Retention of Information from a Mixed Reality Training on Safety Measures Within an Automotive Plant

Retención de Información de un Entrenamiento de Realidad Mixta Sobre Medidas de Seguridad en una Planta Automotriz

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Abstract. This paper inspect the retention capability of subjects that were exposed to a mixed reality training through a security application Integrated on a Metaquest Device, the application was developed from scratch and we show the pursued steps to carry it out, after the users finished the training, we release an evaluation of the topics seen in the mixed reality training, enhancing that only those who had never received training in industrial safety before would be considered, after 1 month the same evaluation was applied again, to obtain both grades, and with this grades, the percentage of knowledge retention was evaluated, in order to compare it with a traditional class. Also, the schedule is presented based on the development of the application and the tests to be performed.

Keywords. Industrial Safety, Mixed Reality, Immersive Trainer, Automotive Industry.

Resumen. En este trabajo se indaga sobre la capacidad de retención de los sujetos que fueron expuestos a un entrenamiento de realidad mixta a través de una aplicación de seguridad integrada en un dispositivo Metaquest, la aplicación se desarrolló desde cero y se muestran los pasos seguidos para llevarlo a cabo, luego de que los usuarios terminaron el entrenamiento, se entrega una evaluación de los temas vistos en el entrenamiento de realidad mixta, resaltando que solo se considerarían aquellos que nunca antes habían recibido capacitación en seguridad industrial, luego de 1 mes se aplicó nuevamente la misma evaluación, para obtener ambas calificaciones, y con estas calificaciones se evaluó el porcentaje de retención de conocimientos, para compararlo con una clase tradicional. Además, se presenta el cronograma en base al desarrollo de la aplicación y las pruebas a realizar.

Palabras Clave. Seguridad Industrial, Realidad Mixta, Entrenador Inmersivo, Industria Automotriz

Previous Studies

Personal accidents inside the industry are a fortuitous event, which is why it is an unexpected and unavoidable event. In spite of being unavoidable, they can be prevented, and we can implement measures to reduce the risk of this happening..

"Since the beginning of history, human beings have had to combat injuries from work-related activities and, through preventive actions, have instinctively tried to preserve their lives with what they have found in their environment." Thus, industrial safety was born, with instinctive and individual actions, rather than with an established system of clear safety rules. (Guerra et al. 2021). "Workplace accidents or unsafe conditions within the work area are the main causes of temporary, permanent illnesses, or even death." Moreover, they could mean a reduction in efficiency and economic losses in productivity. Hence the importance of each company or organization having an industrial safety system; in this way, the risks of accidents and occupational diseases to which workers are exposed are regulated and reduced" (Obregón et al., 2012).

Identifying this and discussing with various engineers about their experiences on new jobs, they explained that inside companies they apply various types of training; nonetheless, depending on the organization, it was imparted in different ways, some receiving it at their first days from the human resources department, others with training videos that the company had prepared for fresh graduate collaborators, and even some where no training was imparted to the new employees because the people in charge of training were doing other activities of higher priority. Listening to these anecdotes, an uncertainty emerged. What if there was a training that was interactive, informative, and also didactic, where the collaborator does not have to watch video after video but rather is guided by the hand of a tutor at any time, not only with explanations but also with didactic activities that strengthen the acquired knowledge before implementing it? That is where the idea of developing an application of training in mixed reality for industrial safety came from, where the education would accomplish the previous points: an interactive and informative class with a tutor that guides and corrects the practiced activity before doing it in the real world and exposing oneself in a production environment, achieving as well that there is standardized training. Nevertheless, there are variables that we have to compare to traditional teaching. To evaluate the real effectiveness of mixed reality capacitation, in this paper we will focus on the variable of the training information retention on mixed reality about industrial safety inside a automotive plant, the variable was chosen because mixed reality offers benefits over traditional teaching, nonetheless, we are interested to know if the percentage of the training retention is at least or even better than a traditional training, since what interest us inside accident prevention is that the security processes are implemented in a effective way, albeit is not a guarantee that they will be used correctly even though the user has the procedures a hundred percent learned, at least we know that if they are not properly learned, they will not be used correctly.

