



LANDSCAPE OF EXPERIENTIAL LEARNING TECHNOLOGIES FOR TEACHING OCCUPATIONAL HEALTH AND SAFETY IN SKILLED TRADES

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Landscape of Experiential Learning Technologies for Teaching Occupational Health and Safety in the Skilled Trades

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EXECUTIVE SUMMARY

Background and Objective

Injuries and illnesses among skilled trades professions accounted for over 25% of all workers' compensation claims in Ontario between 2015 and 2020. Ensuring that skilled trade professionals are equipped with the relevant occupational safety and health (OSH) knowledge, skills, and abilities is critical in mitigating occupational risks and reducing injuries. Low engagement during OSH training has been the primary reason for low retention of OSH-related knowledge; thus, skilled trade professionals and trainees must receive effective and engaging OSH training to ensure that the knowledge is learned, retained, and applied.

Experiential learning technologies (ELTs) (e.g., immersive virtual reality (VR) experiences, simulators, and interactive and serious games) can increase engagement, and knowledge and skills retention when compared to traditional classroom PowerPoint lectures. Given that ELTs may be a powerful tool for teaching OSH, we aim to build an ELT toolbox to support OSH training in the skilled trades. As a first step in developing an ELT toolbox, we conducted an environmental scan to better understand the existing OSH-related ELTs that are commercially available for trainees and professionals working in the skilled trades.

Methods

A systematic web-based search was performed to obtain existing commercially available OSH-related ELTs for the skilled trades; snowballing technique was applied to identify additional results. Key information was extracted from each relevant ELT, including the description of the ELT and its intended occupation, the tasks performed in the ELT, and the OSH topics taught. Software developers who only offered customized ELT solutions were also documented.

Key Findings

- **288** off-the-shelf OSH-related ELTs for skilled trade occupations were identified.
 - Over 50 complimentary ELTs (nearly 20%) can be delivered via highly accessible platforms such as desktops or smartphones.
- **85** unique off-the-shelf ELT developers/distributors were identified.
 - **65%** of the off-the-shelf ELT developers'/distributors' headquarters were in the USA; **11%** were in Canada. **More ELTs need to be developed in Canada or have options to be customized to Canadian safety laws and regulations.**
- **10** different types of delivery mechanisms for OSH-related ELTs emerged.
 - Most of the ELTs are delivered through VR headsets, meaning that, if trainees have access to a VR headset, they can access a vast library of OSH-related ELTs.

- **96** unique topic areas were identified. Thirteen topics were relevant to general skilled trades, 3 were relevant to the service sector, 3 for the automotive sector, 32 for the industrial sector, and 45 for the construction sector.
 - Many of the ELTs identified were relevant to acute injury prevention while few focused on the chronic and long-term consequences of hazardous exposures.
 - ELTs designed for trade-specific occupations (n=192) often focused on the safe work processes and practices of a given task (e.g., painting, welding, machine operations, gas leak inspection) with the integration of OSH concepts.
- **42** software developers who only offered customized ELT solutions were identified.



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1. INTRODUCTION

Every day, skilled trades professionals are exposed to hazardous work processes, materials, machines, environments that put them at risk for occupational injury or illness. In fact, in Ontario between 2015 and 2020, occupational injury and illness claims contributed to over 25% of all worker compensation claims in skilled trades-related occupations (1). Ensuring that skilled trades professionals are equipped with relevant occupational safety and health (OSH) knowledge, skills, and abilities is critical in mitigating occupational injuries.

Although addressing root causes of injury and illness is the most ideal risk mitigation strategy, OSH training may be an effective way to reduce occupational risks and injury rates. However, there are pervasive and ongoing challenges with getting trainees engaged with OSH training. Despite trainees recognizing the importance of OSH training, many, especially younger trainees, perceive OSH training as 'boring', 'common sense', and/or not something they personally needed (2,3). Adding to the challenge, traditional OSH training has been taught with little 'interaction, action, or repetition' (2). OSH is commonly taught through oral instruction, accompanied by videos (4,5); trainees are orally told what to do and what not to do without observing or experiencing a OSH-related incident. Low engagement during OSH training has been shown to be the primary reason for low retention of OSH-related knowledge (4); thus, skilled trades professionals and trainees must receive OSH training that is effective and engaging to ensure that the knowledge is learned, retained, and applied in practice.

A review of emerging technologies for construction safety training concluded that engaging learning experiences are best supported by abandoning passive teaching and adopting simulation technologies (6,7). Studies have also found that trainees learn better when they are required to participate in interactive problem solving and decision-making (8-10). Instructors may engage students by gamifying OSH content, utilizing hazard identification/control activities, having students teach OSH material to each other, or having students look up OSH legislation to answer specific OSH questions. They may also enhance OSH content by sharing trade-specific examples (through testimonies, case studies, and personal experiences). Further, instructors may reinforce OSH training in practical labs by observing how trainees carry out their duties/tasks and provide feedback on OSH-related behaviours and procedures.



Instructors of skilled trades and apprenticeship programs suggested supplementing traditional OSH training approaches with experiential learning technologies (ELTs) to further augment training engagement. ELTs, such as immersive virtual reality (VR) experiences, simulators, and interactive and serious games, immerse trainees into a work environment and allow them to make decisions, problem solve, and visualize the outcome of their choices in a safe virtual environment. Thomas and Brown argue that, rather '*learning about*' something in the traditional classroom setting, ELTs puts learners into an environment where they can '*learn to be*' the professional in their chosen career (11). Compared to traditional classroom PowerPoint lectures, teaching with ELTs was associated with higher engagement, and knowledge and skills retention (12,13). ELTs are particularly beneficial for teaching topics that require scarce, expensive, or non-replaceable resources (e.g., heavy machinery, fuel, paint, human life), or those that involve exposure to dangerous environments (e.g., fire rescue, high voltage areas).

