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# Virtual Reality as a Tool for Sustainable Training and Education of Employees in Industrial Enterprises

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**Abstract:** The paper deals with the possibilities of using Virtual Reality in the training and safety of enterprises active in the raw materials industry. It examines the influence and impact on their employees. The main impetus for starting research in this area has been a need for more use of the full potential of Virtual Reality in the industrial sector. Virtual Reality (VR) has become a promising education and employee training tool. It provides an immersive and interactive learning environment, allowing users to engage with simulations, scenarios, and simulations in real time. VR can facilitate the acquisition of practical skills, help learners retain information better, and foster the development of soft skills, such as communication, teamwork, and leadership. The paper is divided into the following sections. The first two are devoted to the introduction to the issue and a review of the literature. The materials and methods section describes the possibilities of using photogrammetry to create virtual scenes and 3D models usable in Virtual Reality. This section also describes the research methods used to evaluate the approach for teaching and training employees. The last two sections evaluate and discuss the results achieved. Having regarded the research realized, it was found that our approach to researching the education of employees and the development of their skills brings excellent benefits and, compared to the traditional educational approach, is much more time-efficient so that employees can improve their work habits and behavior in a relatively short period. In employee training, VR can simulate real-life scenarios, providing workers with hands-on experience in a safe, controlled environment. This technology can also help companies save time and resources, eliminating the need for travel and reducing expenditure on expensive equipment. However, despite its many benefits, VR in education and training can be cost-demanding and requires specialized hardware and software, which may limit its widespread adoption.

**Keywords:** virtual reality; safety; raw materials industry; communication; teamwork; leadership; photogrammetry; 3D models; employee training

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## 1. Introduction

Modern industrial systems and Industry 4.0 resonate increasingly in the public discourse; therefore, the irreplaceable role of the human factor in production processes must be addressed [1]. One of the critical ideas of Peter F. Drucker can also be seen in this context: "The most valuable assets of a 20th-century company were its production equipment. The most valuable assets of a 21st-century institution, whether business or no business, will be its knowledge workers and their productivity." [2]. Peter F. Drucker's ideas have enduring significance because they transcend specific time frames and continue to provide valuable guidance to readers in 2023. The shift towards a knowledge worker-based economy, the need for continuous innovation and adaptability, the challenges of the digital age, and the importance of ethical leadership are why Drucker's writings remain relevant and worth exploring for anyone interested in effective management and organizational success in the 21st century.

Retaining company employees is related not only to their motivation or their managers' stimulation but also concerns the environment in which the employees work, namely its safety [3–5]. If a company's goals are to be achieved, managers must pay attention to provisions for a safe working environment [6].

A safe environment is determined not only by the reliability of technical equipment [7], and the technologies employed but also concerns the competence of workers to control and use technical equipment [7]. As such, the competence of workers contributes not only to higher productivity but also to eliminating several risks, which implies increasing the reliability of technological equipment and processes [7].

A safe environment represents a key factor for workforce retention, and training and education of employees contribute to sustaining environmental safety standards and the implied productivity requirements [8]. Therefore, managers should address employee training and education, especially if they want to achieve long-term goals. The high-quality performance of a manager in the human resources field contributes to workforce stability and reduces fluctuation, and this is why a safe environment impacts the company's economy [9].

Virtual Reality (VR) is a computer-generated simulation of an immersive, three-dimensional environment that users can interact with and explore through sensory stimuli, typically presented via head-mounted displays and other interactive devices. For example, the review [10] seeks to update our knowledge of using head-mounted displays (HMDs) in education and training. From a scientific perspective, Virtual Reality leverages computer graphics, advanced sensing technologies, and human–computer interaction principles to create a convincing and responsive virtual world to simulate real-world experiences or imaginary scenarios. By engaging multiple sensory modalities, such as vision, hearing, and sometimes touch, VR tricks the brain into perceiving the virtual environment as if it were real, allowing users to feel present within the digitally constructed world and enabling a wide range of applications in fields like entertainment, education, training, therapy, and scientific research [11].

Researchers [12] have explored the benefits and applications of Virtual Reality (VR) in different scenarios. VR possesses much potential, and its application in education has seen much research interest.

The authors of [13] interviewed 62 people across numerous companies from varying disciplines and perspectives. Success stories and existing challenges were highlighted.

The study's goals [14] are to compare the instructional effectiveness of immersive Virtual Reality versus a desktop slideshow as media for teaching scientific knowledge and to examine the efficacy of adding a generative learning strategy to a VR lesson.

Virtual Reality training is an exciting alternative to classic employee training. It will find its application not only in the field of work safety or training of new employees; Virtual Reality also enables workers to acquire or expand their abilities and skills without damaging or destroying objects in the actual environment, which implies economic, social, and environmental benefits. There is a disconnect between education and the world of work, and future professionals need to be updated with new working methods in order to be able to compete in the labor market [1]. Immersive Virtual Reality blurs the boundaries between the real and digital worlds, creating highly immersive scenarios for learners, stimulating students' interest and enthusiasm in learning, and breaking through the difficulties and bottlenecks of traditional teaching [15].

One aspect of sustainability is the efficient use of resources. Traditional employee training methods often require substantial physical resources, including training facilities, equipment, and materials. Virtual Reality allows the creation of realistic and immersive learning scenarios without traditional training methods' associated costs and resource consumption. By leveraging VR technology, our research promotes sustainable learning practices by significantly reducing the need for physical resources.

By incorporating VR simulations into training programs, employees can practice tasks and procedures in a safe and controlled virtual environment. This approach reduces the risks associated with training and enhances the safety of employees. Ensuring the well-being of workers is crucial for the long-term sustainability of both the workforce and the company itself.

Regarding safety training, we understand photogrammetry as a supplementary and auxiliary technology that increases the trained person's immersion (sense of actual presence) in VR. The photogrammetry models are texture-coated relief structures [16].

Virtual Reality, a newer type of audiovisual input on learning, is an essential tool for innovation in education. With its sense of presence and immersion, Virtual Reality constructs an experiential learning process for students to promote their learning engagement and performance [17].

VR can be defined as implementations by which individuals find themselves in a virtually created environment using various tools and interacting with the environment [18]. VR could be defined as experiences in which individuals could walk around in 3D environments developed by computer technologies, and the environment could be observed from all angles. Generally, according to VR implementation definitions, the feelings that individuals directly interact with the environment and feel themselves in the related environment are emphasized [19].

Virtual Reality finds application in many fields. It is widely used by entertainment industries, especially computer games, where players can interact with virtual environments. It is also used by professionals and applied for various purposes: military, aviation, medicine, sports, construction, real estate business, security, advertising, promotion, and many others [1].

Sustainability encompasses not only environmental considerations but also social and economic aspects. That is why this paper focuses on improving the quality of employee training, which leads to enhanced workplace safety. This paper addresses the challenges of sustainable development through the application of Virtual Reality (VR) technology in the training and education of employees in industrial enterprises. This research contributes to the sustainability of human resources by promoting innovative and sustainable learning practices while addressing the challenges faced by industrial enterprises in the modern era. Specifically, this study focuses on verifying the critical parameters of creating a virtual scene using photogrammetry. Reflecting on the conducted research, it became apparent that our method of enhancing employee education and skill development is highly beneficial.

## 2. Review of the Literature

Many professional works have addressed Virtual Reality in industry and employee training. The authors of this paper provide an overview of those contributions they consider to be the most significant, focusing on the specific issues of the raw materials industry.

Seo et al. [4] presented research to establish a secure educational environment for active electronic construction site workers, utilizing VR technology to provide an immersive safety education system. The study yielded various positive effects and implications of this innovative approach, covering cognitive, affective, and behavioral education. The VR-based safety education and training system, developed in their study as a prototype, holds significance in its ability to offer user-centered education, foster interaction between users and the system, and design new industry-specific curricula.

Paszkiewicz et al. [5] proposed a paper where they introduce an innovative approach to integrating Virtual Reality into the educational process to cater to the demands of Industry 4.0. Based on their proposal, their approach has versatile applications, spanning various fields like higher education, aviation, automotive, shipbuilding, energy, and more. The study meticulously examines the merits and drawbacks of VR-based education, significantly influencing its applicability and relevance. Furthermore, the paper showcases the training outcomes conducted through this VR system. The results demonstrate the immense potential of virtual environments for enhancing participants' skills and knowledge. By developing and implementing suitable courses within the VR realm, organizations can effectively curtail costs while simultaneously enhancing the safety and efficiency of their employees' tasks.

Moreno et al. [20] proposed the implementation of a virtual multi-user tool in electromechanical engineering. The proposal aimed to strengthen the theoretical–practical training of maintenance personnel concerning electrical voltage equipment. The tool concerns training in performing medium voltage tasks, of which safety regulations are well defined. A cooperative, multi-user electrical equipment maintenance is concerned with applying Virtual Reality tools. Also, an error rate evaluation and subsequent overall evaluation of Virtual Reality users are considered. The system enables virtual training environments where personnel can find themselves in actual practice. The entire VR application is modeled and programmed, applying the Unity3D development tool.