Problem and Justification

Knowing the necessity that companies look for accident prevention with their employees and that new employees receive training for them to learn the security process inside the organization, we will focus the paper on investigate the impact on the retention percentage that mixed reality training, developed on the Oculus Quest 3, have on the capacitation in industrial security inside an automated car assembly plant powered by robotics, we selected this since an app was developed as a simulation in mixed reality,(MR), that is useful to recreate the experience for learning in a more realistic and interactive way, with this app we will evaluate if it is a viable alternative for learning about industrial security, we will analyze the efficiency on the training thanks to the flexibility that it contributes the mixed reality in terms of positive and negative feedback on real time with animations, sounds, and visual alerts, thanks to this, we will analyze if it really improves the retention of knowledge tackling the different ways of perception of information of the human being.

Nowadays, we can observe how various applications of virtual reality (VR) and augmented reality (AR) are gaining ground in various aspects of life, even now some of the most common applications of these technologies are found in entertainment all the way to education. At the center of these two technologies there is a middle point named mixed reality (AR). In mixed reality we can have different interactions inside of the application of VR while we are observing our real environment where objects or interactions of the AR are present the same way.

Inside companies, training of personnel is a topic that should be treated with the utmost attention, from the capital invested to the efficiency. In the recruitment of new employees, especially if they do not have previous experience of having contact with the industrial processes and critical procedures, it will have a considerable investment, in time and resources.

It is for all these reasons that the present paper will focus on the analysis of; if and immersive training on mixed reality is a viable way in terms of knowledge retention of employees in an automated car assembly plant powered by robotics. In the process of training new personnel is a challenge and an investment of human capital, time, and resources, which transforms on a crucial challenge depending on the complexities of the task that is supposed to be shown. Nevertheless, it is a necessity that new employees learn and execute in a precise, quick, and standardized way the processes that correspond to them, respecting the norms and rules of security to maintain their integrity and the integrity of the equipment and material they use.

Based on this, it was developed to utilize immersive trainers in mixed reality for training security on an automated car assembly plant powered by robotics, despite this, we are conscious that this is the implementation and the the problem, so, to define the root cause we used the “5 Whys method”. This is described here:

1. Why do we use immersive trainers? Because we need to train the new employees without experience in industrial security.
2. Why do I need to train in security for new employees without experience? Because we need them to do the processes of accident prevention.

3. Why do I need employees to do the processes of accident prevention correctly? Because we need to reduce the risk that they have accidents.
4. Why do I have to reduce the risk of accidents happening? To protect the security and health of employees.
5. Why do I have to protect the security and health of employees? En terms of capital, to avoid losing capital covering medical costs and legal issues.

Based on this results of the 5 whys, we can say that the root cause to resolve is:

¿How can we not lose capital because of an accident of an employee?

The key here is, prevention. A correct prevention since training would help to the solution to this complex issue.

My proposal is to evaluate the percentage of retention of the training thanks to the **mixed reality**, because this way, training human capital, having previous experience or being new, with and immersive training, in which they will be exposed to an standardized teaching, exposing them to the full training and process to do in a non invasive simulation, with real time feedback where the employees in training nor the equipment will be exposed since it is a simulation.

Formulation of the Research Problem

Are industrial safety training session using mixed reality trainers viable in terms of information retention for employees in an automobile assembly plant?

Research Objective

The objective of this research is to evaluate the percentage of information retention learned from implementing immersive trainers for safety course using a robot plant scenario into mixed reality, to support the use of virtual reality simulator for industrial training

General Objective

We will evaluate the retention percentage that user have at the end of the training and also a month after taking the industrial safety induction course to determine the viability of using MR technology compared to traditional training.

Specific Objective

The theoretical and practical knowledge acquired after the immersive trainer will be evaluated, and see the viability compared to traditional training.

Research Hypothesis (Hi) (If-Then)

The practice of mixed reality training for safety within an automotive plant improves knowledge retention compared to traditional training regarding safety elements and safety measures, making its implementation viable compared to traditional training methods.

NUll Hypothesis (H0)

There is no improvement in learning through the use of immersive mixed reality trainers for workers in an automobile assembly plant automated by industrial robots, nor does it contribute to an improvement in skill retention.

Independent and Dependent Variables

Independent variable (IV): Implementation of immersive trainers based on virtual reality.

Dependent Variable (DP): Percentage of long-term knowledge retention.