Since ELTs may be a powerful tool for teaching OSH, our aim is to build an OSH ELT toolbox for skilled trades trainees and workers. An OSH-related ELT toolbox will compile accessible tools and resources for instructors to direct their students to for improving and practicing their OHS knowledge and skills. As a first step in developing this database, we performed an environmental scan to better understand the types of OSH-related ELTs that are commercially available for trainees and professionals in the skilled trades.



2. METHODS

We conducted a systematic web-based search to obtain existing commercially available OSH-related ELTs for the skilled trades. The search strategy included multiple searches using the same structure. Each search included terms from three concepts:

1. ELT (i.e., virtual reality/serious games/experiential learning technologies)
2. OSH
3. Skilled trade occupation/sector

For each search, the terms used for ELT and OSH concepts remained the same; however, a different skilled trades occupation or sector

(i.e., construction, industrial, automotive, and service) was introduced. Twenty of the 144 Ontario recognized skilled trades occupations were searched. The selection of the 20 occupations was based on their recognition as a red seal trade, industry reports (e.g., Build Force Canada), and Canada's Apprenticeship Survey. Thus, a total of 24 searches were completed: four skilled trades sectors and 20 skilled trades occupations. The first 100 search results (5 pages) were reviewed, and potentially relevant links were saved onto an excel spreadsheet. Snowballing technique was applied to the first 100 search results to identify additional potentially relevant links.

Potentially relevant links were those pertaining to OSH-related ELTs that apply to skilled trade occupations. ELTs may include serious games, VR simulations, augmented reality, or entire simulation stations/platforms; we excluded board games, pilot projects, and proof of concept projects. In addition, potentially relevant links may be websites, articles, or blog posts from ELT developers/vendors, governments, machinery distributors/manufacturers,

Focus 20 Skilled Trades

1. Auto Body and Collision Damage Repairer
2. Automotive Service Technician
3. Brick and Stone Mason
4. Construction Craft Worker
5. Cook/Chef
6. Drywall, Acoustic, and Lathing Applicator
7. Electrician
8. General Carpenter
9. General Machinist
10. Hairstylist
11. Heavy Duty Equipment Technician
12. Industrial Electrician
13. Industrial Mechanic Millwright
14. Plumber
15. Powerline Technician
16. Refrigeration and Air Conditioning Systems Mechanic
17. Sheet Metal Worker
18. Tool and Die Maker
19. Truck and Coach Technician
20. Welder

OSH training providers, and trade associations. Our search resulted in 241 links that were potentially relevant to ELTs for OSH training.

2.1 Full Review and Data Extraction

All potentially relevant links were reviewed in full for commercially available OSH-related ELTs for skilled trades occupations. As an example of the full review process, we explored the ELT developers'/distributors' websites for their available products, solutions, and case examples and we read blog posts and articles for references to potentially relevant ELTs or ELT developers. The application of snowballing technique led to an additional 94 potentially relevant links, which subsequently underwent full review.

We extracted key information for each relevant ELT identified. Such information included, but not limited to, a description of the ELT, its targeted skilled trade occupation, the tasks performed in the ELT, and the OSH-related topics taught (Table 1). Software developers who only offered customized ELT solutions were also documented.

Table 1. Description of data extraction variables.

Data Extraction Variables	Description
Name of ELT	Name of the ELT
Accessibility	Free vs. paid (cost specified when available)
Date of Release and Version Number	Year ELT was released (latest version number, if available)
Description of the Technology	Developers' description of the ELT
Developer/Distributor	Name of the developer or distributor (may include multiple developers if the ELT was developed by multiple parties)
Website	Reference URL link to ELT (prioritize link to developer/distributors' website)
Location	City and country of the developer/distributors' headquarters
Language	Language(s) in which the ELT is available in
Skilled Trades Occupation	One or more of the 144 Ontario-recognized skilled trades. Left as 'n/a' if ELT covers general OSH topics
Skilled Trade Sector	One or more of the four skilled trades sectors
Tasks/Topics	Tasks/topics specified in the description of the ELT
Key OHS Topic	Key OSH topic based on name and description of ELT
Delivery Mechanism	All specific hardware that the ELT is compatible with
Estimated Duration	Estimated duration to complete the ETL if available/applicable
Research Evidence	Research articles referenced in the development and evaluation of the ELT
Completion Certificate or Credit	The certification that the participants receive upon completion
Curriculum Development	The occupational health and safety standards, regulations, or acts referred to in the ELT

3. RESULTS

We identified 85 unique developers/distributors, which, in total, offered 288 off-the-shelf OSH-related ELTs for skilled trade occupations (Table 2). A summary of the developers/distributors and their ELTs is listed in [Appendix A](#). Of the identified developers and distributors, 61% (n=52) of their headquarters were based in the USA, and 11% (n=9) were in Canada (Table 1). We further summarized the results by first presenting an overview of potential delivery mechanisms for the OSH-related ELTs identified, followed by a summary of the key tasks/ topics covered. There were 42 software developers who only offered customized ELT solutions ([Appendix B](#)).



Table 2. Identified developers and distributors for off-the-shelf OSH-related experiential learning technologies for skilled trades categorized by country.

