From Hammer to SCISSOR™

VR -the new face of effective training

Extended Reality Technology Suite for effective training and performance assessment of low-income blue-collar workers across dangerous and high-risk industries

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1 Overview

The objectives of this report are to summarize the work, results and findings of the 6-month long pilot conducted by Simulanis at GSK Sonepat, as part of which, simulation-oriented Augmented Reality (AR) and Virtual Reality (VR) technology was used to train, assess, and evaluate vulnerable and low-income workers performing high risk tasks while performing Log-out Tag-out (LOTO) operations.

Conventional methods to train workers are not effective to meet the rigours and demands of modern-day factories considering the high level of complexities involved in industrial operations. Moreover, training on such complex and dangerous industrial operations presents a high risk to life, which conventional methods fail to address effectively.

The aim of this project was to leverage AR and VR technologies and build software applications to train the workers in a safe environment and develop a platform which embedded deeper and exhaustive analytics within the AR and VR based training applications to comprehensively study, gauge, and track the learning, retention and development of workers as they handle complex and dangerous tasks while performing LOTO.

Through this project, we were successful in training batches of workers on complex and dangerous industrial operations safely using AR and VR technology which was proven to be effective in achieving the learning outcomes through an advanced 3-tiered cloud-based analytics suite layered on top of the AR and VR based training applications.

The results proved that by receiving training through AR and VR applications, 80% of the batches of workers achieved a reduction in errors committed over successive iterations of learning and training. A 56% reduction in the violation of safety protocols was observed post training using AR and VR applications, along with a 52% increment in cognitive skills instrumental in defining the hazard perception abilities of the workers. All workers were able to learn the operations in a completely 100% safe manner. We obtained insightful and meaningful data on the behaviour of workers and proved that intervention of AR and VR technologies for training positively impacted their confidence levels and motivated them to perform the complex and dangerous industrial tasks in a much-improved way.

2 Problems with conventional training methods: challenging the status quo

2.1 Categorizing conventional methods

The conventional methods used in manufacturing-based industries (such as pharmaceutical, automotive, oil and gas, automation, chemicals, paints, textiles, rubber, leather, power, utilities, and other allied industries to name a few) or in training institutes set up to train all types of workforces are either on-the-job or off-the-job.

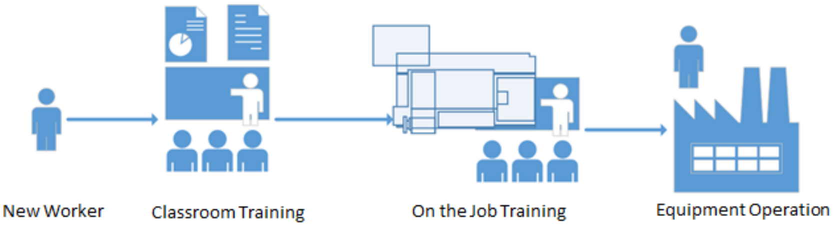


Figure 1: Conventional training flow

In an on-the-job mode (1), the following methods are often adopted:

Figure 2: Position / job rotation

Figure 3:Understudy method

Figure 4: Coaching Method

Figure 5: Job instruction training

Figure 6: Committee Assignment

Figure 7: Apprenticeship Training Method

Figure 8: Special Meetings

In the off-the-job mode (1), the following methods are often employed:

Figure 9: Vestibule Training

Figure 10: Lectures

Figure 11: Role-plays

Figure 12: Conferences and Seminars

Figure 13: Films and Slideshows

Figure 14: Programmed Instructions

Figure 15: Certificate Degree Courses

The choice of an appropriate conventional training method depends on a range of factors (1) such as the audience (white collar/blue collar), best-fit in terms of monetary budget based on a cost-benefit analysis, availability of infrastructure, hierarchical level of personnel or workers within companies and factories across industries, nature of the job, operation and tasks across industries, along with the skills and knowledge required to be gained through the training exercises.

2.2 Limitations of conventional methods

The above methods (both on-the-job and off-the-job) have been employed and implemented across industries to varying levels of success and a wide array of limitations have been cited (2), such as:

2.2.1 Most of the companies and factories do not have formal off-the-job training programs. Moreover, most of the conventional training material is based on Standard Operating Procedures (SOPs) or operating manuals, and due to the underlying text-based nature of the same, training methods are not hands-on and practical, thereby lacking engagement.

Figure 16: SOP based training

2.2.2 Conventional off-the-job training programs lack visualization and are mostly theoretical in nature. This directly affects learning, retention, and recall of technical subject matter, adding to the ineffectiveness of such methods.

2.2.3 Most of the industrial tasks and operations are dangerous and hazardous in nature which pose a grave risk to life, hence making it difficult to impart conventional on-the-job training on those tasks and operations.

Figure 17: Hazardous industrial operations

2.2.4 In many cases, the equipment or process on which the conventional on-the-job training has to be imparted may be inaccessible due to site shut-downs or periodic maintenance, thereby hampering the training activities.

2.2.5 Effectiveness of conventional physical instructor-led delivery of content for off-the-job training is subject to the abilities and competencies of the instructors. Furthermore, effective dissemination of knowledge from the instructors to the workers can be directly attributed to the motivation and experience of the trainers, and due to such factors, it becomes difficult to standardize or homogenize the delivery of training, thereby impeding the overall quality.

2.2.6 Conventional on-the-job training within the factory premises may require lengthy discussions and interactions between the trainer (or supervisor in most cases) and the workers which leads to long downtimes and high idle times for the manufacturing equipment and resources respectively. This trade-off situation presents a challenge to scale the entire activity due to the high operational cost-burden to the factory. Furthermore, during such training sessions, if the equipment gets subjected to damages, the incremental capital cost of repair adds to the burgeoning costs. To further factor-in, if the worker gets injured during training, the costs surmount leading to legal troubles, bad-press and negative social image for the factory, inhibiting their intentions to train the workers on-the-job.

2.2.7 Most of the conventional training methods fail to meet the rigorous demands from the industry and other strict regulations. Hence, a large segment of the worker population does not receive training in any form.

2.2.8 As highlighted in one of the points above, the infrastructural (multiple equipment purchases, training classrooms, furniture, etc.) and operational (instructor salaries) costs of delivering training using conventional methods can be high and hence, factories and training institutes require investments to be made in order to implement the training programs. Due to the complex nature of industrial tasks and operations, coupled with challenges to quantitatively measure and analyse the performance of workers post training, it becomes extremely difficult to measure the return on investment (RoI).

Consequently, in many cases, due to the high infrastructural and operational costs of delivering training using conventional methods, many factories and training institutes do not invest in any form (viz. physical off-the-job trainer-led, equipment-based on-the-job, etc.) at all.

"Our main objective throughout the pilot was to replace the *sage-on-the-stage* lecture style, a typical feature of the traditional and conventional learning model. Here an SME or instructor conducts the training session. They deliver a lecture to the employees with a PowerPoint presentation running behind. The trainer probably didn't learn all that he knows today by just listening to classroom lectures; he learned more on the job, experiencing it himself. Yet here he is today, trying to hammer jargons, concepts, definitions, and numbers in the heads of the (reluctant) learners. As for the learners, they are just going through the motions. They are staring at the sage on the stage and nodding their heads occasionally, but they are bored, confused, and unfocused. Worse, they will forget what they have listened and nodded to as soon as they step out of the classroom. These learnings are followed by a paper-based questionnaire assessment, where the Workers are asked to fill them out based on the knowledge they gained during the session, which leads cheating among Workers just to fill the answers to get the passing percentage.

Also, the demands of a fast-paced economy have made workers restless; they want to learn as many skills as are relevant to their jobs, and they want to do this fast and in the most convenient way. They demand flexibility, a feature that the traditional learning model, with its emphasis on face-to-face training sessions, lacks.

Thus, pen and paper processes ensure little visibility, accountability and engagement, making it impossible to spot trends in time to prevent injury or enhance efficiency.

Lastly, even great content fails to make a mark on the minds of the audience if it is too long or boring. Unfortunately, many companies and factories go to great lengths to create exactly such content. They erroneously think that the more content they cover in an instructor-led training session, the more productive it will be.

The result: bored learners don't learn much, or whatever little they learn, they will forget soon.

"

2.3 The plight of vulnerable workers in India: causes

The limitations of conventional on-the-job and off-the-job training methods detailed earlier are compounded particularly in situations of imparting training to vulnerable (read: young, uneducated, poor, illiterate and less experienced), blue-collar (3) and low-income workers. The underlying causes of these issues include the following:

2.3.1. In India, vulnerable workers are often employed by contractors and sub-contractors hired by corporations across the industries to perform the operations and manufacturing activities. As a result, they are not treated at par when it comes to their training due to the high costs, viewed upon as 'sunk' costs by corporations, of providing infrastructure for such training.