Zhang et al. [21] used Virtual Reality as a new practical approach to fire safety education. They mention that despite the application's lack of interactivity and low practicality, they could achieve a measurable improvement in user reactions to the events investigated. The research took place on campus and involved 80 test subjects. They built the entire system on the HTC Vive VR headset. Performing usability tests and comparative analyses of the application experiments, they concluded that users could apply the VR experience to the natural environment well. In conclusion, they inform that the fire safety education at Central China Normal University currently combines traditional teacher education and Virtual Reality training.

Bell and Fogler [22] report on VR use by chemical industries. Their particular focus was on chemical laboratory accidents, chemical accidents at the university campus, and virtual tours of chemical plants. They developed a free program for all interested parties that includes a survey of inaccessible sites of operating reactors and a demonstration of the consequences of not following safety regulations, and provides valuable advice for foreign visitors to the campus.

Li and Zhang [23] focus on simulating the safety behavior of miners. Their research aims to standardize safety behavior, improve the effectiveness of safety training, and reduce the incidence of coal mine accidents. They used LAMP software (i.e. Linux, Apache, MySQL, and PHP) and the Virtools platform to create the application. In the virtual environment, they included both natural and artificial entities of the coal mine, the simulation of which was based on actual coal mine operation data. Users can easily interact with the entities. In addition to mining environment simulations, the application can also simulate workers' behavior in places where detonations, fires, smog, and the like might occur. The application also includes sound effects to achieve the most realistic impression. The authors maintain that there is no doubt that Virtual Reality can familiarize miners with the environment of mine shafts, recognize root causes of hazards, standardize safety behavior, and behave appropriately in actual workplace situations.

Bo et al. [24] proposed the application of Virtual Reality in mine fire training, and he with his team informed on several disasters that traditional teacher training could not appropriately render. Therefore, they decided to provide a VR application demonstrating typical phenomena occurring in mine fires. The application enables modeling movements of smoke in a mine shaft; it can show the process of fire development, its extinguishing, and, finally, the actual rescue of miners from the mine shaft. Acknowledging that the application development process is a complex and difficult one, the authors conclude that the introduction of Virtual Reality to the training of fire safety in mining can considerably improve the quality and effectiveness of learning and that it stimulates students' learning enthusiasm.

Peña and Ragan [25] researched the use of Virtual Reality for safety in the construction industry. Their research is based on accident reports provided by the Occupational Health and Safety Authority. They focused on the most common possible causes of accidents occurring at construction sites. They succeeded in including them directly in the VR application explicitly designed for the HTC Vive VR glasses. The authors maintain that this is the first step towards designing and creating other similar applications, which they want to deal with in depth.

Vergara et al. [26] investigated the use of Virtual Reality in teaching material engineering. They focused on improving long-term students' knowledge retention. For this purpose, they took advantage of a virtual environment laboratory. They tested 103 students given simple tasks implemented by a VR application. The application was developed using the 3DS Max graphics and the Unreal Engine development tools. The authors point to the fact that some students suffered from dizziness and that it was necessary to use sufficiently powerful hardware. According to their research, the authors concluded that Virtual Reality improved the retention of students' knowledge by 65%.

Pham et al. [27] focused their research on the safety performance improvement of construction industries. The authors decided to use Virtual Reality to interactively educate students, using safety test scenarios derived from practical construction intelligence. Using photogrammetry, they mapped a part of the construction site, which they then converted into a 3D model. A VR application was created that functions via a web interface.

Gabajová et al. [28] conducted research on implementing augmented and Virtual Reality through university teaching methods. Their research was based on the requirements of Slovak industrial enterprises. The study's main goal was to test and document how useful immersion technologies can be in the teaching process. This study involved a group of students whose task was to build an assembly structure, first without using Virtual Reality and then aided by augmented and Virtual Reality. The results of this study were recorded and analyzed. The conclusion was that the time required to assemble the structure was reduced by 44.07% if aided by augmented and Virtual Reality.

Tadeja et al. [29] used photogrammetry methods to create digital twins, using several approaches to provide the best possible 3D model based on the original image acquisition. Concerning the results of their research, they addressed six experts in the field to perform engineering measurements to assess which of their approaches was the most fruitful in providing the best-quality 3D model. Several quantities were examined in the study, which are listed in the conclusion of their work. The authors maintain that by using very high-resolution images and high-quality 3D model exports, the models obtained by photogrammetry methods can be of better quality than models created by computer-aided design (CAD) systems.

The research results on the given topic prove that several recent research projects have dealt with various creation techniques and uses of Virtual Reality. All aimed to create the most accurate and reliable digital twins mirroring actual conditions. Most of these projects focused on creating 3D models, taking advantage of traditional CAD modeling systems and programs providing vector graphics. In contrast, only a few projects created Virtual Reality by employing photogrammetry.

VR scene implementations differ. Detailed modeling or accurate laser scanning is often used, which implies high financial and time costs. The authors of this paper decided to use photogrammetry as the optimal method for their project.

Queisner et al. [30] used photogrammetry for virtual scene realization to simulate surgical interventions. Based on their paper, the authors' approach improves the link between theoretical expertise and the practical application of knowledge and shifts the learning experience from observation to participation. A technical workflow to record and present volumetric videos of surgical interventions in a photorealistic virtual operating room was developed from the technical point of view. Users can experience and navigate surgical workflows as if they were physically present.

Triantafyllou et al. [31] decided to use photogrammetry for Virtual Reality scenes because it produces high-quality models for large-scale objects; such an approach is relatively low-cost and not demanding.

Aggarwal et al. [32] proposed a study to develop a photogrammetry-based Augmented Reality and Gesture Recognition projection system. They see huge application potential in healthcare, education, defense, and geography.

Herrera et al. [33] presented a study that showed that the reconstruction of 3D virtual environments through photogrammetry can generate geometries applicable to virtual environments using only 2D photographs as a source. Their work uses photographs as the only source of information. The main reason for this approach is the ease of access to a camera and the ready availability of a dataset of photographs of indoor and outdoor scenes. Based on their research, it is possible to use photogrammetry-based methods to generate virtual environments quickly if they do not require them to be minutely detailed.

Tolle et al. [34] presented a method for digitizing historical relics by photogrammetry. The process consists of four phases. Application of the method for the Badut Temple shows that the photogrammetry approach is efficient for creating 3D models of historical relics.

Fernandez et al. [35] proposed to employ photogrammetry to recreate realistic 3D scenes by taking a series of images and combining them by analyzing which points they have in common. The conclusion of their work: "There is research on the use of VR and Photogrammetry for purposes such as recreating ruins, cities, or biological purposes. There is not much research on using this method for recreating spaces for education".

Krajčovič et al. [36] describe the 360° video technology method, enabling verification of whether VR teaching works. Already 3, 7, 10, and 30 days after the lesson delay, they could quantify students' success scores.

Hernández-Chávez et al. [37] describe a tutorial scene designed for the Oculus Rift. They focus on using Industry 4.0. The result acquisition is based on student response questionnaires.

Krajčovič et al. [38] explored the advantages of AR and VR as tools for strengthening the link between education and practice. Students compared 2D paper-based learning with 3D interactive device learning space. The evaluation is questionnaire-based. The average time required to assemble the product is also given, being significantly less (by tens of percent) when AR/VR is employed.

## 3. Materials and Methods

### *3.1. Photogrammetry for Modeling Scenes of Virtual Reality Applications*

Our research focused on a fully immersive digital twin Virtual Reality.

Photogrammetry entails creating a digital twin of a real object or space using original photographic images. As such, it deals with the reconstruction of shapes, determining the position and dimensions of objects depicted by photographic images [39].

Photogrammetry is based on parallax. Three-dimensional models are generated from multiple 2D images. The first theoretical mention of photogrammetry was in 1851, and it was first applied ten years later when a topographic map was made [40].

Photogrammetry is classified by the following:

- Positional location (terrestrial, aerial, satellite);
- Number of images (single-image, multi-image);
- Processing technology (analog, analytical, digital) [40].

Our research focused on terrestrial multi-image digital photogrammetry. Terrestrial multi-image photogrammetry was chosen regarding the location of the objects in the company where the research took place. These mainly were closed rooms with equipment accessible to a researcher equipped with a quality camera.

Photogrammetry is based on photographic image analyses and processing by specialized software. It is implemented by the following steps [41]:

1. Natural Feature Extraction: This step aims to extract characteristic groups of pixels that are invariant to changing camera positions while taking the images. This function searches the images for fundamental similarity, and during this step, many input photos are discarded from the further evaluation process. By analyzing the photos discarded, subsequent image-taking practice can be considerably improved.
2. Image Matching: This step aims to find images representing views of the same scene. To this end, we use image retrieval techniques to find images that share some features without trying to resolve matches for all features. The ambition is to simplify the

image with a compact image descriptor function that enables an efficient calculation of distances between all image descriptors.

3. Features Matching: This step aims to compare all similarities between pairs of candidate images. First, we perform photometric matches between a set of descriptors from a couple of input images. For each element in image A, we obtain a list of candidate elements in image B.
4. Structure From Motion: This step aims to understand the geometric relationship behind all the observations provided by the input images and derive a rigid structure of the scene (3D points) with the position, orientation, and internal calibration of all cameras.
5. Depth Maps Estimation: We select the N best/closest cameras in the vicinity for each image. We select front parallel planes based on the intersection of the optical axis with the pixels of the selected neighboring cameras.
6. Meshing: This step aims to create a dense geometric surface representation of the scene. First, we merge all depth maps into a global one in which compatible depth values are merged into cells.
7. Texturing: This step aims to texture the generated mesh to obtain a realistic model.