<p>USA (n=52)</p> <ul style="list-style-type: none"> • 3M 7 • Advanced Training Systems LLC. • Arcadicus • Archvirtual • CAT • certifyme.net • ChalkBites • CSE Software Inc. • Ditch Witch • Elite VR Training • FL-Simulators Inc. • Forklift University • Fun2 • FreeRangeXR • Groove Jones • Hard Hat VR • Heartwood • Humulo Engineering • Industrial Training International • IVRY Technologies • JLG • Lennox • Lincoln Electric • Missing Digit • NextWave Safety Solutions Inc. • Oberon Technologies • Occupational Safety and Health Administration • Pixaera • PIXO VR • Purdue University • Realityworks • Really Virtual • Red Dot Games • Simcoach Games • Simformation • Skillcatapp • SkillMill • Strata Tech • Streamline Simulations • Tauris Tech • Technical Laboratory Systems, Inc • Technology and Maintenance Council • Texas Mutual • Texas Safety Solutions LLC • Peak Activity LLC • trainPOINT • TRANSFR, Inc. • University of Idaho VTD • University of Washington DEOSH CEP • VARtech LLC • Vectre • zSpace 		
<p>Canada (n=9)</p> <ul style="list-style-type: none"> • Bit Space Development Ltd. • Construction Ontario • Energy Safety Canada • Melcher Studios • NORCAT • Serious Lab • SIMLOG • Virtual Reality Training Solutions • WorkSafeBC 	<p>Australia (n=3)</p> <ul style="list-style-type: none"> • Immersive Technologies • Sentient Computing • Tradiebot 	<p>Belgium (n=1)</p> <ul style="list-style-type: none"> • OneBonsai <p>Brazil (n=1)</p> <ul style="list-style-type: none"> • Inside Techologia <p>China (n=1)</p> <ul style="list-style-type: none"> • Shenzhen GTA Education Tech Ltd. <p>Greece (n=1)</p> <ul style="list-style-type: none"> • SQLearn <p>Northern Ireland (n=1)</p> <ul style="list-style-type: none"> • Ulster University <p>New Zealand (n=1)</p> <ul style="list-style-type: none"> • Mindgames Media <p>Poland (n=1)</p> <ul style="list-style-type: none"> • Flint Systems <p>Singapore (n=1)</p> <ul style="list-style-type: none"> • Aviation Virtual <p>South Africa (n=1)</p> <ul style="list-style-type: none"> • Thoughttec Simulation <p>Turkey (n=1)</p> <ul style="list-style-type: none"> • Rodlab Engineering <p>Ukraine (n=1)</p> <ul style="list-style-type: none"> • Digital Engineering and Magic
	<p>Germany (n=3)</p> <ul style="list-style-type: none"> • Astragon Entertainment GmbH • VR Direct • VR Inn 	
	<p>India (n=3)</p> <ul style="list-style-type: none"> • Buzzark • Skillveri • Tecknotrove Systems (1) PVT Ltd. 	
	<p>Finland (n=2)</p> <ul style="list-style-type: none"> • Finish Institute of Occupational Health • Varwin 	
	<p>France (n=2)</p> <ul style="list-style-type: none"> • Acreos • Mimbus 	



3.1 Available Delivery Mechanisms for OSH-Related ELTs

Through a ground-up approach, 10 different types of delivery mechanisms for OSH-related ELTs emerged. Many ELTs offered multiple methods of delivery. We describe each method and provide examples below; [Appendix A](#) summarizes all the ELTs and their available delivery mechanisms.

3.1.1 VR headset with controllers



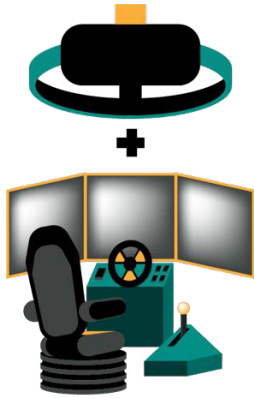
A head-mounted device that fully immerses the user into a 360-degree simulation. Hand-held controllers can be used to interact with objects and perform tasks within a virtual environment. Examples of VR headsets include the HTC Vive and the MetaQuest. The benefits of using VR headsets are that they are applicable for various types of OSH-related training and immerse the user into the complex environment of a worksite.

3.1.2 Simulator system

Simulator systems often involve an operator platform along with realistic machine-specific controls. Some simulators have a modular design where controls and accessories can be swapped and/or reconfigured to simulate different machines. Simulator systems may even be integrated onto a motion platform for realistic tactile feedback for acceleration, decelerations, and shocks and jolts. As for visual display, simulator systems may use one or more monitors/screens. The benefits of using simulation systems are that it does not take the actual equipment out of service for training, and users can learn from mistakes in the simulation without any real-world consequences. Using simulation systems also helps save on fuel and reduces the wear and tear of actual equipment. Training for the operation of heavy equipment vehicles is generally delivered using this method.



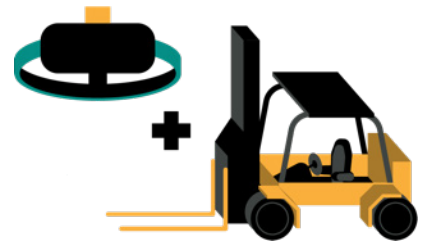
3.1.3 Simulator system with VR



This delivery mechanism combines both the simulator system and the VR headset, allowing the users to reap the benefits of both delivery mechanisms. This method fully immerses the users into the simulated environment while allowing them to use the realistic controls and configuration of the operator station. The tactile feedback of a motion platform further increases the immersive experience and can reduce the risk of motion sickness commonly associated with VR headsets. These tools are mainly used for machinery operation and welding. Some systems may include a forward-facing camera to show the location of the user's hands within the immersive experience.