2.3.2. The vast size and scale of India (7th largest in terms of area and 2nd largest in terms of population) presents an enormous challenge to conduct training in remote areas where the population of vulnerable low-income and unskilled workers is dense and access to resources to conduct conventional training is extremely limited.

2.3.3. Lack of a proper training system and quality trainers to deliver hands-on and practical training on dangerous industrial operations especially tailored for vulnerable, blue-collar and low-income workers is one of the primary causes why conventional methods fail in their effectiveness.

Figure 18: Lack of a proper training

2.3.4. Illiteracy (rate of 26% across India) and the inability to read / write / comprehend languages are some of the major impediments in training poor workers on dangerous operations using conventional methods, and educating them on the hazards to their health, safety and wellbeing. Uninspiring, unengaging, non-retentive, and theoretical conventional training methods (viz. SOPs, operating manuals, etc.) further compound the problems of workers not being able to grasp the relevant expertise required to perform complex and dangerous industrial operations.

"Census data released said at least 55.5 million workers in India do not get employment for even six months a year and a big chunk of them are illiterate.

The census data on workers and their educational levels goes on to reveal that a lion's share of the total Indian workforce is either illiterate or educated up to the secondary level, indicating its poor level of competence.

Of the workers who get less than six months' employment, called marginal workers, nearly 40% are illiterate. And, of the 362.6 million workers who are employed for more than six months a year, called main workers, 104 million are illiterate.

"Census 2011 has shown that out of about 55.5 million marginal workers seeking/available for work in India, 21.9 million are illiterate, followed by 20.9 million (37.6%) who have studied below secondary level," the data released by the Registrar General and Census Commissioner of India underlined. The rest are matriculates or above.

Among the 60.7 million "non-workers seeking work in India", 33.6% are literate, having studied up to matriculation level, followed by 31.1% who have received education between secondary and below graduation levels. Some 17.2% of these non-workers are illiterate.

Of the 362.6 million main workers, 130.2 million (35.9%) are literate but have studied below the secondary level. Besides, 71.5 million (19.7%) have studied between matriculation and undergraduate levels. " (4)

2.3.5. Lack of motivation coupled with the monotonous nature of tasks increases the chances and risk of workers to get harmed whilst inattentively performing the dangerous industrial operations viz. hazardous material handling, working with hot surfaces, moving machine parts, working at heights, etc.

Figure 19: Ineffective training

2.3.6. Lack of an updated factory's act (created in 1948) to encapsulate latest trends in machinery, operations and practices, coupled with a lackadaisical enforcement of health and safety-oriented labour laws stipulated by the government at the ground-level are some of the other causes why conventional methods fail in their effectiveness to train vulnerable blue-collar workers.

2.3.7. Difficulty to track learners' abilities especially because the target audience is not literate enough is another reason why conventional method fail in their overall effectiveness to train vulnerable blue-collar workers.

2.4 Consequences of ineffective training

As highlighted above, owing to the dangerous nature of industrial tasks and operations, in most circumstances it becomes practically difficult to deliver training which benefits the workers through conventional methods.

Subsequently, the lack of proper training becomes one of the predominant factors which contributes to "risky" worker behaviour [1]. Workers who are not trained properly as per the required standards lack the cognitive ability to evaluate potential hazards and risks, which increases the probability of occurrence of dangerous incidents and ultimately lead to an unsafe work environment.

Young, uneducated, poor, illiterate and less experienced workers in the industries usually do not read the operating or safety instructions carefully and as a result, do not perform the related activities that require special care and caution. The well-experienced workers, on the other hand, often become overly self-confident and then do not strictly follow the safety instructions, relying on their inherent skills. The monotonicity of the job causes a decrease in concentration when the same operations have to be performed multiple times, thereby, increasing the possibilities of accidents [2].

Figure 20: Lack of focus while training

Figure 23: Jaipur fuel depot fire (8), (9), (10)

According to an article [4], the fatality and accident rates in Other Asia and Islands (OIA) which excludes India and China are 21.5 and 16,434 per 100,000 workers respectively, and Sub-Saharan Africa (21 and 16,012 per 100,000 workers respectively), which consist mainly of developing countries, are much higher than that of Established Market Economies (4.2 and 3240 per 100 000 workers), which consists of developed countries. Though not implicit, through such statistics, an inference pertinent to India can be drawn that the lack of effective training including a rigorous health and safety training across industries is one of the main causes leading to accidents.

Bhopal gas tragedy, termed as the world's worst industrial disaster, over 15,000 people were killed after methyl isocyanate leaked on the intervening night of December 2-3, 1984 from the pesticide plant of Union Carbide India Limited (UCIL) in the city. More than five lakh people were affected due to the toxic leak
Thirty-four years after the Bhopal gas tragedy, survivors continue to demand proper rehabilitation and adequate compensation besides proper medical treatment for ailments caused by the toxic leak.

Figure 22: Bhopal Gas Tragedy (5), (6), (7)

In fact, when a devastating fire broke out in IOCL's fuel depot in Jaipur in October 2012, an independent expert committee set up by the Ministry of Petroleum and Natural Gas Government of India, blamed a lack of safety procedures and human error which ultimately led to the death of 12 people and injury to over 200. The fire was classed as a major incident with an unprecedented in terms of deaths, injury, loss of business, property and man-days, displacement of people, environmental impact in Jaipur (17).

In April 2010, the locality of Mayapuri was affected by a serious radiological accident. An AECL Gamma cell 220 research irradiator owned by Delhi University since 1968, but unused since 1985, was sold at auction to a scrap metal dealer in Mayapuri on February 26, 2010. The orphan source arrived at a scrap yard in Mayapuri during March, where it was dismantled by vulnerable workers unaware of the hazardous nature of the device. This event subsequently caused the most severe radiation accident reported in India to date, resulting in seven radiation injuries and one death (11).

In general, industrial safety remains a pressing concern in India where 1,660 people died in factory or machine-related accidents between 2013 and 2016, according to an article from DNA. An additional 4,045 people reportedly received fatal injuries in Indian factories during the same time period.

These statistics and incidents severely highlight the need for a revolutionary and a more effective method of imparting training to vulnerable workers. This project is an attempt in this direction (12).

3 Solution to challenges: Augmented Reality (AR) and Virtual Reality (VR) Technologies

The ineffectiveness of existing conventional (on-the-job and off-the-job) methods to train vulnerable workers, Augmented Reality (AR) and Virtual Reality (VR) technologies are novel and cutting-edge methods to address these challenges.

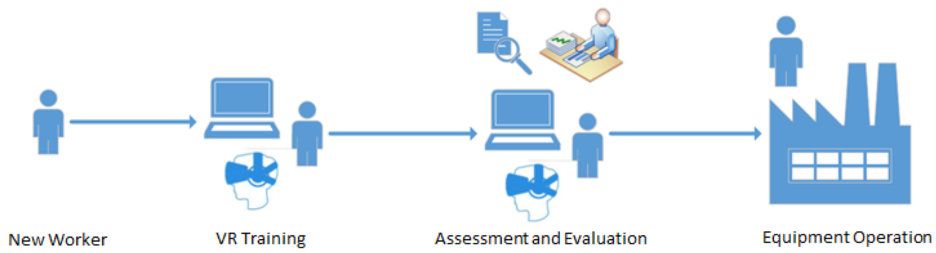


Figure 24: VR training flow

3.1 Technology Summary

Augmented, Virtual and Mixed Reality fall under the same family of immersive technologies which can have a remarkable effect to alter our perceptions and enhance our visualization capabilities. While AR and MR adds overlays of information on our existing reality, VR on the other hand leaves us blind to our surroundings and transposes us to a different—simulated—world all together. While the ultimate objective of VR is true immersion, the value of it is a more intuitive way to interact with the digital world.

