students on the signs and symptoms of childbirth. A comparison was drawn between those who were trained with the traditional approach and those exposed to VR training. The experiment was conducted in the Northern Taiwan College of nursing on 64 nursing students. The design of the SVVR was favoured as it is a low-cost 360o panoramic view immersive option and founded on a proposed instructional design model called ADDIE. It was revealed by the research findings that students who are subjected to the SVVR witnessed an improved satisfaction and achievement in learning, which revealed that a 360o inferred VR comes in handy to enable student diffuse the world and improves learning efficiency, which eventually adds to the intrinsic and extrinsic learning attitude and performance in childbirth education. However, the study is limited due to the minute sample size, eventually limiting generalisation of findings. Hence, future studies should be concerned about the application of VR technology to other aspects of health with improved sample size.

The popularity of VR surgery training has come to stay in clinical education. This prompted [64] to appraise the application of VR technology in clinical education by conducting an experiment on VR laparoscopic for surgical training of medical students. During the experiment, students were exposed to VR-based laparoscopic surgery simulators (VRLS) to avail ways of enhancing surgery skills on identified dimensions Fig. 5.

Figure 5. Training tasks (fixed point haemostasis, peg transfer, picking beams and colon resection) on VR Laparoscopic surgery simulator [64].

The performance of the students at the end of the experiment was graded by senior surgeons by employing a newly designed Global Operative Assessment of Laparoscopic Skills (GOALS) standard for colon reaction exercise [64]. The authors resulted in enlisting physiological approaches to assess the influence of the VRLS on Fifty-one medical students'

performance. The research revealed that the application of VRLS tend to greatly influence the performance of student positively and enable them to attain requisite experience with reduced cognitive load. The study is however limited to determining the relationship between cognitive load and performance of students. Subsequently, other studies should assess functional relations like linearity and non-linearity as well as the exponential linkage between students' performance and cognitive load with the aid of VRLS.

Adopted for surgery preparatory tasks, [65] applied a virtual 3D-model to surgical planning with a focus on its adoption in liver surgery. An immersive VR application was designed by the authors for the preoperative 3D models Fig. 6. Five HPB Surgeons were enlisted as the sample size for the study. VR controllers were used for communicating with the 3D liver model designed. The study concluded that the application of immersive VR for preoperative planning of 3D liver surgery is indeed beneficial judging by its System Usability Scale score of 76.6% and has an advantage over the known 3D PDF and 3D print in planning preoperative liver surgery.

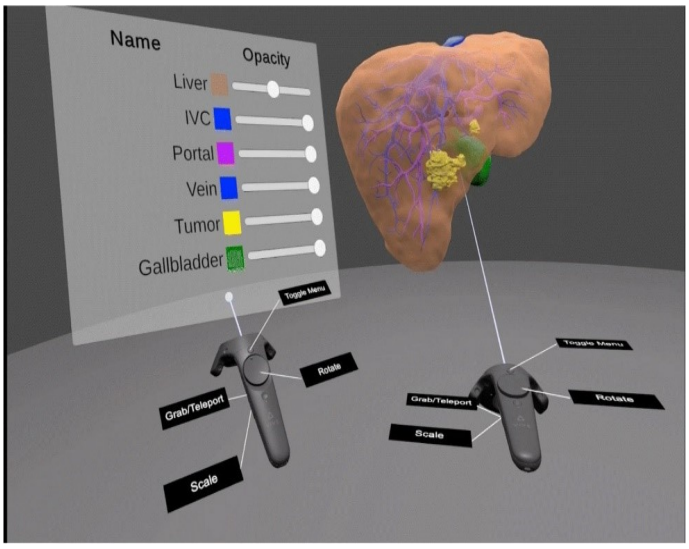
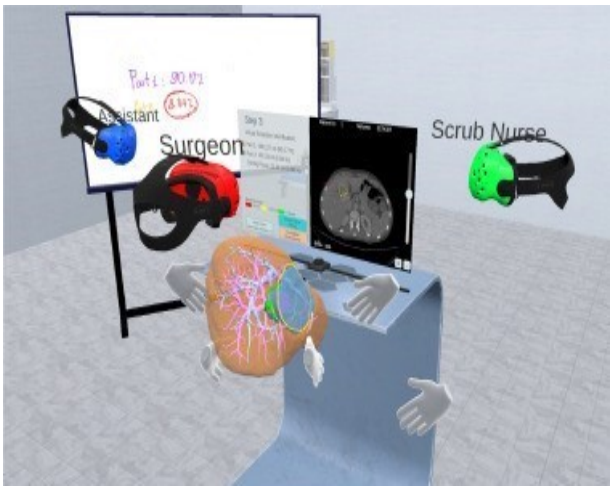


Figure 6. VR application for the preoperative demonstration of 3D liver model [65]

Furthermore, a cogent element for tumour disease treatment is the surgical planning software which needs a high level of shared understanding and coordination amongst surgery crew, hence the research [66] exploring a collaborative VR environment to aid and enhances liver related surgeries. This was embarked on to enhance virtual resection for planning amongst surgeons. Three qualified surgeons were enlisted to apply the design to patients. The collaborative risk environment of VR technology at the start enables visualisation of the risk map with the aid of vascular structure, and 2D slices enable projection of the tumour contour, which presents a real-time and up to date visual display for safety nets around tumours [66]. The prototype was examined for usability using the System Usability scale, and it received an average score of 84.17 % from all participants, suggesting that it is generally straightforward to use. It is thus concluded that a collaborative VR environment ensures that surgeons are well equipped with the requisite data on safety and critical areas around a faulty tumour in liver operations with the assistance of VR technology. Fig. 7 depicts collaborative use in the VR scenario during surgical planning.



(a) Users in the immersive VR environment

(b) Users in the real world

Figure 7. Multiple users performing surgical planning: (a) Users as depicted in the immersive VR environment, (b) Users in the real world [66].

[68] explored the applicability of VR to control preoperative anxiety of patients in ambulatory surgery. The study set out to reveal if VR presented in a natural environment is capable of being included in a new

therapy to reduce preoperative anxiety in patients with skin cancer being the major focus. The study was conducted at the Henri Mondor Teaching Hospital in France, comprising of twenty patients with a medical history of having a high-stress level of above eleven (11) as measured by the French version of the Amsterdam Preoperative Anxiety and Information Scale (APAIS). The study assessed the patients' stress levels prior to and after experiencing the VR treatment by applying a visual analogue scale (VAS) to ascertain the level of salivary cortisol and determine heart coherence score [68]. Findings revealed a significant drop in the VAS from an initial average score of 3.3 to 2.85 after the VR simulation, and the same can be said of the salivary cortisol which experienced a significant difference from an initial 14.55 to 12.86 after the VR test, while the heart rate remained unchanged. Conclusively, the management of preoperative anxiety is enhanced by the innovative strategy offered by VR, which efficiently manages the preoperative anxiety of patients while having no negative externalities to the healthcare team. In the same vein, [70] research investigated the adoption of Virtual Reality Exposure (VRE) as a preparatory tool for selected day care surgery in children known with reduced anxiety level. The study explored a comparative analysis with children in the care as usual (CAU) group. The experiment lasted for nineteen months, from March 2017 through October 2018, on 200 children enlisted for elective day care surgery. An immersive virtual version of an operating theatre was administered to children receiving VRE to acclimatise and get familiar with the operating room and overall anaesthesia process Fig. 8.

Figure 8. Immersive VR scenarios. (a) The Child welcomed by the receptionist to the holding area. (b) The Child being transported through the corridor of operating theatre. (c) The Child in the operating room and able to point to different instruments to get more information. (d) The Child waking up in the recovery room [70].