We must take into account that this research was conducted with the available resources, which were Quest 3 glasses with the application developed for a mixed reality induction for industrial safety in an automotive plant. herefore, no additional variables will be covered, and based on the survey results, only the percentage of long-term information retention will be evaluated. Also, on this occasion, we are not considering the money factor due to not having direct access to that information from the companies. These analyses assume the case where training is used on a large scale in a specific position that has high turnover or continuously trains new members. This factor will be investigated later, analyzing from how many people it is beneficial to use this type of technology in the case that in this research the hypothesis is positive and it turns out that using this technology is equally or more effective in knowledge retention.

Type of Retention

In the proposed research, it will be classified as experimental research. Experimental research consists of manipulating an independent variable to observe its effects on a dependent variable, with the intention of establishing relationships between the variables and thereby determining if the manipulation of the independent variable is indeed producing changes in the dependent variable.

Experimental Methodology: The experimental approach will be used to examine the influence of the implementation of immersive trainers based on mixed reality in the training of safety teams and safety measures for inexperienced staff and students in an industrial environment of an automotive plant. An Experimental Group will be employed to evaluate the impacts of the independent variable, the implementation of immersive trainers, which implies that controlled experiments will be conducted along with surveys, and in the end, they will be analyzed to assess the impact of the implementation of immersive trainers based on Mixed Reality for team training and safety measures within an automotive plant.

Experimental Method

In a pure experimental design, at least one independent variable is manipulated to observe its effect on a dependent variable, while controlling for other potentially confounding variables. This is achieved through the random assignment of subjects to experimental and control groups, ensuring that each subject has the same probability of being assigned to any group. Experimental designs allow for the establishment of causal relationships between variables, which is essential for testing specific hypotheses. The precise measurement of variables is crucial for obtaining valid and reliable results, which involves the proper selection of measurement instruments and the rigorous implementation of the data collection process. (Sampieri et al. 2014)

The experimental method that will be used is the Experimental Group method with a comparative model. In this experimental method, a group will be formed, which will experience the implementation of immersive trainers.

Experimental Design: An experimental group design with random assignment will be implemented. The Experimental Group will undergo training using immersive trainers, and upon completion, the group will be evaluated with questions on topics covered in the training for a knowledge assessment. One month later, the same evaluation will be conducted to analyze knowledge retention. This will allow for a rigorous comparison of the results obtained between both groups.

Experimental Group: People who will experience training through the application of immersive training in industrial safety in an automated automotive plant.

Data Collection and Analysis:

Measurement Instruments: Questionnaires will be used, and the Knowledge Retention Index formula will be applied. (Knowledge Retention Index, KRI)

Statistical Analysis: Statistical analyses will be applied to determine the significance of the differences between the groups.

Theoretical Framework

“Human beings have different ways of perceiving information. The VAK model allows identifying the best of the three perception channels: visual, auditory, kinesthetic.” (Reyes et al. 2017)

It is important to know what the VAK model is because within the application of Mixed Reality, we seek to cover all possible perception channels to have more information inputs.

"VR is defined as 'that technology which enables the user, through the use of an VR headset, to immerse themselves in three-dimensional scenarios in first person and in 360 degrees.'" (Zambrano et al.2023)

"AR offers the possibility to mix and combine two environments: the physical and the digital, all in real-time, using emerging and easily accessible technologies, such as smartphones or tablets." (Cabero et al. 2019)

"In practice, computer-generated images are overlaid on images of the real world and displayed on video projectors, computers, or tablets." MR, a hybrid of AR and VR, is the result of combining the physical world with the digital world and has recently garnered attention, mitigating the limitations of VR's exclusion from the real-world environment and AR's inability to interact with three-dimensional data packets. XR is a general term that encompasses VR, AR, and MR. XR refers to all combined real and virtual environments between human-generated inputs and computer-processed inputs to create an interactive environment. (Morimoto et al. 2022)

Types of VAK learning in Human Beings:

Visual: Subjects who perceive through this channel think in images and have the ability to grasp a lot of information quickly; they are also capable of abstracting and planning better than the following styles. They learn through reading and presentations with images.

Auditory: Subjects who use the auditory channel in a sequential and orderly manner learn better when they receive oral explanations and when they can talk and explain certain information to another person. This channel is fundamental in the study of music and languages.

