applied sciences

MDPI

Review

A Scoping Review on Virtual Reality-Based Industrial Training

Jose E. Naranjo [1,†], Diego G. Sanchez [2,†], Angel Robalino-Lopez [3,†], Paola Robalino-Lopez [3,†], Andrea Alarcon-Ortiz [4,†] and Marcelo V. Garcia [1,5,*,†]

1 FISEI, Universidad Tecnica de Ambato, UTA, Ambato 180206, Ecuador; jnaranjo0463@uta.edu.ec
2 FI, Universidad Nacional de La Plata, UNLP, Buenos-Aires 1900, Argentina; dsanchez@orizontel.ec
3 Instituto Superior Tecnologico Victoria Vasconez Cuvi, ISTVVC, Latacunga 050103, Ecuador; arobalino@institutovvc.edu.ec (A.R.-L.); paorobalino@institutovvc.edu.ec (P.R.-L.)
4 Instituto Superior Tecnologico Guayaquil, ISTG, Ambato 180205, Ecuador; aalarcon@institutos.gob.ec
5 DISA, University of the Basque Country, EHU/UPV, 48013 Bilbao, Spain
* Correspondence: mgarcia294@ehu.es or mv.garcia@uta.edu.ec; Tel.: +593-998-267-906
† These authors contributed equally to this work.

Received: 21 October 2020; Accepted: 15 November 2020; Published: 20 November 2020

check for updates

Abstract: The fourth industrial revolution has forced most companies to technologically evolve, applying new digital tools, so that their workers can have the necessary skills to face changing work environments. This article presents a scoping review of the literature on virtual reality-based training systems. The methodology consisted of four steps, which pose research questions, document search, paper selection, and data extraction. From a total of 350 peer-reviewed database articles, such as SpringerLink, IEEEXplore, MDPI, Scopus, and ACM, 44 were eventually chosen, mostly using the virtual reality haptic glasses and controls from Oculus Rift and HTC VIVE. It was concluded that, among the advantages of using this digital tool in the industry, is the commitment, speed, measurability, preservation of the integrity of the workers, customization, and cost reduction. Even though several research gaps were found, virtual reality is presented as a present and future alternative for the efficient training of human resources in the industrial field.

Keywords: virtual reality; industrial training; scoping review

1. Introduction

Staff training is a continuous process that must be focused on the needs of each company, and it is also vital for the proper development of institutions. At the industrial level, the same thing happens, the correct training of workers helps to achieve the strategic objectives and to establish its productive value. However, despite being so necessary, continuous training is undervalued by top management, generating outdated human resources, and, therefore, low-quality products/services [1–3].

In many cases, learning during job performance affects the stability of processes. For this reason, it must be decided whether the learning and training of personnel should be carried out during the actual operation, with possible loss of time; or, in a previous phase without compromising the efficiency of the process [4,5]. Learning opportunities in the value chain are limited due to the variability of its environment, i.e., it is complex to implement changes during production execution. At this point, putting the quality, safety, and efficiency of the production line and workers at risk is unacceptable [6].

To solve these problems, in recent years, industry 4.0 has arisen, whose objective is to improve processes and increase the productivity of industries. Among the technologies that have been used to fulfill this purpose, the industrial internet of things (IIoT), intelligence and artificial vision, virtual reality (VR), and augmented reality (AR) can be mentioned [7].

VR, which is the aim of this study, can be defined as a virtual recreation of the real world. Its objective is to transport the user to fully digitized and interactive environments. This technology was originally conceived for video games; however, it has reached various fields, such as industry, medicine, army, education, and tourism [8].

VR has allowed for the creation of simulation environments for real processes and situations. Furthermore, it has proven to be an adequate way to reduce training times, prevent errors, or even improve the quality of products [9]. The motivation to implement this technology arises from the fact that it is presented as a low-cost alternative when it comes to training and preparation for the use of specialized equipment. VR offers the user an immersive, interactive, and innovative learning process, in contrast to traditional teaching, whose monotony generates rejection and boredom [10,11]

Unity 3D is one of the most used software to develop VR, a graphic engine that, together with head-mounted displays (HMD), provides an intuitive and friendly programming environment, in addition to allowing a high degree of immersion for its users [9,12–15].

Several aspects can be studied regardign industrial training based on VR, such as characteristics, devices, approaches, specific applications, among others, as described in previous paragraphs. As a result, this article develops a scoping review in order to better understand the use of this type of technology in industrial training because it is one of the key-technologies where VR will be useful within five years according to the Digital Twin Consortium [16].

This article has five Sections, including the introduction and it is structured, as follows: Section 2 presents the methodology followed to select the VR articles, Section 3 itemizes the literature review and obtained results, Section 4 shows the benefits, predictions, and possible future uses of VR, and finally, Section 5 details the conclusions.

2. Methodology

Like other systematic literature and scoping reviews [17–20], and following the PRISMA guidelines [21], the review methodology has focused on databases, to which the authors have access, such as SpringerLink, IEEEXplore, MDPI (Institute for Multidisciplinary Digital Publication), Scopus, and ACM (Association for Computing Machinery), and consisted of four steps: (i) research questions, (ii) document search, (iii) paper selection, and (iv) data extraction.

2.1. Research Questions

The number of four research questions were established. These questions fulfill the purpose of covering the topic of the use of VR within industrial training. It is worth mentioning that three viewpoints have been taken into account to carry out this analysis: (VP1) non-industrial training based on VR, (VP2) industrial training, and (VP3) industrial training based on VR. Table 1 shows the formulated questions.

Table 1. Research questions.

Number	Research Question (RQ)	Motivation
RQ1	What are the uses of VR in non-industrial training?	Identify the approaches used.
RQ2	What types of technologies are used in industrial training other than VR?	Identify other technologies, apart from VR, used in industrial training.
RQ3	What devices are used for VR industrial training?	Identify the devices used to generate immersive environments.
RQ4	What are the users' benefits of applying VR in industrial training?	Identify the advantages of VR in industrial training.

2.2. Document Search

A literature search spanning from 2015 to 2020 was conducted. This time range has been selected, because technology advances exponentially, so the research team considered that five years is an accurate time to evaluate the most current uses of this digital tool and understand the approaches and possible futures in terms of VR [22,23].

Specific terms were used according to the three perspectives described in the previous section. For VP1 ((“training” OR “instruction” OR “teaching” OR “education” OR “preparation”) AND (“virtual reality”)) were established, for VP2 ((“industrial” OR “technical” OR “manufacturing” OR “industry” OR “production”) AND (“training” OR “teaching”)) were used. Finally, for VP3, ((“industrial training” OR “factory instruction” OR “industrial teaching” OR “4.0 industry”) AND (“virtual reality” OR “digital tools”)) were selected. Based on titles and abstracts, the documents were reviewed, in detail, by two expert reviewers.

2.3. Paper Selection

This section was divided into four parts. In the first phase, inclusion and exclusion criteria were applied. Here, several aspects were taken into account, such as the language of the papers, the date of publication, the subject matter, among others (see Table 2). In the second phase, documents were ordered by relevance, perspective, title, abstract, and keywords. It allowed for a faster and more efficient review of each article. In the third stage, it was reviewed whether the information shown in the introduction and conclusions section provided the necessary evidence to answer the research questions.

Finally, the references were verified. It was performed to confirm that each one is correctly placed, corresponds to the detailed information, and it aligns with the context of each perspective. The summary of the obtained documents in each phase is presented according to the PRISMA guidelines presented in Figure 1.

Table 2. Inclusion and exclusion criteria.

Number	Inclusion	Exclusion
C1	Articles related to purposes of using virtual reality in industrial training	Duplicates from different databases
C2	Articles published from 2015 to 2020	Articles not related to virtual reality and industrial training
C3	English written articles	Thesis
C4	Articles related to purposes of using virtual reality in non industrial training	Studies published in other areas of knowledge
C5	Articles related to non-VR industrial training	Review articles

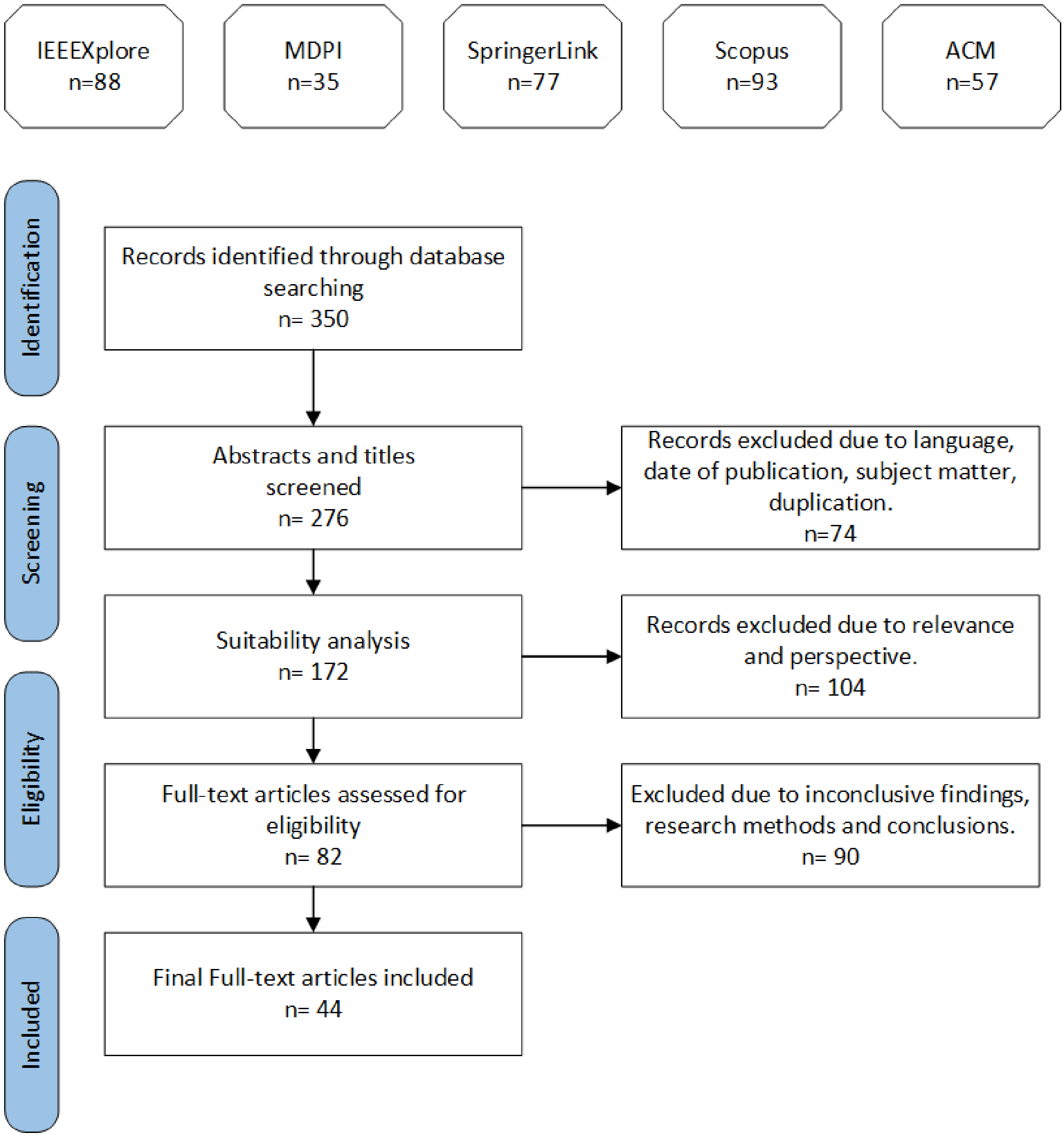

Figure 1. PRISMA flow diagram.

2.4. Data Extraction

The final 44 papers were reviewed again by four members of the research team, thus corroborating that the selection was appropriate. Table 3, presents these articles arranged by year of publication. The information extracted from each document is based on answering the research questions. Various aspects, such as the fields in which VR is developed for education and training, technology, level of immersion and efficiency, advantages, disadvantages, and the gaps of this digital tool, have been considered.