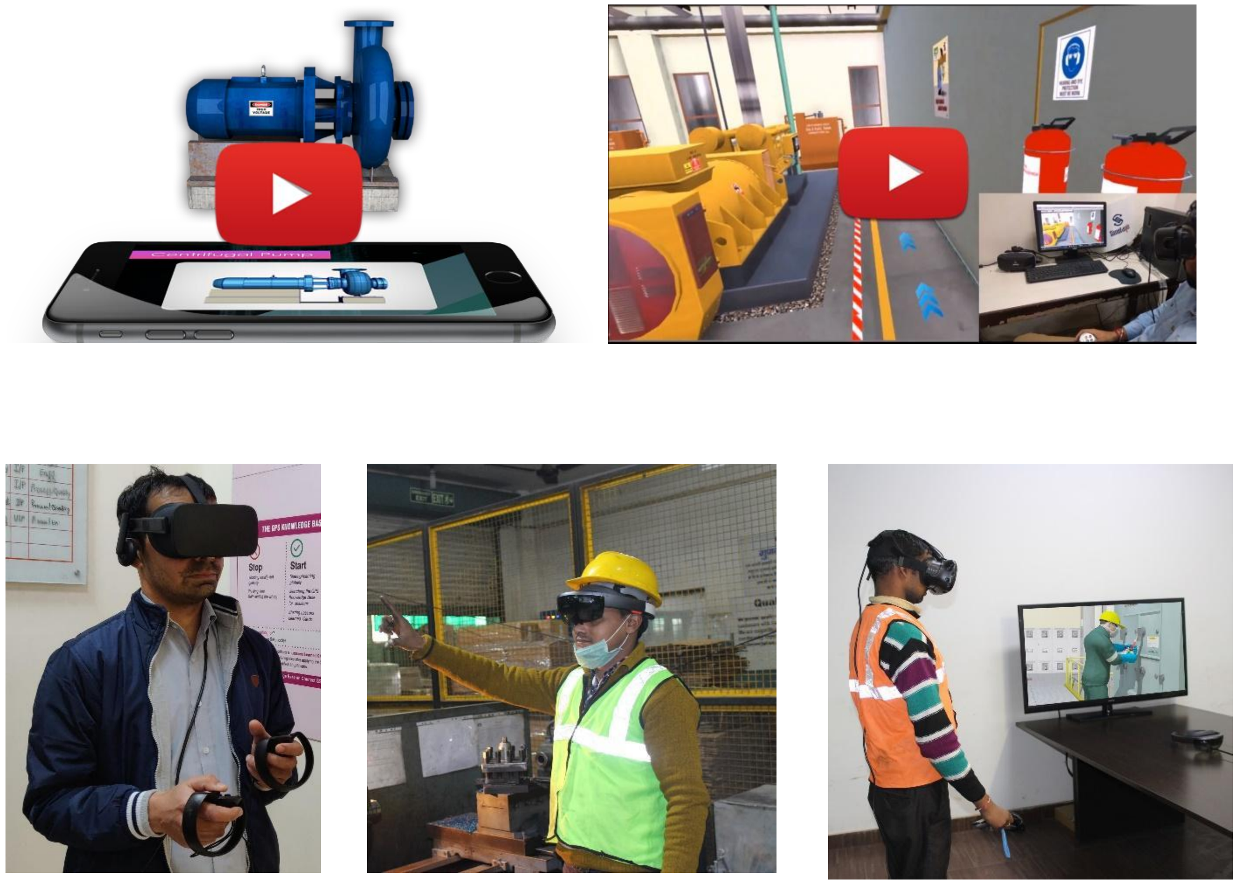


Figure 28: AR-VR technologies

3.2 Need for AR and VR technologies for training

The key issues in the manufacturing sector are that the technology landscape has evolved and employers are looking for multi-skilled employees who can perform various tasks.

The acquisition of skill requires practice. Merely repeating a task alone, however, does not ensure the acquisition of a skill. Skill acquisition is achieved when an observed behaviour has changed due to experience or practice. This is known as learning and is not directly observable.[8] The information processing model, which incorporates this idea of experience, proposes that skills develop from the interaction of four components central to information processing.[8] These components include: processing speed, the rate at which information is processed in our processing system; breadth of declarative knowledge, the size of an individual's factual information store; breadth of procedural skill, the ability to perform the actual skill; and processing capacity, synonymous with working memory. The processing capacity is of importance to procedural memory because through the process of proceduralization an individual stores procedural memory. This improves skill usage by linking environmental cues with appropriate responses.

Since the majority of the employees in the manufacturing sector are blue collared workers, many of them have a low literacy level which can make teaching complex tasks, concepts and skills a challenge for organizations. In particular, training such workers on health, safety and regulatory compliance a major challenge that organizations often face. The traditional classroom training programs and Instructor-Led Training (ILT) can become lengthy, expensive and resource intensive. Furthermore, many of these training programs lack the level of engagement necessary for effective training to take place. Due to the workers operating under hazardous manufacturing conditions, in-effective training and neglecting HSE compliance can lead to fatal and catastrophic accidents.

It is therefore vital for a different approach to training, one that is more engaging, safe and simple enough for blue collared workers to comprehend, understand and implement.

3.3 What makes AR and VR technologies "effective" in training?

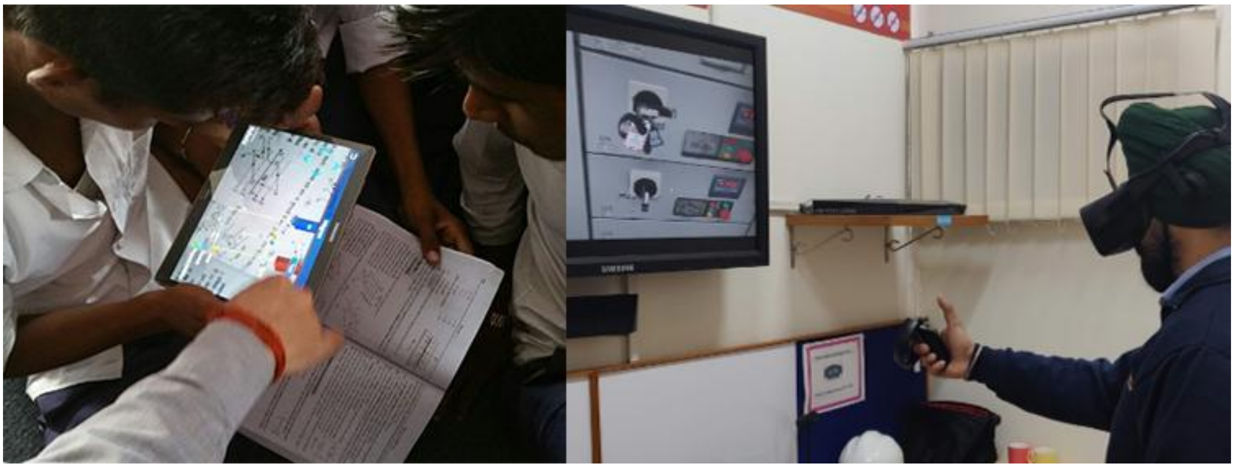


Figure 29: Immersive learning in AR-VR

"Virtual reality has unlimited possibilities. We're looking at every opportunity we can right now. You can train people faster, and people learn faster in a VR environment"

- Laura Collings, training manager at UPS (13)

VR technologies have proven to be a game-changer to address the problems discussed in the above section. The section below summarizes the advantages of adopting AR-VR technologies for industrial training:

- **Engagement**: Engagement is a critical factor in learning and training outcomes, conventional training methods which lack engagement are often ones which are least effective. VR experiences which are both immersive and interactive, boost engagement levels which turn have a positive impact on the effectiveness of training.

- **Cuts down access barriers:** VR cuts down access barriers by having the capability of exposing individuals to experiences which they otherwise can't access due to financial, geographical or resource constraints.

- **Accelerated learning:** Because VR is so immersive and compelling, learners absorb information faster and retain what they have learned longer. Memory formation is linked to emotional response, and VR is an emotionally charged experience. A study by Sowndararajan found that an immersive VR system can help in better procedural learning because of the following reasons:
    1. Visual imagery helps memory.
    2. Spatial encoding helps memory.
    3. Use of proprioception helps spatial understanding

Sowndararajan concluded that for a procedural learning purpose, "every step in the procedure could be remembered better with a VR system that possesses higher levels of immersion." (14)

- **Learn by doing:** The immersive nature of Virtual Reality enables a practical or experiential learning to take place. Workers are encouraged to actually perform the task instead of plainly reading and memorizing them from a textual or verbal source. This has been widely known to be one of the most effective methods of improving worker understanding.

- **Practice makes perfect:** The replay ability factor thereby allows users to practice a training module multiple times and sharpen their skills at their convenience. It hence better prepares the user by increasing the workers' confidence in operating hazardous equipment and reducing the risk of accidents – viz. harm to human life and damage to equipment

- **Safely explore unsafe consequences:** Because all training is virtual, workers can take risks they usually wouldn't take; or pursue creative, high-risk solutions to problems. It allows workers to learn and practice their operating procedures in a completely safe virtual environment before they try their hands on the real operations.

- **Previewing:** VR technology allows workers to perform test runs of new initiatives to see how employees respond.