Based on the photogrammetric 3D model created by following the steps mentioned above, a VR application can be created according to the methodology demonstrated by the following process chart in Figure 1.

The samples were taken at an industrial plant processing crude oil. The equipment of the refining column and other technological units selected by the company's management were scanned. The devices were scanned throughout the entire operation, located in both external and internal spaces, and it was necessary to observe all safety conditions. Several 3D models of the device were scanned and subsequently created. The ACE Model R+MM unit was chosen because it was photographed in constant light and accessible conditions inside the building, and it was also a newly acquired device that the management of the company wanted to make visible.

Individual volunteers can be tested in the created VR scene with a programmed task scenario, and conclusions can be drawn from the data provided by implementing specific research tasks.

The objective of our research team was to establish a training center and provide an ACE device, which would measure the cetane number of the diesel fuel used by our institute, see Figure 2.

Images of the existing technological equipment processed by photogrammetry are provided to create 3D models. The image overview is listed in Table 1.

Several software tools can create 3D models (e.g., 3DF Zephry, Mushroom, and others). As part of the comparison, the results published by the authors of [42] found that the most suitable tool is RealityCapture. The choice of the RealityCapture software (ver. 1.2.0.16813RC) tool was supported by [43–49], where authors demonstrated the effectiveness of this tool for photogrammetry. The advantage of the tool is mainly its user interface, the resulting quality of 3D models, and the possibility of setting varying attributes of input and output data.

The programming of the virtual scene itself took place in the Unity development environment, which is a software engine for creating VR content and offers a large number of options for modifying the attributes of individual 3D models. The development environment supports the drag-and-drop functions for inserting essential parts in the scene, which the primary interface can edit. After inserting the objects that provide the VR scene, it is possible to switch the application to the extension view mode and to implement C# programming, which enables the programming of the plethora of other functions that depend only on the programmer's imagination [39]. The simulation task was programmed in the C# programming language [39]. Unity version 2021.1.14f1 was used, and the classified images of individual objects were processed by the software tool, RealityCapture, version 1.2.0.16813RC. Those were the current versions of software tools during the research [39].

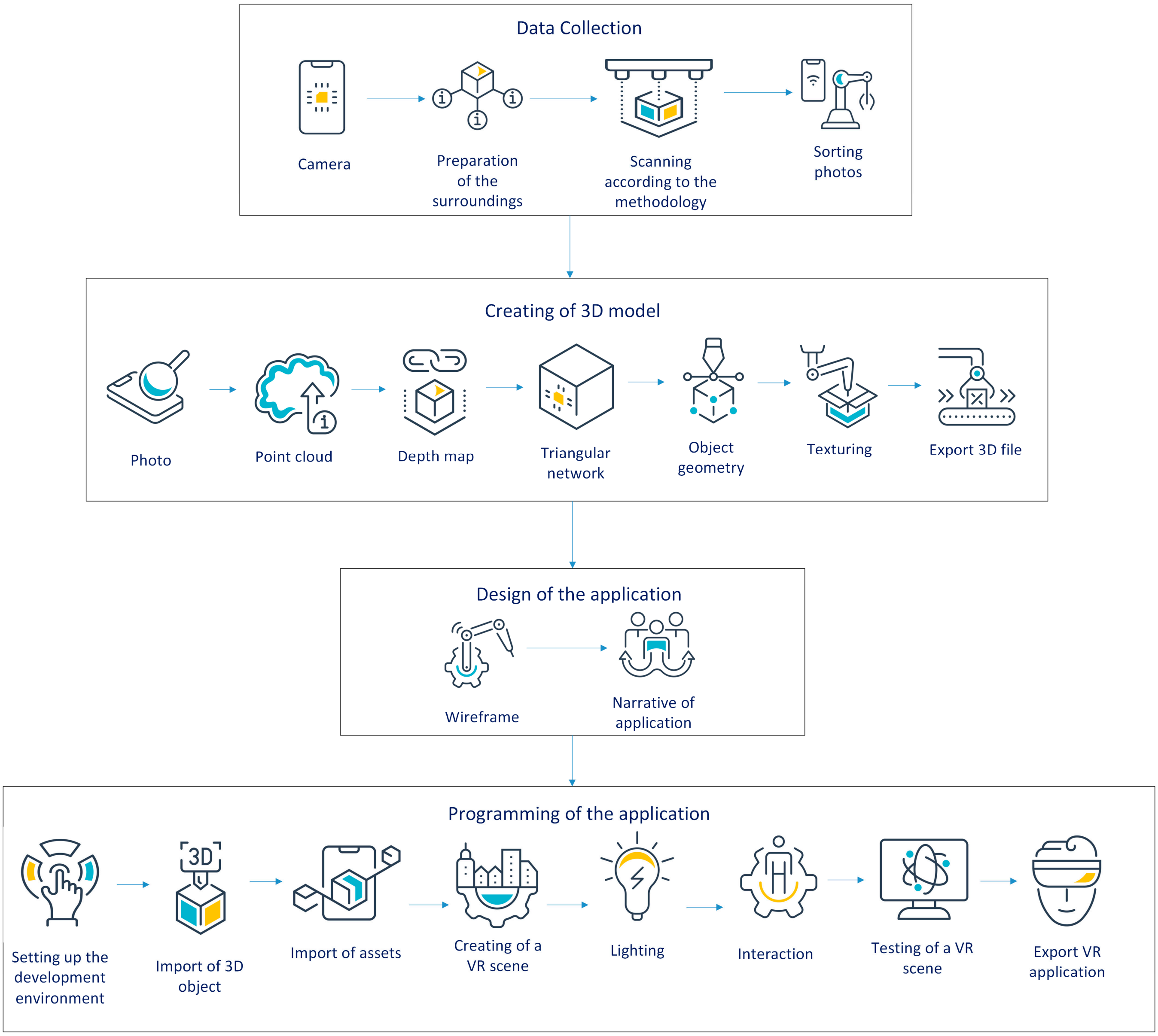


**Figure 1.** Process chart of 3D model creation.

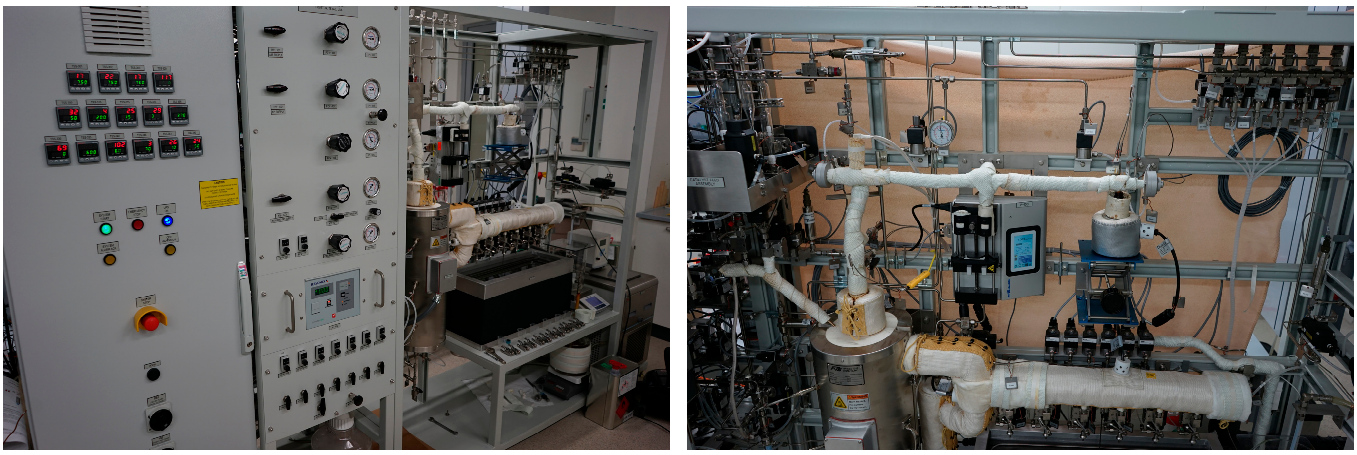

**Figure 2.** ACE Model R+MM unit.

**Table 1.** Database.

| Parameter | Value |
| --- | --- |
| Number of images | 256 images |
| Number of images applied | 252 images |
| Individual image size | ~9.5 MB |
| Individual image resolution | 6000 × 4000 px |

Figure 2 illustrates a ACE device. For this model, three different meshes have been created, which differ in the network density (sorting preview, normal details, high details).

The mesh model creation settings and their time demands are listed in Table 2.

**Table 2.** Mesh model settings.

| Details | Images Downscale | Time |
| --- | --- | --- |
| Low details | 2 | 7571 s |
| Normal details | 5 | 2288 s |
| High details | 10 | 87 s |

The mesh model was then coated with the texture generated in three different qualities. A 3D model was created from each quality class, which volunteers further evaluated (sorting, low/normal/high details).

The following settings listed in Table 3 were used for the texture coating of the mesh model, indicating creation time demands.