Results from the study revealed that VRE is less required as it has no significant impact on pain and anxiety of the children in VRE and CAU groups. Although, upon conducting surgery for higher pain, children subjected to the VRE group required lesser analgesic, which is clinically relevant resulting from the externalities associated with analgesic drugs [70]. The implication is such that VRE is attached to enhance patient comfort and reduced the need for postoperative care. The limitation of the study can be found in the conduct of a single assessment inside the recovery room as well as targeting only the children with lower anxiety levels. Thus, future studies should conduct multiple assessments on the postoperative effects in the recovery room and also investigate children with higher levels of anxiety in pre-operative situations while equally considering the timing of VRE [70].
Research investigated the impact of EyeSi surgical VR simulators on Posterior Capsule Rupture (PCR) in cataract surgery performed by first- and second-year surgeon interns. The study was conducted in 29 secondary cares setting of NHS Ophthalmology Units comprising 265 surgeon trainees exposed to the EyeSi VR simulation adopting RCOphth NOD for seven consecutive NHS years from 2009 through 2016. A significant drop from 4.2% to 2.6% in the unadjusted PCR rate of trainee surgeons was experienced, which is quite beneficial to cataract surgery patients. The 38% decrease in complication rates witnessed coincides with the EyeSi VR simulator training introduction [71]. Summary of reviewed articles for application of VR in health as shown in table 3

5. Application of VR in Transport

Ninety-two participants from Medellin and Bogota, Colombia were engaged in a study [73] to investigate the application of VR in appraising the impacts of security opinion on the choice of transport mode by adopting VR in reproducing trip channels to offer a situation likened to natural trip condition for participants. An immersive 3D video likened to natural trip conditions was provided to determine participants' choices and travel attitudes. Results depicted a change in environmental-related perception of security which is determined by travel period and knowledge of the environment, thereby making VR a critical tool supporting transport-related studies, which presents an active view of transport mode choice.

In an effort to improve pedestrian safety and comfort while interacting with other pedestrians, personal mobility vehicles and ordinary vehicles, a study [74] attempted an evaluation of the characteristic behaviour of pedestrian cognition in relation to Personal Mobility Vehicles (PMV) and other pedestrians with the aid

Table 4. Summary of Reviewed Articles for Application of VR in Transportation

Year	Focus	Findings	Novelty	Ref
2021	Application of VR in appraising the impacts of security opinion on the choice of transport mode	There is a change in environmental related perception of security which is determined by travel period and knowledge of the environment thereby making VR a critical tool supporting transport related studies which presents an active view of transport mode choice	360-degree immersive videos, Veer OASIS VR headphones, Smartphones, VaR's VR player PRO.	[73]
2018	The characteristic behaviour of pedestrian cognition in relation to Personal Mobility Vehicles (PMV) and other pedestrians with the aid of virtual reality technologyApplication of virtual reality VR technology in ensuring pedestrian safety	VR participants keep a wider lateral distance than in real spaces in avoidance of other pedestrians while subjective danger seems less concerned about the subjective danger tends to be less sensitive to the tangential space between participants of VR and the PMV	Oculus Rift, Models, tables, charts and graphs.	[74]
2017	Application of virtual reality VR technology in ensuring pedestrian safety	The simulator developed is a critical method for collecting information about the attitudes of pedestrian in a crosswalk scenario	HTC Vive, Unity software, Chi-square test, repeated measure ANOVA.	[[75]
2021	Pedestrian crossing behaviour as a crucial element of urban dynamics as it affects the automated vehicles presence	The presence of automated vehicles on roads, lane widths, and road density amongst others is the major factors enhancing longer time to wait at crosswalks	Interpretable machine learning framework, Cox Proportional Hazards (CPH) model, Survival analysis, tables, charts and images.	[76]

of VR technology. A modification of the social force model of Specification II was adopted as the base model for the study coupled with a VR environment which was developed using UC-Win/Road, a Forum 8 VR software Fig. 9. The comparison was drawn between pedestrians using VR and those in the real spaces (RS), and findings showed that VR participants keep a wider lateral distance than in real spaces in avoidance of other pedestrians, while subjective hazard seems subtle to the side space between participants of VR as well as the PMV. Participant easily identifies the distance between them and the PMV in both RS and VR space when the PMV approaches from the rear or front, availing them with additional lateral margins in avoiding one another. The results from this study enable the provision of relevant approaches for planning VR experiments.

In the same perspective, [69, 75] conducted a research on the application of VR technology in ensuring pedestrian safety in risky traffic conditions such as extreme traffic volume, high-speed regions, adverse weather situations, and intoxicated commuters, thereby evaluating the use of VR system as a pedestrian simulation tool. A new pedestrian simulator was developed by adopting HTC Vive head-mounted display and Unity 5 software which enables freedom of movement in all directions in a virtual space. The result from a sample size of 26 participants confirmed that the simulator developed is effectively useful with a SUS score of 79.75%, also stating that the system is a critical method for collecting information about the attitudes of the pedestrian in a crosswalk scenario. Participants were found to be pleased with the experience of the virtual environment from the findings since the pedestrian simulator can enhance many merits over existing technology. The study is, however, limited in some ways since the designed tool has a steep learning curve mostly on participants who had no experience in the adoption of VR.

In a similar manner, [76] investigated pedestrian crossing behaviour as a critical element of urban dynamics as it affects the presence of automated vehicles by adopting and integrating a widescale VR design method to visualise futuristic environments and circumstances that respondents could perhaps find unsafe to execute in real life. One hundred and eighty participants were drawn from the Greater Toronto Area to partake in the designed experiment made up of flexible and immersive VR. Results from this VR environment experiment revealed that the presence of automated vehicles on roads, lane widths, and road density amongst others is the major factors enhancing longer time to wait at crosswalks. Going forward,

revised traffic rules, improved safety measures and a host of others are considered important for the migration to urban areas that are pedestrian friendly.

(a) Participant wearing HMD in real world

(b) VR view

Figure 9. (a) VR environment. Participant wearing HMD in real world, (b) VR view [74].

Summary of reviewed articles for application of VR in transportation discussed in table 4.

6. Application of VR in Sports

The transfer of skill from VR sports training to the real world was investigated by [77] using table tennis as a variable with an adoption of a mixed-model analysis of variance. The study was conducted in the Magill Campus of the South Australia University (UniSA) where fifty-seven participants were drawn as sample for the study and divided into two training controlled and no-training controlled groups. Snellen Eye Chart, RAF Rule and FondaAnderson Reading Chart were all employed to ascertain the participant's visual acuity.Participants were subjected to a competitive table tennis contest with an artificial intelligence opponent. Results indicated a significant improvement in the skills and performance of the group that participated in the VR training session with a pre-test score of M=92.46 to post-test score of M=189.93, contrary to the control group which had a pre-test score of M = 80.62 and post-test score of M = 111.14 [77]. Therefore, future studies should consider the effect of VR training on other sports since this study is limited to only table tennis.
Similarly, another research [78] presented a prototype smart VR simulator for training in Ski jumping modelled after the ski jumping hill of Granåsen in Trondheim, Norway Fig. 10.

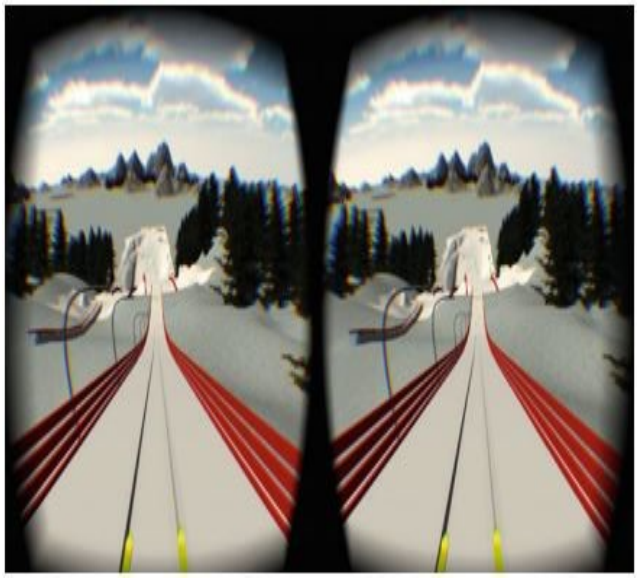


Figure 10. Granåsen VR Ski jumping simulator [57].