> Research is showing that VR can be a powerful tool for impacting people's perceptions and actions in the real world.
>
> **STEPHANIE MOFFET**
> Spokesperson
> FEMA

3.4 Taking AR and VR based training to the next level

It is important to note that simply building interactive and immersive AR and VR applications is not enough to address the challenges as cited in the earlier sections.

For vulnerable workers, who find it difficult to read or write, it is challenging to track their assessment. It is therefore necessary to build an exhaustive, deep set of analytics to measure and evaluate the performance of workers as they get trained on VR.

The incorporation of analytics into the modules will help in keeping a track of various important metrics (viz. eye tracking, session time, number of errors committed, etc.) which will in return help in analysing a worker (the overall performance of a worker, the parts of a module where a worker faces an issue and the number of times a worker commits an error) without compromising on safety. Additionally, Workers receive valuable information on their physiological processes such as variations in their heart rate and brain waves which provide an insight on how the body responds to the training process. On the other hand, the measurement of psychometric data such as cognitive (memory, visuospatial abilities, attention and retention), behavioural and personality traits will increase the trainer and Worker awareness to help improve over subsequent iterations.

VR allows organisations to create scenarios in which employees are given the freedom to make mistakes and learn from them. In most enterprise learning environments, experiential learning is often the most difficult to deliver, yet it often has the biggest impact. Learners can see how they'll react in stressful situations and identify performance gaps that are standing in their way. In essence, they can gain valuable online training experience and prepare for every eventuality before they enter the workplace.

4 Introducing Simulanis

Figure 30: Journey of Simulanis

To address the challenges posed by ineffective conventional methods of training to train vulnerable workers as cited earlier, Simulanis was conceptualized and started in November 2013, with a mission to bring about effective change and improvement in the existing methods of training.

The period between 2013 and 2015 was marked by a string of pilots across industries and sectors to test the demand from the market for AR-VR technologies, and the journey can be seen from the pictures below.

In 2014, we delivered training courses directly to workers following a hybrid model in which we physically delivered the training coupled with AR-VR products. By 2016, we eventually pivoted to delivering a completely AR-VR product-based offering, and this is the core domain in which we are involved since then.

We help transform skill development and training institutes equipping them AR-VR based product solutions viz. hardware and software, because we firmly believe that only a technology as cutting-edge as AR-VR which has the potential to scale, can surmount a challenge to address the Skill India mission of training 400m people by 2022.

We have pioneered the way forward in the country to build AR-VR systems tailored for training and have been recognized by the Ministry of Skill Development for our work and gained recognition at India's most prestigious social impact forum – the Sankalp forum. This came on the back of some ground-breaking work done within the skilling ecosystem and proving the effectiveness of VR to train vulnerable low-income workers.

Figure 31: Simulanis wins NEAS 2017 in Education Category

Figure 32: Simulanis wins the Sankalp award for social impact

"We can confidently proclaim that we have proved through an elaborate quantitative metric-driven analytics system that AR-VR technologies are effective in addressing the skilling challenge at scale."

5 Setting the context for the project

Figure 33: Identifying the critical process for the pilot

5.1 Selecting the geographies of focus

In order to address the challenges of training vulnerable blue-collar workers on industrial tasks and operations, for the pilot project, other than areas around our headquarter office in the National Capital Region (Delhi-NCR), we focussed on specific geographies where the manufacturing activities were dense: typically, in the west Indian states of Gujarat and Maharashtra, the two states contributing the maximum to India's GDP and together employing 36% people in manufacturing across the country with a share of 56% of all reported fatal and non-fatal incidents (2011 Labour Bureau Data). Next in-line, south Indian states of Andhra Pradesh and Tamil Nadu were focussed at, which came next in terms of contributing towards GDP and jointly employed 29% people in manufacturing across the country with a share of 18% of all reported fatal and non-fatal incidents (2011 Labour Bureau Data) (15).

Figure 34: Most accident-prone geographical areas in India

The industries in the regions describe above typically expose the workers to dangerous environments owing to the inherent nature of operations involved viz. exposure to hot surfaces, unguarded machinery, flammable substances and extremely high-decibel noise, working at heights leading to trips and falls, handling substances hazardous to health such as chemicals, fumes, and dusts. On the back of these demographics, these regions were the core focus for this pilot project.

5.2 Selecting the key industrial task and operation

Post selection of the key geographies of focus based on manufacturing activity and nature of dangerous tasks, selecting appropriate industrial tasks and operations was critical in order to validate the overall success of the analytics suite we had envisaged.

We wanted to select operations which (were):

5.2.1. Standard across all core industries viz. pharmaceutical, FMCG, chemicals, power, oil and gas, automotive, and automation to name a few.
5.2.2. Had a high element of danger or risk accompanying them.
5.2.3. Had a high proportion of vulnerable blue-collar workers operating them.
5.2.4. Had a high degree of manual intervention where any error in the operating sequence could have led to catastrophic consequences.
5.2.5. Required a moderate-to-high level of cognitive and motor skills for the retention of technical subject matter which could be applied to perform the complex operation.

Considering all the factors highlighted above, after brainstorming internally and externally with key stakeholders (viz. workers, factory-owners, industry experts, and senior technical subject matter experts), among a host of industrial tasks and operations, for the pilot project, **we decided to base our work around the Lock-Out-Tag-Out or LOTO procedure being conducted at GSK Sonepat site with whom we partnered for the pilot project.**

LOCKOUT/ TAGOUT

STANDARD: 1910.147

TOTAL VIOLATIONS: 2,923

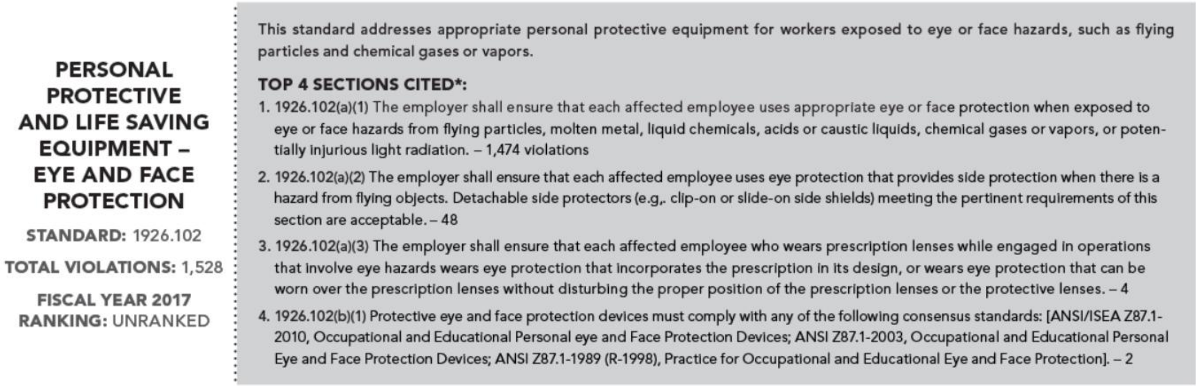
FISCAL YEAR 2017 RANKING: NO. 5 (3,131 VIOLATIONS)

This standard outlines minimum performance requirements for the control of hazardous energy during servicing and maintenance of machines and equipment.

TOP 5 SECTIONS CITED:

1. **1910.147(c)(4)(i)** Procedures shall be developed, documented and utilized for the control of potentially hazardous energy when employees are engaged in the activities covered by this section. – 587 violations
2. **1910.147(c)(6)(i)** The employer shall conduct a periodic inspection of the energy control procedure at least annually to ensure that the procedure and the requirements of this standard are being followed. – 342
3. **1910.147(c)(1)** The employer shall establish a program consisting of energy control procedures, employee training and periodic inspections to ensure that before any employee performs any servicing or maintenance on a machine or equipment where the unexpected energizing, startup or release of stored energy could occur and cause injury, the machine or equipment shall be isolated from the energy source and rendered inoperative. – 332
4. **1910.147(c)(7)(i)** The employer shall provide training to ensure that the purpose and function of the energy control program are understood by employees and that the knowledge and skills required for the safe application, usage, and removal of the energy controls are acquired by employees. – 262
5. **1910.147(d)** Affected employees shall be notified by the employer or authorized employee of the application and removal of lockout devices or tagout devices. Notification shall be given before the controls are applied, and after they are removed from the machine or equipment. – 179

Figure 35: LOTO ranked as 5th amongst the most cited violations (16)



PERSONAL PROTECTIVE AND LIFE SAVING EQUIPMENT – EYE AND FACE PROTECTION

STANDARD: 1926.102

TOTAL VIOLATIONS: 1,528

FISCAL YEAR 2017 RANKING: UNRANKED

This standard addresses appropriate personal protective equipment for workers exposed to eye or face hazards, such as flying particles and chemical gases or vapors.