Kinesthetic: They are individuals who learn through sensations and executing body movements. It is the slowest system compared to the previous ones, but its advantage is that it is deeper; once the body learns certain information, it is very difficult to forget it.(Reyes et al. 2017)

Virtual reality in training: "An important area of application for virtual reality systems has always been training for real-life activities." The appeal of simulations is that they can provide training equal to or almost equal to practice with real systems, but at a reduced cost and with greater safety.

Virtual Reality opens the door to new educational possibilities and experiential and meaningful learning through the following three characteristics:

- Ease of learning from a constructivist approach.

- Provide alternative forms of learning.

- Enable collaboration among students beyond the physical space." (Pérez et al.,2021)

Game, gamification, and game-based learning

"Juego: Un juego se refiere a un juego estructurado con reglas, objetivos y desafíos con el propósito de entretener.

"Game: A game refers to a structured game with rules, objectives, and challenges with the purpose of entertaining.

Gamification: The term gamification first emerged in 2008 and gained increasing relevance since the 2010s. Unlike games, gamification is characterized by its serious purpose. Definitions of gamification vary and generally focus on game elements and mechanics or on the game process and game experiences in serious contexts. Game elements include, for example, levels, points, badges, leaderboards, avatars, missions, social graphs, or certificates, highlighting the use of "game-based mechanics, aesthetics, and game thinking to engage people, motivate action, promote learning, and solve problems." (Krath el al.,2021)

Game-based Learning or game-based learning: Game-based learning refers to the achievement of defined learning outcomes through game content and play, and the enhancement of learning by involving problem-solving spaces and challenges that provide students, who are also players, with a sense of accomplishment. Game-based learning aims to educate. It is based on a complete game, commonly called a serious game.(Krath el al.,2021)

Percentage of retention in a traditional class:"Based on comparative studies of teaching methods, knowledge retention in traditional classes has been estimated to be between 60% and 67% after three months of learning." (Freeman et al., 2022)

Methodology

The methodology used for the development of the application that helped us deliver the mixed reality class in industrial safety training was based on the software development life cycle, starting with research on the training with an expert in industrial safety to understand the content we need to learn and seek to implement within the application, after having all the information, we had to develop the application with the mixed reality training, and once the application was ready, it was presented to a security expert to evaluate the training that would be given. He would provide feedback on whether we need to add more information, correct something, or add something to ensure the application is correct regarding the class information and the way it is taught, if something is found to be lacking, a modification would need to be made regarding the identified area of opportunity, and the application would be shown again until it passes the first filter with the expert who traditionally provides this training. Once it passes this filter, it will go to a control group to evaluate the application on aspects such as whether it is intuitive, whether it is interactive, and other details related to the user experience. If a positive response is not received, modifications will be made; however, if a positive response is received, the final product will be presented to begin tests focused on knowledge retention. (Fig.1)