The study concludes that adaptation and adoption of the designed simulator are open to various users with differing interface configurations. The VR prototype ensures users are provided with a responsive scenario of consistent feedback and measurement of performance. Perfecting jumping time by professional ski jumpers is feasible with minor improvements coupled with a provision of secured and immersive real ski jump experience; non-professionals are equally equipped with basic skiing skills.

Furthermore, the application of VR technology in physical education and sports training was explored in another study where it was submitted that VR technology could effectively assist physical education activities and improve students' learning efficiency [79]. Students' efficiency in sports has increased by 30%, and at the same time, two-thirds of people believe that their interest in sports training has increased by 80%, and another 90% of college coaches believe that the use of VR technology in physical education is very necessary,

Table 5. Summary of Reviewed Articles for Application of VR in Sports

Author & Year	Focus	Findings	Novelty	S/N
Michalski, Szpak, Saredakis, Ross, Billinghurst and Loetscher, 2019	Transfer of skill from VR sports training to the real world	There is a significant improvement in the skills and performance of participant in the real world after undergoing a VR training session	Mixed-model ANOVA.	[77]
Staurset and Prasolova-Førland, 2016	A prototype smart VR simulator for training in ski jumping	Adaptation and adoption of the designed simulator is open to various users with differing interface configuration. The prototype ensures users are provided with a responsive scenarios consistent measurement of performance.	Oculus Rift DK1, a smart VR simulator, Questionnaire.	[78]
Li, Yi and Gu, 2021	Application of virtual reality technology in physical education and sports training	VR technology can effectively assist physical education activities and improve students' learning efficiency	Interactive virtual scene algorithms, semi supervised framework, Q statistics, and classifier's neighbour confidence.	[79]
Woyo and Nyamandi, 2021	The adoption of VR technology in relation to Comrades Marathon in times of a global health pandemic	There is a mixed perception in relation to the adoption and application of VR technology in sport	Thematic analysis	[81]

which can improve the technical level and training quality of athletes in college sports [79].

From another perspective, [81] investigated the adoption of VR technology in relation to the Comrades Marathon in times of a global health pandemic. An online interview was employed in collecting data from comrade runners globally who participated in the 2020 virtual model of the marathon competition, themed "Race the Comrades Legends". The qualitative approach of research was deemed suitable for the study by the researcher, considering the COVID-19 safety regulations. The result of the study provides managers with requisite information in understanding the acceptance rate of VR in sports, also demonstrating virtualization of a race can provide experiences that contribute to the development of an innovative and more robust marathon competition model. Additionally, the adoption of VR technology will minimise the need for physical travel, helping to lower carbon dioxide emissions and environmental deterioration as the current Comrades Marathon concept entails drawing significant numbers of people who travel from one location to the cities of KZN province while raising awareness in relation to the importance of agility in management of events and sport, mostly in environment flagged as risky during the pandemic. As reported by the study, there is a mixed perception in relation to the adoption and application of VR technology in sports. It, therefore, recommends that participants in the Comrades Marathon should adopt flexibility with dynamism and embrace VR since the world will never remain as it was [81]. The need to conduct larger quantitative studies for understanding the relevance of adopting VR in sports and local tourism should be considered by subsequent studies. Table 5 show summary of reviewed articles for application of VR in sports.

7. Application of VR in Other Sectors

Notably, applications of VR technology in other human endeavours like agriculture, governance, security, and media is gradually peaking the interest of scholars. Research on the adoption of VR technology in other economic sectors include but are not limited to agriculture and food production sector [82, 83], in governance [84, 86, 87], security [88, 89], media [20], and tourism [23].

Several studies have attempted an application of VR in the agriculture and food production sector. For instance, [82] is a study conducted in China and developed a virtual display and interactive experience platform, Fig. 11, of farming culture which is hinged on virtual exhibition and interactive experience

technology. A virtual scene alongside a fixed-point triggering coupled with the application of Unity 3D and HTC Vive interactive VR experience all served as the methodology applied for this study.

Figure 11. Interactive VR experience of various crops [82].

In contrary to the manual construction of scenes made of numerous model loadings, the proposed VR methods enable reduction of time required and are suitable for projects, while a point matching of voices to subtitles and roaming points that promoted effective integration of multimedia resources was enhanced by the proposed method of fixed-point triggering [82]. More so, the ease of sorting historical development in agriculture was enhanced by the platform design, which increases the diverse display of farming culture in China. More so, the result of the study revealed that the developed VR technology is capable of sorting farming culture origin as well as various developments in methods of farming as well as agro-ecosystems formation with the aid of VR display technologies and roaming.

In addition to the above, another research was conducted to investigate the influence of a head-wearable VR device as a potent tool in accurate livestock farming [83]. The study was conducted in the University of Sassari agriculture department. An Italian company product, the GlassUp F4 Smart Glasses (F4SG) was adopted as the device of this study which is specially designed glass for industrial purposes. A Series of tests were conducted both in the laboratory and on the farm to determine the effect of the advanced technology on livestock farming activities, with the tests conducted such that livestock farming activities like breeding, nursing, milking and a host of others are simulated followed by integrating the on-farm data on QR codes [83] as shown in Fig. 12. Various merits of F4SG application on livestock farming was highlighted ranging from a clearly stated and timely understanding of information issues both in small and large farms. Similarly, the F4SG ensures remote assistance to farmers to support them in the daily farm activities. With the aid of the VR F4SG, retrieval of information on different farming activities previously stored on the device memory is easily accessed. Application of manual command rather than a voice command was implemented to guide against farm noise interference for optimum results.

Contrastingly, VR techniques have been found useful in governance and decision making. Managing and overseeing an urban environment alongside local communities is fundamental to sustainable development and enhancement of social need. It is on this premise that a study was conducted on the application of VR tool for consulting the public in environmental planning and management in the south-eastern part of the Suwałki town northeast of Poland [84]. The design and development of an ArchitektVR application utilising improved 3D visualisation and VR was employed as the methodology of this study to undertake management of space in the depleted gravel pit. The proposed area development developed in the VR environment is shown in Fig. 13.

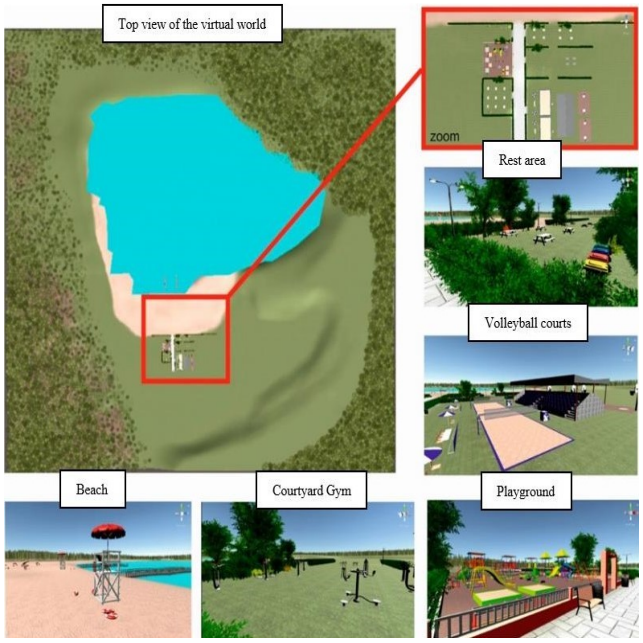


Figure 13. Proposed area development in VR world based on Local area development plan [84].