TOP 4 SECTIONS CITED*:

1. 1926.102(a)(1) The employer shall ensure that each affected employee uses appropriate eye or face protection when exposed to eye or face hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation. – 1,474 violations
2. 1926.102(a)(2) The employer shall ensure that each affected employee uses eye protection that provides side protection when there is a hazard from flying objects. Detachable side protectors (e.g,. clip-on or slide-on side shields) meeting the pertinent requirements of this section are acceptable. – 48
3. 1926.102(a)(3) The employer shall ensure that each affected employee who wears prescription lenses while engaged in operations that involve eye hazards wears eye protection that incorporates the prescription in its design, or wears eye protection that can be worn over the prescription lenses without disturbing the proper position of the prescription lenses or the protective lenses. – 4
4. 1926.102(b)(1) Protective eye and face protection devices must comply with any of the following consensus standards: [ANSI/ISEA Z87.1-2010, Occupational and Educational Personal eye and Face Protection Devices; ANSI Z87.1-2003, Occupational and Educational Personal Eye and Face Protection Devices; ANSI Z87.1-1989 (R-1998), Practice for Occupational and Educational Eye and Face Protection]. – 2

Figure 36: PPE violations ranked as 10th amongst the most cited violations (16)

The lock and tag not only create a barrier to prohibit usage, but also create awareness to employees so they know not to use or go near the machinery or equipment on LOTO.

6 Project Phase 1

6.1 Understanding the industrial operation

Figure 37: Understanding the LOTO procedure

Lock-out tag-out or simply LOTO is a safety procedure that protects employees and visitors from uncontrolled *hazardous energy* that may escape from machines or equipment during isolation or maintenance. The different types of energies associated with LOTO are electrical, pneumatic, thermal, radiation, magnetic and chemical. LOTO is an integral activity for any industrial operation, and it is paramount to never underestimate the risks involved with machines or the hazardous energies they emit.

When a potentially hazardous equipment is identified for maintenance, LOTO is performed on it and this procedure involves adding a visual lock and tag to the energy isolation points. The lock and tag not only create a barrier to prohibit usage, but also create awareness to workers so that they don't go near the near the machinery or equipment assigned on LOTO.

The consequences of committing an error whilst performing LOTO can have grave consequences on not only the workers who are directly involved in the operation but others who are working elsewhere in the factory, such as death due to electrocution and risks of fire or explosion in the plant.

Figure 38: Consequences of committing an error while performing LOTO (17)

6.2 Commencing with on-site activities

The project activities on-site commenced with gathering the pre-requisite data needed to build the corresponding VR application and the 3-tiered Analytics suite for the same.

Figure 39: Our team on site for data gathering

The data gathering phase saw our team of engineers, designers and data scientists capture the LOTO activity in-person being applied to a machine at the GSK Sonepat site. This required multiple visits to the site as the quantum of data required to be collected was large and owing to its indispensable requirement for building the VR application and the Analytics suite, it was vitally important to ensure it was collected correctly and responsibly.

Figure 40: On site for data gathering

Crediting the subject matter expertise of our engineering team, we understood the process in detail and constructed the entire script and storyboard of the VR application.

The expertise of the design team came to the fore as they captured the necessary data needed to replicate the real environment in VR with the purpose of ensuring a better memory recall for workers who would eventually play the module built as part of the application.

Figure 41: 3D Rendition of the environment

Our data science team captured the key data points of the procedure by closely studying the operation as it was done routinely in real-life by the experienced and well-trained workers on-site and compared it with the standard operating procedure put in place by the factory. This comparative study helped us to understand the anatomy of the *errors* and *deviations* which emanated from worker behaviour, attitude towards safety and knowledge of the risks and dangers involved in the activity being performed by the workers. It was important to record these errors meticulously as they would form the basis to build the Analytics suite layered within the corresponding VR application.

Figure 42: Our data science team capturing the key data points

6.3 The work in-house

Post the data gathering stages, the action shifted in-house where the engineering teams worked with the design teams to create the VR environments using the inputs collected from the on-site visits.

Figure 43: Brainstorming sessions of design team

The engineering, data science and design teams worked together to create the architecture of the VR application which was handed over to the technology development team.

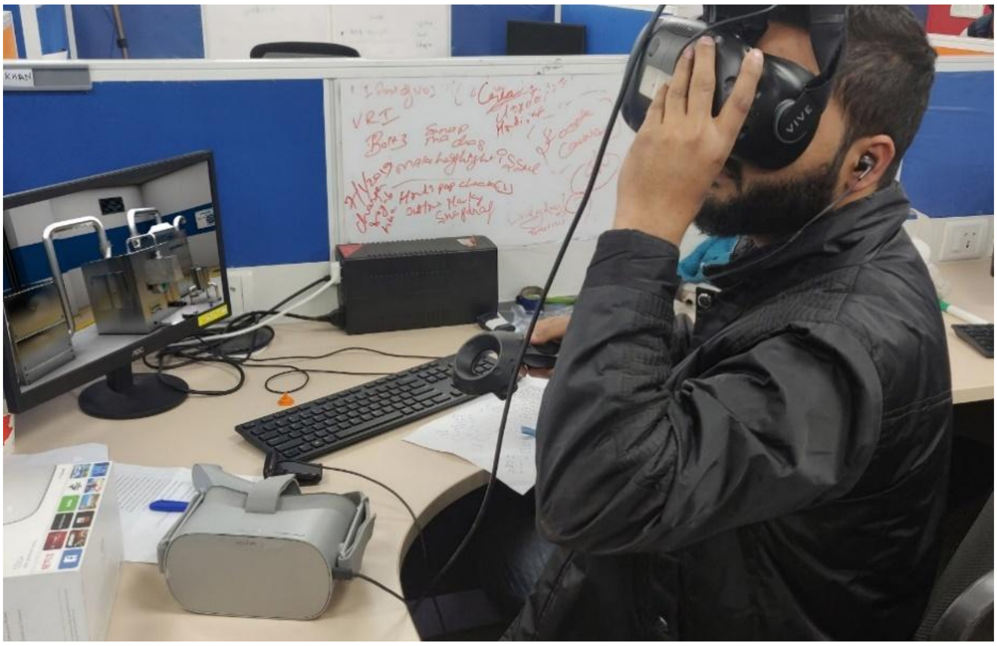


Figure 44: Development phase

The bulk and 'heart' of the entire project was the technology powering the pilot project: coding to build VR using popular game engines along with back-end and front-end dashboard development. As an innovative technology intervention and value-add to the pilot, we integrated wearable devices with the Analytics dashboard to comprehensively study the contribution of physiological aspects towards worker behaviour.

At this stage, the beta versions of the application and analytics were built and were made ready to be tested.

7 Phase 2

7.1 Testing the VR in beta

Building VR environments replicating the real-world of plants and machinery in the factories required testing from the workers to validate our hypothesis for memory recall, and an important step before finalizing the development of the VR application.

The VR application was tested at the GSK Sonepat site with the workers and their feedback along with inputs from the site stakeholders was taken to improve the final product.

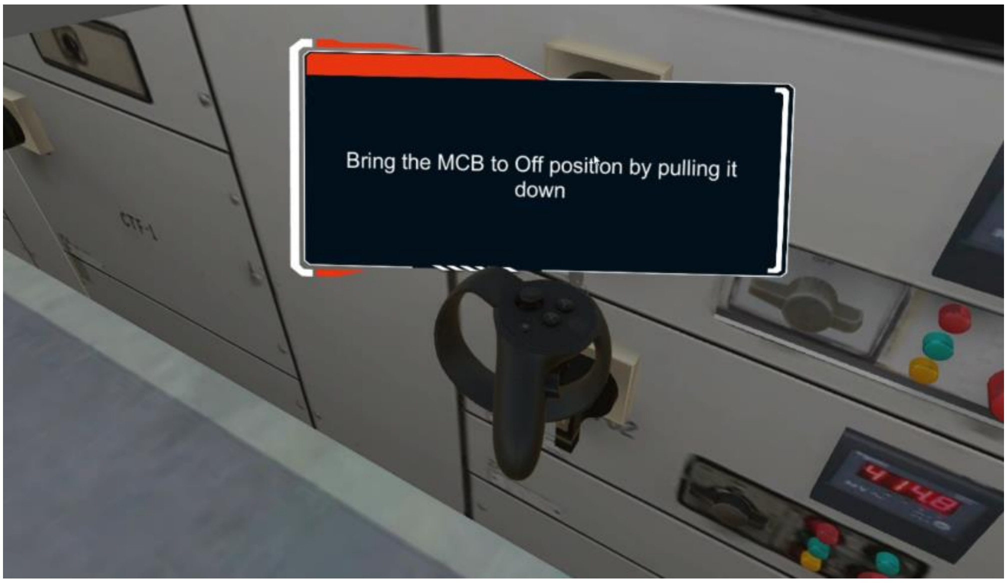


Figure 45: Beta testing of the module

7.2 Setting-up the experiment to test the Analytics engine

We employed a split A/B methodology to test the Analytics engine integrated with the VR application by taking a sample population of a set of workers and subjected one batch to training in VR and the other to training through conventional on-the-job and off-the-job training methods.