3.1.4 System with VR

A fully immersive experience can also be delivered by connecting a VR headset with the actual machinery. The machinery **DOES NOT** operate in reality, but in *virtual* reality. This delivery mechanism is best suited for training and familiarizing users with the controls, functions, and operations of the specific equipment that they will be using. However, the machine must be taken out of service for training. An example of this delivery mechanism is the lift operations training for Raymond Forklifts, developed by FreeRangeXR.



3.1.5 Smartphone with VR goggles



VR goggles can be used to convert regular smartphones into VR headsets and provide an immersive VR experience. Many VR mobile apps are free to download and use. Users may use the visual gaze technique to navigate the virtual environment, learn more about an area, and even answer multiple-choice questions. Compared with VR headsets, VR goggles are relatively inexpensive and can still give users a sense of the work environment and practice identifying safety hazards and controls.

3.1.6 Desktop computer with accessories (including VR headsets)

ELTs can also be delivered through a desktop computer that is equipped with various controllers and accessories, including VR headsets, steering wheels, joysticks, foot pedals, and other customized controllers/accessories. Unlike simulation systems, this delivery mechanism does not provide tactile feedback to the user; however, it is less expensive and more portable. Many ELTs using simulator systems also offer a mobile/lite version using a desktop computer with accessories.



3.1.7 Desktop computer or laptop



ELTs can also be delivered only using a desktop computer or laptop. These ELTs usually come in the form of a desktop application that can be downloaded onto the computer, while others can be delivered directly through a web browser. Users use their mouse and keyboard to interact with the ELT. This delivery method is cost-effective as many students already have a personal computer, and do not require additional accessories.

3.1.8 Tablet or smartphone



There are also ELTs that come in the form of mobile applications. They can be downloaded from an app store and onto the phone/tablet; these ELTs may use technologies within the mobile device (accelerometer, cameras, touchscreen) to make the ELT more interactive. For example, some of these ELTs may, using the camera, create an augmented reality (AR) experience by superimposing interactive data or computer-generated images onto real-world videos and images; it does not require a headset or smart glasses. Often, these ELTs consist of mini games.

3.1.9 Three-dimensional projection system

The combination of 3D glasses and a specialized flatscreen display are used to allow users to interact with a 3D pop-out display of an object. This delivery mechanism is commonly used to help users visualize the internals of machinery and understand its operation.



3.1.10 Video game console



Some of the ELTs identified can be delivered through traditional video game consoles such as Nintendo, PlayStation, or Xbox. Games can be purchased through the consoles' online stores or from physical stores.

3.2 OHS-Related ELTs for Skilled Trades

We identified 95 unique tasks/topic areas for the skilled trades involving aspects of OSH. These tasks/topic areas are presented based on their relevancy to various skilled trades. Some OSH-related topics are applicable to most skilled trades, regardless of sector or occupation while some are specific to a sector or occupation. We first present ELTs with OSH topics that are relevant for most skilled trades, followed by more sector-specific tasks/topics.

3.2.1 ELTs with OSH topics relevant to most skilled trades

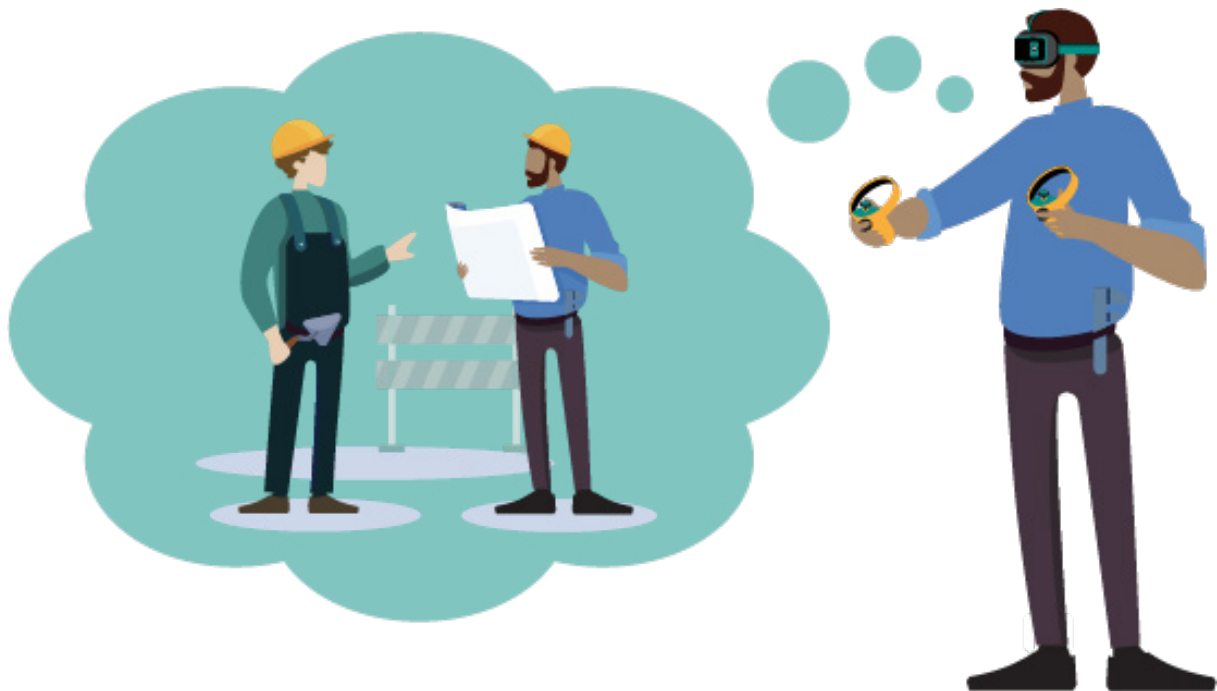
We identified 13 OHS-related topics relevant to most skilled-trades. There was one additional ELT that provided comprehensive training for various skilled trades, which we had categorized as *various topics* (Table 3). Topics covered include confined spaces, driving safety, emergency preparedness, fall safety, fire safety, first aid, hazards awareness, general safety, lockout tagout, forklift driving, manual materials handling, permit to work, and personal protective equipment (PPE). These ELTs are suitable for providing end users with an introduction to the OSH topic.