On the other hand, Table 4 presents a detailed description of the studies included in the review.

Table 3. Selected papers objective.

Code	Title	Database	Year	Viewpoint	Authors	Objective
P1	Low cost virtual reality for medical training	IEEEXplore	2015	VP1	Mathur, A.S.	Using devices such as the Oculus Rift and Razer Hydra the authors propose a low cost virtual reality set-up for medical training and instruction purposes.
P2	A Virtual Reality Based Training System for Cultural Tourism	SpringerLink	2015	VP1	Tseng, S.P.; Huang, M.W.; Liu, H.J.; Chung, C.C.; Chiu, C.M.	This paper proposes a web-based 3D-panorama training system for tour guides to be applied in both the classroom and the scenic field.
P3	How a Plant Simulator can Improve Industrial Safety	Scopus	2015	VP3	Nazir, S.; Manca, D.	The article presents a solution for immersive training of industrial operators called Plant Simulator (PS). It combines a process and an accident simulator to reproduce typical and abnormal/accident scenarios dynamically.
P4	Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks	Scopus	2015	VP3	Gavish, N.; Gutiérrez, T.; Webel, S.; Rodríguez, J.; Peveri, M.; Bockholt, U.; Tecchia, F.	Evaluate VR and AR systems efficiency and effectiveness compared to traditional training methods. It is done using four training groups in an electronic actuator assembly task.
P5	Design of a virtual reality training system for human–robot collaboration in manufacturing tasks	Scopus	2015	VP3	Matsas, E.; Vosniakos, G.C.	This research presents an interactive virtual reality training system called "beWare of the Robot" in terms of a game that simulates the cooperation between industrial robotic manipulators and humans.
P6	A Case Study on Virtual Reality American Football Training	ACM	2015	VP1	Huang, Y.; Churches, L.; Reilly, B.	Using the Oculus Rift HMD, a study of American football training through the use of virtual reality is presented. It is focused on student-athletes in an immersive virtual reality environment, where trainees experience the football gameplays created by their coaches.
P7	New employee education using 3D virtual manufacturing	IEEEXplore	2016	VP2	Mechlih, H.	This work presents a system using existing virtual manufacturing technology to improve the quality of new employee training, reduce the cost and the time consumed in preparation.
P8	Breaking Bad Behavior: Immersive Training of Class Room Management	ACM	2016	VP1	Latoschik, M.E.; Lugrin, J.L.; Habel, M.; Roth, D.; Seufert, C.; Grafe, S.	This article developed an immersive portable, low-cost Virtual Reality system to train classroom management skills. The trainee's interface uses HMD and earphones for output.

Table 3. *Cont.*

Code	Title	Database	Year	Viewpoint	Authors	Objective
P9	Training of Tannery Processes Through Virtual Reality	SpringerLink	2017	VP3	Andaluz, V.H.; Pazmiño, A.; Perez, J.; Carvajal, C.	The virtualization of the industrial tanning process to train operators through a virtual environment is presented. It uses the graphic engine Unity 3D and the Oculus Rift HMD.
P10	Interactive simulation-based-training tools for manufacturing systems operators: an industrial case study	Scopus	2017	VP3	Vergnano, A.; Berselli, G.; Pellicciari, M.	This paper reports a successful industrial case study concerning a new Simulation-Based-Training workbench used for steel plant operator training. It discusses both the virtual prototyping phase and the development of a real-time simulation architecture.
P11	Immersive Virtual Reality Training Tool for IoT Device Placement	ACM	2017	VP1	Jia, Y.; Campbell, A.G.	This paper outlines the results of creating a VR simulation of a generic space where IoT devices can be placed and then evaluated in real-time to test if their placement will be a viable network.
P12	Design of a Virtual Reality and Haptic Setup Linking Arousals to Training Scenarios: A Preliminary Stage	IEEEXplore	2018	VP1	Kournaditis, K.; Chinello, F.; Venckute, S.	This research develops an appraised, well-crafted VR puzzle game, questionnaires and sensors (skin conductance response/pulse) to design a two-phase explorative experiment linking arousal and performance during training in a Virtual Reality (VR) environment.
P13	Visual computing technologies to support the Operator 4.0	Scopus	2018	VP3	Arbelaiz, Ander; Álvarez, Hugo; Simões, Bruno; Posada, Jorge; García-Alonso, Alejandro; Ugarte, Ramón	Present several practical developments where Visual Computing enables the augmented operator, the virtual operator and the collaborative operator.
P14	Comparing HMD-based and Paper-based Training	IEEXplore	2018	VP2	Werrlich, Stefan; Daniel, Austino; Ginger, Alexandra; Nguyen, Phuc Anh; Notni, Gunther	Measure the training transfer of an engine assembly training task.
P15	A Virtual Reality Rehabilitation Training System Based on Upper Limb Exoskeleton Robot	IEEEXplore	2018	VP1	Zheng, J.; Shi, P.; Yu, H.	The authors present a training system that consists of virtual reality rehabilitation games and data communication. A virtual reality training system based on an exoskeleton rehabilitation robot was designed for patients with upper extremity motor dysfunction.

Table 3. *Cont.*

Code	Title	Database	Year	Viewpoint	Authors	Objective
P16	Design and development smart industrial training management software with artificial neural network (ANN) on Java	IEEEXplore	2018	VP2	Efanntyo.; Cahyono, M.R.A.	The authors present a smart industrial training design with ANN that aims to divide users into several levels and simplify the printing of reports.
P17	TPS training course for the production staff	IEEEXplore	2018	VP2	Phakphonhamin, V.; Wongsawad, R.; Vichitwongsakorn, T.	The research study aimed to develop a training course for the Toyota Production System for production staff and apply it to the standard course of the necessary knowledge about this system.
P18	Augmented reality as an instrument for teaching industrial automation	IEEEXplore	2018	VP2	Martin, J.; Bohuslava, J.	It introduces a learning system focused on teaching subjects from the field of industrial automation using the A-Frame framework in combination with the AR.js project.
P19	The Other Kind of Machine Learning: Modeling Worker State for Optimal Training of Novices in Complex Industrial Processes	IEEEXplore	2018	VP2	Thomay, C.; Gollan, B.; Haslgrübler, M.; Ferscha, A.; Heftberger, J.	A training station e-learning concept is detailed, with the purpose to automatically teach a novice worker the necessary steps to assemble an alpine ski without the need for constant human supervision.
P20	Teaching industrial automation concepts with the use of virtual/augmented reality-The IEC 61499 case	IEEEXplore	2018	VP3	Chrysoulas, C.; Homay, A.; Lemac, M.	A framework for teaching complex industrial automation concepts with the help of Virtual/Augmented reality to support higher education students better understand complex industrial automation concepts is developed.
P21	Virtual simulator for forklift training	IEEEXplore	2018	VP3	Lustosa, E.B.S.; DeMacEdo, D.V.; Rodrigues, M.A.F.	The Oculus Rift HMD and haptic control interfaces to train workers with a virtual simulator for forklift training are detailed.
P22	Indy: A virtual reality multi-player game for navigation skills training	IEEEXplore	2018	VP3	Mas, A.; Ismael, I.; Filliard, N.	Here it is developed Indy, a virtual reality system consisting of a collaborative game of treasure hunting. It improves learners' attention on navigation tasks, implies their active engagement, and provides feedback on their achievements.
P23	Training for Bus Bodywork in Virtual Reality Environments	SpringerLink	2018	VP3	Herrera, D.F.; Bolívar Acosta, S.; Quevedo, W.X.; Balseca, J.A.; Andaluz, V.H.	The authors detail the Unity 3D graphic engine as a viable solution to develop a training system on electric welding applied to the automotive body assembly industry.

Table 3. *Cont.*

Code	Title	Database	Year	Viewpoint	Authors	Objective
P24	Training in Virtual Environments for Hybrid Power Plant	SpringerLink	2018	VP3	Chiluisa, M.; Mullo, R.; Andaluz, V.	This study describes a Virtual Environments application for professionals in Electrical Power Systems training. The app is developed in the Game Engine Unity 3D and features three different modes.
P25	A low-complexity method for authoring an interactive virtual maintenance training system of hydroelectric generating equipment	Scopus	2018	VP3	Li, B.; Bi, Y.; He, Q.; Ren, J.; Li, Z.	An interactive virtual maintenance system of an entire hydroelectric generating equipment based on this apparatus's interactive operation is established.
P26	Virtual Reality Training System for Surgical Anatomy	ACM	2018	VP1	Wang, X.; Wang, X.	This paper proposes a simulation anatomy system that can be applied to medical students' anatomy learning. The system consists of scene construction, result determination and UI interface development.
P27	Evaluation of a virtual reality-based baseball batting training system using instantaneous bat swing information	IEEEXplore	2019	VP1	Zou, L.; Higuchi, T.; Noma, H.; Roberto, L.G.; Isaka, T.	The researches propose a Virtual Reality-based (VR) baseball batting system that provides instantaneous information as feedback. This information includes exact bat-ball impact location and angle, replay for swing timing and speed.
P28	AirwayVR: Virtual reality trainer for endotracheal intubation-design considerations and challenges	IEEEXplore	2019	VP1	Rajeswaran, P.; Kesavadas, T.; Jani, P.; Kumar, P.	This paper proposes the design considerations and challenges of a virtual reality-based simulation trainer for intubation training. It is twofold, an introductory platform to learn and practice intubation and as a Just-in-time training platform.
P29	Incorporating virtual reality into the teaching and training of Grid-Tie photovoltaic power plants design	MDPI	2019	VP3	Lopez, J.M.G.; Betancourt, R.O.J.; Arredondo, J.M.; Laureano, E.V.; Haro, F.R.	This paper reviews an initiative within the teaching-learning context, which aims to show the advantages of using virtual reality, to achieve teaching goals in a renewable energy course.
P30	Virtual reality gait training versus non-virtual reality gait training for improving participation in subacute stroke survivors: study protocol of the ViRTAS randomized controlled trial	SpringerLink	2019	VP1	Rooij, I.J.M.D.; Port, I.G.L.V.D.; Visser-meily, J.M.A.; Meijer, J.w.G.	The primary aim of this study is to examine the effect of VR gait training on participation in community-living people after stroke.

Table 3. *Cont.*

Code	Title	Database	Year	Viewpoint	Authors	Objective
P31	Design on the Virtual Maintenance Training System of Some-Type Equipment Based on the Virtual Reality	SpringerLink	2019	VP3	Bao, Z.; Wang, Y.; Yang, Z.; Zhu, C.; Jin, C.	By analyzing the current problems of the type of equipment maintenance training and the advantages of virtual maintenance technology, this paper clarifies the system's functional requirements. It also proposes a hierarchical and modular system design plan.
P32	Application of Virtual Reality in the Training of Operators and Servicing of Robotic Stations	SpringerLink	2019	VP3	Muszyn'ska, M.; Szybicki, D.; Gierlak, P.; Kurc, K.; Burghardt, A.; Uliasz, M.	The article uses virtual reality environments; thus, they are interactive and allow advanced operations without damaging expensive equipment. It discusses the use of virtual reality in training the service and maintenance of robots and robotic stations.
P33	The Application of Virtual Reality Technology in Logistics Training	SpringerLink	2019	VP3	Li, Y.; Wang, D.; Liu, Y.	This article researches the application of VR technology and the current situation of logistics training. It analyzes the specific directions of this application.
P34	Industrial robot control and operator training using virtual reality interfaces	Scopus	2019	VP3	Pérez, L.; Diez, E.; Usamentiaga, R.; García, D.F.	This paper runs on the synergies between virtual reality and robotics, presenting commercial gaming technologies' use to create an immersive environment based on virtual reality.
P35	A training system for Industry 4.0 operators in complex assemblies based on virtual reality and process mining	Scopus	2019	VP3	Roldán, J.J.; Crespo, E.; Martín-Barrio, A.; Peña-Tapia, E.; Barrientos, A.	It presents a training system for industrial operators in assembly tasks. First, expert workers use an immersive VR interface to perform assemblies according to their experience. Then, process mining algorithms are applied to obtain assembly models from event logs.
P36	A Framework for Virtual Reality Training to Improve Public Speaking	ACM	2019	VP1	Pellett, K.; Zaidi, S.F.M.	This article proposes the use of 4.0 technologies to help people with problems to speak in public. The application of VR allows users to practice their type of speech and improve their linguistic skills.
P37	Authoring-by-Doing: Animating Work Instructions for Industrial Virtual Reality Learning Environments	IEEEXplore	2020	VP3	Wolfartsberger, J.; Niedermayr, D.	This paper describes the prototype for a Virtual Reality-supported learning and training application. It presents a concept to simplify the authoring process of content with additional focus on animating assembly procedures.
P38	Health safety training for industry in virtual reality	IEEEXplore	2020	VP3	Lacko, J.	The authors have developed a VR system that allows training operators in terms of safety and health at work. Various immersive environments are proposed to help workers make decisions at times of high stress within the industry.