**Table 3.** Texture coating settings.

| Details | Images Downscale | Time |
| --- | --- | --- |
| Low details | 1 | 406 s |
| Normal details | 5 | 198 s |
| High details | 10 | 93 s |

A close-up of the model was made to represent individual models' quality better. (sorting, low/normal/high details).

The differences between the models were evaluated by 64 participants, who assessed whether qualitative differences were visible between them. The differences in quality can be seen in Figures 3–5.

The existence of 3D models made it possible to create the Virtual Reality application itself. The application meets the Virtual Reality and user interaction demands. For the application, 3D models of industrial enterprise actual operation objects were placed in the virtual space.

The application is made so that all 3D models can be viewed, some elements can be interacted with, and subsequently, a cascade of other tasks associated with the passage of safety training can be launched. The user is guided by pop-up, semi-transparent windows that navigate his/her movement in VR and display the possibilities of his/her behavior in space and the possibilities of interaction with objects.

To complete the idea, the authors created a wireframe of the virtual scene with the layout of the individual functional elements of the scene (see Figure 6).

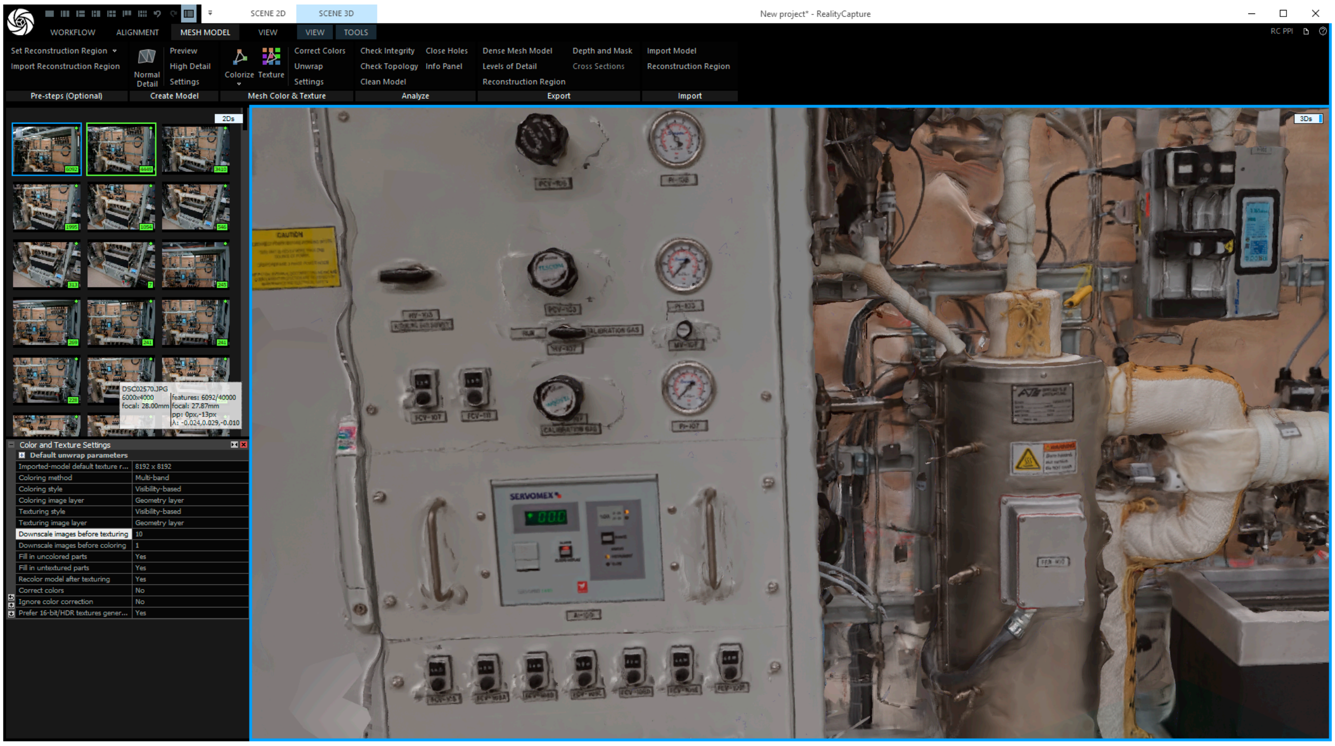


**Figure 3.** Texture coating in low details.

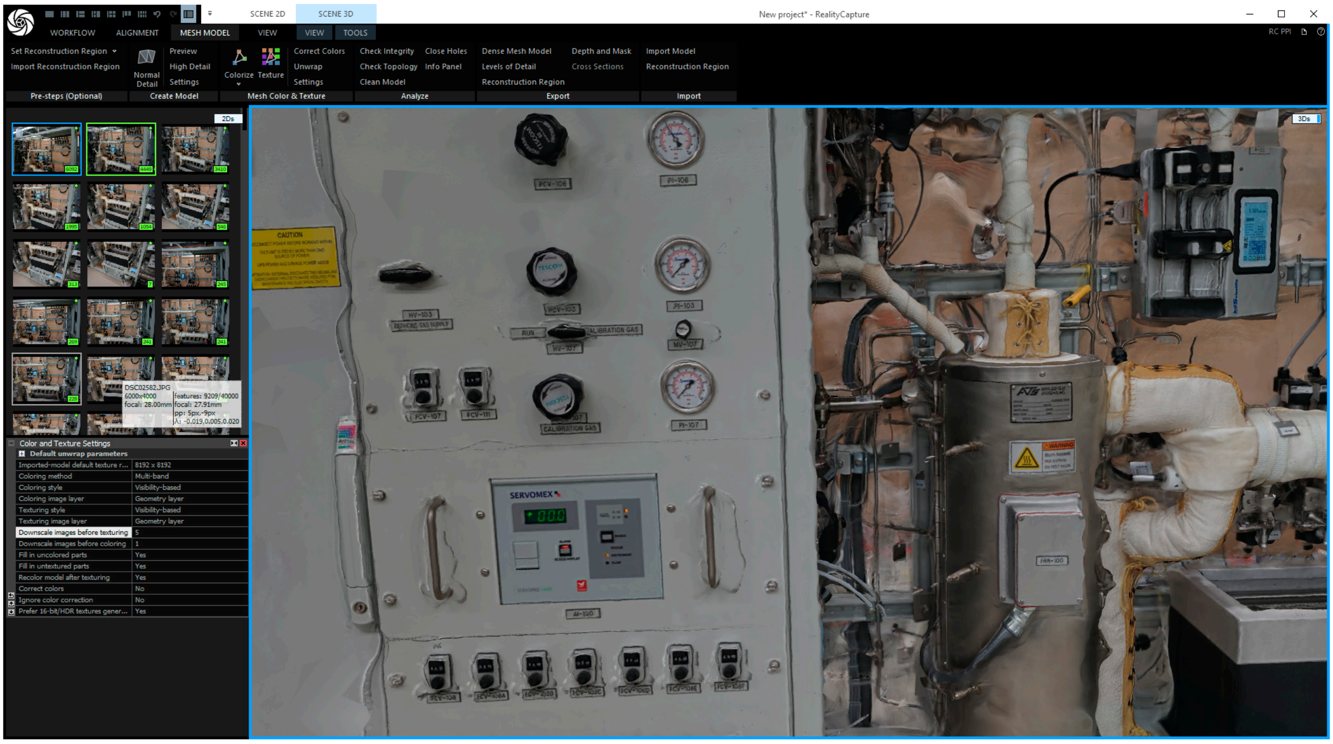


**Figure 4.** Texture coating in normal details.

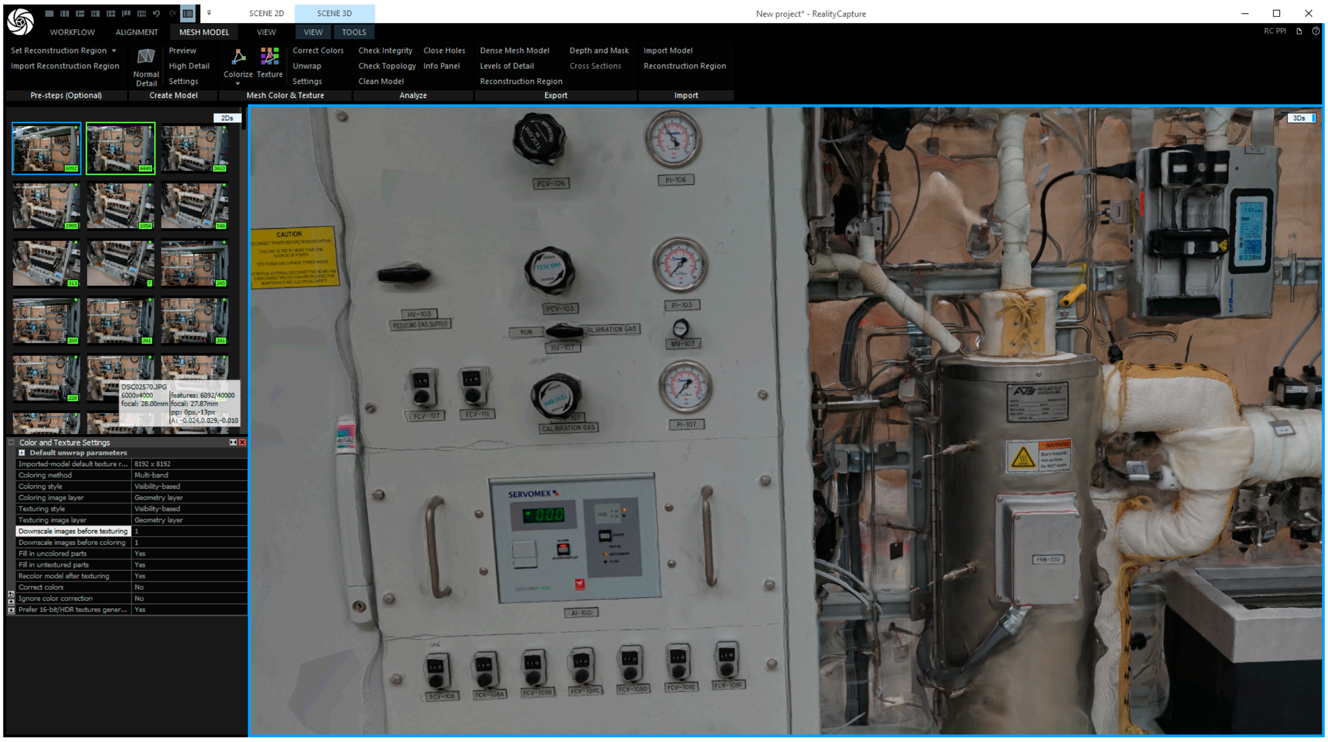