Workers subjected to training in VR were exposed to the virtual environment which mimicked and replicated the real-world. The application (read: module) was immersive and simulated the entire LOTO operation taking place on a virtual shop-floor.

To test the technical understanding of the workers, tests and assessments related to the LOTO operation were interspersed within the VR module. Cognitive, psychometric, and behavioural tests were an integral part of the overall testing and evaluation of retention and on-the-job application skills of the workers, and a series of tests in VR were built to analyse worker performance on these parameters.

Workers subjected to training through conventional methods of classroom training through presentations and instructor-led on-the-job training were tested via paper-based assessments and questionnaires taken in a timed manner under invigilation and supervision.

Figure 46: Conventional training v/s VR training

8 Phase 3

8.1 Deploying the final product

Post the phase of testing and gathering valuable feedback and insights from the experiments conducted on-site, the final product was deployed within the factory and made accessible for the workers to get trained in VR. At this stage, we sought views from the entire stakeholder chain and based on their resoundingly positive feedback, we got immense confidence that we were on the right path to succeed in meeting the targets of the pilot.

Figure 47: Final deployment by our team

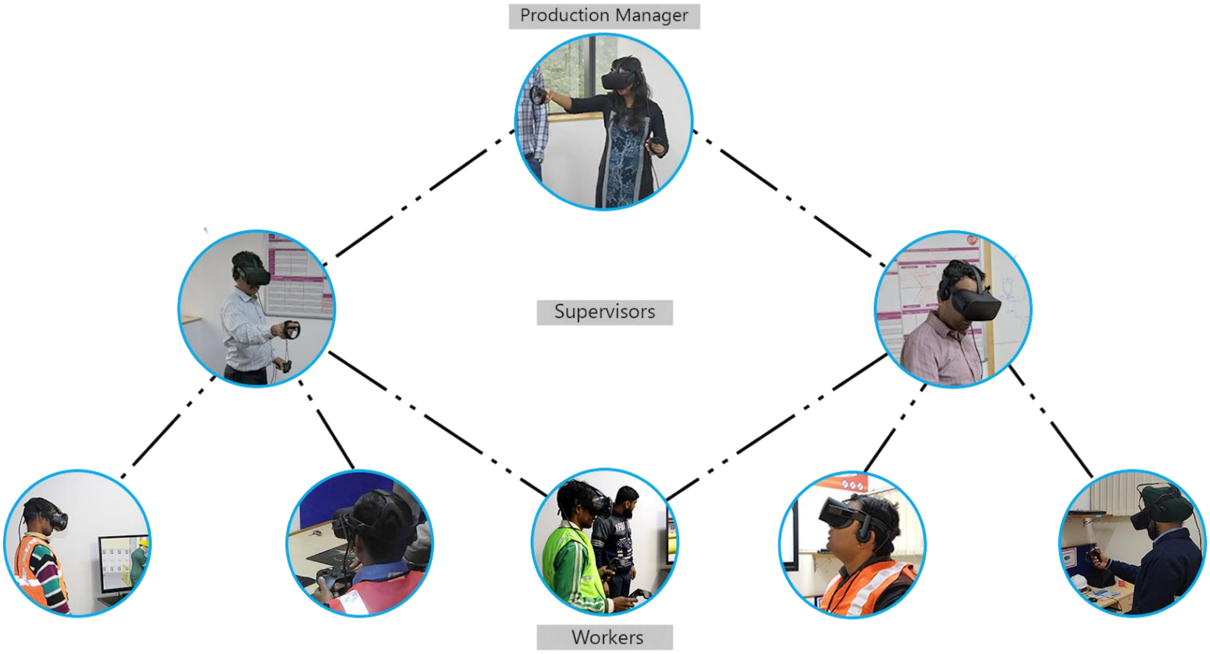


Figure 48: A training mechanism acknowledge by the entire GSK site

8.2 Results and findings

In summary, the overall results of the pilot successfully proved and validated the hypothesis that VR based training was more effective and better suited than conventional training methods to train vulnerable, low-income and blue-collar workers, as qualitatively:

- The workers who were trained in VR on the operations (on LOTO) performed better in assessments and tests conducted post training as compared to those who got trained and assessed on the operations (on LOTO) through conventional methods of training.
- The workers were trained faster in VR to perform the operations (on LOTO) as compared to those who got trained through conventional methods of training.
- The workers trained on VR committed fewer violations of safety protocols whilst performing the operations (on LOTO) as compared to those who got trained through conventional methods of training.
- Training workers in VR led to an increased rate of retention and attention amongst them as well as improved their visual awareness.
- Training workers in VR led to improvements in positive emotions and reductions in negative emotions as they performed the operations (on LOTO).

These results were supported by a unanimous vocal feedback [video interview link here from workers] as they claimed that due to the immersive nature of the VR training which replicated the entire operating procedure and allowed them to interact with the machines and process equipment in VR, "they could easily remember and recall the operating procedure of the industrial task (LOTO in this case) with far more ease" post VR training and visually analysing their own performance through the Analytics dashboard. Furthermore, the workers were impressed by the fact that they were able to learn and get trained on the industrial task without exposing themselves to risks or dangers to their lives.

A quantitative and an account of the results and findings has been detailed below:

8.2.1. The average score of the performance of workers who were trained on VR in assessments and tests conducted post training was 75% as compared to an average score of 52% achieved by those who were trained using conventional methods. The improvement in scores obtained by the workers who received training in VR (on LOTO) can be directly attributed to their improvement (trend below) in performing the industrial operation (LOTO) whilst getting trained in VR (on LOTO) as there was an 87.5% average reduction in the number of operational errors committed whilst performing the operation (LOTO) over the course of training in VR (on LOTO).

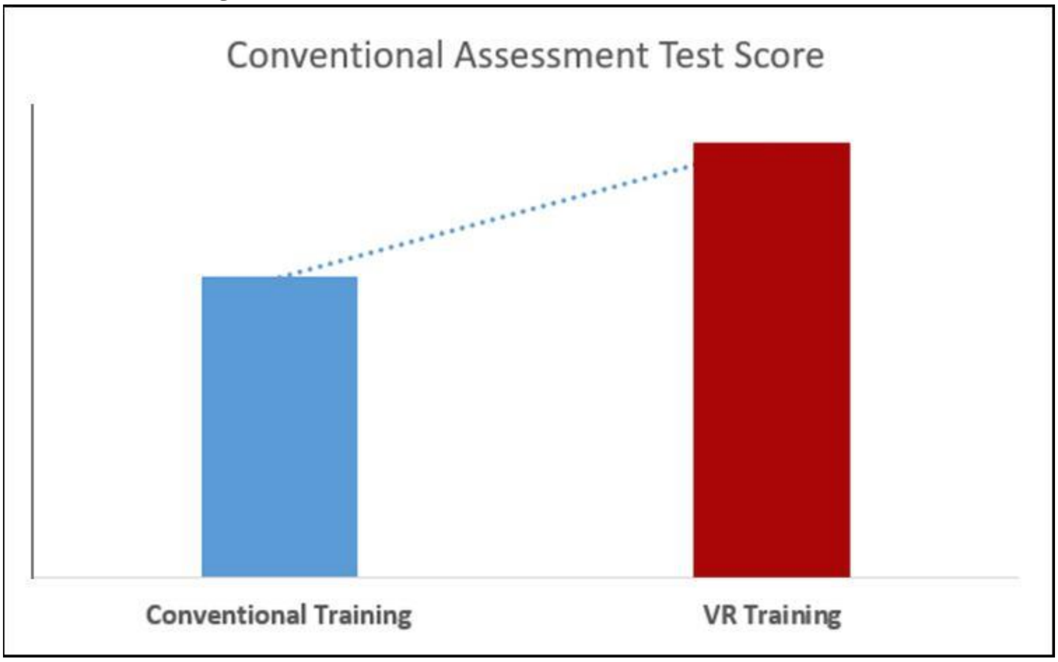


Figure 49: Results revealing effectiveness of VR based training over conventional training