The development and adoption of the ArchitektVR application is favoured for its capabilities of ensuring mass participation of the local community at the stages

(a) The Emitting operator on field. **(b)** The receiving operator working remotely

Figure 12. Remote assistance during milking machine inspection using VR device. (a) The Emitting operator on field. (b) The receiving operator working remotely [83].

of preparing the planning documentation, design, and implementation of the area development concept. Subsequently, the application will be improved in line with the suggestions and tested on a mass scale by the local community [84]. The use of VR in public consultations streamlines the communication process and enables the presentation of future changes in space which allows for the creation of many scenarios of future area development. Results from the preliminary tests further prove that VR creates an avenue for renewed communication between decision makers and citizens via an efficient and easy to digest visual displays which in turn encourage public participation in local matters and eventual implementation of sustainable plans emanating from better decisions [84]. A similar study on the application of virtual reality in enhancing public participation in governance in Beit Hanoun–Gaza–Palestine was embarked on to ascertain its effects and otherwise on public participation in decision making in a bid to solve the problem emanating from the current practise [86]. In order to achieve the study's aim, an interactive VR employing Vizard software was developed and exported as a 3D model forwarded to participants (citizens) over the internet to ascertain the tool's applicability in urban design decision making and by so doing bridging the time and place gap between participants [86].

Results revealed an improved communication and information sharing between policy makers and the citizens with the aid of the designed VR techniques which solved the problems emanating from applying the traditional tools for public participation coupled with uncertainty with relation to time and space where participation and decision-making occurs. The application of a 3-dimensional VR model for decision making process is further enhanced by the findings of this study since citizens can move freely without restriction while going through a plan to be decided on and not limited to a specific location and spend lengthy time [86]. However, the limitations and shortfalls of the study is that some groups of the citizens who have no access to computer or the internet are excluded and their voice matters as well in decision making. Thus, future studies should create an avenue for inviting citizens from remote locations that have no access to the internet. In the same vein, [87] submitted that a new means of engaging and involving citizens in urban planning process by government is combination of 3D modelling and immersive VR techniques. This was revealed by the authors while investigating the implication of VR techniques in participatory urban planning in view of a decision-making process in a municipal design of a public park. Publicity was made to call for public participation in the decision making of the parks redesigning to sample residents' opinion on the best design suited for the municipal and a total of 1,302 citizens participated. The 3D-rendered park design variants were made available through various mediums for viewing such as paper plans, personal computers, and VR headsets. The application of 3D modelling techniques of the completed designs and VR headsets for immersive experience ensures that users are adequately guided and able to activate a discussion and debate with experts on making the right choice from competing designs. The experiment process and VR environment are shown in Fig. 14.

Table 6. Summary of Reviewed Articles for Application of VR in Other Aspects

Sector	Year	Focus	Findings	Novelty	Ref
Agriculture	2018	Virtual display and interactive experience platform of farming culture which is hinged on virtual exhibition and interactive experience technology	The proposed VR technology is capable of sorting farming culture origin as well as various developments in methods of farming and agro-ecosystems formation with the aid of VR display technologies and roaming	HTC Vive, 3DS Max, C#.	[82]
Agriculture	2019	Influence of head-wearable VR device as a potent tool in accurate livestock farming	With the aid of the VR F4SG, retrieval of information on different farming activities previously stored on the device memory is easily accessed	Smart glasses, GlassUp F4 Smart Glasses (F4SG).	[83]
Governance	2021	Application of VR tool for consulting the public in environmental planning and management	The use of VR in public consultations streamlines the communication process and enables the presentation of future changes in space which allows for the creation of many scenarios of future area development	ArchitektVR application, Unity3D graphic engine	[84]
Governance	2018	Application of virtual reality in enhancing public participation in governance	VR techniques enhance communication and information sharing between policy makers and citizens, overcoming limitations of traditional tools for public participation.	Vizard software	[86]
Governance	2018	Implication of VR techniques in participatory urban planning in view of a decision-making process in a municipal design of a public park	The application of 3D modelling techniques of the completed designs and VR headsets ensures that users are adequately guided and able to activate a discussion and debate with experts on making the right choice of design	Photorealistic 3D rendering, VR headsets.	[87]
Security	2015	Designing a VR tool to aid the planning strategies, action and security of the Instituto de Engenharia Nuclear (IEN) nuclear research	The generated images from the virtual cameras had a proportionality which is equivalent to the one observed by photos of the real facility while the virtual CCTV surveillance camera system enables environmental supervision	Virtual CCTV surveillance system, natural and artificial illumination.	[88]

Security	2016	The feasibility of selected VR authentication mechanism	A password system of 3D has the potential for a high level of security amongst the three methods i.e., 3D patterns, PIN system and 2D sliding patterns while pattern lock	Oculus Rift DK2, C#, Leap Motion.	[89]
Tourism	2022	Factors influencing and determining acceptance of AR and VR in tertiary tourism education	Usefulness, motivation alongside price value are the leading factors determining the adoption and application of AR/VR techniques in tourism education	Technology Acceptance Model (TAM), Questionnaire	[23]
Media	2021	The influence of virtual reality vibrancy and interactivity of consumers/customers and their perception about media quality as it affects their quest for information and sharing attitude	Vividness of virtual reality is important as it immensely contributes to quality of information in media	Media richness theory, Mean Standard Deviation.	[20]

(a) Visualisation and navigation of the park design in VR environment

(b) Residents viewing the park designs using VR headsets and on paper

Figure 14. (a) Visualisation and navigation of the park design in VR environment. (b) Residents viewing the park designs using VR headsets and on paper [87].

Result from the findings showed that the participants' ability to constantly review and criticise design alternatives with the aid of immersive 3D positively influenced their engagement in the workgroup [87]. The participatory design project had an important social impact on the neighbourhood since it was obvious that the design outcome closely reveals the needs and wishes of the inhabitants near the park. The municipality's decision to involve all inhabitants, in response to discontentment about the park, has also contributed to the relationship between the neighbourhood and the municipal government [87].

In an attempt to apply virtual reality to the physical security sector of a nuclear plant in Rio de Janeiro, Brazil [88] embarked on designing a VR tool to aid the planning strategies, action and security of the Instituto de Engenharia Nuclear (IEN) research centre by coming up with a design of a virtual nuclear site. Environmental modelling comprising of Unity 3D and Autodesk 3Ds Max alongside functionalities implementation which is made up of auxiliary equipment like virtual cameras as well as parameters configuration with the aid of C#.

Results showed that the generated images from the virtual cameras had a proportionality which is equivalent to the one observed by photos of the real facility. Equally, with the aid of the proposed methods, users are able to appraise strategies relating to physical security in various dimensions such as varying climatic condition, natural and man-made illumination from varying viewpoints in the virtual model. The virtual

CCTV surveillance camera system enables environmental supervision. The results further made a case for the tools of VR in modelling a virtual environment with interactions within it having the ability to build a virtual nuclear facility with semblance to real nuclear site which aids evaluation of security personnel's reaction in uncertain scenarios. The adopted methodology involved construction of algorithm model in an environment simulated by VR. Generally, the constructed algorithm for this study has a positive reaction industrial control system attacks in a VR simulated environment providing a basis for its application in industrial monitoring.