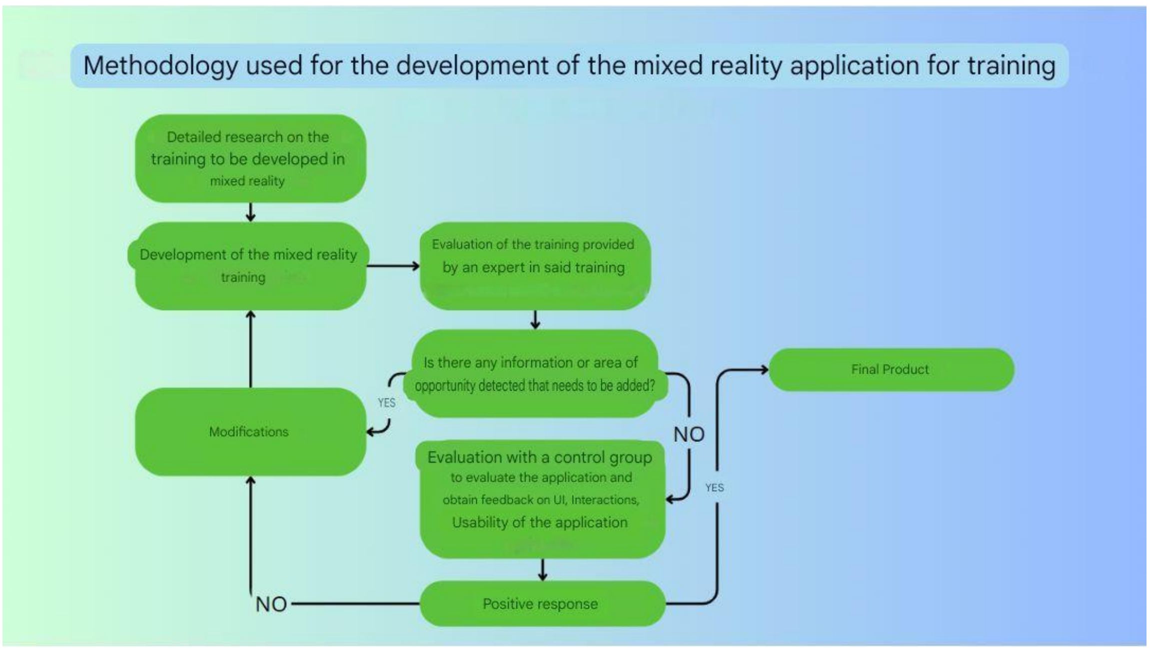

Figure 1. Methodology used for the development of the mixed reality application for training.

The mixed reality class on industrial safety in a robot-automated plant begins with an explanation of safety concepts and safety equipment. The class is conducted interactively with didactic animations that provide a graphical explanation to reinforce the explanations in a didactic manner. At the end of the class, there is an activity where questions are asked to provide feedback with gestures of correct or incorrect responses to what was learned during the class.

We can observe a bit about the application of Mixed Reality in industrial safety training in Figures 2 and 3 presented below.

Fig.2 Explanation on how to prevent fires due to unsafe actions in Mixed Reality Industrial Safety Training

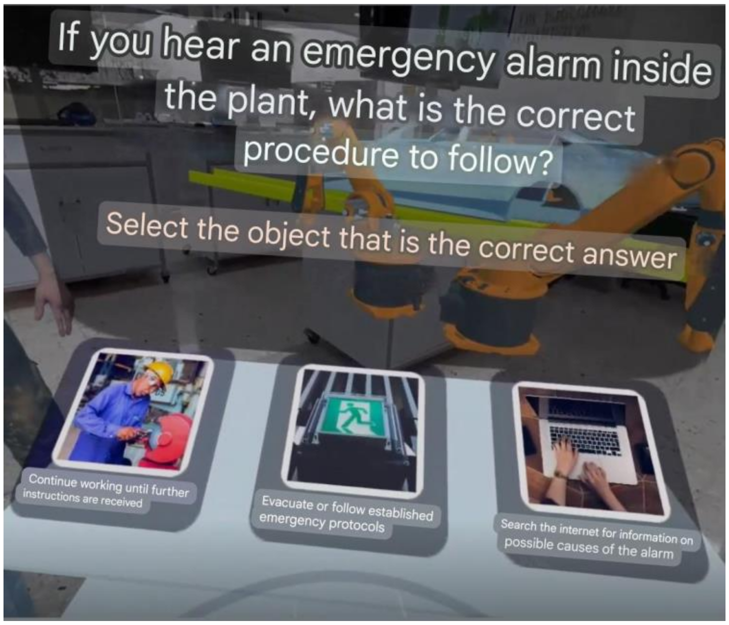

Fig3. Evaluation conducted at the end of the training to provide feedback on the knowledge covered in the Mixed Reality Industrial Safety Training

To evaluate the percentage of knowledge retention, we used the Experimental methodology to conduct tests on the percentage of information retention. We started by taking an experimental group to receive training in mixed reality with the developed application, and then they individually answered an evaluation about the topics covered during the training. They were informed that in a month they would receive another evaluation that would be exactly the same. However, the participants were not told that it would be exactly the same to avoid affecting the results. Additionally, no prior evaluation on industrial safety was conducted, so they received the class without feedback about the evaluation that would come later, to prevent the results from being affected by them paying more attention simply because they would know in advance that they would be evaluated on industrial safety later. After the participants completed the first evaluation, they would take a second evaluation one month later to calculate the information retention percentage with both results and draw the conclusions of the article. (Fig.4)