Table 3. Experiential learning technologies with OSH topics relevant to most skilled trades.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Confined Spaces	Bit Space Development Ltd.	MHBA Confined Space Virtual Reality
	FreeRangeXR	Confined Spaces
	Humulo Engineering	Confined Spaces
	Pixaera	Confined Space Training
	PIXO VR; Vectre	Confined Spaces
	UoI VTD; UW DEOHS CEP	Permit-Required Confined Space Entry
Driving Safety	Pixaera	Driving Safety
Emergency Preparedness	OneBonsai	VR Evacuation Training
	PIXO VR	Low Voltage Rescue
		Pole Top Rescue
	SQLearn	Fire in the Engine Control Room Lifeboat Launching Procedure VR course
Fall Safety	3M	3M Fall Protection Harness Inspection
		3M Fundamentals of Fall Protection VR Pro
		3M Working at Heights Awareness
	Archvirtual	ASSP Fall Protection VR Experience
	Bit Space Development Ltd.	MHBA Fall Protection App
		MHBA Scaffolding Safety Awareness App
	FreeRangeXR	Fall Protection
	Humulo Engineering	Fall Safety
		Fall Safety: Communication Towers
		Fall Safety: Ladders
		Scaffolding Safety
	Melcher Studios; VRTS	VR Fall Arrest
	Mimbus	Scaffolding Safety
	NextWave Safety Solutions, Inc.	Fall Prevention
		Scaffold Safety
	Pixaera	Working at Height
	PIXO VR	Fall Protection
	PIXO VR; Inside Technologia	Working at Heights Training - Oil and Gas Platform
	Purdue University	Fall Safety VR Training Simulator
	Sentient Computing	Working at Heights VR Training
	Simcoach Games	Harness Hero
		Harness Hero - Bridge Edition
		Site Coach: Ladder Safety
Site Coach: Fall Hazards		
trainPOINT	Fall Protection - Harness Inspection	
VARtech LLC	OSHA Portable Ladder Safety VR	
WorkSafeBC	The Ladder Challenge Game	
Fire Safety	Elite VR Training	Fire Extinguisher Training
	FreeRangeXR	Fire Suppression
	Humulo Engineering	Fire Safety
	Melcher Studios; VRTS	VR Fire Extinguisher Training
	Norcat	FiAR
	Oberon Technologies	Titania® Fire Equipment Training
	OneBonsai	VR Fire Training
	Pixaera	Line of Fire Training
	PIXO VR; Aviation Virtual	Fire Extinguisher Training
	PIXO VR; ITT	Fire Prevention - Construction Site
Sentient Computing	Fire Extinguisher Safety VR Training	

Table 3. (cont.)

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
First Aid	FreeRangeXR	AED Education
		CPR Education
General Safety	Mindgames Media	Workplace Sim
	Redlab Engineering	Redsafe
	Technical Laboratory Systems, Inc.	VR Workplace Safety Training Program
	Texas Mutual	Safety in a Box 2.0
Hazard Awareness	Bit Space Development Ltd.	LevelUp VR 2
	Oberon Technologies	Virtual Reality Training for Hazardous or Dangerous Environments
	OSHA	OSHA's Hazard Identification Training Tool
	Pixaera	Hot Work Safety
	PIXO VR	Hazard Recognition
	Sentient Computing	Hazard Recognition VR Training
	ChalkBites	OSHA Safety Simulator
Lockout/Tagout	Groove Jones; Toyota	Prevent the Fall
	FreeRangeXR	Lockout Tagout
	Heartwood	Lockout-Tagout (LOTO)
	Humulo Engineering	Lock-out/Tag-out
	NextWave Safety Solutions, Inc.	Lockout-Tagout (LOTO)
	Oberon Technologies	Titania® Lockout/Tagout Procedure Training
	Pixaera	Bypassing Safety Controls
		Energy Isolation
PIXO VR; Vectre	Lockout/Tagout	
Simcoach Games	Electric Protector	
Forklift Driving	Acreos	Forklift Truck
	certifyme.net	Virtual Reality Training for Forklifts
	ChalkBites	Enterprise Forklift OSHA Training Simulator
	FL-Simulators Inc.	VR Forklift Simulator (Sit Down CB)
		VR Forklift Simulator (Stand Up Reach/ CB)
	Flint Systems	Forklift
	Forklift University	Premium Virtual Forklift Simulator
		Virtual Forklift Mobile
	FreeRangeXR; Raymond	Forklift Virtual Reality Simulator
	Humulo Engineering	Forklift Fundamentals Training
	NextWave Safety Solutions, Inc.	Forklift Operator
	Really Virtual	Real-Forklift Simulator
	SIMLOG	Forklift Personal Simulator (Version 2.0)
Reach Lift Truck Personal Simulator		
Streamline Simulations	3-D Forklift	
Tecknotrove Systems (1) PVT LTD	TecknoSIM Forklift Simulator	
Manual Materials Handling	SimCoach Games	Best Built Plans: Manual Materials Handling
		Lift Coach: Plan Your Route
		Lift Coach: Plan Your Lift
Permit to Work	Pixaera	Work Authorization
PPE	Bit Space Development Ltd.	CSAM/RMP/MHCA PPE Course Companion
	Oberon Technologies	Titania® PPE Protocol Training
Various topics	SkillMill	Personal Interplay Learning Subscription