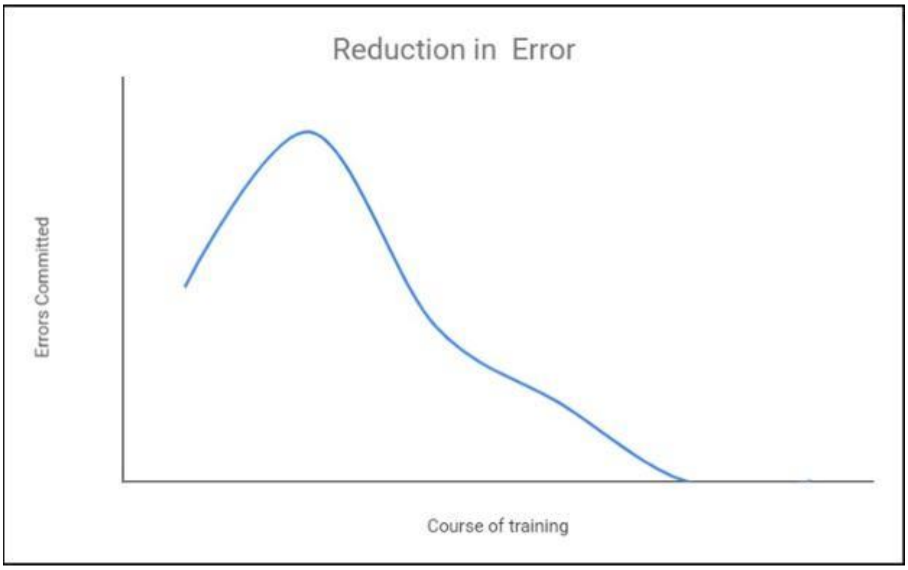


Figure 50: A graph from the dashboard depicting reduction in error within VR

8.2.2. The violations of safety protocols, critical to health, committed by workers whilst training within VR were reduced by 56% over the course of training in VR (on LOTO).

8.2.3. The time taken by the workers to complete the industrial operation (LOTO) in VR was reduced by 17% over the course of training in VR (on LOTO).

Figure 51: A graph from the dashboard depicting reduction in time within VR

8.2.4. The results of training workers in VR (on LOTO) and testing their cognitive skills further revealed a 37% increase in the retention abilities over the course in training in VR (on LOTO). Along the same lines, results revealed a 60% increase in visual awareness (visuo-spatial abilities) over the course of training in VR (on LOTO).

8.2.5. By capturing the data on the gaze and focus of workers (image below) as they were getting trained in VR (on LOTO) and performing the industrial operation (LOTO) in VR, it was found that 90% of the workers attentively focused only on the areas where the tasks had to be performed.

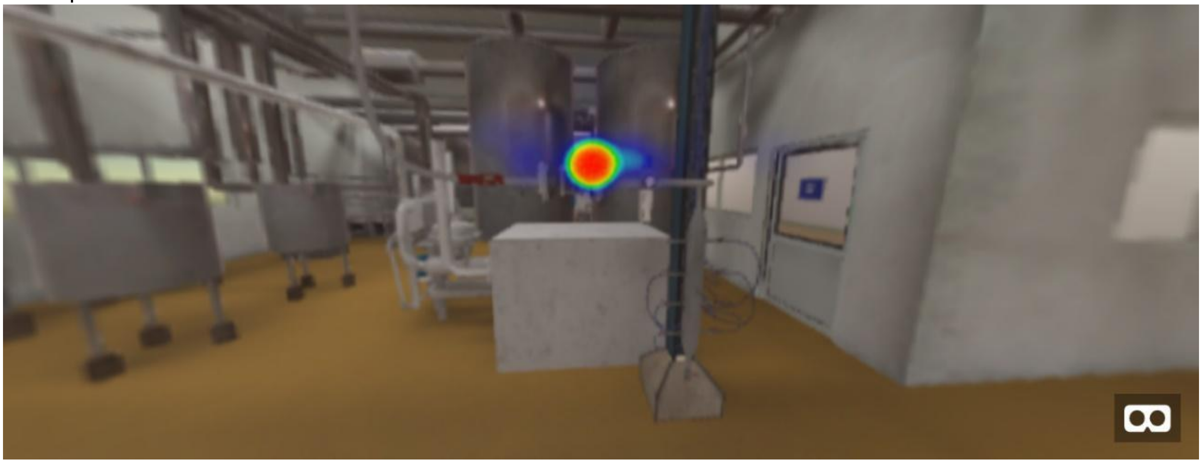


Figure 52: A workers' heat map

8.2.6. In a remarkable set of observations on worker emotions as they received training in VR, it was seen that their negative emotions related to performing the operation (LOTO) in VR reduced (on average) from 55.9% before training (in VR) to 3.8% post training (in VR) and positive emotions improved from 61% before training (in VR) to 71% post training (in VR).

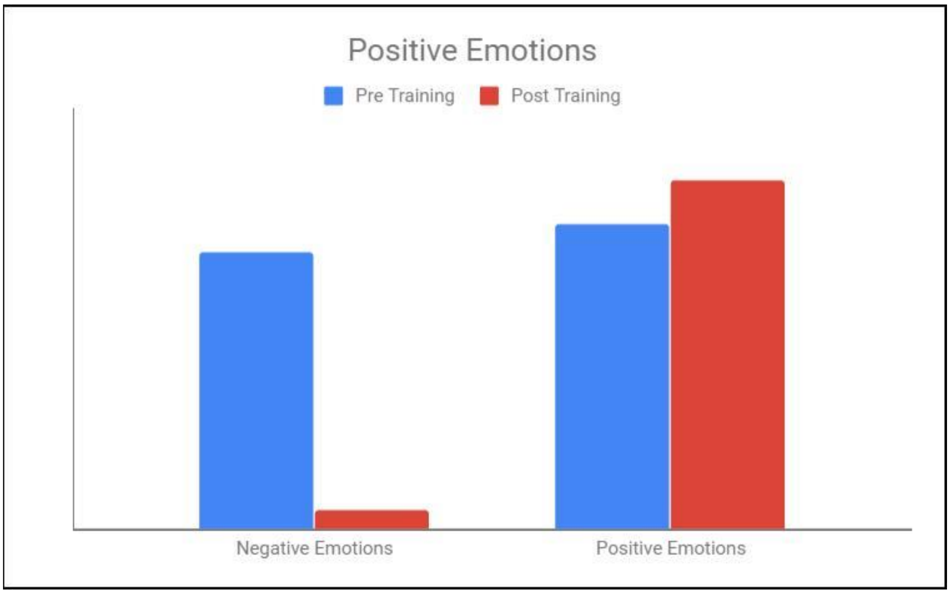


Figure 53: VR based training creating positive impact

8.2.7. Through our Analytics dashboard, we obtained a comprehensive psychometric profile of the workers based on well-established psychological research-based (five-factor personality taxonomy by Costa & McCrae, 1950s) personality tests (viz. openness to experience, conscientiousness, extraversion, agreeableness, neuroticism and empathy).

8.2.8. Through our Analytics dashboard, we also obtained a comprehensive behavioural profile of the workers evaluating the motivation (intrinsic and extrinsic), directive behaviour causing the workers to initiate or repeat an action, acquired and inherited mental and emotional entity, as well as values and ethics or the principles in life that the worker would abide-by to live according to societal norms.

9 Impact Created

Delivering an impact to the vulnerable, low-income and blue-collar workers, by delivering a better training experience addressing the needs and challenges faced by them was the primary objective of this pilot.

We achieved the *impact* by conceiving a methodology of training leveraging VR technology and building a comprehensive Analytics suite {the "*output*") linked with the VR application to impart training on a dangerous industrial operation (use-case: LOTO operation).

The results and findings of the pilot were the outcomes which led us to determine the impact and quantify *effective change* against relevant performance metrics and baseline, target and current indicators, as elaborated in an account of *outcomes* below and summarized in the table below:

Performance Metric	Indicator Baseline	Indicator Target (near-term)	Current Value (immediate)
Reduction in operational errors (in VR)	100	10 (↓90%)	12.5 (↓87.5%)
Reduction in safety protocol violations (in VR)	100	75 (↓25%)	44 (↓56%)
Overall (average) effectiveness of VR for training	100	150 (↑50%)	153 (↑53%)

9.1 Reducing the number of operational errors in VR

The average performance of workers who received training in VR improved (from 52% to 75%) as opposed to those who got training through conventional methods, and this improvement was due to the reduction in errors (by 87.5%) committed by the workers whilst performing the industrial operations in VR.