In addition, it was opined while investigating the feasibility of selected VR authentication mechanism that a password system of 3D has the potential for a high level of security amongst a list of three methods i.e., 3D patterns, PIN system and 2D sliding patterns while pattern lock alongside the PIN lock system is subjected to be more usable [89]. [20] In an attempt to elicit the influence of virtual reality vibrancy and interactivity of consumers/customers and their perception about media quality as it affects their quest for information and sharing attitude revealed that the vividness of virtual reality is important as it immensely contributes to the quality of the information in media. The study was hinged on the media richness theory which illustrates the efficient perception of communication by an individual or group, with a Virtual Tour of destinations like event centre, civic centres, hotels, and point of attractions in Santa Clara USA as the methodology applied to test the research hypotheses. A virtual tour of Santa Clara was conducted on potential customers with the provision of detailed organic information via dynamic view functions, 3-dimensional maps and images, and visual and audio displays connected with 3-dimensional travel routes between different locations. The study enlisted the service of an online survey firm to select 300 participants who served as the population for the study, while 273 who had previous knowledge of virtual reality and completed the virtual tour task were selected as the final sample for the study.The study concludes by confirming the relevance of media richness and the attitude of customers in the quest for information as it affects virtual reality development while recommending the inculcation of vividness in the development of virtual reality to enhance customers' perception, also bridging the gap between media richness and application of VR in service innovation and offers industry implications for enhancing VR features in the hospitality and tourism sector [20]. Table 6, summary of reviewed articles for application of VR in other sspects.

8. VR Adoption and Challenges

[91] explored the views of undergraduates on application of virtual reality in higher institutions of learning. Specifically, the study attempted to determine the perception student about the applicability of VR technology on their programmes from a pedagogical approach to elicit the embedded challenges facing the adoption of VR technology. A mixed method was employed for this research by designing a close and open-ended questionnaire adopted as the instrument of data collection and administered to undergraduate students at the University of the West of Scotland in the creative industries and the collected data were quantitatively and qualitatively analysed. The study adopted the Mann–Whitney and Kruskal–Wallis tests statistical method of analysis while the qualitative statements were drafted within a general view of the research revealing that the identified and relevant opinions are synonymous to the ones available in literature.

The predominant findings from the study indicated that the application of VR is viewed by most students to be beneficial to pedagogical implications with a little percentage having contrary opinion. The percentage of undergraduates who submitted that VR had more benefit are those in the animation and game section of creating computing while those in the web and mobile section had contradicting view of adopting VR though minute. An informed decision will eventually be made on infusing or negating VR in educational curriculum and pedagogical approaches [91]. The associated problem to adopting the technology is therefore more of the high expense of the VR equipment coupled with potential health problems like motion sickness and delay in adapting to its usage by students. Targeting undergraduates from the creative computing discipline is a major limitation of the study as its findings cannot be generalised for all other course of study. A comparative analysis of various disciplines would have been more suitable to determine the implications of VR technology in higher education. More so, future study should explore application of theories like TAM, TTF as well as diffusion innovation [91].

It was reported [23], that the usefulness, motivation alongside price value are the leading factors determining the adoption and application of AR/VR techniques in tourism education, concluded from a study aimed to identify factors influencing and determining acceptance of AR and VR in tertiary tourism education premised on the Technology Acceptance Model [11, 23]. A sample of 630 undergraduate students was drawn from tourism students in fourteen Chinese Universities with the largest percentage (61%) drawn from the Tourism Department, Ningbo University, Zhejiang Provence of China. The researchers decided to use non-probability sampling and purposive technique of

administering questionnaire. Testing of the proposed models was achieved by using PLS-SEM while the SmartPLS 3 software was adopted for data analysis. Collection of relevant information was obtained via questionnaire. The validity and potency of TAM model for educational purposes was further enhanced by this study which improves the knowledge of smart technologies application in universities.

In a bid to understand the reactions of consumers to wearable VR glasses, a study [92] collected data with the assistance of a professional market-research firm from 611 consumers of varying social background in Germany across ages, gender and location and the respondents were financially appreciated for taking part in the study. A seven-point Likert scale was adopted in measuring the variables alongside a confirmatory factor analysis. Results revealed that the adoption of VR intention tends to be high when consumers anticipate an avenue where they are like another person coupled with the virtual presence of being in a different location, though the presence of a single feeling of the two tends to have negative effects [93].

Virtual Reality (VR) finds applications across diverse domains, encompassing education, robotics, health, transport, sports, agriculture, governance, security, and media. while the application of VR is widespread across domains, the specific objectives, metrics, and outcomes differ depending on the unique characteristics and goals of each domain. The findings pertaining to the comparative analysis of virtual reality (VR) across diverse sectors are graphically depicted in Fig. 15

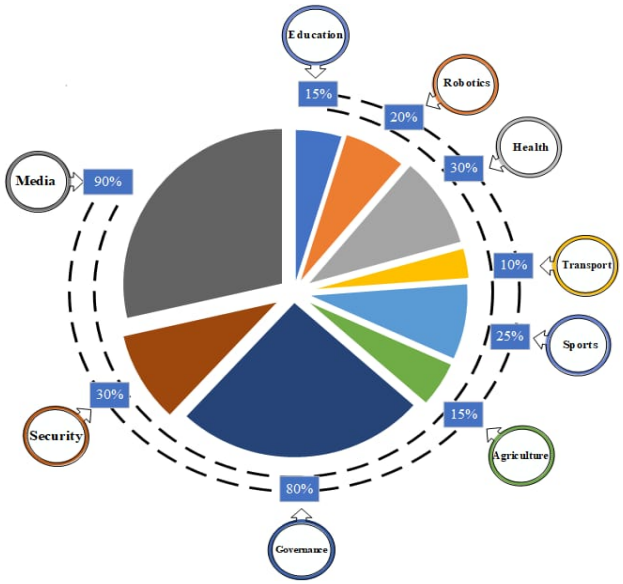


Figure 15. The VR application over the statistical use

As it shown in Fig 15, An examination of the statistical comparisons reveals that within the realm of education, VR enhances learning experiences through the creation of immersive and interactive environments. Measurable indicators of students' performance and assessments conducted prior to and following the employment of VR illustrate promising outcomes. For example, the utilization of VR in education resulted in an average improvement of 15% in test scores. In the field of robotics, VR technology enables simulation and control of robots. Performance metrics, such as accuracy, speed, and efficiency, effectively demonstrate the advantages of VR-assisted methods. For instance, the assembly speed of robots increased by 20% through the use of VR. In the realm of health, VR applications applied in therapy, rehabilitation, and medical training have displayed positive results. Treatment effectiveness can be quantified by variables such as pain reduction and enhancement of motor function. Notably, VR therapy led to a 30% decrease in pain intensity. Concerning transport, VR is employed for aviation and driving simulations, as well as to enhance safety protocols. Performance measures, including reaction times and accident rates, can be compared between individuals trained with VR and those employing traditional methods. Pilots trained with VR exhibited an average reduction of 10% in reaction time. In the context of sports, VR technology aids in performance analysis and game simulations. Variables such as accuracy, speed, and technique can be compared between athletes utilizing VR-based training and those employing traditional methods. A noteworthy enhancement was observed, with a 25% increase in shooting accuracy following VR training. In the field of agriculture, VR applications concentrate on crop monitoring, farm planning, and resource optimization. Statistical comparisons can be drawn in terms of crop yield, resource utilization efficiency, and cost-effectiveness. For instance, the implementation of VR-based techniques yielded a 15% increase in crop yield. In the realm of governance, VR finds applications in urban planning, policy simulations, and public engagement. User feedback, preferences, and comprehension of policy scenarios can be evaluated. As an illustration, 80% of participants reported an improved understanding of policies when employing VR. In the domain of security, VR is employed in security training and simulations. Performance measures, such as response time, accuracy, and threat detection, can be compared between security personnel trained with VR and those employing traditional methods. VR-trained personnel exhibited a 30% enhancement in response time. Finally, within the media landscape, VR revolutionizes storytelling, filmmaking, and entertainment experiences. User engagement, emotional responses, and viewer preferences can be assessed. For instance, 90% of viewers reported a

heightened sense of immersion when experiencing VR films.