**Figure 5.** Texture coating in high details.

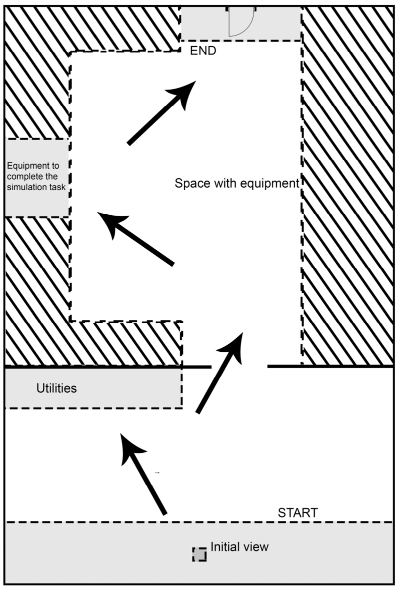


**Figure 6.** Virtual scene wireframe.

Subsequently, a virtual scene was created employing the Unity development environment (see Figures 7 and 8).

The developed VR application represents 3D models of natural objects in actual operation areas. They are recorded by the photogrammetry method, so their actual existence corresponds to their rendering in VR. The surrounding spaces are approximated to the actual condition so that an employee acting in an actual operation condition knows which object is located in which place.

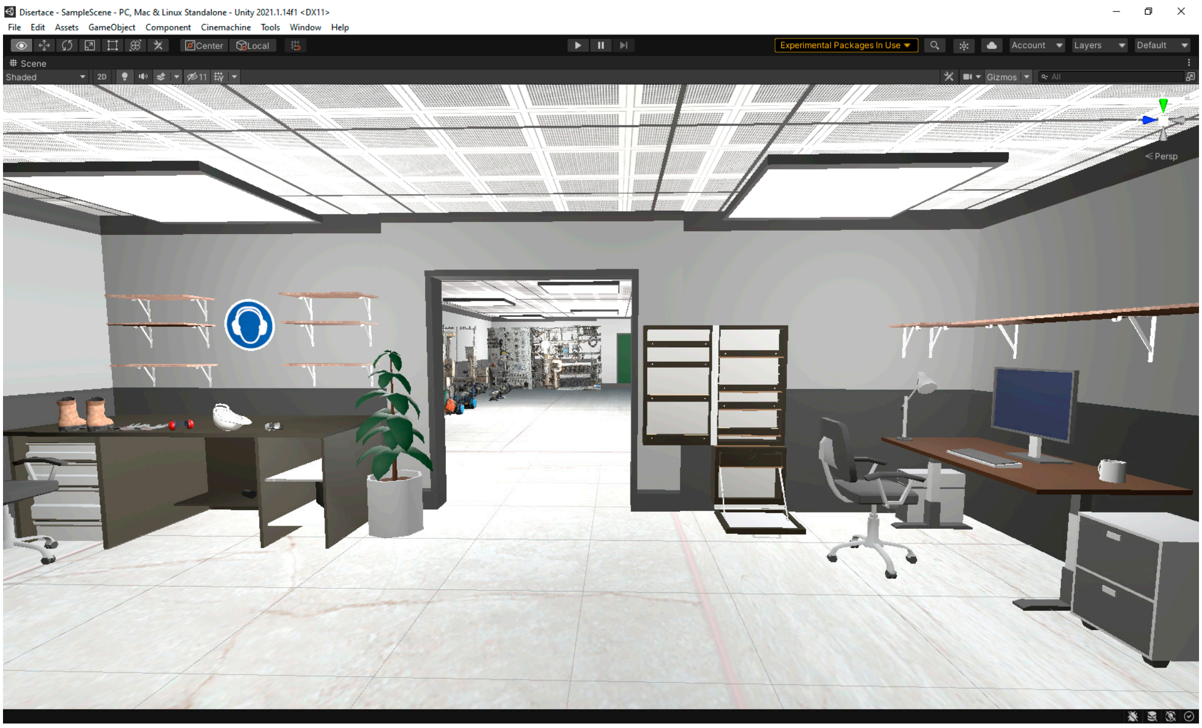

**Figure 7.** Programming VR application 1.

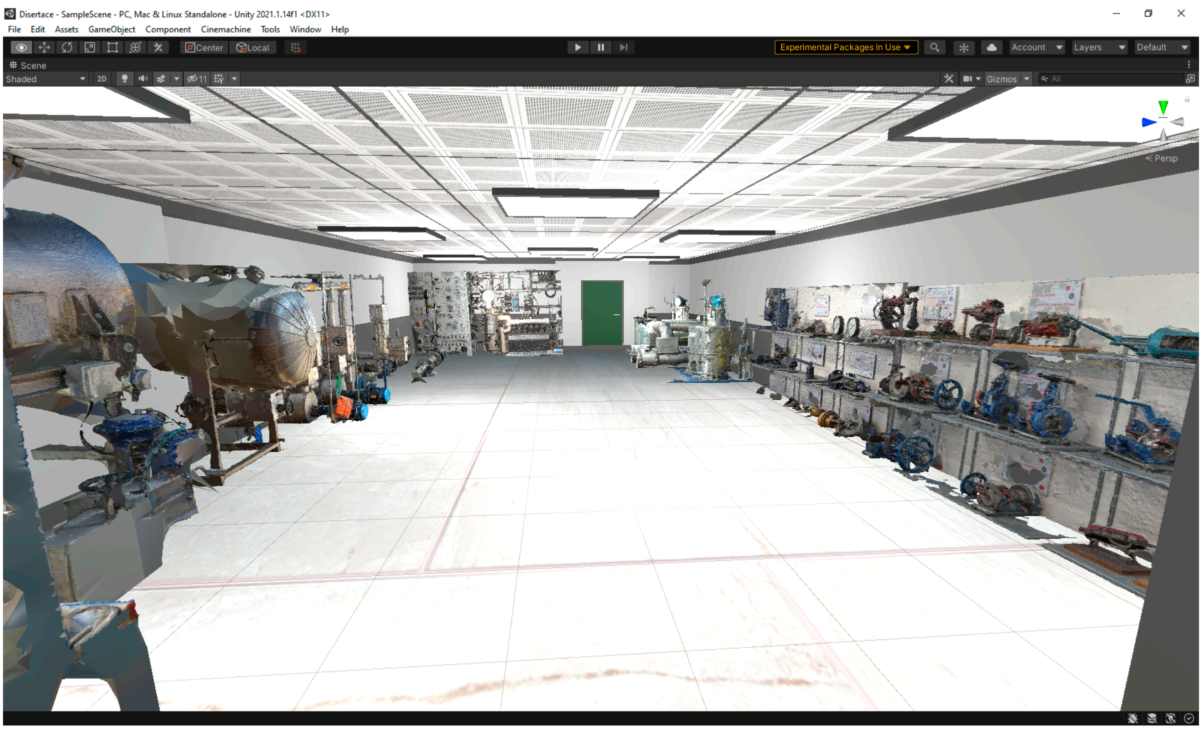

**Figure 8.** Programming VR application 2.

The participant's simulation task is to pass an area when the timer is started, put on protective gear, approach the device, perform the procedure of tightening the cap, and leave the area when the timer is stopped. If the simulation task is carried out successfully, the user is shown the time it took him/her to complete the simulation task. If the simulation task is not fulfilled, the device simulates exploding and catching fire.

For the created virtual application to play its proper role, which is to train employees in the field of occupational safety, it is necessary to test the application first.

The simulation task was tested on volunteers including university students and employees. A sample of 49 participants was tested five times, and then the collected data were evaluated. Figures 9–12 illustrate the testing process.