3.2.2 ELTs for skilled trades in the construction sector

One-hundred and twenty-six ELTs were identified and categorized as relevant to the construction sector. Forty-two of those were focused on general OSH-related knowledge that may be suitable for most occupations in construction. Of the remaining, 65 were related to operations of heavy machinery, 7 for heating, ventilation, and air conditioning (HVAC), 8 for electrical safety, and 4 for painting.

3.2.2.1 General Competencies for Workers in the Construction Sector

The 42 ELTs presented in this section would be relevant to anyone working in the construction sector (Table 4). Topics include framing, general safety in construction, general safety on mining sites, hazards awareness on construction sites, lifting tools, traffic control, rebar tying, rigging, trench safety, and operation of table saw, band saw, jointer, and router.

Table 4. Experiential learning technologies that support general competencies for working in construction.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT	
Framing	Bit Space Development Ltd.	MCSC Framer	
	zSpace; VIVED	VIVED Carpentry	
General Safety in Construction	Bit Space Development Ltd.	IBEW Safety VR	
	Construction Ontario	Construction Ontario Virtual and Mixed Reality Training	
	Finnish Institute of Occupational Health	Virtuario™ - Occupational Safety Training in Virtual Reality	
	Hard Hat VR	Hard Hat VR Training Toolbox	
	Immersive Technologies	Worksite VR Quest	
	Mimbus	Worksite Safety	
	NextWave Safety Solutions, Inc.	Construction Site Safety	
	PIXO VR	Stand-by Activities	
	PIXO VR; ITT	Housekeeping Safety Rules - Construction Site	
	Simcoach Games		Future Road Builders
			Ground Up Construction
			Road Builder Blitz
			Site Coach: Start Smart
	Texas Safety Solutions LLC; Peak Activity LLC	Hazards AR Training System (H.A.R.T.S)	
TRANSFR, Inc.	Construction Safety		
VR Direct	Enviro - Safety Construction Training		
General Safety on Mining Sites	Energy Safety Canada	Experience the Energy: Take the Tour	
		Experience the Energy: Take the Challenge	
		Adapting Futures	
Immersive Technologies	Mine Training Standards		
Hazard Awareness on Construction Sites	Bit Space Development Ltd.	IBEW Slips Trips & Falls	
		United Association Safety 360	
	CAT	Cat@ Safety VR	
	Humulo Engineering	General Hazard Recognition	
		Underground Utilities	
	ITI Industrial Training	VR Construction Hazard ID Assessment	
	PIXO VR; ITT	Hazard Recognition (Construction)	
	Simcoach Games	Infection Control Risk Assessment for Construction	
Future Construction Inspectors			
trainPOINT	Construction Hazard Identification		
	Outdoor Hazardous Conditions		
Lifting tools	Pixaera	Safe Mechanical Lifting	
Management	Simcoach Games	Future Construction Managers	
Rebar Tying	Simcoach Games	Reinforcers (CAWP Arcade)	
Rigging	Humulo Engineering	Rigging: Mobile Towers and Cranes	
	Varwin	Varwin Rigging VR Lab Virtual Training Simulator	
Tool/equipment Operation: Table Saw, Band Saw; Jointer; Router	Mimbus	WOOD-ED	
Traffic Control	Bit Space Development Ltd.	Flagpersons Safety Training	
	SimCoach Games	Traffic Control (CAWP Arcade)	
Trench Safety	Humulo Engineering	Trench Safety	

3.2.2.2 Heavy Machinery Operations

We identified 65 ELTs that focused on teaching the safe and efficient operation of various heavy machinery, including dozers, excavators, backhoe loaders, cranes, and more (Table 5). Most ELTs for heavy machinery operations are delivered using simulator systems; some have options for a lite or portable version delivered using a desktop and controller accessories. Premium ELTs have an integrated motion platform that will provide tactile feedback. The VR headset may be another option for some of these ELTs to offer a more immersive experience. Many of the simulators have a modular design where controls can be swapped to match various heavy machinery software packages.

ELTs for machinery operations help familiarize users with controls of the equipment and develop basic driving and operation skills under a wide range of operational scenarios (e.g., various locations, terrains, and weather conditions). Some heavy equipment manufacturers also produce simulators that are replicas of their machinery's controls (e.g., Raymond, Cat). These ELTs would be helpful for those pursuing a career as a heavy equipment operator (for dozers, excavators, or backhoe loaders) or a hoisting engineer (for mobile or tower cranes). These ELTs may also be relevant for other occupations that may need to operate heavy machinery as a part of their work.