Table 3. *Cont.*

Code	Title	Database	Year	Viewpoint	Authors	Objective
P39	A study on design and case analysis of virtual reality contents developer training based on industrial requirements	MDPI	2020	VP3	Kang, H.; Kim, J.	An industrial demand-customized educational model and its operations based on a cooperative relationship between training institutions and industrial companies using collaborative projects and mentoring was designed.
P40	Design of Sports Training Information Platform Based on Virtual Reality	SpringerLink	2020	VP1	Li, J.	This paper proposes a specific way of designing a sports training information platform based on virtual reality and canny edge detection algorithms. It speeds up the construction of the information platform and provides a certain theoretical basis for future research on relevant aspects.
P41	Virtual Reality Training Platform in Onshore Pipeline	SpringerLink	2020	VP3	Abdul Aziz, F.; Alsaeed, A.S.M.A.; Sulaiman, S.; Ariffin, M.K.A.M.; Al-Arhabi, A.R.Y.	The oil and gas industry often requires people to work in hazardous environments. Thus, this paper reviews the possibility of implementing a VR training platform for industrial maintenance.
P42	Immersive Safe Oceans Technology: Developing Virtual Onboard Training Episodes for Maritime Safety	MDPI	2020	VP3	Markopoulos, E.; Luimula, M.	A VR system called Immersive Safe Oceans is presented. It is a cost-effective, portable technology that can be used on-board just in time or in maritime training centers. Four safety training scenarios were developed.
P43	Feasibility and Tolerability of a Culture-Based Virtual Reality (VR) Training Program in Patients with Mild Cognitive Impairment: A Randomized Controlled Pilot Study	MDPI	2020	VP1	Park, J.H.; Liao, Y.; Kim, D.R.; Song, S.; Lim, J.H.; Park, H.; Lee, Y.; Park, K.W.	The present study examined whether a culture-based VR training program is feasible and tolerable for patients with amnestic mild cognitive impairment. The VR-based program was designed based on Korean traditional culture and used attention, processing speed, executive function and memory conditions to stimulate cognitive function.
P44	Sustainable Water Management: Virtual Reality Training for Open-Channel Flow Monitoring	MDPI	2020	VP3	Mirauda, D.; Capece, N.; Erra, U.	The VR tool designed by these authors, aimed at technical and non-technical workforces in field activities, represents a Virtual Laboratory able to train on the standard techniques for the accurate monitoring of the water discharge in open-channel flows.

Table 4. Characteristics of the included studies.

Code	Sample Size	Devices	User Feedback	Experience
P1	None noted	Oculus Rift and Razer Hydra	Visual, haptic	Learn by doing.
P2	79 questionnaire, including 29 males and 50 females.	Flat screen (PC and smart tablet)	Visual, auditory	Virtually exploring places without physical visit.
P3	None noted	Flat screen (PC)	Visual, auditory	Empowering the understanding, performance, responsiveness, and precision of industrial operators.
P4	40 expert technicians	Flat screen (PC)	Visual, auditory	Improve the efficiency of an electronic actuator assembly task.
P5	30 prefinal year mechanical engineering students.	Kinect, Leap Motion, Oculus Rift	Visual, auditory, haptic	Selection, manipulation, navigation, and, system control for building aerospace composite parts.
P6	17 football players, who all play the quarterback position ranging from 7th grade to collegiate juniors.	Oculus Rift, wireless Xbox controller	Visual, auditory, haptic	Experience the gameplay in the immersive virtual environment, freely switching camera views from bird's-eye mode to 3rd-person mode following certain player on the field, and even directly be inside the player's helmet.
P7	None noted	Flat screen (PC)	Visual, auditory	Learn the theory behind an industrial robot and control an actual industrial robot through a web-based robot teach.
P8	Simultaneously involved participant pairs of teacher and instructor.	Oculus Rift, Kinect	Visual, auditory	Manage disruptive student behavior in face-to-face, one-to-many teaching scenarios.
P9	None noted	Leap Motion and Oculus Rift	Visual, auditory	Identification of instruments, machinery, processes, instructions and safety regulations of a tannery process.
P10	None noted	Flat screen (PC)	Visual, auditory	Learn how to command complex automated machineries.
P11	None noted	HTC VIVE	Visual	Gain intuitive knowledge into how they can correctly place devices in a building to create either a mesh network or fit into an existing wireless network infrastructure.
P12	12 trainees	Conductance and heart rate sensors, HTC VIVE, two single motors.	Visual, auditory, haptic	Link performance and arousal with VR stimulus.
P13	None noted	The Oculus Rift HMD and the Leap Motion sensor.	Visual, auditory	The operator will learn very quickly and safely how a robotic arm behaves, reducing the stress produced with a real robotic arm.
P14	30 participants	The Microsoft HoloLens, a depth camera, integrated microphones, a light sensor, and a 2MP photo/ HD video camera.	Visual, auditory	Experiment the difference between conventional training and an HMD-based training.
P15	None noted	Flat screen (PC)	Visual, auditory	Rehabilitation assessment, rehabilitation training and data management.

Table 4. *Cont.*

Code	Sample Size	Devices	User Feedback	Experience
P16	20 participants	Flat screen (PC)	Visual	Archiving system efficiently and effectively.
P17	30 workers	Flat screen (PC)	Visual, auditory	Gain expertise in TPS.
P18	None noted	Flat screen (PC, tablet)	Visual	Identify individual components or entire subsystems used in solving tasks.
P19	None noted	RGB camera, 2 Kinects	Visual, auditory	Learn the necessary steps to assemble an alpine ski without the need for constant human supervision.
P20	None noted	HTC VIVE	Visual, auditory	Learn complex industrial automation concepts with the help of Virtual/Augmented reality.
P21	11 participants	Logitech Driving Force GT steering wheel, the Microsoft Sidewinder Force Feedback 2 joystick stick and the Oculus Rift	Visual, auditory, haptic	Improve the skills of workers in the use of heavy machinery.
P22	None noted	HTC VIVE	Visual, auditory	Focuses learners' attention on navigation tasks.
P23	None noted	HTC VIVE	Visual, auditory, haptic	Strengthen the recognition of automotive assembly processes.
P24	None noted	HTC VIVE and Gear VR	Visual, auditory, haptic	Ensure a correct analysis and diagnosis of Hybrid Generation Systems.
P25	None noted	Flat screen (PC)	Visual, auditory	Separate complex equipments into independent IVEs.
P26	None noted	HTC VIVE	Visual, auditory, haptic	Learn the human chest anatomy.
P27	VR-group and BC-group (5 left-handed and 5 right-handed people).	HTC VIVE	Visual, auditory	Obtain an instantaneous bat swing information as feedback.
P28	None noted	HTC VIVE and Oculus Rift	Visual, auditory, haptic	Mentally prepare experts for a complex case prior to medical procedures.
P29	28 final year students in electrical engineering from the University of Colima.	Oculus Rift	Visual, auditory	Achieve teaching goals in a renewable energy course.
P30	Virtual reality gait training (VRT) group and non-virtual reality gait training (non-VRT) group.	Flat screen (PC)	Visual, auditory, haptic	Experiment an in-tensive, variable and enjoyable therapy.
P31	None noted	Flat screen (PC)	Visual, auditory	Improve the maintenance and support capability of the equipment.

Table 4. *Cont.*

Code	Sample Size	Devices	User Feedback	Experience
P32	None noted	Oculus Rift	Visual, auditory, haptic	Allow advanced operations without the risk of damaging expensive equipment.
P33	None noted	Flat screen (PC)	Visual	Understand the specific directions of this application in logistics.
P34	12 people of three different profiles and experience (4 of each one) have participated in the validation and tests: (a) Robotic application engineers, (b) Robot operators, and (c) Assistant operators.	Oculus Rift and HTC VIVE	Visual	Understand the synergies between virtual reality and robotics.
P35	20 volunteers	HTC VIVE	Visual, auditory	Learn assembly tasks from expert workers.
P36	None noted	HTC VIVE	Visual, auditory	Overcome glossophobia.
P37	None noted	HTC VIVE	Visual, auditory	Simplify the authoring process of content with additional focus on animating assembly procedures.
P38	Group A (37 users) and Group B (32 users)	HTC VIVE and Oculus Rift	Visual	Prevent injuries and economic damage in industries.
P39	27 trainees	Oculus Rift and Gear VR	Visual, auditory, haptic	Learn from an industrial demand-customized educational model
P40	None noted	Flat screen (PC)	Visual, auditory	Improve sports skills
P41	None noted	HTC VIVE	Visual, auditory, haptic	Learn maintenance in oil and gas industry
P42	None noted	HTC VIVE	Visual, auditory, haptic	Make decisions under dangerous situations
P43	VR group (n = 10) and a control group (n = 11)	HTC Vive	Visual, auditory	Improve cognitive function in these patients
P44	35 people	Oculus Rift	Visual, auditory	Support to technical and non-technical workforces in field activities.

3. Results

3.1. Literature Review

Below is the summary of the selected works, which have been reviewed while taking into account the points of view VP1, VP2, and VP3 mentioned in Section 2.1.

3.1.1. Non-Industrial Training Based on Virtual Reality

VR has become a very useful tool in recent years. It has gone from being an exclusive system for video games to an option within medical education, among others. The most prominent non-industrial approaches to this technology are described below.

Koumaditis et al. [24] present a two-phase exploratory experiment, in which the excitement and physical performance of several participants concatenate while using a virtual puzzle. A questionnaire was established to carry out the development of this research, in which the collaborators consented their intervention in the experiment and filled-in data on their profile. Furthermore, sensors were used in order to measure the conductance of her skin and heart rate.

Initial observations indicated that the participants performed better after being trained with the proposed system, obtaining a minimum number of failures, performing the tasks more efficiently, and taking their heart rate to higher levels than normal. With this, it was concluded that the application of VR systems manages to stimulate the senses of the users, providing them with a much more significant learning experience.

Zou et al. [25] propose a VR-based baseball batting system whose goal is to immediately provide feedback on user performance. This allows the player not only to rely on subjective guesses about his batting technique, but also to help him through real data, such as the exact location of the ball's impact, angle of arrival, speed, and batting time, in order to quantitatively adjust his swing.

The sample consisted of five people. Four hitters improved their performance considerably. However, a lower performance was observed in the last player. This anomaly was associated with the fact that this user did not adapt to the proposed immersive technology. The study establishes that, to correctly determine the usefulness of the VR system, larger samplings, with longer periods, should be carried out.

A methodology for designing a training platform based on VR and Canny's algorithm was proposed by Li [26]. In this new form of training, the aim is to improve the abilities of athletes through more effective information processing. As a result of this mix of technologies, it is established that the creation of a platform, with adequate feedback and information storage, promotes new flexible forms of sports training.

A VR technology for training tour guides was detailed by Tseng et al. [27]. The developed program is web-based and can be applied within a classroom as well as during a real sightseeing tour. Once this system was followed, a survey was applied to several students who were studying the last year of tourism. It was observed that more than 72% of the interviewees agree that the proposed system is helpful within the academic and professional fields.