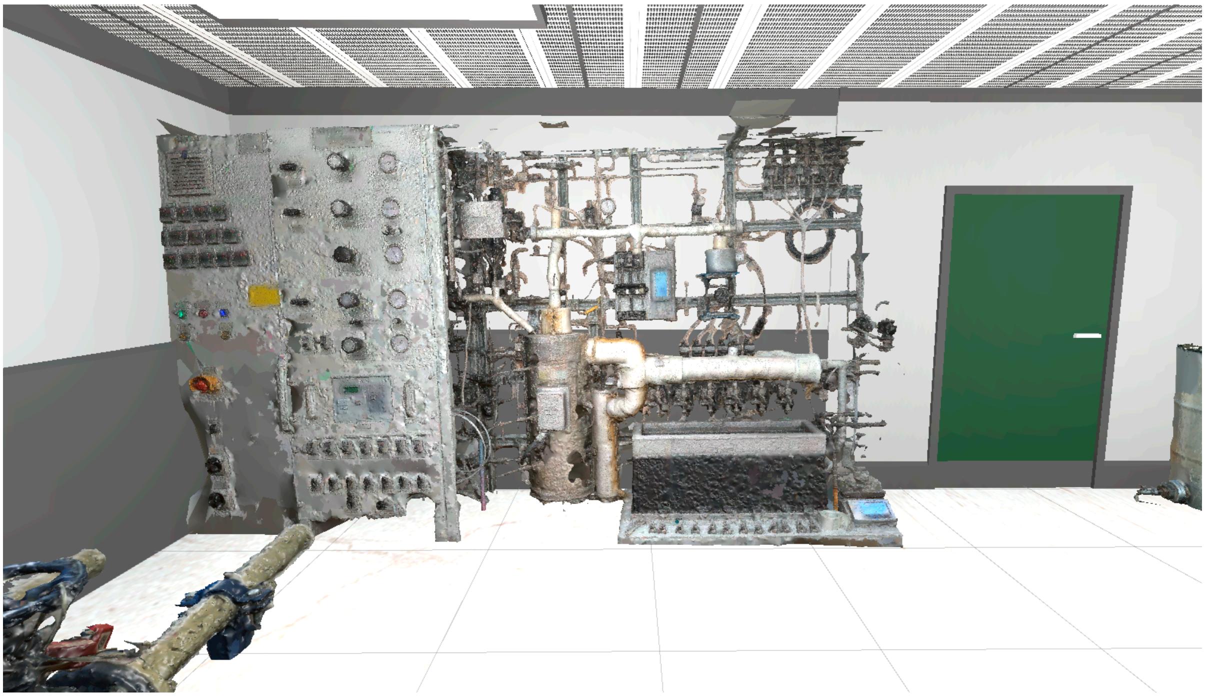

**Figure 9.** ACE device 3D model in VR.


**Figure 10.** Testing of simulation task 2.

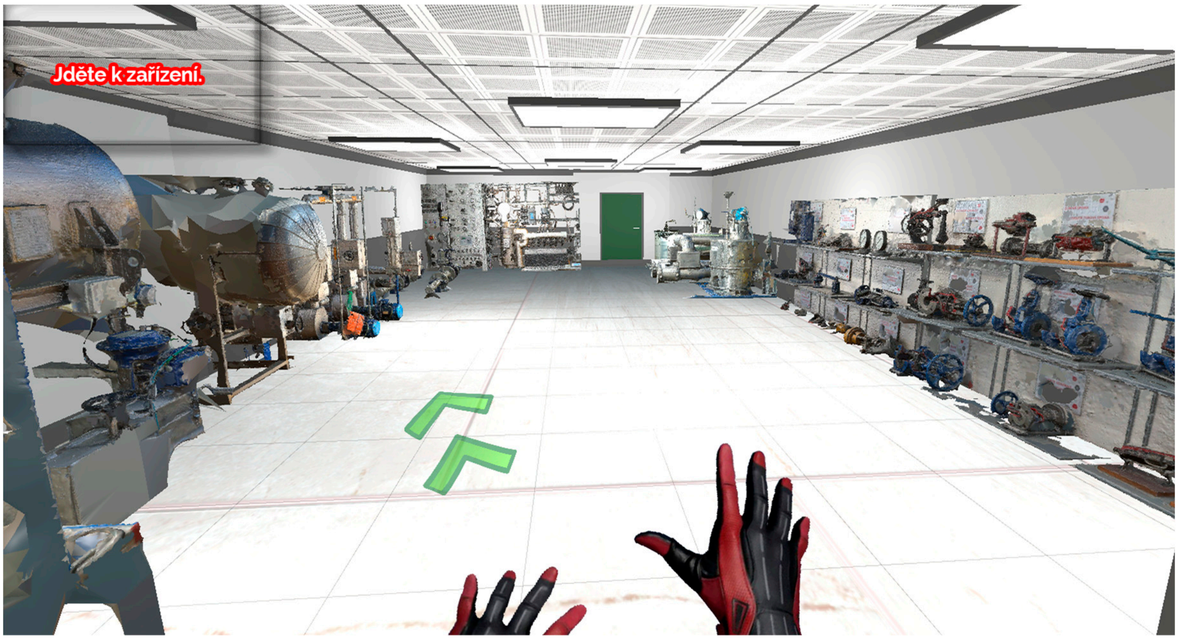


**Figure 11.** Testing of simulation task 3.

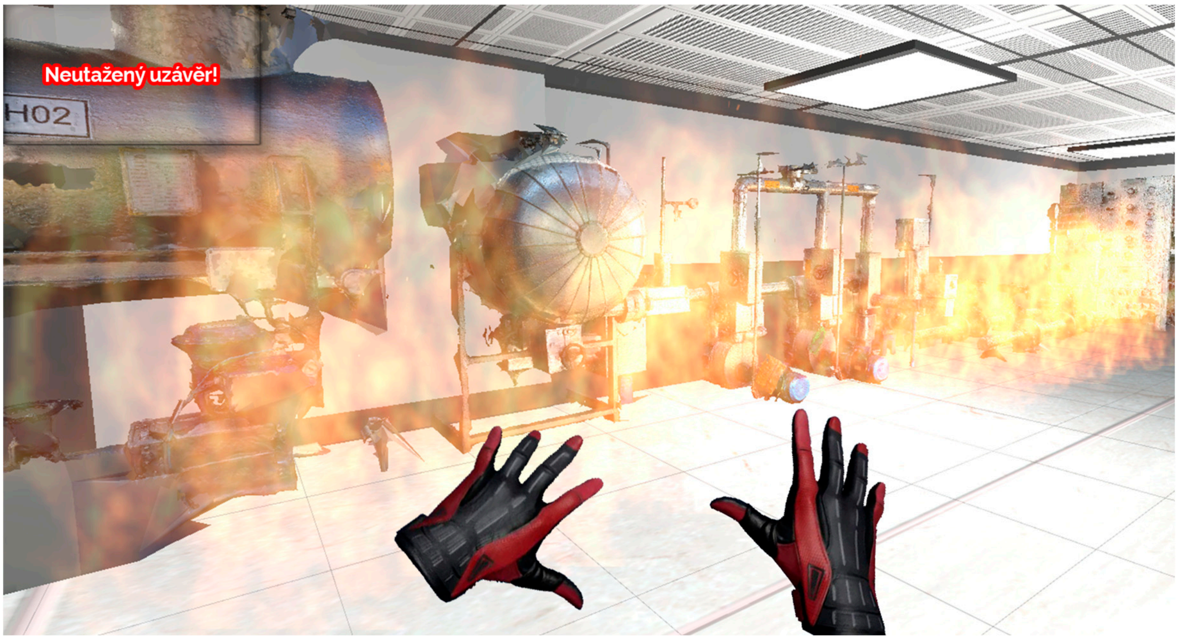


**Figure 12.** Testing of simulation task 4.

Each participant was subjected to the simulation task five times, and the elapsed time from the beginning to the task completion was measured and recorded.

The response time criterion was chosen, as it is about a simulation of a safety task, where time is a decisive factor that minimizes the damage caused to equipment and employees' health. In traditional training, the response time for evaluating the completion of the simulation task is also used.

The response time criterion was chosen, as it is a simulation of a safety task, where time is a decisive factor that influences the damage caused to equipment and the health of employees. In traditional training, the response time is also used for evaluating the completion of the simulation task.

### 3.2. Improving Safety Skills and Employee Training

Employee training is crucial for the success of an organization. It helps employees develop the necessary skills and knowledge to perform their jobs effectively, improves job satisfaction and motivation, and increases productivity. Additionally, training helps employees stay current with industry developments, aligns employees with the company's goals and values, and prepares employees for future advancement opportunities. It also helps to reduce turnover and minimize the risk of errors and accidents in the workplace. Overall, investing in employee training is a wise business decision that benefits both the employees and the company.