Compared against the indicator targets of near-term (90% in 1-2 years), these immediate outcomes (87.5%) lead us to positively believe that within this time-frame, positive impact will be delivered by improving the technical proficiency and skills of the workers, thereby leading to better job growth and more compensation and benefits.

9.2 Reducing the violation of safety protocols in VR

Results revealed that the violations in safety protocols, critical to health, were reduced by 56% amongst the workers trained in VR, further proving the effectiveness of VR as a training tool to safely deliver training to the workers, and tying-in well with the improvement of their technical proficiency and skills.

Compared against the indicator targets of near-term (25% in 1-2 years), these immediate outcomes (56%) lead us to positively believe that within this time-frame, the workers will be able to safeguard themselves from the various risks and hazards posed by dangerous industrial tasks and minimize the probability of endangering their lives.

9.3 Reducing the time to get trained

The time taken by the workers to complete the industrial operation in VR was reduced by 17% over the course of training in VR, thereby proving that workers were more engaged within VR due to the high degree of interactivity and immersivity offered by the technology. This performance metric contributed positively towards improving the overall effectiveness of VR for training the workers.

Analysing the metric of overall effectiveness of VR for training the workers, compared against the indicator targets of near-term (50% in 1-2 years), these immediate outcomes (53%) lead us to positively believe that within this time-frame, more workers will be able to get trained effectively using VR in a short time-span, thereby resulting in improved skill levels, job growth and opportunities, more compensation and benefits,

9.4 Improving the cognitive abilities of workers

Training workers in VR led to improvements in their cognitive skills in the form of a 37% increment in retention abilities and 60% increment in visual and spatial awareness, thereby proving that VR as a technology tool for training led to effective memorization of standard operating procedures and offered a better recall to the workers as they performed the industrial operations physically.

One of the primary reasons for improvement in cognitive skills is the likeliness and replication of real-world operations with high-quality, detailed and interactive virtual environments coupled with repeated exposure to the industrial operation in VR which gives the workers a completely immersive and *next-to-real* experience of practising the tasks multiple times and getting trained safely.

The impact of better cognitive abilities can lead to significant improvements in long-term memory and quicker reaction times to safety-related incidents reducing their possibilities to meet with accidents

9.5 Improving the focus

Data on gaze of workers captured as they performed the industrial operations in VR proved that 90% of the workers were found to be less distracted and more focused on critical tasks of the industrial operations whilst performing them in VR.

The impact of improved focus whilst performing dangerous industrial operations can make the workers more aware of the potential risks and hazardous situations around any industrial operation and make them more responsible towards their own safety, thereby reducing their probability of meeting with accidents whilst at work.

9.6 Positive emotions

Data on emotions of workers captured as they performed the industrial operations in VR proved that their negative emotions related to performing the operation (LOTO) reduced (on average) from 55.9% before training (in VR) to 3.8% post training (in VR) and positive emotions improved from 61% before training (in VR) to 71% post training (in VR)

The story of impact and effective change has been visually captured in a video underlining our achievements to meet the targets and objectives of the project:

The impact of increased positive emotions whilst training can make the workers more productive at work.

10 Conclusions and Next Steps

Simulanis envisions a future where any worker can have a desired level of skill set, a growing level of confidence which will deliver a better future for the blue-collared worker ensuring a stable lifestyle.

This project highlighted the grave need for a training mechanism for vulnerable workers to ensure a safe and effective form of training leading to better job growth, more compensation and benefits.

More than a training solution

We met several workers during the course of the pilot including those who were working far away from their home towns, who were hired on a daily basis and those who would constantly live in the fear of being without a job the very next days (daily contractors).

Delivering training to workers was not a barrier for industries to achieve but to assess the immersivity and the level of understanding of the technical procedures among the workers who took the training was a clear barrier. Currently, the training methodology adopted across majority of industries is conventional form of training that is neither secure, just or sustainable. The current training methodologies just create an environment of vulnerability, restricted growth and poor technical proficiency among the blue collared workers. This means a form of training has to be implemented that not only provides an immersive form of training that captures the effectiveness of the training but also implement a solution that assess the emotional and psychological state of the workers. Thus, a training method that supports each worker as much as it helps the organization and ensures the overall growth.

A training method for a vulnerable blue-collared worker and a secured future to come together.

The first and foremost thing on our radar is Extended Reality (XR) and making sure our training tools are not limited to just VR as a medium but can also be taken forward to other mediums like AR, MR, PCs, mobile and more. In the recent past, we were able to deploy our analytics suite in AR for an automobile giant further strengthening our belief that we can build something that is robust enough to be deployed on different platforms and is truly cross platform as well.

In under-developed and developing nations, a common pattern has been the latest generation skipping computers for smartphones as their first internet enabled computing device. Serving this audience is key to scaling up our solution and hence cross platform training modules are our biggest priority at the moment.

We plan to make further developments to our analytical suite by working towards a solution which will be smart enough to provide support or guidance to the worker based on his performance in the training module. Thus, we will aim to include machine learning and artificial intelligence which will set the difficulty levels of the training programs based on the performance on the workers. In parallel, we will build an **employee engagement app** which will focus primarily on the following:

- Create a database for all the workers.
- Provide a communication channel between the organization and the workers.
- Ensure continuous growth of a worker by communicating important updates and feedback from team leads.

"VR is unique in creating a sense of presence, like you're right there with another person or in another place. If you can't think of any way that your reality can't be better, then you're not thinking hard enough, It's not about escaping reality, it's about making it better"

-Mark Zuckerberg

11 Key Definitions

11.1 Virtual Reality

Virtual reality is an interactive computer-generated experience taking place within a simulated environment. It incorporates mainly auditory and visual feedback, but may also allow other types of sensory feedback like haptic. This immersive environment can be similar to the real world or it can be fantastical.

11.2 Manufacturing Industry

The branch of manufacture and trade based on the fabrication, processing, or preparation of products from raw materials and commodities. This includes all foods, chemicals, textiles, machines, and equipment.

11.3 Blue collared workers

A blue-collar worker is a working-class person who performs manual labour. Blue-collar work may involve skilled or unskilled manufacturing, mining, sanitation, custodial work, textile manufacturing, commercial fishing, food processing, oil field work, waste disposal, and recycling, construction, mechanic, maintenance, warehousing, technical installation, and many other types of physical work. Blue-collar work often involves something being physically built or maintained.

11.4 SOP

A standard operating procedures manual is a written document that lists the instructions, step-by-step, on how to complete a job task or how to handle a specific situation when it arises in the workplace.

11.5 Simulated environment

A simulation-based learning environment is a setting for learning that includes a controlled, shielded and often simplified copy of a real-world process or system to be studied.

11.6 Analytics

Analytics is the discovery, interpretation, and communication of meaningful patterns in data; and the process of applying those patterns towards effective decision making.

11.7 Eye tracking

Eye tracking is a sensor technology that enables a device to know exactly where your eyes are focused. It determines your presence, attention, focus, drowsiness, consciousness or other mental states.

11.8 Visuospatial

Visuospatial refers to cognitive processes necessary to "identify, integrate, and analyze space and visual form, details, structure and spatial relations" in more than one dimension. Visuospatial skills are needed for movement, depth and distance perception, and spatial navigation.

11.9 Instructor-led training

Instructor-led training, or ILT, is the practice of training and learning material between an instructor and learners, either individuals or groups.

11.10 Immersion

Immersion into virtual reality is a perception of being physically present in a non-physical world. The perception is created by surrounding the user of the VR system in images, sound or other stimuli that provide an engrossing total environment.

11.11 Lockout-tagout

Lockout-tag out (LOTO) is a safety procedure used in industry and research settings to ensure that dangerous machines are properly shut off and not able to be started up again prior to the completion of maintenance or repair work.

11.12 Hazardous energy

Hazardous energy is any electrical, mechanical, hydraulic, pneumatic, chemical, nuclear, thermal, gravitational, or other energy that can harm personnel working on machines.

11.13 Pneumatic Energy

Pneumatic energy is the energy stored within pressurized air. Like hydraulic energy, when under pressure, air can be used to move heavy objects and power equipment. Examples include spraying devices, power washers, or machinery.

11.14 Affect

Affect is a concept used in psychology to describe the experience of feeling or emotion.

11.15 Guided module

Guided module is a form of training where a user is provided audio (voice overs) and visual(pop-ups) guidance throughout the course of training

11.16 Freestyle Module

Freestyle module is the assessment form of training where a user is not provided any guidance and he has to finish the training the training on his own, also during the the course of this training his performance will be assessed.

11.17 Marker less AR

Marker less AR is a term used to denote an Augmented Reality application that does not need any pre-knowledge of a user's environment to overlay 3D content into a scene and hold it to a fixed point in space.

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