Huang et al. [28] present a VR system for football training. This system has two modalities; the first is based on the use of non-immersive VR, i.e., while using a standard computer screen, while the second focuses on the use of an HMD. For evaluating this system, user evaluation was conducted in order to quantify its effectiveness. Seventeen student-athletes participated in a three-day training session. The results that were obtained from this estimate showed that there was a 30% improvement in most of their skills.

The creation of various VR environments for the correct placement of IoT devices is presented by Jia and Campbell [29]. The UNITY 3D graphics engine and the HTC VIVE HMD were used in the development of this system. The project consisted of three different modes, the first is a Virtual Room, the second focused on the development of 3D environments of a university, and finally, the last model takes into account a real design, i.e., obstacles and signal propagation models were considered.

This system allows users to examine the topology of any network in real-time and, based on that, make decisions regarding the exact device location. It differs from other jobs in this area since it is not limited to the display of information in two dimensions, that is, it allows both inexperienced and experienced operators to use this tool.

Latoschik et al. [30] present a low-cost portable VR system to enhance skills within a classroom. The control of the simulation was done through an instructor who manages 24 semi-automatic virtual agents through a graphical interface. On the other hand, the students' interface used an HMD and headphones, so that they can have adequate feedback.

The system has been evaluated in terms of anxiety, tension, energy, behaviour, technology, acceptance, and performance. Although the study is still under development, preliminary results show that user acceptance for both instructors and students is high.

Pellet y Fawad [31] detail the construction of a VR prototype for the training of people who have difficulties in speaking in public. The programmed environments have been completed through a dictation recognizer to perform speech to text conversions. The idea of these authors is to immerse users in an environment, where they can overcome their glossophobia, improve their language skills, and achieve efficient communication with the public.

The environments are designed in such a way that, when the user begins their training, letters with the content of their conference automatically appear, so that they have a guide to the subject to be covered. The HTC Vive's tracking to assess eye contact with the audience has been used.

On the other hand, VR has been an important feature when it comes to training in the medical field, as demonstrated by Rajeswaran et al. [32], who have developed a system called "AirwayVR", focused on endotracheal intubation training. This VR system was intended for two different purposes, the first focused on the practice and training of beginning students, while its second objective was to use this technology as a training platform for medical professionals. In this last stage, the Just-in-Time methodology was also implemented, for experts in the field of endotracheal intubation to be trained for complex and special cases.

In this same way, Mathur [33] expose a low-cost VR system for daily medical routine training. They used the Oculus Rift HMD and Razer Hydra controls to deliver an immersive and interactive experience. The tasks proposed in these scenarios range from identifying certain organs to making complex incisions. This prototype illustrates, in a practical way, that the implementation of training systems should not necessarily be expensive and complex.

On the other hand, there has always been a debate regarding whether the daily use of virtual reality techniques allows for patients to correctly rehabilitate from strokes. Due to this, Rooij et al. [34] proposed a study, called ViRTAS, in which two experimental groups are compared.

The first group was assigned to a VR rehabilitation, while the second group focused on training and conventional rehabilitation. Currently, this training program is still running.

Park et al. [35] examine the effectiveness of VR programs within the rehabilitation of patients with mild cognitive impairment. A VR system was designed based on traditional Korean culture and consisted of the processing speed and conditions that are necessary to help people with this type of condition. Even though the results of this training system were not significant, as compared to a traditional system, the immersion, and culture implemented improved the patient experience.

An immersive system for learning human anatomy was developed by Xin Wang and Xiuyue Wang [36]. This system is based on the development of a complete module in order to identify the anatomy of the chest. This module is divided into three parts, (i) the construction of the scenes, (ii) determination of results, and (iii) development of the user interface.

There are various studies conducted in order to demonstrate the use of virtual reality for Industry 4.0 in real environments, for example, Posada et al. [37] show a systematic literature review, where the authors overview and point the future scenarios where visual computing technology will be used.

This paper as conclusions shows that this kind of technology will be the "glue factor" in solutions for smart industries.

This experiment is flexible, as it leaves open the possibility of extending it to learn the anatomy of the human neck, lungs, and heart. In the end, it is established that, for future work, the authors intend to make this holistic model, that is, to add the modules mentioned above and improve their three-dimensional (3D) model to study muscle tissues.

Finally, Shi et al. [38] detail a different alternative to conventional rehabilitation methods for strokes. In this research, the use of an exoskeleton and various VR environments, which are connected through serial communication and the Modbus protocol, are combined in order to generate targeted rehabilitation exercises for patients with motor dysfunction in their upper extremities. Among the advantages of this system, it is worth mentioning its response time, which, when compared to camera-dependent systems for capturing patient information, is much more efficient.

3.1.2. Industrial Training

Training in the industry must be a continuous and updated, efficient process to obtain workers with the necessary skills to move a company forward. In this section, the works focused on industrial training without the intervention of VR are presented.

Assistive systems made while using Head-Mounted displays (HMDs) are becoming important in huge virtualization domains, especially for the industrial training domain, because they improve the efficiency and quality of procedural tasks. However, most studies are limited because of inadequate task complexity, lacking comparisons, and measured variables. The research that was conducted by Werrlich et al. [39] introduced a novel multimodal HMD-based training application and compared it to paper-based learning for manual assembly tasks. The research is performed in 30 participants, where it measures the training transfer of an engine assembly training task, user satisfaction, and perceived workload during the experiment. The participants perform faster while using the virtual system than when using paper-based instructions.

Efanntyo et al. [40] develop a training system for archiving information through artificial intelligence in JAVA. The purpose of this research is focused on facilitating the printing of files and classifying each worker according to his rank in the company, so that his entry into the database can be efficient. As a result, surprisingly, it is emphasized that the proposed system operates perfectly, which is, without any error.

A method that employs 3D simulations for new employee training, cost reduction, and induction process time is proposed by [41]. The selected processes for applying this methodology have been thoroughly evaluated, while taking the difficulty and precision they require into account. These areas include robotics, maintenance, and manufacturing.

On the other hand, this new methodology consists of different stages, which allow the operator to organize the knowledge that he is acquiring and put it into practice according to the company's requirements.

Phakphonhamin et al. [42] focus their research on developing a Toyota Production System (TPS) training course. This training was addressed to all production personnel, which represented a sample of 30 people. It is worth mentioning that the participants took a test about their knowledge of TPS before and after this training.

Finally, this work obtained the results that, based on the carried out evaluations, the production staff improved their knowledge and skills regarding the Toyota production system by 37.5%.

When speaking of industrial training, it is essential to mention the technological advances of recent years, the results of which have allowed the creation of increasingly efficient training models. In this context, Martin et al. [43] proposed the use of augmented reality as a training tool to acquire skills in the field of industrial automation.

The presented solution is based on an open-source platform, for which the cost of the system is considered to be affordable. The use of the A-Frame web tool, in combination with the JavaScript project called AR.js, allowed for developing interfaces to monitor, in real-time, the level of the AFB production line designed by Festo Didactics.

As a final description of this section, the work that was carried out by Thomay et al. [44], who discussed the concept of e-learning in a training station, intended to teach new or novice workers the steps to follow to assemble a ski without the need for frequent human supervision. The training technique developed allows, based on the needs and behavior of the user, the delivery of the necessary information and instructions in order to complete their task.

The training system consists of a work bench, which is necessary for mounting and supporting the skis, as well as racks that store the essential parts to complete the assembly. On the other hand, an RGB camera and two depth sensors are also used in order to capture and interpret the movements of the operator in the most precise way. Once the user has finished his work shift, the system displays a general evaluation of his performance, showing his shortcomings and successes that will allow him to take corrective actions in order to improve his operating process.

3.1.3. Industrial Training Based on Virtual Reality

Industry 4.0, which is also known as the fourth industrial revolution, has grown exponentially in recent years, raising the level of development of technologies, such as VR, and allowing this type of digital tools to be used for training and creating qualified human resources. Wolfartsberger et al. [45] formulated a VR training prototype for assembly tasks. The main part of this study focuses on the fact that, within several previously programmed VR environments, an expert performs familiar works procedures. These actions are recorded to be reproduced in the next stage of the experiment.

In phase two, an operator or professional without knowledge in the assembly area intervenes. Here, this user, called student, observes and follows the expert's recording step-by-step, giving an orientation of "practical authorship" to the research. This concept has great potential within industrial areas, such as (i) process planning, since, through remote inspection, it is possible to verify how the assembly procedures are being carried out, (ii) design reviews, to record, control, and care for the quality of the final product; and, (iii) maintenance, to keep a record of instructions for situations that are complex or very rare and, thus, avoid wasting human and economic resources.

Perez et al. [46] propose a low-cost architecture, which includes the use of virtual reality to control an industrial robot manipulator, in order to train operators in a fully immersive environment. The proposed environment was developed in Blender and it had the same characteristics as the real workstation. On the other hand, the human-machine interaction has been implemented through Unity 3D.

The teleporting function has been used, so that the operator can move around and interact with the entire programmed environment. For validating this system, 12 people divided into three groups, (i) robotic application engineers, (ii) robot operators, and (iii) assistant operators. Twelve questions were applied and scored on the Likert scale. The results were encouraging; and, the participating professionals concluded that the integration of a training system, simulation and robotic control increased the efficiency in carrying out their tasks.

A training system specifically designed for Industry 4.0 through the use of process mining and virtual reality is detailed by Roldan, et al. [47]. The use of this system focuses on two groups of participants; the first centred on expert workers and second aimed at trainees or apprentices.

The objective of this system is that expert workers, through an immersive interface, make assemblies that can vary, according to their experience. After this, improved assembly models are created through the application of algorithms for process mining. Apprentice operators use this information to train and get adequate feedback on their tasks. By applying the one-way ANOVA, it was found that immersive training is significantly better than conventional training in terms of performance, learning, results, and mental demand.

Gavish et al. [48] introduce a virtual training platform for IMA (industrial maintenance and assembly) tasks. Additionally, they establish that to evaluate the operation of these systems; it is necessary to measure both their efficiency and effectiveness. In this way, forty expert technicians were randomly assigned to various training groups to carry out an electronic actuator assembly task. These groups were divided into four sections, (i) training with the virtual reality platform, (ii) see a demonstration of the filmed activity, (iii) training with the augmented reality platform, and (iv) training with the real actuator and guide of a video demonstration.

The conclusions that were obtained from this study were encouraging for virtual platforms, since, despite requiring higher concentration, they allowed operators in order to develop their activities in a better way. However, at the end of this study, it is established that it is necessary in order to further evaluate these technologies to have more support in their usability in industry 4.0.

Li et al. [49] propose a method for interactive training within the field of industrial maintenance. This research is specifically focused on the maintenance of hydroelectric generators. The developed environments allow each device to be broken down into interactive and standardized virtual elements. In this way, the maintenance time is reduced and much more efficient teaching processes can be applied for this type of machinery.

Even though this system presents good results in terms of its efficiency, the authors establish that the use and recognition of support tools for this type of maintenance still needs to be improved, so that training times can be shortened. Besides, they also mention that, with an adjustment of the perspective offered by the proposed system, the efficiency in terms of user experience could be better.

A Virtual Reality Training System (VRTS) that simulates the use of industrial manipulator robots to perform simple manufacturing tasks was developed by Matsas et al. [50]. The developed environments allow for improving the capacities of the operators to handle in tape-laying for building aerospace composite parts.

The results showed that the system obtained a high score in various aspects, such as (i) presence by involvement and (ii) navigation issues. The operators who underwent this type of training stated that the immersion sensation was excellent and the level of detail of the 3D elements made them feel as if they were working in a real workstation.

Nazir and Manca [51] deploy a solution for the training of industrial operators in an utterly immersive environment. The central idea of this research is based on providing training on how to act within established parameters of industrial safety. Two case studies are presented, (i) the sudden flange rupture in a butane pipe, and (ii) the polymerization process for the production of propylene. These allow workers to make decisions under pressure, understand the risks that may exist, and find the best solutions for each case.