Table 5. Experiential learning technologies for operation of heavy equipment vehicles.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Dozer	Acreos	Bulldozer
	SimCoach Games	Dig In: A Dozer Game
	SIMLOG	Bulldozer Personal Simulator
	Tecknotrove Systems (1) PVT LTD	TecknoSIM Dozer Simulator
Excavator	Acreos	Excavator
		Mining Excavator with Shovel Bucket
		Mining Excavator with Backhoe Bucket
	Simcoach Games	Excavator Game (CAWP Arcade)
		Dig in: An Excavator Game
	SIMLOG	Hydraulic Excavator Personal Simulator (v 2.5)
Tecknotrove Systems (1) PVT LTD	TecknoSIM Excavator and Shovel Simulator	
Backhoe Loader	Acreos	Backhoe Loader
	SIMLOG	Backhoe Loader Personal Simulator
	Tecknotrove Systems (1) PVT LTD	TecknoSIM Backhoe Loader Simulator
Crane	Acreos	Crawler Crane
		Mobile Crane
		Ship to Shore Container Crane
		Tower Crane
	Flint Systems	Tower Crane
	IT1 Industrial Training; Serious Labs	Boom Truck VR Simulator
		Carry Deck Crane VR Simulator
		Down Cab Rough Terrain Simulator
		Heavy Lift Crawler VR Simulator
		Lattice Boom Crawler Crane Operator Simulator
		Overhead Bridge Crane VR Simulator
	IT1 Industrial Training; Serious Labs (cont.)	Polar Crane Simulator
		Rough Terrain Mobile Crane Operator Simulator
		Tower Crane Operator Simulator
	Simcoach Games	Hooked: A Tower Crane Game
		Construction Crane Signals
		Construction Crane Rigging
SIMLOG	Mobile Crane Personal Simulator (Advanced Edition)	
	Tower Crane Personal Simulator	



Table 5. (cont.)

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Various Heavy Equipment	astragon Entertainment GmbH	Construction Simulator 3
	CAT; CSE Software Inc.; Simformotion	Cat® Construction Simulator
		Cat® Forestry Simulator
		Cat® Mining Simulator
	Ditch Witch	Ditch Witch HDD VR Simulator
	Tecknotrove Systems (1) PVT LTD	TecknoSIM Truck Driving Simulator and Heavy Vehicle Training Simulator
Thoughttec Simulation	CYBERMINE Full Mission Mining Simulators	
	CYBERQUIP Full Mission Simulators	
Pre-trip Inspection (Heavy Equipment)	Immersive Technologies	Pre-start Inspection
Other Heavy Equipment Vehicles		
Autonomous and Remote Equipment	Immersive Technologies	Autonomous and Remote Equipment
Dill Jumbo	SIMLOG	Drill Jumbo Personal Simulator
Dumper Truck	Acreos	Articulated Dump Truck
		Dumper
	Tecknotrove Systems (1) PVT LTD	TecknoSIM Dumper Truck Simulator
		TecknoSIM Tipper Simulator
Forwarder	SIMLOG	Forwarder Personal Simulator
Harvester	SIMLOG	Harvester Personal Simulator
MEWP	JLG	Access Ready Fusion XR
	Serious Labs	MEWP VR Simulator
Milling Machine	Acreos	Milling Machine
Mining Truck	SIMLOG	Mining Truck Personal Simulator (Version 2.0)
Motor Grader	Acreos	Motor Grader
Off Highway Truck	SIMLOG	Off-Highway Truck Personal Simulator
Rope Shovel	SIMLOG	Electric Rope Shovel Personal Simulator
Skid Steer Loader	SIMLOG	Skid Steer Loader Personal Simulator
Snowplow	Melcher Studios; Virtual Reality Training Solutions	VR Snowplow Training
Straddle Carrier	Acreos	Straddle Carrier
Telehandler	Acreos	Telehandler
Wheel Loader	Acreos	Mining Wheel Loader
		Wheel Loader
	SIMLOG	Wheel Loader Personal Simulator (Version 2.0)
Wheeled Material Handler	SIMLOG	Wheeled Material Handler Personal Simulator

3.2.2.3 Heating, Ventilation, and Air Conditioning (HVAC)

We identified seven ELTs that may be relevant to those pursuing a career as a refrigeration and air conditioning systems mechanic or a residential air conditioning systems mechanic. These ELTs are delivered mainly through VR headsets, desktops, or a 3D projection system; smartphones or tablets may also be an option. Examples of tasks and topics taught in these ELTs include the basics of refrigeration and air conditioning; manifold gauge hookup; refrigerant charging and recovery; evacuation and leak testing; and heat pump installation. Of note, Lennox, an appliance manufacturer, developed VR simulations to train technicians in troubleshooting their products in residential settings. The Lennox VR & WebVR Training includes built-in faults to train technicians in troubleshooting dirty blower wheels, over/under charging, refrigerant leaks, faulty diaphragms, faulty pressure switches and gas valves, bad reversing valves and defrost boards, and more. There were also ELTs (i.e., Skillcat, HVAC Basic/ Heat Pump Installation) that were complete HVAC training programs, which included several modules/courses, to prepare students for the EPA 608 Certification exam.