9. Conclusion

This comprehensive literature review delves into the adoption, applicability, significance, and challenges of Virtual Reality (VR) across emerging fields of human endeavor, encompassing education, robotics, health, transportation, security, governance, agriculture, and more. The findings underscore the thriving landscape of VR adoption in the education sector, where virtual training has demonstrated superior performance compared to traditional teaching methods, making VR an essential technology for cognitive teaching and knowledge retention beyond the confines of classrooms. In the healthcare sector, the transformative potential of immersive VR becomes apparent in the treatment of burns, pain reduction, patient and student preparation for surgical procedures, as well as the management of stroke and other neurological disorders. Surgeons benefit from VR's detailed organ visualization, enabling precise surgical operations, as exemplified in liver ailment preparations. In the realm of robotics, VR has significantly mitigated strain and muscle cramps among factory workers involved in lifting heavy equipment, particularly in aircraft and engineering assembly plants.

However, several limitations were observed, including limited acceptability, small sample sizes, lack of application of educational theories in VR studies, statistical rather than systematic analysis and presentation of findings, focus on specific student populations and technologies, and limited interactivity. Password privacy and usability issues were also identified, as the shuffling of the keypad for pin entry impedes the authentication process in VR applications for security. Nevertheless, VR exhibits diverse applications and proves to be a unique technology that enhances understanding and facilitates task execution, surpassing the capabilities of traditional methods. The review recommends future studies with larger populations and comparative analyses across different educational fields, incorporating real-time feedback from participants before and after adopting VR technology. Additionally, efforts should be made to ensure the availability and affordability of the necessary technologies for successful and sustainable VR adoption, as financial constraints remain a significant obstacle.

As the first review of its kind encompassing empirical articles across various VR application fields, this study identifies research gaps across all spheres of VR implementation. Scholars and researchers will benefit from a plethora of future studies exploring the pros and cons of VR application, thereby contributing to a more comprehensive understanding of this transformative technology. Investigating and evaluating the effect of virtual reality (VR) in the robotic domain as an important and applicable area for future research.

References

[1] Moshayedi AJ, Kolahdooz A, Liao L. Unity in Embedded System Design and Robotics: A Step-by-step Guide. CRC Press; 2022 Jul 29.

[2] Uddin NM, Moshayedi AJ, Shuxin Y. The Face Detection/Recognition, Perspective and Obstacles In Robotic: A Review. EAI Endorsed Transactions on AI and Robotics. 2022 Dec 15;1(1):e14-.

[3] Lombard M. The concept of presence: Explication statement. International Society for Presence Research. http://ispr. info/about-presence-2/about-presence. 2000.

[4] Kolahdooz A, Shakeri M, Jabbari A, Gol S. Design, simulation and fabrication of a permanent magnet brush DC motor. Majlesi journal of electrical engineering. 2009;2(2):39-48.

[5] Moshayedi AJ, Roy AS, Kolahdooz A, Shuxin Y. Deep Learning Application Pros And Cons Over Algorithm Deep Learning Application Pros And Cons Over Algorithm. EAI Endorsed Transactions on AI and Robotics. 2022 Feb 18;1(1).

[6] Esfahani OT, Moshayedi AJ. Accuracy of the Positioning Systems for the Tracking of Alzheimer's Patients-A Review. International Journal of Applied Electronics in Physics & Robotics. 2014 Nov 22;2(2):10-6.

[7] Moshayedi AJ, Gharpure DC. Development of position monitoring system for studying performance of wind tracking algorithms. InROBOTIK 2012; 7th German Conference on Robotics 2012 May 21 (pp. 1-4). VDE.

[8] Kolahdooz A, Shakeri M. A new BLDC motor for propulsion application. International Review of Electrical Engineering (IREE). 2010 Sep 1;5(5):1872-8.

[9] Araiza-Alba P, Keane T, Kaufman J. Are we ready for virtual reality in K–12 classrooms?. Technology, Pedagogy and Education. 2022 Aug 8;31(4):471-91.

[10] Ortiz JS, Palacios-Navarro G, Andaluz VH, Guevara BS. Virtual reality-based framework to simulate control algorithms for robotic assistance and rehabilitation tasks through a standing wheelchair. Sensors. 2021 Jul 27;21(15):5083.

[11] Moshayedi AJ, Li J, Sina N, Chen X, Liao L, Gheisari M, Xie X. Simulation and validation of optimized pid controller in agv (automated guided vehicles) model using pso and bas algorithms. Computational Intelligence and Neuroscience. 2022 Nov 14;2022.

[12] Kolahdooz A, Shakeri M, Jabbari A, Gol S. Design and thermal analysis of a 300 watt BLDC motor. Majlesi journal of electrical engineering. 2009;3(4):35-43.

[13] Ottogalli K, Rosquete D, Rojo J, Amundarain A, María Rodríguez J, Borro D. Virtual reality simulation of human-robot coexistence for an aircraft final assembly line: process evaluation and ergonomics assessment. International Journal of Computer Integrated Manufacturing. 2021 Sep 2;34(9):975-95.