Vergnano et al. [52] present a successful case study in the steel industry. For this experiment, they used a hybrid simulation, i.e., they combined a virtual model with physical elements and various human-machine interfaces. Among the essential characteristics that this article presents, it can be mentioned that it has, (i) a high level of interaction, (ii) efficient connectivity in real-time between virtual environments and physical devices, (iii) a level of detail adapted to the skills of the user, and finally (iv) high profitability in the use and application of this system.

Chrysoulas et al. [53], set out a framework for teaching complex concepts of industrial automation. They use Industry 4.0 technologies, such as VR and augmented reality, to easily and intuitively build systems through the IEC 61499 standard, allowing them to parameterize the function blocks used.

The proposed architecture includes four main components, (i) a distributed industrial automation and control runtime environment, an open-source project, which simulates and executes applications through function blocks, (ii) a distributed industrial automation and control structure, an integrated development environment, also open source, which provides a programming based environment in Controllable Logic Programmers that combines the aforementioned standard with the IEC 61131-3 standard, (iii) VR and AR environments, developed in Unity 3D, because it is free to use and has great advantages in development, portability, support between users and in pre-prepared computer-aided designs for immediate import and use.

Additionally, they have a set of devices for this type of technology, such as HTC's haptic glasses and controls, along with infrared tracking cameras; and, (iv) case studies, developed within the context of the automation of liquid tanks and conveyor belts. It is necessary to mention that for this section the authors have chosen to build their 3D models of the elements already described, to provide flexibility when developing the training program.

Lacko [54] describes the development of a VR system, in the first and third person, to train and evaluate industrial workers in the field of health and safety. To fulfill this purpose, several scenarios were created whose objective is to show correct practices, as well as the possible failures that an operator, within the industrial field, may have.

These scenarios were divided into three main categories, (i) the minimization of risks during the normal operation of machinery, simulation of machine failure as well as workflow, while taking into account incorrect procedures that would expose the physical integrity of the worker, (ii) minimization of risks in the production area, here the risks arising from the movement of equipment within industrial facilities, overcoming obstacles, such as stairs or short spaces, in addition to the use of corridors, and (iii) minimization of risks in emergencies, evaluation of the behavior of workers during dangerous situations, such as fire attacks, explosions, the detonation of alarms, among others.

In this experiment, two test groups were selected, group A and group B. In the first group, 37 workers were conventionally trained, which is, without the use of immersive technologies, following a plan of videos and talks by their supervisor. In the last group, which consisted of 32 workers, virtual reality systems were applied.

To compare these two groups, a survey of 20 questions was carried out, which was immediately fulfilled in each group after their training. The results showed that group A obtained 87% effectiveness in their evaluation, while group B obtained 97% of correct answers. This same questionnaire was applied to the same sample after one month, obtaining 68% of correct answers for the first group and 87% for the second group.

Finally, it was concluded that immersive VR systems significantly help to train operators efficiently and innovatively. Besides, it was demonstrated that the use of this type of technology is appropriate when long-term understanding and the storage of information is required, proving to be a useful digital tool in the field of industrial health and safety.

The cost of face-to-face training to operate specialized machinery is high, in addition to implying a latent risk for workers. Because of this, Silva et al. [55] show a virtual simulator for training in the use and handling of forklifts, developed with haptic control interfaces, which is, with the use of joysticks to obtain tactile feedback.

The VR system consisted of two modules. The first evaluated the operator's inspection capacity as well as his familiarity with the instruments and controls of the forklift trucks. Here, the user was presented, interactively and didactically, a questionnaire with multiple options. The objective focused on ensuring the safety of the procedure. On the other hand, in the second module, they were trained in the correct stacking of material through the forklift; this was done through instruction in how to use essential components, such as the towers and forks of the crane.

As the last point in this research, a survey, in which parameters to know the level of perceived difficulty and immersion, was applied. From this analysis, it was concluded that the participants consider VR to be a dynamic, immersive, and highly useful tool for heavy machinery training.

Mas et al. [56] state that working in complex industrial facilities requires special spatial navigation skills, which are only obtained through time and experience. Conventional training sessions for acquiring this type of skill are time-limited and can only be experienced once.

To solve these problems, the authors of this research have developed a VR system that consists of a collaborative treasure hunt game called "Indy". This proposal has several advantages, such as the fact that it focuses students' attention on navigation tasks, commits them to actively fulfill their objective, and also provides feedback on their achievements.

Indy was developed with Unity 3D, works as a network application, and provides three participation roles, (i) trainer, shows the map of the industrial facilities and offers broader views and controls on the environments, (ii) apprentice 1, displays the 3D model of the facilities through the HTC Vive head-mounted display; and, (iii) apprentice 2, who does not have immersive characteristics, however, shows the maps using 360° photos. The displacement is done with the keyboard and mouse.

As a result of this work, it can be mentioned that, by offering a variety of environments and scenarios, users can correctly adapt to a specific work profile. Additionally, by converting the learning experience into a collaborative and entertaining process, the attention of the operators is improved, which leads to better-founded knowledge and experiences.

The virtualization of an industrial tanning process, in order to train new operators to acquire the necessary skills in this process was developed by Andaluz et al. [12]. The focus of this work concentrated on training operators to avoid their exposure to chemical, biological, ergonomic, and psychological risks that are very common in this industry.

The steps that have been followed in this investigation include the collection of information, identification of the production system, plant distribution, and verification of the supply chain. On the other hand, SolidWorks software has been used for the 3D design of the work floor and machinery. After this, Blender was the appropriate system for texturing 3D elements, in addition to serving as a means for exporting these designs to Unity 3D.

Herrera et al. [6] detail the use of an immersive VR system aimed at learning electric welding in the context of the vehicle assembly industry. A teaching-learning process has been applied in order to obtain trained operators in the welding area, reduce workplace accidents, and reduce the greatest amount of waste.

The presented case study details the use of the HTC Vive HMD and haptic controls in combination with Unity 3D, whose functionality allows the transformation processes of a chassis to a functional bus to be correctly carried out through its assembly, welding, and painting. The obtained results show an efficient system oriented to human-machine interaction, which, through the development of psychosomatic skills, allows for improving the skills of operators in the auto body industry.

The planning and design of a voltaic power plant through a virtual world is described by Gonzalez et al. [57]. Learners can interact with the designed immersive system by learning its technical characteristics and installation details while learning with visual, auditory, and kinesthetic teaching activities.

In order to compare this teaching methodology with a traditional one, an evaluation was carried out in the fifth week of the use of the training tool. The results showed significant differences, (i) the conventional training time was three times higher than the first one and (ii) the evaluation results showed an average performance of 8.7/10 with the VR tool, while the traditional training group obtained a rating of 7.35/10.

Chiluisa et al. [58] describe the application of virtual environments for the training of professionals in hybrid energy systems. A Unity 3D-based system has been developed divided into three training modes, (i) immersion, (ii) interaction and failure, and (iii) operation of electrical processes. To complement this proposal, the mathematical models of a wind turbine and photovoltaic panel have been determined, so that the training is a reflection of everyday industrial situations.

As an evaluation of the experiment, the efficiency of the application has been determined through a survey. It was concluded that interactivity, developed environments, and fault feedback contribute to the learning process and development of skills for understanding and managing energy systems.

Bao et al. [59] clarify the functional reRquirements of a VR system and propose a hierarchical and modular design plan. This proposal allows to efficiently solve the virtual training process in the field of industrial maintenance. The usefulness of this design is focused on generating training areas with more opportunities and available at any time.

Muszyńska et al. detail a virtual training system for operators in the field of maintenance and service of robotic stations [60]. Oculus Rift VR glasses, a computer with powerful graphics capabilities, and RobotStudio software were used. Within the developed environments, scenarios were created to detect failures, make repairs, and provide maintenance service. The methodology used began with explaining the characteristics of a faulty robotic station, the operation of the calibrating robot, and the process to replace the gear oil.

The fact that, in recent years, the main oil and gas companies worldwide have opted for virtual training systems focusing on sustainable development is exposed by Aziz et al. [61]. Besides, they are developing a VR system that consists of three stages: (i) VR documentation and design, (ii) testing and evaluation of the effectiveness of this type of technology for the extraction and installation of heat pipes in the gas industry and oil, and (iii) comparison between process times during the execution of an immersive environment.

Li et al. [62] establish that the application of VR systems in the logistics area is of great importance, since, even though there is little research in this area, its potential use allows for updating conventional teaching methodologies, interactively training users, and optimize the way processes are displayed. All pf this for logistics professionals to consider the best options when making a decision, saving money, time, and reducing the risk that the industry represents.

The development and improvement of four VR scenarios, for maritime security, called Immersive Safe Oceans, which can be used within the academic field as well as in the professional world, is in charge of Markopoulos and Luimula [63]. The central idea of this work is to develop environments that test users and train them in order to make crucial decisions in various situations (i) within the command bridge, (ii) machine room, (iii) crane management and, (iv) fires.

Mirauda et al. [64] propose a training tool focused on technicians and beginners for monitoring water discharge in open-channel flows. This system was developed in the Unity 3D graphics engine in conjunction with the Oculus Rift HMD.

To evaluate this system, a survey of 18 questions was applied, which aimed to determine the quality of the system, interactivity, performance, impact, and achievements. The results showed that the system is robust and allows for holistic training for all types of users.

Finally, Kang et al. [65] provide a study on educational courses that are linked to VR. This research identifies the current state of VR within the industry and estimates the VR content taught by prestigious institutions. As a result of these analyzes, an educational model was designed combining the needs of the industrial world with the knowledge and tools of the academic world.

This model was implemented in a specialized course for VR developers, whose launch was in 2018 with the support of institutions dedicated to information technology. The training consisted of 960 h for 27 apprentices, of whom 21 were men and six were women.

This selection criterion was used while taking into account the rate of employment and entrepreneurship that this technology offers, besides, the interest of people in the development of digital tools and their ability to understand in the software branch was considered. Subsequently, in order to evaluate the satisfaction of the participants, a survey of 13 questions was carried out, which provided an average rating of 4.4 on the Likert scale, concluding that the contents, methodology, and instructors were appropriate.

3.2. Paper Selection

Most of the articles included presenting a user experience focused on learning and improving workers' performance skills. Besides, most studies' feedback includes, at a minimum, visual and auditory feedback, leaving the haptic feedback for studies with greater depth in its development.

Because not all papers propose devices external to a computer, it is necessary to mention that there can be two types within virtual reality. Immersive VR, whose objective is to offer a complete experience to the user, i.e., that their sense of sight, touch, and hearing are thoroughly mixed in a virtual world, and Non-immersive VR, which only makes use of a flat-screen and conventional devices, such as a keyboard, mouse, and speakers.

In Figure 2, it can be seen that, of the 44 selected articles, 31.82% corresponded to viewpoint 1 (non-industrial training based on VR), 13.64% focused on viewpoint 2 (industrial training) and finally, 54.54% concentrated on viewpoint 3 (industrial training based on VR). In Figure 3, it can be seen a percentage analysis of each selection phase concerning the explored databases. For IEEXplore, from phase 1 to the final phase, there was a paper reduction of 78.67%. In MDPI, there was a reduction of 82.14%, for SpringerLink, there was a difference of 81.13% between the screening phase and the articles included. For Scopus, there was a reduction of 90.59%, and finally, for ACM, there was a reduction of 85.71%. Furthermore, as can be seen, the databases that contain the most relevant information among those explored are IEEEXplore, SpringerLink, and Scopus. Finally, in Figure 4, it can be noticed that, from 2018 to 2020, there are approximately 75% of the reviewed literature.