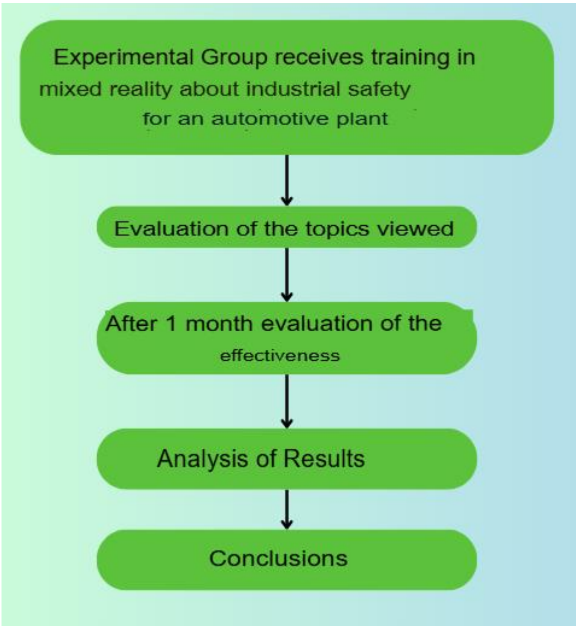

Fig.4 Steps Experimental Methodology to Evaluate Knowledge Retention in the Class Conducted in Mixed Reality on Industrial Safety

To evaluate the "Knowledge Retention Effectiveness" based on the 2 grades obtained by the users who received the training, the Knowledge Retention Index formula was used. (Knowledge Retention index.KRI)

The KRI formula is defined as: KRI = (P2/P1) * 100

Where:

P1 is the score obtained on the exam immediately after the training.

P2 is the score obtained on the same exam one month after its administration.

Once we have the KRI of each person, we will calculate the average KRI to obtain the final result.

To recruit the users who would be evaluated, we randomly invited them to try a mixed reality application and informed them that they would also undergo some evaluations. We did not mention what the application was or what the research was about to avoid biasing the results, and knowing that they would have an evaluation of the information they would be viewing would make them pay more attention to what would normally be done if they had a regular class, thus avoiding biasing the results and ensuring that the users' responses were as natural and comfortable as possible. They were later informed that they would receive another evaluation in a month for feedback, and it was also not mentioned that this evaluation would be the same one they would have to answer, to prevent them from studying or reviewing the topic moments before their response.

Results

A total of 95 people attended the mixed reality induction class on industrial safety, of which 86 responded to the first survey. After a month, the participants were contacted again, and 27 people responded, of which only 23 responses are valid since they answered both surveys, had never taken industrial safety training before, and answered all the evaluation questions. Some did not provide their names, so they could not be followed up, or in some cases, their names did not appear in the first survey.

From the valid responses, the results were analyzed using the KIR formula (Table 1).

Puntos 1ra evaluación	Puntos 2da Evaluación	KRI
100	95	95
100	100	100
100	100	100
100	90	90
100	100	100
100	100	100
100	100	100
100	100	100
94	94	100
100	100	100
100	100	100
100	100	100
100	100	100
100	100	100
100	94	94
100	100	100
100	100	100
100	100	100
100	100	100
100	100	100
89	94	105.6179775
100	100	100
100	100	100

Table 1. Results of the 2 evaluations and KRI obtained

After this, the average was calculated by summing all the results and dividing them by 23, resulting in a long-term retention percentage of 99.3% for mixed reality industrial safety training.

Conclusions

After the results, we can confirm that a mixed reality training practice for safety, where various inputs from the VAK learning model are integrated, improves long-term knowledge retention, making it viable for implementation compared to the 60%-67% retention of traditional training methods.

For future research, it is proposed to use practical knowledge of a process in the plant that is risky and could compromise the safety of the operator or the machine. I invite the experiment to be repeated but with more people in the control group to compare the results. Additionally, economically speaking, it is suggested to investigate the monetary benefit of using these technologies compared to traditional induction training methods. Also, for future research, a mixed reality application will be implemented that lasts longer and covers a topic that is not intuitive at all, and that most new workers or even experienced workers might have difficulty learning. Based on that, the information retention percentage will be analyzed in the same way and the results will be compared to gather more information on the information retention percentage of this technology in its various applications.

Mixed reality offers us multiple benefits when used to improve productivity in daily activities.

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