[14] Soliman M, Pesyridis A, Dalaymani-Zad D, Gronfula M, Kourmpetis M. The application of virtual reality in engineering education. Applied Sciences. 2021 Mar 23;11(6):2879.
[15] Moshayedi AJ, Roy AS, Taravet A, Liao L, Wu J, Gheisari M. A secure traffic police remote sensing approach via a deep learning-based low-altitude vehicle speed detector through uavs in smart cites: Algorithm, implementation and evaluation. Future Transportation. 2023 Feb 3;3(1):189-209.
[16] McGovern E, Moreira G, Luna-Nevarez C. An application of virtual reality in education: Can this technology enhance the quality of students' learning experience? Null. 2020;95(7):490-496.
[17] Ford CG, Manegold EM, Randall CL, Aballay AM, Duncan CL. Assessing the feasibility of implementing low-cost virtual reality therapy during routine burn care. Burns. 2018 Jun 1;44(4):886-95.
[18] Bermúdez i Badia S, Quintero LV, Cameirão MS, Chirico A, Triberti S, Cipresso P, Gaggioli A. Toward emotionally adaptive virtual reality for mental health applications. 2019.
[19] Gan L, Wang D, Wang C, Xiao D, Zhang M, Wang Z, Li F. Design and implementation of multimedia teaching platform for situational teaching of music appreciation course based on virtual reality. The International Journal of Electrical Engineering & Education. 2021 Apr 11:0020720920986090.
[20] Lee SA, Lee M, Jeong M. The role of virtual reality on information sharing and seeking behaviors. Journal of Hospitality and Tourism Management. 2021 Mar 1;46:215-23.
[21] Moshayedi AJ, Sambo SK, Kolahdooz A. Design and development of cost-effective exergames for activity incrementation. In2022 2nd International Conference on Consumer Electronics and Computer Engineering (ICCECE) 2022 Jan 14 (pp. 133-137). IEEE.
[22] Sadeghi M, Andani ME, Parnianpour M, Fattah A. A bio-inspired modular hierarchical structure to plan the sit-to-stand transfer under varying environmental conditions. Neurocomputing. 2013 Oct 22;118:311-21.
[23] Shen S, Xu K, Sotiriadis M, Wang Y. Exploring the factors influencing the adoption and usage of Augmented Reality and Virtual Reality applications in tourism education within the context of COVID-19 pandemic. Journal of hospitality, leisure, sport & tourism education. 2022 Jun 1;30:100373.
[24] Shin DH. The role of affordance in the experience of virtual reality learning: Technological and affective affordances in virtual reality. Telematics and Informatics. 2017 Dec 1;34(8):1826-36.
[25] Moshayedi AJ, Gharpure DC. Priority based algorithm for Plume tracking Robot. In2012 1st International Symposium on Physics and Technology of Sensors (ISPTS-1) 2012 Mar 7 (pp. 51-54). IEEE.
[26] Miller LM, Chang CI, Wang S, Beier ME, Klisch Y. Learning and motivational impacts of a multimedia science game. Computers & Education. 2011 Aug 1;57(1):1425-33.
[27] Mayer RE. Should there be a three-strikes rule against pure discovery learning?. American psychologist. 2004 Jan;59(1):14.
[28] Emadi Andani M, Bahrami F. COMAP: A new model to describe human movement planning level based on coordinated minimum angle jerk policy and six universal movement elements. Hum Mov Sci. 2012;31:1037-1055. doi: 10.1016/j.humov.2012.01.001.
[29] Jensen CG. Collaboration and dialogue in virtual reality. Journal of Problem Based Learning in Higher Education. 2017 Sep 18;5(1).
[30] Moshayedi AJ, Xu G, Liao L, Kolahdooz A. Gentle Survey on MIR Industrial Service Robots: Review & Design. J. Mod. Process. Manuf. Prod. 2021;10(1):31-50.
[31] Chen YL. The effects of virtual reality learning environment on student cognitive and linguistic development. The Asia-Pacific Education Researcher. 2016 Aug;25:637-46.
[32] Chavez B, Bayona S. Virtual reality in the learning process. InTrends and Advances in Information Systems and Technologies: Volume 2 6 2018 (pp. 1345-1356). Springer International Publishing.
[33] Fromm J, Radianti J, Wehking C, Stieglitz S, Majchrzak TA, vom Brocke J. More than experience?-On the unique opportunities of virtual reality to afford a holistic experiential learning cycle. The Internet and higher education. 2021 Jun 1;50:100804.
[34] Xu G, Khan AS, Moshayedi AJ, Zhang X, Shuxin Y. The Object Detection, Perspective and Obstacles In Robotic: A Review. EAI Endorsed Transactions on AI and Robotics. 2022 Oct 18;1(1).
[35] Moshayedi AJ, Gharpure DC. Development of position monitoring system for studying performance of wind tracking algorithms. InROBOTIK 2012; 7th German Conference on Robotics 2012 May 21 (pp. 1-4). VDE.
[36] BCC-Publishing. Global virtual & augmented reality market: Size, & industry report [Internet]. BCC Publishing; Aug. 2018.
[37] Martínez-Navarro J, Bigné E, Guixeres J, Alcañiz M, Torrecilla C. The influence of virtual reality in e-commerce. Journal of Business Research. 2019 Jul 1;100:475-82.
[38] Baceviciute S, Terkildsen T, Makransky G. Remediating learning from non-immersive to immersive media: Using EEG to investigate the effects of environmental embeddedness on reading in Virtual Reality. Computers & Education. 2021 Apr 1;164:104122.
[39] Esfe MH, Eftekhari SA, Alizadeh AA, Emami N, Toghraie D. Investigation of best artificial neural network topology to model the dynamic viscosity of MWCNT-ZnO/SAE 5W30 nano-lubricant. Materials Today Communications. 2023 Jun 1;35:106074.
[40] van Ginkel S, Gulikers J, Biemans H, Noroozi O, Roozen M, Bos T, van Tilborg R, van Halteren M, Mulder M. Fostering oral presentation competence through a virtual reality-based task for delivering feedback. Computers & Education. 2019 Jun 1;134:78-97.
[41] Sholihin M, Sari RC, Yuniarti N, Ilyana S. A new way of teaching business ethics: The evaluation of virtual reality-based learning media. The International Journal of Management Education. 2020 Nov 1;18(3):100428.
[42] Emadi Andani M, Bahrami F, Jabehdar Maralani P, Ijspeert AJ. MODEM: a multi-agent hierarchical

structure to model the human motor control system. Biological cybernetics. 2009 Dec;101:361-77.
[43] Stojšić I, Džigurski AI, Maričić O, Bibić LI, Vučković Dj. Possible application of virtual reality in geography teaching. Journal of Subject Didactics. 2016;1(2):83-96.
[44] Hussein M, Nätterdal C. The benefits of virtual reality in education-A comparision Study.
[45] Wang Y. Application of virtual reality technique in the construction of modular teaching resources. International journal of emerging technologies in learning (ijet). 2020 Jun 1;15(10):126-39.
[46] Moshayedi AJ, Roy AS, Sambo SK, Zhong Y, Liao L. Review on: the service robot mathematical model. EAI Endorsed Transactions on AI and Robotics. 2022 Feb 23;1(1).
[47] Zhang H, Zhang J, Yin X, Zhou K, Pan Z. Cloud-to-end rendering and storage management for virtual reality in experimental education. Virtual Reality & Intelligent Hardware. 2020 Aug 1;2(4):368-80.
[48] Dimitrokalli A, Vosniakos GC, Nathanael D, Matsas E. On the assessment of human-robot collaboration in mechanical product assembly by use of Virtual Reality. Procedia Manufacturing. 2020 Jan 1;51:627-34.
[49] Togias T, Gkournelos C, Angelakis P, Michalos G, Makris S. Virtual reality environment for industrial robot control and path design. Procedia CIRP. 2021 Jan 1;100:133-8.
[50] Emadi Andani M, Bahrami F, Jabehdar Maralani P. AMA-MOSAICI: An automatic module assigning hierarchical structure to control human motion based on movement decomposition. Neurocomputing. 2009 Jun 1;72(10-12):2310-8.
[51] Moshayedi AJ, Gharpure DC. Evaluation of bio inspired Mokhtar: Odor localization system. In2017 18th international carpathian control conference (ICCC) 2017 May 28 (pp. 527-532). IEEE.
[52] Wang F, Zhang C, Guo F, Sheng X, Ji J, Xu Y, Cao Z, Lyu J, Lu X, Yang B. The application of virtual reality training for anastomosis during robot-assisted radical prostatectomy. Asian Journal of Urology. 2021 Apr 1;8(2):204-8.
[53] Cohavi O, Levy-Tzedek S. Young and old users prefer immersive virtual reality over a social robot for short-term cognitive training. International Journal of Human-Computer Studies. 2022 May 1;161:102775.
[54] Karagiannis P, Togias T, Michalos G, Makris S. Operators training using simulation and VR technology. Procedia CIRP. 2021 Jan 1;96:290-4.
[55] Moshayedi AJ, Xu G, Liao L, Kolahdooz A. Gentle Survey on MIR Industrial Service Robots: Review & Design. J. Mod. Process. Manuf. Prod. 2021;10(1):31-50.
[56] Murhij Y, Serebrenny V. An application to simulate and control industrial robot in virtual reality environment integrated with IR stereo camera sensor. IFAC-PapersOnLine. 2019 Jan 1;52(25):203-7.
[57] Moshayedi AJ, Hosseini MS, Rezaee F. WiFi based massager device with NodeMCU through arduino interpreter. Journal of Simulation and Analysis of Novel Technologies in Mechanical Engineering. 2019 Dec 14;11(1):73-9.
[58] Sokołowska B. A novel virtual reality approach for functional lateralization in healthy adults. Brain Research. 2021 Sep 1;1766:147537.
[59] Kolbe L, Jaywant A, Gupta A, Vanderlind WM, Jabbour G. Use of virtual reality in the inpatient rehabilitation of COVID-19 patients. General Hospital Psychiatry. 2021 Jul 1;71:76-81.
[60] Birckhead B, Khalil C, Liu X, Conovitz S, Rizzo A, Danovitch I, Bullock K, Spiegel B. Methodology for clinical trials of virtual reality in healthcare: Recommendations from an international working group (preprint). JMIR mental health. 2019;6.
[61] Fertleman C, Aubugeau-Williams P, Sher C, Lim AN, Lumley S, Delacroix S, Pan X. A discussion of virtual reality as a new tool for training healthcare professionals. Frontiers in public health. 2018 Feb 26;6:44.
[62] Chang CY, Sung HY, Guo JL, Chang BY, Kuo FR. Effects of spherical video-based virtual reality on nursing students' learning performance in childbirth education training. Interactive Learning Environments. 2022 Feb 17;30(3):400-16.
[63] Moshayedi AJ, Reza KS, Khan AS, Nawaz A. Integrating Virtual Reality and Robotic Operation System (ROS) for AGV Navigation. EAI Endorsed Transactions on AI and Robotics. 2023 Apr 21;2(1):e3-.
[64] Yu P, Pan J, Wang Z, Shen Y, Li J, Hao A, Wang H. Quantitative influence and performance analysis of virtual reality laparoscopic surgical training system. BMC Medical Education. 2022 Dec;22(1):1-0.
[65] Boedecker C, Huettl F, Saalfeld P, Paschold M, Kneist W, Baumgart J, Preim B, Hansen C, Lang H, Huber T. Using virtual 3D-models in surgical planning: workflow of an immersive virtual reality application in liver surgery. Langenbeck's archives of surgery. 2021 May;406:911-5.
[66] Chheang V, Saalfeld P, Joeres F, Boedecker C, Huber T, Huettl F, Lang H, Preim B, Hansen C. A collaborative virtual reality environment for liver surgery planning. Computers & Graphics. 2021 Oct 1;99:234-46.
[67] Abbasi A, Moshayedi AJ. Trajectory tracking of two-wheeled mobile robots, using LQR optimal control method, based on computational model of KHEPERA IV. Journal of Simulation and Analysis of Novel Technologies in Mechanical Engineering. 2018 Jan 20;10(3):41-50.
[68] Ganry L, Hersant B, Sidahmed-Mezi M, Dhonneur G, Meningaud JP. Using virtual reality to control preoperative anxiety in ambulatory surgery patients: A pilot study in maxillofacial and plastic surgery. Journal of stomatology, oral and maxillofacial surgery. 2018 Sep 1;119(4):257-61.
[69] Esfe MH, Eftekhari SA, Alizadeh AA, Aminian S, Hekmatifar M, Toghraie D. A well-trained artificial neural network for predicting the optimum conditions of MWCNT–ZnO (10: 90)/SAE 40 nano-lubricant at different shear rates, temperatures, and concentration of nanoparticles. Arabian Journal of Chemistry. 2023 Feb 1;16(2):104508.
[70] Eijlers R, Dierckx B, Staals LM, Berghmans JM, van der Schroeff MP, Strabbing EM, Wijnen RM, Hillegers MH, Legerstee JS, Utens EM. Virtual reality exposure before