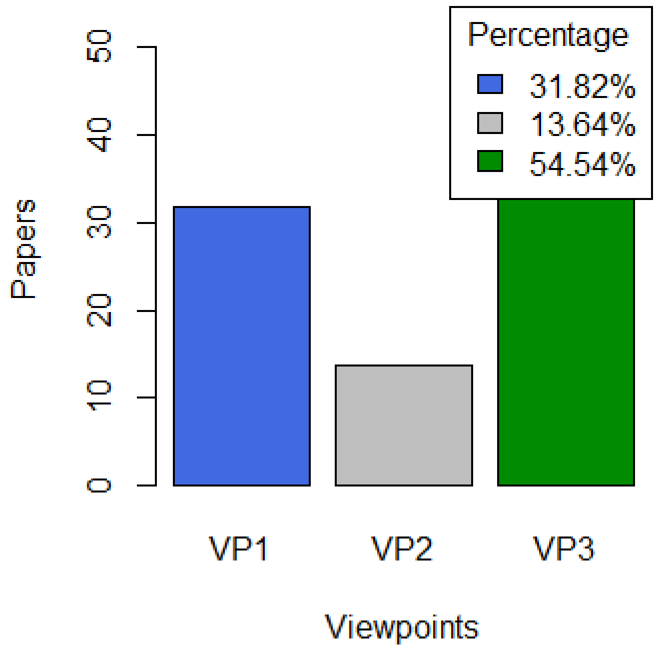

Figure 2. Selected papers classification.

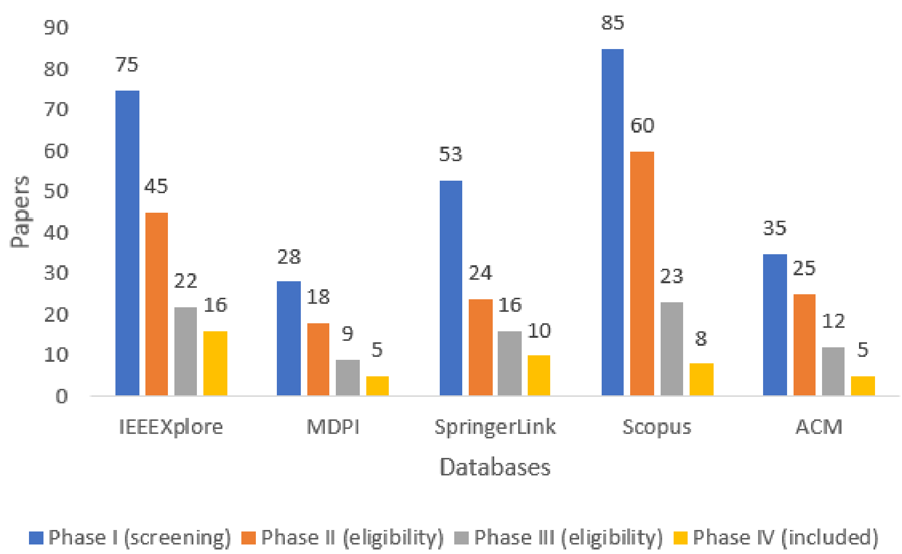

Figure 3. Phases analysis.

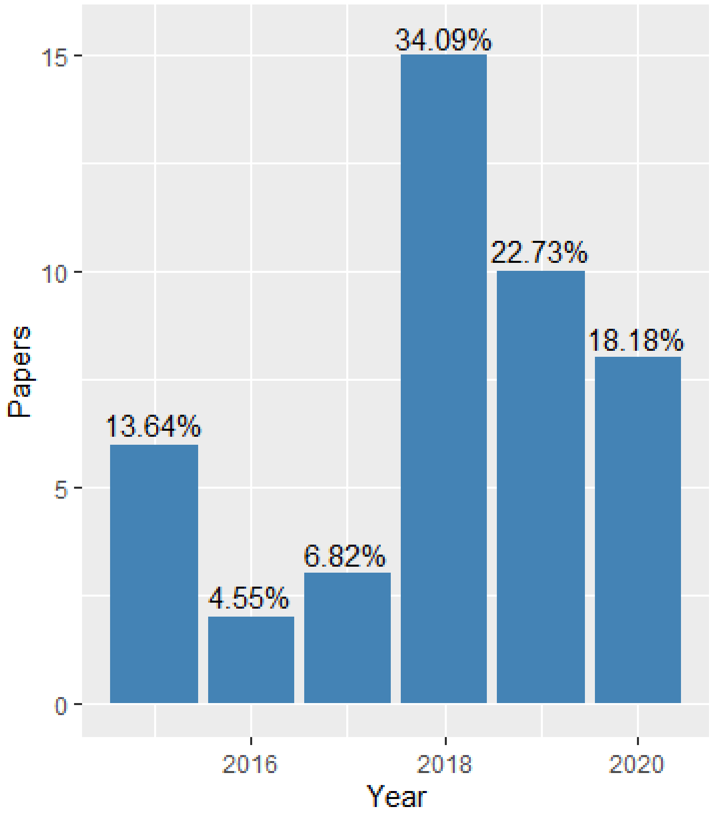

Figure 4. Years analysis.

4. Discussion

4.1. Research Questions

The 44 articles previously selected containing the necessary information to understand how industrial training has progressed along with emerging technologies, as well as how these, due to their versatility, can be focused on different areas. Next, the response to the RQs that is presented in Section 2.1 is presented.

RQ1: What are the uses of VR in non-industrial training?

Even though VR has several applications, both inside and outside the industrial field [66,67], in this literature analysis it was seen that this technological tool is destined, for the most part, to medical training.

Today, the medical field stands out for the participation of multidisciplinary professionals and complex decision making. This evolution has forced both students and professionals to keep up-to-date and improve their academic training, since they will have to face new problems and provide adequate responses to the needs of patients. This is how, through VR and robotics, various scenarios have been generated that allow for acquiring new skills within the field of health while using specialized medical equipment, and recognizing the structure of each organ of the human body.

With an immersive VR system, developers can recreate any environment or situation. The psychological treatment of traumas and phobias benefits from this technology without endangering the patient. In this way, a situation of stress that increases progressively and in a controlled way is virtually recreated to diagnose and treat the phobia or trauma (claustrophobia, arachnophobia, or glossophobia). With this technology, the patient adapts to the uncomfortable situations that he could face in real life. This system allows for recreating scenarios of specific phobias, such as the fear of flying.

VR can also be adapted to the field of surgery. With the help of 3D animation and modeling software, it is possible to faithfully simulate the anatomy of the patients as well as to perform any type of medical treatment before carrying it out. By adopting this tool, the use of dead bodies for academic practices can be reduced, malpractice in real patients is avoided, since training can be repeated as many times as necessary. It will also help to accurately analyze the risk of operation and postoperative treatments.

RQ2: What types of technologies are used in industrial training other than VR?

Industry 4.0 has gained great importance within the industrial field, so tools such as artificial intelligence (AI) and AR have made it possible to significantly improve operator training processes.

Unlike VR, which immerses its users in fully virtualized scenarios, AR provides information added to real space, i.e., it adds virtual elements to the environment. The application of AR reduces manufacturing times, increases profitability, and efficiency in the industry. It is important to mention that the use of immersive environments that familiarize its users with elements of the real world and favors more effective mental and physical learning.

Furthermore, the potential exhibited by new AI techniques that are based on self-learning has shown that complex tasks that humans are not capable of performing can be fully achieved. The latest advances focus on developing machines that are capable of improvement through experience, recognize the limitations of their knowledge, interact with their environment, and make independent decisions. These techniques based on changing algorithms allow for predicting, with a low percentage of error, when a machine may break down or when it is necessary to update the knowledge of the human resource.

RQ3: What devices are used for VR industrial training?

Currently, the technology market offers a wide variety of VR devices. However, not all have the same characteristics or utility, i.e., there are great differences in functionality, portability, and price. Because of this, it has been seen that, for industrial training functions, the most used equipment is HTC VIVE and Oculus Rift.

HTC Vive allows for users to have a fully immersive experience with recognition of physical movements, also enables the user's hands to be part of the game, thus seeing their actions reflected in real-time. It also has haptic controls that improve the user experience, providing feedback on the position and turn within programmed environments.

On the other hand, Oculus Rift presents an architecture that is similar to the HTC VIVE set. However, its movement precision is lower, since it has a maximum field tracking of 1.5 to 3.3 m. The Oculus Rift's tracking stations can only perceive what the user is doing from a frontal angle, so the precision in the detection of movement is less accurate.

RQ4: What are the users' benefits of applying VR in industrial training?

VR makes it easier for companies and industries to carry out training in various scenarios in an effective and completely real way. It provides an opportunity for employees to face adverse situations without risk while learning how to react and work under unfavorable circumstances.

Among the key advantages that VR offers for the training of workers, the following can be mentioned: (i) commitment, conventional training methodologies can become boring, so workers are unlikely to pay the necessary attention. Immersive environments and 3D representations make users more interested and committed to their training, (ii) speed, due to the creative and attractive way that this digital tool offers, workers can obtain and retain information in an efficient way. VR allows for training through emotional response, the best method to not forget what has been learned [68,69]. (iii) Measurability, because it works with computer-generated environments, researchers can easily obtain any required statistics, such as the time that it takes an operator to carry out a certain activity, the most common accidents or the procedure with less difficulty, (iv) reduction of work accidents, the use of VR offers a much safer scenario, in which users can practice obtaining the necessary skill without the need to risk their integrity, (v) personalization, scenarios can adapt to the requirements of each worker, and, (vi) reduction of costs, VR helps to reduce infrastructure, materials, time, and personnel expenses that are required by real simulations [70].

4.2. Paper Selection Analysis

As can be observed, most of the articles are aimed at improving the capabilities of operators within an industrial environment. This digital tool, despite having a broad background, has become popular due to its versatility, constantly evolving technology, and ease of implementation. In general, what is sought is to optimize times, reduce costs, and dabble in the fourth industrial revolution.

Additionally, it can be understood that within industry training, VR has become an indispensable tool when it comes to training both administrative and shop floor workers. The combination of this tool with physical elements such as microcontrollers, powerful computers, robots and efficient HMDs has allowed for it to be applied in a useful way in most industries.

On the other hand, the use of the PRISMA guidelines through the application of several phases for the selection of the articles analyzed in this literature review, allowed for maintaining a clear and transparent methodology for the collection of the essential documents regarding the last five years industrial training.

Even though VR has existed since 1959, experts continuously analyze future trends and possible uses that will stand out in industrial training. Every year, several companies worldwide opt for VR. It means that developers in this field must be in the process of continuous innovation. This scoping review was carried out until the first months of 2020, and the limitation that could be found is that some of the selected studies did not have information regarding the sample size. Most of the papers present innovative ideas that are in an early stage of development, but with encouraging experimental results. In this way, it can be understood that, in the future, more research and information can be published to provide higher sustenance to 4.0 training.

4.3. VR Challenges

VR has ceased to be a project for the future to become a reality to which we are trying to adapt. Most of the world's major industries have begun to compete in this area, with a clear inclination to become fully accustomed to the fourth industrial revolution.

From improving customer service or workplace safety to accelerating product development, there is a multitude of efficient applications. There will be a larger allocation of funds to this sector in order to develop and implement hardware solutions, i.e., adapt equipment and infrastructures to perform more efficient processes [71].

The digital transformation process is crucial in the industry, as it will have to adapt to the demands of consumers who will necessitate quality products, responsibly manufactured, personalized, and integrated into a digital whole. In addition, all of this will be delivered more comfortably and in less time. The entire production chain will be affected by this tool in the next decade [72].

VR will find its space in the test of new configurations of the production chain, shortening and speeding up the startup of new assembly lines and even entire factories, working directly on its virtual model. In this way, the correct operation of all production systems will be ensured before starting them up, thus avoiding production delays, planning errors, and the inefficient scheduling of automated systems.

Rapid growth will come due to innovations from leading technology giants, with advancements in software and hardware. Besides, the sale of devices such as VR glasses, haptic controls, and tablets or cell phones with more powerful graphic processors, will put companies, like Samsung, Sony, Microsoft, HTC, among others, in a fight of interest [73,74].

In order to confront this imminent digital transformation, the information technology structures will also have to evolve. Cases of virtual applications, such as Pokemon Go, have shown that the massive demand for connectivity, within this type of digital tools, can result in connection failures. As a solution to this inconvenience, 5G technology has emerged, which has been in testing processes since 2019 and whose results have announced an improvement in mobile broadband, an efficient transmission time of information packets, and a much more satisfying user experience.

Another challenge facing the virtual technology industry focuses on the need to defend against cyberattacks. Even though the Industrial Internet of Things (IIoT) devices are known to provide many benefits, they have suffered countless malware incidents, which causes a loss of confidential information and vulnerability.