Some methods and materials for improving employee skills and education in safety management include the following:

(1) On-the-job training: Hands-on training and observation by experienced staff members can provide employees with the skills they need to perform their duties safely.
(2) Workshops and seminars: Workshops and seminars can be held to educate employees on the importance of safety and the best practices for working safely.
(3) E-Learning courses: Online courses or modules can provide employees with the knowledge they need to work safely at their own pace and in their own time.
(4) Safety manuals: Detailed safety manuals can be provided to employees as a reference for safe work practices.
(5 Safety incentives: Implementing safety incentives, such as rewards for safe work practices, can encourage employees to prioritize safety in the workplace.
(6) Safety drills: Regular safety drills can help employees become familiar with emergency procedures and improve their response time in the event of an emergency.
(7) Regular safety meetings: Regular safety drills can help employees become familiar with emergency procedures and improve their response time in an emergency.
(8) Virtual Reality approach: VR simulations can recreate real-life scenarios, allowing employees to practice their skills in a safe and controlled environment. This technology can reduce the cost of training by eliminating the need for physical travel and other expenses associated with traditional training methods. VR training can be customized to meet the specific needs and goals of the organization, and it can provide measurable results, such as improved accuracy and performance, allowing organizations to track the effectiveness of the training and make any necessary improvements. At least, VR can simulate dangerous situations, allowing employees to practice emergency procedures and improve their response time during an emergency.

For this paper, we decided to compare the traditional approach (the teacher approach) and the novel approach (the VR approach) for employees' training and education. Each of these approaches has its advantages and disadvantages. The benefits flow mainly to specific fields such as construction, medicine, civil engineering, history, and others. Students can immerse themselves in tasks with several senses at once, which leads to better memorization of the learning material [1].

### 3.3. Research Methods

Quantitative and qualitative research represent research approaches that differ in their objectives, methods, and data collection techniques. Table 4 summarizes the main objectives of these research approaches.

Both approaches have strengths and weaknesses and are used in different situations depending on the research questions, goals, and available resources.

Questionnaire research is a commonly used method in both qualitative and quantitative research. In qualitative research, questionnaires are used to gather descriptive and open-ended data. In quantitative research, questionnaires are used to gather numerical data and perform statistical analysis. The nature of the questions and the type of data collected determine if a questionnaire is being used for qualitative or quantitative research.

**Table 4.** Research approaches.

| Quantitative Research | Qualitative Research |
|---|---|
| It focuses on collecting and analyzing numerical data, often through large-scale surveys or experiments, to test hypotheses and establish causal relationships. | It explores and understands people's experiences, attitudes, and behaviors through in-depth interviews, observations, and other non-numerical data sources. |
| It uses statistical methods to analyze the data and draw inferences about the study population. | It uses interpretive and inductive methods to analyze the data and understand the underlying meanings and patterns. |
| The goal is to generalize the results to a larger population. | The goal is to gain a deeper understanding of a particular phenomenon. |

Research involves a set of written questions that are either self-administered or administered by a researcher, and the responses are recorded for analysis. Questionnaires can be structured with closed-ended questions that provide limited response options or open-ended questions that allow for more descriptive answers. The advantage of using questionnaires is that they can reach many participants quickly and efficiently, and the data collected can be easily quantified for statistical analysis. However, the validity of the results depends on the questions' quality and the participants' response rate. Questionnaire research helps gather data on attitudes, opinions, behaviors, and demographic information (Table 5).

**Table 5.** Pros and cons of questionnaires in research.

| Pros | Cons |
|---|---|
| **Cost-effective:** Questionnaires are relatively cheap to administer and can be distributed to many participants. | **Low response rate:** The response rate for questionnaires can be low, especially if the participants are not motivated to complete it. |
| **Convenient:** Participants can complete the questionnaire at their own pace and in their own time, which can increase the response rate. | **Limited data quality:** The data collected from questionnaires can be limited by the participant's ability to accurately understand and answer the questions. |
| **Easy to analyze:** The data collected from questionnaires can be easily analyzed using statistical software, making it possible to generate accurate results quickly. | **Bias:** The questionnaire may contain biases, such as leading questions or social desirability bias, that can affect the validity of the results. |
| **Anonymous:** Participants can provide honest and candid answers without fear of judgment or retaliation, as the questionnaire is usually anonymous. | **Lack of depth:** The data collected from questionnaires may not provide a deep understanding of the research topic, as participants can only provide brief answers. |

For this research, we decided to use a questionnaire research method to evaluate the quality differences between 3D models and trainees' opinions on the VR training approach.

## 4. Results and Discussion

Sixty-four volunteers from the ranks of university students and employees were tested on the qualitative differences among 3D models, and the questionnaire results are listed in Table 6 and can be seen in Figures 13–15.

From the recorded data of five transits through the VR simulation task, an analytical evaluation of the simulation task was performed using descriptive statistics. The actual evaluation was performed using the Statgraphics Centurion 19.5.01 software tool. The obtained results are presented in the tables.

**Table 6.** Qualitative differences.

| Details | Difference between Low and Normal Details | Difference between Low and High Details | Difference between Normal and High Details |
|---|---|---|---|
| Yes | 59 | 61 | 3 |
| No | 5 | 3 | 61 |
| Positive response percentage | 92.19 | 95.31 | 4.69 |

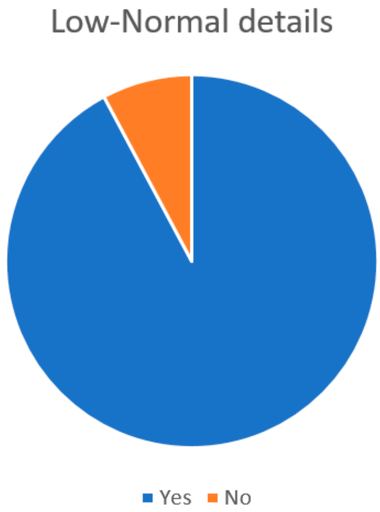


**Figure 13.** Low–Normal details chart.

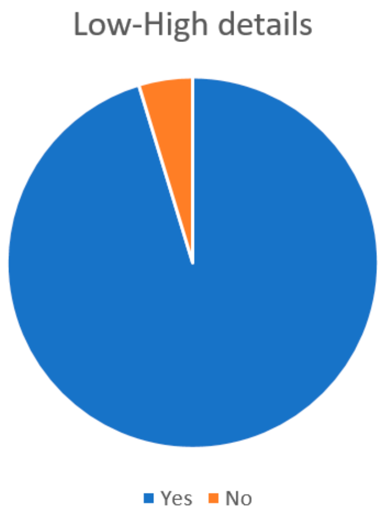


**Figure 14.** Low–High details chart.

"Statgraphic Centurion" is a software application for statistical analysis and data visualization. It offers various statistical methods and techniques to help users explore, analyze, and interpret data, as demonstrated by [50–54]. The tool includes features for data manipulation, hypothesis testing, regression analysis, time series analysis, and various graphs and charts to present the results effectively. As with any statistical software, it would likely be used in various fields such as social sciences, business, engineering, and research to gain insights from data, make data-driven decisions, and draw meaningful conclusions.

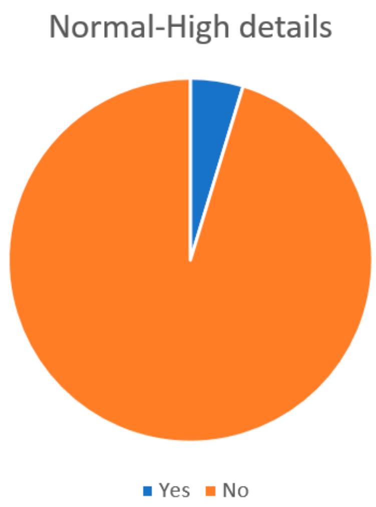


**Figure 15.** Normal–High details chart.

Analysis of Variance (ANOVA) was used to collect the necessary data. ANOVA enables comparisons of several medium values of independent random samples [55]. ANOVA is a valuable statistical method for comparing means across multiple groups. It provides a comprehensive analysis, efficiently utilizes data, decomposes variance, produces interpretable statistics, enables post hoc analysis, accommodates different experimental designs, and can be extended to handle various data structures. These attributes make ANOVA a versatile and powerful tool in statistical analysis [55]. It is widely used in various fields, including psychology, biology, economics, and engineering, to name a few.

The Analysis of Variance test has been a crucial tool for researchers investigating studies involving multiple experimental groups and one or more control groups for a considerable time [56–65].

Analysis of Variance in its parametric form assumes normality of distribution and so-called homoscedasticity (identical variances).

As shown in Table 7, an improvement can be identified regarding transit time minimums that improved by 12 s and transit time maximums that improved by 7.2 s; the average time improved by 8.6 s.

**Table 7.** Basic statistical information for time measurements.

| | Count | Average | Standard Deviation | Variance | Minimum | Maximum | Range |
|---|---|---|---|---|---|---|---|
| 1. Test time | 49 | 54.1082 | 3.40862 | 11.6187 | 47.8 | 62.8 | 15.0 |
| 2. Test time | 49 | 50.1 | 2.97776 | 8.86708 | 42.1 | 56.4 | 14.3 |
| 3. Test time | 49 | 48.4143 | 3.25634 | 10.6038 | 40.5 | 53.7 | 13.2 |
| 4. Test time | 49 | 46.4878 | 3.21738 | 10.3515 | 39.2 | 52.6 | 13.4 |
| 5. Test time | 49 | 45.549 | 3.99865 | 15.9892 | 35.8 | 55.6 | 19.8 |
| Total | 49 | 48.9318 | 4.52815 | 20.5041 | 35.8 | 62.8 | 27.0 |

Sampling skewness expresses the asymmetry of the distribution of variable values around their mean values (Table 8, Figure 16). Sample kurtosis expresses the concentration of variable values around their mean values. The measurement values of skewness and kurtosis imply data normality [55].