elective day care surgery to reduce anxiety and pain in children: A randomised controlled trial. European journal of anaesthesiology. 2019 Oct;36(10):728.
[71] Ferris JD, Donachie PH, Johnston RL, Barnes B, Olaitan M, Sparrow JM. Royal college of ophthalmologists' national ophthalmology database study of cataract surgery: Report 6. the impact of EyeSi virtual reality training on complications rates of cataract surgery performed by first and second year trainees. Br J Ophthalmol. 2020;104(3):324-329.
[72] Moshayedi AJ, Li J, Sina N, Chen X, Liao L, Gheisari M, Xie X. Simulation and validation of optimized pid controller in agv (automated guided vehicles) model using pso and bas algorithms. Computational Intelligence and Neuroscience. 2022 Nov 14;2022.
[73] Agudelo-Vélez A, Sarmiento-Ordosgoitia I, Córdoba-Maquilón J. Virtual reality as a new tool for transport data collection. Archives of Transport. 2021;60(4).
[74] Iryo-Asano M, Hasegawa Y, Dias C. Applicability of virtual reality systems for evaluating pedestrians' perception and behavior. Transportation research procedia. 2018 Jan 1;34:67-74.
[75] Deb S, Carruth DW, Sween R, Strawderman L, Garrison TM. Efficacy of virtual reality in pedestrian safety research. Applied ergonomics. 2017 Nov 1;65:449-60.
[76] Kalatian A, Farooq B. Decoding pedestrian and automated vehicle interactions using immersive virtual reality and interpretable deep learning. Transportation research part C: emerging technologies. 2021 Mar 1;124:102962.
[77] Michalski SC, Szpak A, Saredakis D, Ross TJ, Billinghurst M, Loetscher T. Getting your game on: Using virtual reality to improve real table tennis skills. PloS one. 2019 Sep 10;14(9):e0222351.
[78] Staurset EM, Prasolova-Førland E. Creating a smart Virtual Reality simulator for sports training and education. InSmart Education and e-Learning 2016 2016 (pp. 423-433). Springer International Publishing.
[79] Li D, Yi C, Gu Y. Research on college physical education and sports training based on virtual reality technology. Mathematical Problems in Engineering. 2021 Feb 18;2021:1-8.
[80] Moshayedi AJ, Gharpure DC. Priority based algorithm for Plume tracking Robot. In2012 1st International Symposium on Physics and Technology of Sensors (ISPTS-1) 2012 Mar 7 (pp. 51-54). IEEE.
[81] Woyo E, Nyamandi C. Application of virtual reality technologies in the comrades' marathon as a response to COVID-19 pandemic. Development Southern Africa. 2022 Jan 2;39(1):20-34.
[82] Cheng C, Kang L, Cai S, Li J, Sun R. Virtual display and interactive experience platform of farming culture based on Unity3D. IFAC-PapersOnLine. 2018 Jan 1;51(17):637-42.
[83] Caria M, Sara G, Todde G, Polese M, Pazzona A. Exploring smart glasses for augmented reality: A valuable and integrative tool in precision livestock farming. Animals. 2019 Nov 1;9(11):903.
[84] Szczepańska A, Kaźmierczak R, Myszkowska M. Virtual reality as a tool for public consultations in spatial planning and management. Energies. 2021 Sep 23;14(19):6046.
[85] Esfe MH, Hajian M, Esmaily R, Eftekhari SA, Hekmatifar M, Toghraie D. Designing the best ANN topology for predicting the dynamic viscosity and rheological behavior of MWCNT-CuO (30: 70)/SAE 50 nanolubricant. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 2022 Oct 20;651:129691.
[86] Fares F, Taha DS, Sayad ZT. Achieving public participation in inaccessible areas using virtual reality a case study of Beit Hanoun–Gaza–Palestine. Alexandria Engineering Journal. 2018 Sep 1;57(3):1821-8.
[87] Van Leeuwen JP, Hermans K, Jylhä A, Quanjer AJ, Nijman H. Effectiveness of virtual reality in participatory urban planning: A case study. InProceedings of the 4th Media Architecture Biennale Conference 2018 Nov 13 (pp. 128-136).
[88] da Silva MH, do Espírito Santo AC, Marins ER, de Siqueira AP, Mol DM, de Abreu Mol AC. Using virtual reality to support the physical security of nuclear facilities. Progress in Nuclear Energy. 2015 Jan 1;78:19-24.
[89] Yu Z, Liang HN, Fleming C, Man KL. An exploration of usable authentication mechanisms for virtual reality systems. In2016 IEEE Asia Pacific Conference on Circuits and Systems (APCCAS) 2016 Oct 25 (pp. 458-460). IEEE.
[90] Moshayedi AJ, Zanjani SM, Xu D, Chen X, Wang G, Yang S. Fusion BASED AGV Robot Navigation Solution Comparative Analysis and Vrep Simulation. In2022 8th Iranian Conference on Signal Processing and Intelligent Systems (ICSPIS) 2022 Dec 28 (pp. 1-11). IEEE.
[91] Baxter G, Hainey T. Student perceptions of virtual reality use in higher education. Journal of Applied Research in Higher Education. 2019 Apr 5;12(3):413-24.
[92] Herz M, Rauschnabel PA. Understanding the diffusion of virtual reality glasses: The role of media, fashion and technology. Technological Forecasting and Social Change. 2019 Jan 1;138:228-42.
[93] Xia JS, Khabaz MK, Patra I, Khalid I, Alvarez JR, Rahmanian A, Eftekhari SA, Toghraie D. Using feed-forward perceptron Artificial Neural Network (ANN) model to determine the rolling force, power and slip of the tandem cold rolling. ISA transactions. 2023 Jan 1;132:353-63.