Finally, it can be mentioned that the future of VR will be linked to the production of new virtual reality formats. Furthermore, the resolution on the screens should be increased, the graphic processing capacity should be significantly improved, and developers will have to create specific software [75].

VR is emerging as a promising technology within industrial digitization. It can also be confirmed that the areas of most significant application and interest will continue to be education, entertainment, training, art, and medicine. Space exploration is another field with a successful and essential future. Here, digital tools will be used for several projects that can range from developing scenarios in order to improve astronauts' capabilities to create environments in which significant decisions must be made under dangerous circumstances.

5. Conclusions

This paper has presented a scoping review that summarizes information from the last five years regarding how VR has been implemented in the field of industrial training. Sophisticated virtual systems have been analyzed that allowed for establishing a way of training human resources, reducing costs, avoiding exposing them to dynamic environments, and preserving the integrity of the production chain.

The use of heterogeneous architectures of VR, together with advanced artificial intelligence techniques, are also promising alternatives for future work in industrial simulated applications, which will allow for the reduction of time, complexity, and computational costs for industrial training in hazardous tasks. Currently, heterogeneous architectures are used only in the systematization of training tasks, so it is an opportunity to create new and efficient applications while using analysis techniques in union with VR.

VR has the potential to significantly improve the skills that an operator must have to be considered efficient within a company. Even though most studies still present preliminary results, they augur a promising future within Industry 4.0. Finally, the application of a well-defined protocol allowed for identifying the future and challenges of VR, various research gaps, and extracting relevant information regarding the usefulness of training with digital tools.

Author Contributions: Conceptualization, J.E.N. and M.V.G.; methodology, D.G.S.; software, J.E.N. and A.R.-L.; validation, M.V.G.; investigation, J.E.N., P.R.-L. and M.V.G.; writing–original draft preparation, J.E.N. and M.V.G.; writing–review and editing, J.E.N. and M.V.G.; visualization, A.A.-O.; supervision, M.V.G.; funding acquisition, J.E.N. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by Instituto Superior Tecnológico Victoria Vásconez Cuvi. The authors appreciate the opportunity to analyze topics related to this paper. The authors must also recognize the supported bringing by Universidad Tecnica de Ambato (UTA) and their Research and Development Department (DIDE) under project CONIN-P-256-2019, and SENESCYT by grants "Convocatoria Abierta 2011" and "Convocatoria Abierta 2013".

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Jaworski, C.; Ravichandran, S.; Karpinski, A.C.; Singh, S. The effects of training satisfaction, employee benefits, and incentives on part-time employees' commitment. *Int. J. Hosp. Manag.* **2018**, *74*, 1–12. [CrossRef]
2. Moreno, A.; Segura, Á.; Zlatanova, S.; Posada, J.; García-Alonso, A. Benefit of the integration of semantic 3D models in a fire-fighting VR simulator. *Appl. Geomat.* **2012**, *4*, 143–153. [CrossRef]
3. Besbes, B.; Collette, S.N.; Tamaazousti, M.; Bourgeois, S.; Gay-Bellile, V. An interactive Augmented Reality system: A prototype for industrial maintenance training applications. In Proceedings of the 2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Georgia Tech, GA, USA, 5–8 November 2012. [CrossRef]
4. Segura, Á.; Diez, H.V.; Barandiaran, I.; Arbelaiz, A.; Álvarez, H.; Simões, B.; Posada, J.; García-Alonso, A.; Ugarte, R. Visual computing technologies to support the Operator 4.0. *Comput. Ind. Eng.* **2020**, *139*, 105550. [CrossRef]
5. Romero, D.; Stahre, J.; Taisch, M. The Operator 4.0: Towards socially sustainable factories of the future. *Comput. Ind. Eng.* **2020**, *139*, 106128. [CrossRef]
6. Herrera, D.F.; Bolívar Acosta, S.; Quevedo, W.X.; Balseca, J.A.; Andaluz, V.H. Training for Bus Bodywork in Virtual Reality Environments. In *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*; Springer International Publishing: Cham, Switzerland, 2018; Volume 10850, pp. 67–85. [CrossRef]
7. Garcia, C.; Naranjo, J.; Ortiz, A.; Garcia, M. *An Approach of Virtual Reality Environment for Technicians Training in Upstream Sector*; IFAC-PapersOnLine; Elsevier B.V.: Frankfurt, Germany, 2019; Volume 52. [CrossRef]
8. Cýrus, J.; Krčmařík, D.; Petrů, M.; Kočí, J. Cooperation of Virtual Reality and Real Objects with HoloLens. *Adv. Comput. Vis.* **2020**, 94–106. [CrossRef]
9. Dixken, M.; Diers, D.; Wingert, B.; Hatzipanayioti, A.; Mohler, B.J.; Riedel, O.; Bues, M. Distributed, Collaborative Virtual Reality Application for Product Development with Simple Avatar Calibration Method. In Proceedings of the 2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR), Osaka, Japan, 23–27 March 2019; pp. 1299–1300. [CrossRef]
10. Naranjo, J.E.; Ayala, P.; Altamirano, S.; Brito, G.; Garcia, M.V. Intelligent Oil Field Approach Using Virtual Reality and Mobile Anthropomorphic Robots. In *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*; Springer International Publishing: Cham, Switzerland, 2018; Volume 10851; pp. 467–478. [CrossRef]
11. Naranjo, J.; Lozada, E.; Espín, H.; Beltran, C.; García, C.; García, M. Flexible Architecture for Transparency of a Bilateral Tele-Operation System implemented in Mobile Anthropomorphic Robots for the Oil and Gas Industry. *IFAC-PapersOnLine* **2018**, *51*. [CrossRef]
12. Andaluz, V.H.; Pazmiño, A.; Perez, J.; Carvajal, C. Training of Tannery Processes Through Virtual Reality. In *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*; Springer International Publishing: Cham, Switzerland, 2017; Volume 2, pp. 75–93. [CrossRef]
13. Andaluz, V.; Sanchez, J.; Sanchez, C.; Quevedo, W.; Varela, J.; Morales, J.; Cuzco, G. Multi-user Industrial Training and Education Environment. In *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*; Springer International Publishing: Cham, Switzerland, 2018; pp. 533–546.
14. Garcia, C.A.; Naranjo, J.E.; Alvarez-M, E.; Garcia, M.V. Training virtual environment for teaching simulation and control of pneumatic systems. In *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*; Springer International Publishing: Cham, Switzerland, 2019; Volume 11613 LNCS, pp. 91–104.
15. Caiza, G.; Garcia, C.A.; Naranjo, J.E.; Garcia, M.V. Flexible robotic teleoperation architecture for intelligent oil fields. *Heliyon* **2020**, *6*, e03833. [CrossRef]
16. Bécue, A.; Maia, E.; Feeken, L.; Borchers, P.; Praça, I. A New Concept of Digital Twin Supporting Optimization and Resilience of Factories of the Future. *Appl. Sci.* **2020**, *10*, 4482. [CrossRef]

17. Pusdá-Chulde, M.R.; Salazar-Fierro, F.A.; Sandoval-Pillajo, L.; Herrera-Granda, E.P.; García-Santillán, I.D.; De Giusti, A. Image Analysis Based on Heterogeneous Architectures for Precision Agriculture: A Systematic Literature Review. In *Advances and Applications in Computer Science, Electronics and Industrial Engineering*; Advances in Intelligent Systems and Computing; Springer International Publishing: Cham, Switzerland, 2020; Volume 1078, pp. 51–70.
18. Detmer, F.J.; Hettig, J.; Schindele, D.; Schostak, M.; Hansen, C. Virtual and Augmented Reality Systems for Renal Interventions: A Systematic Review. *IEEE Rev. Biomed. Eng.* **2017**, *10*, 78–94. [CrossRef]
19. Fernandez, A.; Insfran, E.; Abrahão, S. Usability evaluation methods for the web: A systematic mapping study. *Inf. Softw. Technol.* **2011**, *53*, 789–817. [CrossRef]
20. Kurniawan, C.; Rosmansyah, Y.; Dabarsyah, B. A Systematic Literature Review on Virtual Reality for Learning. In Proceedings of the 2019 5th International Conference on Wireless and Telematics, ICWT 2019, Yogyakarta, Indonesia, 25–26 July 2019; pp. 1–4. [CrossRef]
21. Tricco, A.C.; Lillie, E.; Zarin, W.; O'Brien, K.K.; Colquhoun, H.; Levac, D.; Moher, D.; Peters, M.D.; Horsley, T.; Weeks, L.; et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann. Intern. Med.* **2018**, *169*, 467. [CrossRef] [PubMed]
22. Hoyer, C.; Gunawan, I.; Reaiche, C.H. The Implementation of Industry 4.0—A Systematic Literature Review of the Key Factors. *Syst. Res. Behav. Sci.* **2020**, *37*, 557–578. [CrossRef]
23. Fonseca, L.M. Industry 4.0 and the digital society: Concepts, dimensions and envisioned benefits. *Proc. Int. Conf. Bus. Excell.* **2018**, *12*, 386–397. [CrossRef]
24. Kournaditis, K.; Chinello, F.; Venckute, S. Design of a Virtual Reality and Haptic Setup Linking Arousals to Training Scenarios: A Preliminary Stage. In Proceedings of the 25th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2018—Proceedings, Reutlingen, Germany, 18–22 March 2018; pp. 613–614. [CrossRef]
25. Zou, L.; Higuchi, T.; Noma, H.; Roberto, L.G.; Isaka, T. Evaluation of a virtual reality-based baseball batting training system using instantaneous bat swing information. In Proceedings of the 26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019—Proceedings, Osaka, Japan, 23–27 March 2019; pp. 1289–1290. [CrossRef]
26. Li, J. Design of Sports Training Information Platform Based on Virtual Reality. In Proceedings of the International Conference on Cyber Security Intelligence and Analytics (CSIA 2020), Haikou, China, 28–29 February 2020; pp. 10–17.
27. Tseng, S.P.; Huang, M.W.; Liu, H.J.; Chung, C.C.; Chiu, C.M. A Virtual Reality Based Training System for Cultural Tourism. In *Advances in Web-Based Learning—ICWL 2013 Workshops*; Lecture Notes in Computer Science; Springer: Berlin/Heidelberg, 2015; Volume 8390, pp. 272–277. [CrossRef]
28. Huang, Y.; Churches, L.; Reilly, B. A Case Study on Virtual Reality American Football Training. *ACM Int. Conf. Proc. Ser.* **2015**, 1–5. [CrossRef]
29. Jia, Y.; Campbell, A.G. Immersive virtual reality training tool for IoT device placement. *ACM Int. Conf. Proc. Ser.* **2017**, 81–86. [CrossRef]
30. Latoschik, M.E.; Lugrin, J.L.; Habel, M.; Roth, D.; Seufert, C.; Grafe, S. Breaking bad behavior: Immersive training of class room management. In Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST, New York, NY, USA, 2 April 2016; pp. 317–318. [CrossRef]
31. Pellett, K.; Zaidi, S.F.M. A framework for virtual reality training to improve public speaking. *Proc. ACM Symp. Virtual Real. Softw. Technol. VRST* **2019**, 1–2. [CrossRef]
32. Rajeswaran, P.; Kesavadas, T.; Jani, P.; Kumar, P. AirwayVR: Virtual reality trainer for endotracheal intubation-design considerations and challenges. In Proceedings of the 26th IEEE Conference on Virtual Reality and 3D User Interfaces, VR 2019—Proceedings, Osaka, Japan, 23–27 March 2019; pp. 1130–1131. [CrossRef]
33. Mathur, A.S. Low cost virtual reality for medical training. In Proceedings of the 2015 IEEE Virtual Reality Conference, VR 2015—Proceedings, Arles, France, 23–27 March 2015; pp. 345–346. [CrossRef]
34. Rooij, I.J.M.D.; Port, I.G.L.V.D.; Visser-meily, J.M.A.; Meijer, J.W.G. Virtual reality gait training versus non-virtual reality gait training for improving participation in subacute stroke survivors: Study protocol of the ViRTAS randomized controlled trial. *Trials* **2019**, *20*, 89. [CrossRef]
35. Park, J.H.; Liao, Y.; Kim, D.R.; Song, S.; Lim, J.H.; Park, H.; Lee, Y.; Park, K.W. Feasibility and tolerability of a culture-based virtual reality (VR) training program in patients with mild cognitive impairment: A randomized controlled pilot study. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3030. [CrossRef]