The ANOVA decomposes the data variance into a between-group component and a within-group component. In Table 9, we can see that the F-ratio, which in this case equals 48.89, is the ratio of the between-group estimate to the within-group estimate. Since the $p$-value of the F-test is less than 0.05, there is a statistically significant difference between the means of the five variables at the 95.0% confidence level. To determine which means differ significantly, we used the Multiple Range Test.

**Table 8.** Skewness and kurtosis table.

| | Std. Skewness | Std. Kurtosis |
|---|---|---|
| 1. Test time | 0.442152 | −0.300114 |
| 2. Test time | −1.65789 | 1.36076 |
| 3. Test time | −1.26748 | −0.403727 |
| 4. Test time | −1.01272 | −0.608321 |
| 5. Test time | 0.0303627 | 1.04377 |
| Total | 0.154852 | 0.0405092 |

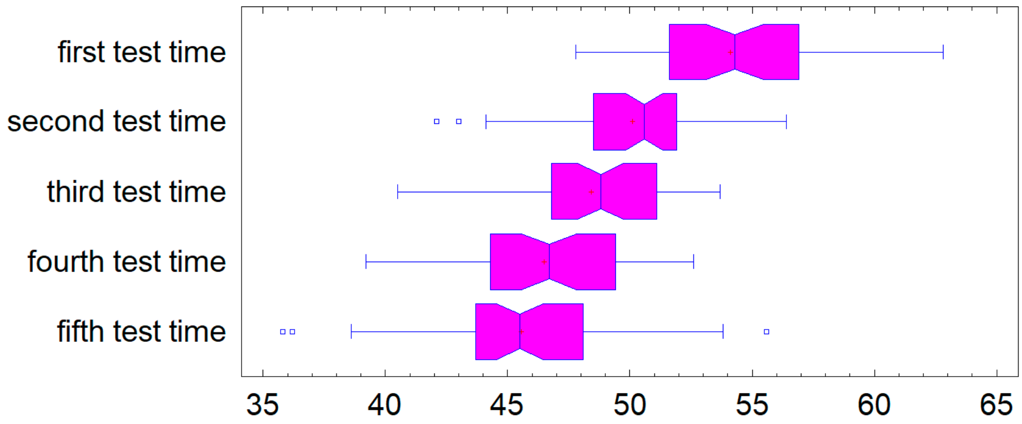


**Figure 16.** Box plot.

**Table 9.** Time measurement variance analysis.

| | Sum of Squares | Df | Mean Square | F-Ratio | *p*-Value |
|---|---|---|---|---|---|
| Between groups | 2246.36 | 4 | 561.59 | 48.89 | 0.0000 |
| Within groups | 2756.65 | 240 | 11.486 | | |
| Total (Corr.) | 5003.01 | 244 | | | |

The Multiple Range Test table informs on applying a multiple-comparison procedure to determine which means differ significantly from other mean values. The bottom half of the output shows the estimated difference between each pair of mean values. An asterisk has been placed next to nine pairs, indicating that these pairs show statistically significant differences at the 95.0% confidence level. Table 10 shows four homogenous groups identified using columns of Xs. Within each column, the levels containing Xs form a group of means within which there are no statistically significant differences. The method currently used to discriminate among the means is Fisher's Least Significant Difference (LSD) procedure. With this method, there is a 5.0% risk of calling each pair of means significantly different when the actual difference equals 0.

Based on the evaluation of the data, it can be concluded that the F-value, which in this case is equal to 48.89, is the ratio of the between-group estimate to the within-group estimate. Since the *p*-value of the F-test is less than 0.05, there is a statistically significant difference between the means of five variables at the 95.0% confidence level. The results show differences between the groups, but this difference is statistically insignificant after the fourth measurement.

Therefore, making four attempts significantly affects the time to complete this simulation task. After these four attempts, the time difference is statistically insignificant.

**Table 10.** Multiple Range Test.

| | Count | Average | Homogeneous Groups |
|---|---|---|---|
| 5. test time | 49 | 45.549 | X |
| 4. test time | 49 | 46.4878 | X |
| 3. test time | 49 | 48.4143 | X |
| 2. test time | 49 | 50.1 | X |
| 1. test time | 49 | 54.1082 | X |
| **Contrast** | **Difference** | | **+/− Limits** |
| 1. test time–2. test time | * 4.00816 | | 1.3488 |
| 1. test time–3. test time | * 5.69388 | | 1.3488 |
| 1. test time–4. test time | * 7.62041 | | 1.3488 |
| 1. test time–5. test time | * 8.55918 | | 1.3488 |
| 2. test time–3. test time | * 1.68571 | | 1.3488 |
| 2. test time–4. test time | * 3.61224 | | 1.3488 |
| 2. test time–5. test time | * 4.55102 | | 1.3488 |
| 3. test time–4. test time | * 1.92653 | | 1.3488 |
| 3. test time–5. test time | * 2.86531 | | 1.3488 |
| 4. test time–5. test time | 0.938776 | | 1.3488 |

Statistically significant difference is marked with "*".

*Discussion*

The findings from this study indicate that the use of different 3D models in the VR simulation task had a significant impact on participants' performance. Overall, the introduction of 3D models resulted in improved transit times. However, the effect became statistically insignificant after participants made four or more attempts at the task. This insight suggests that the number of attempts significantly influences performance, and after a certain point, the type of 3D model used becomes less critical. The results from this study could have implications for VR simulation design and could help optimize training scenarios for various applications in fields such as education, training, and research. Nevertheless, it is essential to acknowledge some limitations, such as the relatively small sample size and the specific characteristics of the 3D models used, which may impact the generalizability of the findings. Therefore, future research with larger and more diverse samples and variations in 3D model characteristics could further enrich our understanding of the relationship between 3D model quality and VR simulation performance.

## 5. Conclusions

Three-dimensional models were provided for a virtual scene implying a simulation task, consulting the industrial enterprise management of the company where the research was conducted. The experiments demonstrated that the multiple passages through the Virtual Reality scene gradually improved the training participants. At the same time, during the research, we had the opportunity to verify how photogrammetry can be helpful in the creation of the virtual scene itself in the case of safety training.

The photogrammetry method is, in principle, applicable in almost all branches of industry. However, there are instances where there are better options than the method, as it requires the availability of sufficient illumination and direct access to the objects of depiction.

Therefore, it is suitable, for example, for imaging the equipment of surface quarry operations. However, it is easily adaptable for depicting the equipment of underground mines if optional illumination is not available.

The results evidence that four VR simulation attempts significantly affect the time of the simulation task completion. After more than four attempts, time differences are statistically insignificant.

The theoretical contribution based on our results confirms that photogrammetry is a suitable method for processing virtual scenes. Although it may not be optimal for capturing detailed parts of models, it is excellent for capturing the surroundings and giving the impression that the user is there. Creating virtual scenes for employee training fulfills a complementary role by enhancing the user's immersion in the given environment. Another theoretical contribution is recognizing that the application benefited Virtual Reality training. Users improved their results by repeatedly going through it. During one of the experiments comparing the visual quality of models created using photogrammetry, we found suitable settings for processing 3D models regarding computer performance demands and eye-recognizable output quality.

Therefore, the practical implication for our team lies in the confirmation that we can continue to deal with photogrammetry as one of the possibilities to improve the quality of the virtual scenes we produce. During the presentation of the results to the company, whose operation and safety training we tried to process, there was also a mutual agreement that these topics should be further developed as follow-up projects. The practical consequence for the readers of our article is that they can easily imitate our steps and procedures with their example and create a similar application for companies with which their university or workplace cooperates.

With the progressing development of the software and hardware tools mentioned in this work, it will be possible to provide a better graphical environment, which can be of broad applicability and inclusive, deepening the knowledge of safety training in various industries. This work is a universal guide for creating VR applications employing photogrammetry methods, which can be expanded and updated in the future.

Although the authors are convinced that the findings and knowledge brought about by their work are relevant and applicable in industrial practice, they are also aware that the development of technologies in Virtual Reality is very dynamic. This fact encourages the search for new solutions that would lead to an even more authentic rendering of virtual scenes that could be used in employee training, not only in industrial enterprise's occupational safety.

Understandably, the search for new solutions should be led by an effort to achieve greater efficiency, because otherwise, Virtual Reality would become mere entertainment, and it would not be cost-effective. The authors focused on creating a Virtual Reality application using the photogrammetry method. However, other approaches would be appropriate to compare and evaluate, for example, work efficiency or data redundancy. A 3D scanner using LiDAR is a suitable tool for such comparison. The authors believe that using artificial intelligence can make part of the work more accessible, for example, by sampling images. The authors would like to continue their work and thus contribute to developing an exciting and attractive field, which Virtual Reality undoubtedly represents.

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**Institutional Review Board Statement:** According to the ethics committee of our university, our research does not fall under the issue of the opinion of the ethics committee, as it is a study of educational methods. The statement of the Head of the Department was sent directly to the editor. We also attached the Ethical Framework of Research and Code of Ethics of VSB-TUO.

**Informed Consent Statement:** Written informed consent has been obtained from the participant(s) to publish this paper and was sent to editor.

**Data Availability Statement:** This data can be found here: https://rfid-1.vsb.cz/data/article_data_final.zip (accessed on 24 August 2023).

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