36. Wang, X.; Wang, X. Virtual Reality training system for surgical anatomy. *ACM Int. Conf. Proc. Ser.* **2018**, 30–34. [CrossRef]
37. Posada, J.; Toro, C.; Barandiaran, I.; Oyarzun, D.; Stricker, D.; de Amicis, R.; Pinto, E.B.; Eisert, P.; Dollner, J.; Vallarino, I. Visual Computing as a Key Enabling Technology for Industrie 4.0 and Industrial Internet. *IEEE Comput. Graph. Appl.* **2015**, *35*, 26–40. [CrossRef] [PubMed]
38. Zheng, J.; Shi, P.; Yu, H. A Virtual Reality Rehabilitation Training System Based on Upper Limb Exoskeleton Robot. In Proceedings of the 2018 10th International Conference on Intelligent Human-Machine Systems and Cybernetics (IHMSC), Hangzhou, China, 25–26 August 2018; pp. 220–223. [CrossRef]
39. Werrlich, S.; Daniel, A.; Ginger, A.; Nguyen, P.A.; Notni, G. Comparing HMD-Based and Paper-Based Training. In Proceedings of the 2018 IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Munich, Germany, 16–20 October 2018. [CrossRef]
40. Cahyono, M.R.A. Design and development smart industrial training management software with artificial neural network (ANN) on Java. In Proceedings of the 2018 International Conference on Information and Communications Technology, ICOIACT 2018, Yogyakarta, Indonesia, 6–7 March 2018; pp. 220–225. [CrossRef]
41. Mechlih, H. New employee education using 3D virtual manufacturing. In Proceedings of the 2016 13th Learning and Technology Conference, L and T 2016, Jeddah, Saudi Arabia, 10–11 April 2016; pp. 33–35. [CrossRef]
42. Phakphonhamin, V.; Wongsawad, R.; Vichitwongsakorn, T. TPS training course for the production staff. In Proceedings of 2018 5th International Conference on Business and Industrial Research: Smart Technology for Next Generation of Information, Engineering, Business and Social Science, ICBIR 2018, Bangkok, Thailand, 17–18 May, 2018; pp. 546–549. [CrossRef]
43. Martin, J.; Bohuslava, J. Augmented reality as an instrument for teaching industrial automation. In Proceedings of the 2018 Cybernetics & Informatics (K&I), Lazy pod Makytou, Slovakia, 31 January–3 February 2018; pp. 1–5. [CrossRef]
44. Thomay, C.; Gollan, B.; Haslgrübler, M.; Ferscha, A.; Heftberger, J. The Other Kind of Machine Learning: Modeling Worker State for Optimal Training of Novices in Complex Industrial Processes. In Proceedings of the ICETA 2018—16th IEEE International Conference on Emerging eLearning Technologies and Applications, Stary Smokovec, Slovakia, 15–16 November 2018; pp. 577–582. [CrossRef]
45. Wolfartsberger, J.; Niedermayr, D. Authoring-by-Doing: Animating Work Instructions for Industrial Virtual Reality Learning Environments. In Proceedings of the 2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), Atlanta, GA, USA, 22–26 March 2020; pp. 173–176. [CrossRef]
46. Pérez, L.; Diez, E.; Usamentiaga, R.; García, D.F. Industrial robot control and operator training using virtual reality interfaces. *Comput. Ind.* **2019**, *109*, 114–120. [CrossRef]
47. Roldán, J.J.; Crespo, E.; Martín-Barrio, A.; Peña-Tapia, E.; Barrientos, A. A training system for Industry 4.0 operators in complex assemblies based on virtual reality and process mining. *Robot. Comput. Integr. Manuf.* **2019**, *59*, 305–316. [CrossRef]
48. Gavish, N.; Gutiérrez, T.; Webel, S.; Rodríguez, J.; Peveri, M.; Bockholt, U.; Tecchia, F. Evaluating virtual reality and augmented reality training for industrial maintenance and assembly tasks. *Interact. Learn. Environ.* **2015**, *23*, 778–798. [CrossRef]
49. Li, B.; Bi, Y.; He, Q.; Ren, J.; Li, Z. A low-complexity method for authoring an interactive virtual maintenance training system of hydroelectric generating equipment. *Comput. Ind.* **2018**, *100*, 159–172. [CrossRef]
50. Matsas, E.; Vosniakos, G.C. Design of a virtual reality training system for human–robot collaboration in manufacturing tasks. *Int. J. Interact. Des. Manuf.* **2017**, *11*, 139–153. [CrossRef]
51. Nazir, S.; Manca, D. How a Plant Simulator can Improve Industrial Safety. *Process Saf. Prog.* **2015**, *25*, 326–330. [CrossRef]
52. Vergnano, A.; Berselli, G.; Pellicciari, M. Interactive simulation-based-training tools for manufacturing systems operators: An industrial case study. *Int. J. Interact. Des. Manuf.* **2017**, *11*, 785–797. [CrossRef]
53. Chrysoulas, C.; Homay, A.; Lemac, M. Teaching industrial automation concepts with the use of virtual/augmented reality-The IEC 61499 case. In Proceedings of the 2018 17th International Conference on Information Technology Based Higher Education and Training, ITHET 2018, Olhao, Portugal, 26–28 April 2018; pp. 1–6. [CrossRef]

54. Lacko, J. Health safety training for industry in virtual reality. In Proceedings of the 30th International Conference on Cybernetics and Informatics, K and I 2020, Velke Karlovice, Czech Republic, 29 January–1 February 2020; pp. 1–5. [CrossRef]
55. Lustosa, E.B.S.; De MacEdo, D.V.; Rodrigues, M.A.F. Virtual simulator for forklift training. In Proceedings of the 2018 20th Symposium on Virtual and Augmented Reality, SVR 2018, Foz do Iguacu, Brazil, 28–30 October 2018; pp. 18–26. [CrossRef]
56. Mas, A.; Ismael, I.; Filliard, N. Indy: A virtual reality multi-player game for navigation skills training. In Proceedings of the 2018 IEEE 4th VR International Workshop on 3D Collaborative Virtual Environments, 3DCVE 2018, Reutlingen, Germany, 19 March 2018; pp. 1–4. [CrossRef]
57. Lopez, J.M.G.; Betancourt, R.O.J.; Arredondo, J.M.; Laureano, E.V.; Haro, F.R. Incorporating virtual reality into the teaching and training of Grid-Tie photovoltaic power plants design. *Appl. Sci.* **2019**, *9*, 4480. [CrossRef]
58. Chiluisa, M.; Mullo, R.; Andaluz, V. Training in Virtual Environments for Hybrid Power Plant. *Adv. Visual Comput.* **2018**, *8034*, 193–204. [CrossRef]
59. Bao, Z.; Wang, Y.; Yang, Z.; Zhu, C.; Jin, C. *Design on the Virtual Maintenance Training System of Some-Type Equipment Based on the Virtual Reality*; Springer: Singapore, 2019; Volume 527, pp. 479–487.
60. Muszyńska, M.; Szybicki, D.; Gierlak, P.; Kurc, K.; Burghardt, A.; Uliasz, M. Application of Virtual Reality in the Training of Operators and Servicing of Robotic Stations. In *Collaborative Networks and Digital Transformation. PRO-VE 2019. IFIP Advances in Information and Communication Technology*; Springer International Publishing: Cham, Switzerland; 2019; Volume: 568, pp. 594–603. [CrossRef]
61. Abdul Aziz, F.; Alsaeed, A.S.M.A.; Sulaiman, S.; Ariffin, M.K.A.M.; Al-Arhabi, A.R.Y. Virtual Reality Training Platform in Onshore Pipeline. In *Advances in Material Sciences and Engineering. Lecture Notes in Mechanical Engineering*; Springer: Singapore, 2020; pp. 207–216. [CrossRef]
62. Li, Y.; Wang, D.; Liu, Y. The Application of Virtual Reality Technology in Logistics Training. In *Advances in Intelligent, Interactive Systems and Applications. IISA 2018. Advances in Intelligent Systems and Computing*; Springer International Publishing: Cham, Switzerland, 2019; Volume 885, pp. 668–675.
63. Markopoulos, E.; Luimula, M. Immersive Safe Oceans Technology: Developing Virtual Onboard Training Episodes for Maritime Safety. *Future Intrernet* **2020**, *12*, 80. [CrossRef]
64. Mirauda, D.; Capece, N.; Erra, U. Sustainable Water Management: Virtual Reality Training for Open-Channel Flow Monitoring. *Sustainability* **2020**, *12*, 757. [CrossRef]
65. Kang, H.; Kim, J. A study on design and case analysis of virtual reality contents developer training based on industrial requirements. *Electronics* **2020**, *9*, 437. [CrossRef]
66. Pavan Kumar, B.N.; Balasubramanyam, A.; Patil, A.K.; Chethana, B.; Chai, Y.H. GazeGuide: An eye-gaze-guided active immersive UAV camera. *Appl. Sci.* **2020**, *10*, 1668. [CrossRef]
67. Sror, L.; Vered, M.; Treger, I.; Levy-Tzedek, S.; Levin, M.F.; Berman, S. A virtual reality-based training system for error-augmented treatment in patients with stroke. In Proceedings of the 2019 International Conference on Virtual Rehabilitation (ICVR), Tel Aviv, Israel, 21–24 July 2019. [CrossRef]
68. Akkil, D.; James, J.M.; Isokoski, P.; Kangas, J. GazeTorch: Enabling Gaze Awareness in Collaborative Physical Tasks. In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, San Jose, CA, USA, 7–12 May 2016; Association for Computing Machinery: New York, NY, USA, 2016; pp. 1151–1158. [CrossRef]
69. Pavan Kumar, B.N.; Patil, A.K.; Chethana, B.; Chai, Y.H. On-site 4-in-1 alignment: Visualization and interactive cad model retrofitting using uav, lidar's point cloud data, and video. *Sensors* **2019**, *19*, 3908. [CrossRef]
70. Zhang, G.; Hansen, J.P.; Minakata, K. Hand- and Gaze-Control of Telepresence Robots. In Proceedings of the 11th ACM Symposium on Eye Tracking Research & Applications, Denver, CO, USA, 25–28 June 2019; Association for Computing Machinery: New York, NY, USA, 2019. [CrossRef]
71. Anthes, C.; García-Hernández, R.J.; Wiedemann, M.; Kranzlmüller, D. State of the art of virtual reality technology. In Proceedings of the 2016 IEEE Aerospace Conference, Big Sky, MT, USA, 5–12 March 2016; pp. 1–19.
72. Coburn, J.Q.; Freeman, I.; Salmon, J.L. A Review of the Capabilities of Current Low-Cost Virtual Reality Technology and Its Potential to Enhance the Design Process. *J. Comput. Inf. Sci. Eng.* **2017**, *17*, 031013. [CrossRef]

73. Alizadehsalehi, S.; Hadavi, A.; Chuenhuei Huang, J. Virtual Reality for Design and Construction Education Environment. *J. Constr. Eng. Manag.* **2019**, 294–308. [CrossRef]
74. Chang, S.; Chen, W. Does visualize industries matter? A technology foresight of global Virtual Reality and Augmented Reality Industry. In Proceedings of the 2017 International Conference on Applied System Innovation (ICASI), Sapporo, Japan, 13–17 May 2017; pp. 382–385.
75. Turner, C.J.; Hutabarat, W.; Oyekan, J.; Tiwari, A. Discrete Event Simulation and Virtual Reality Use in Industry: New Opportunities and Future Trends. *IEEE Trans. Hum. Mach. Syst.* **2016**, *46*, 882–894. [CrossRef]