Table 6. Experiential learning technologies for heating, ventilation, and air conditioning.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
General	Tauris Tech	HVAC Basics / Heat Pump Installation (Course)
	zSpace; Labtech	HVAC Fundamentals
		HVAC Residential
	Skillcatapp	Skillcat
Maintenance and Repair	Lennox	Lennox VR & WebVR Training
Refrigerants	Mimbus	Refrigerant Accreditation
Hookup Manifold Gauge	Arcadicus	HVAC Virtual Simulation



3.2.2.4 Electrical

Construction and maintenance electricians, domestic and rural electricians, industrial electricians, signal maintenance electricians and others who perform electrical work may find the ELTs categorized into *Electrical* relevant in their OSH training (Table 7). All of these ELTs are available through a VR headset. Depending on the ELT, users may explore high-voltage electrical substation equipment and power substation layouts, operate feeder protection relay devices, carry out sampling procedures for transformer oil, and more.

Table 7. *Experiential learning technologies for electrical work.*

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
General	Groove Jones; IVRY Technologies	Virtual Electrical Training
	Mimbus	Electrical Qualification
General Safety	Digital Engineering and Magic	OSH VR Training for Electricians
Electrical Substation Maintenance	Digital Engineering and Magic	HV Electrical Substation Training
	PIXO VR; Buzzark	Electrical Substation Maintenance
Feeder Protection Relay	Digital Engineering and Magic	Feeder Protection Relay Training
Maintenance and Repair	Mimbus	Electrical Maintenance
Transformer Oil Sampling	Digital Engineering and Magic	Transformer Oil Sampling in Virtual Reality

3.2.2.5 Painting

Four ELTs were relevant to occupations requiring spray painting, including automotive painters (automotive sector), commercial and residential painters and decorators, and industrial painters and decorators (Table 8). All of these ELTs are delivered via VR headsets; some offer a custom spray gun controller mount to provide a more realistic feel in the hand. These ELTs immerse learners into a virtual spray booth or industrial environment to train and improve their techniques, including auto body painting, industrial painting, construction painting, and sandblasting. Further, in one of the four paint-related ELTs, learners are introduced to standardized steps for troubleshooting common paint robot issues encountered in an automotive manufacturing paint booth environment.

Table 8. Experiential learning technologies that teach spray painting.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Paint Robot Troubleshooting	TRANSFR, Inc.	Paint Robot Trouble Shooting
Painting	Mimbus; VRSim, Inc	SimSpray/ SimSpray Go
	Skillveri	Skillveri Chroma® Spray Painting Simulators
	Tradiebot	Spray VIS

3.2.3 ELTs for skilled trades in the industrial sector

Fifty-four OSH-related ELTs were identified for the industrial sector. Of these, nine covered general OSH-related knowledge while the remainder were specific to occupational tasks, including maintenance and repair of industrial machinery (n=6); operation of production line tools/equipment (n=5), driving tractor-trailers (n=6), welding (n=9), maintaining railway (n=9), and maintaining gas and utilities (n=10). The following further describes each of the categories.

3.2.3.1 General Competencies for Workers in the Industrial Sector

Potentially relevant ELT topics for those working within the industrial sector included blueprint reading (n=1), general industrial safety (n=3), hazard awareness in industrial settings (n=2), and precision measurement (n=1) (Table 9).

Table 9. Experiential learning technologies that support general OSH competencies for working in the industrial sector.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Blueprint Reading	TRANSFR, Inc.	Blueprint Reading
General Industrial Safety	NextWave Safety Solutions, Inc.	General Industry Safety
	Technical Laboratory Systems, Inc.	VR Industrial Safety Training Programs
	TRANSFR, Inc.	Plant Safety
Hazard Awareness	Oberon Technologies	Titania® Warehouse Hazard Recognition Training
	trainPOINT	Atomic Energy Hazard Identification
		Warehouse Hazard Identification
Precision Measurement	TRANSFR, Inc.	Precision Measurement

3.2.3.2 Industrial Machinery (Maintenance and Repair)

The five ELTs categorized into *Maintenance and Repair of Industrial Machinery* would be most relevant for hydraulic/pneumatic mechanics, general machinists, and facilities mechanics (Table 10). Many of these programs, distributed through zSpace, are delivered through a 3D projection system, allowing learners to virtually disassemble and assemble various components of machinery and visualize its operation.

Table 10. Experiential learning technologies that train safe maintenance and repair of industrial machinery.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Industrial Robots	zSpace; Shenzhen GTA Education Tech Ltd.	Industrial Robotics Mechanic
		Industrial Robotics Expert
Hydraulics	zSpace; Fun2	Advanced Manufacturing Hydraulics
Pneumatics	zSpace; Fun2	Advanced Manufacturing Pneumatics
Mechanical Components	zSpace; Fun2	Advanced Manufacturing Mechanical
Mechatronics	TRANSFR, Inc.	Mechatronics

3.2.3.3 Welding

We identified nine ELTs that train users on safe and accurate welding (Table 11). These ELTs would be most relevant for welders, pressure systems welders, and those required to perform welding tasks as a part of their job. Generally, the welding ELTs are delivered via a VR headset and controller accessories that replicate welding equipment. These ELTs teach users various welding techniques, including shielded and gas metal arc welding, and allow them to practice through a series of exercises. Real-time feedback on the quality of the welds is also provided.

Table 11. Experiential learning technologies that train safe and accurate welding.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Welding	3M	3M Welding Demonstration
	Lincoln Electric	VRTEX 360
		VRTEX Engage
		VRTEX Transport
	Mimbus; zSpace	Wave NG Welding
	Realityworks	guideWELD VR Simulator
	Redlab Engineering	Redweld
Skillveri	Skillveri AURA® Z+ Welding Simulator	
Strata Tech	OcuWeld	

3.2.3.4 Tractor-Trailer

We identified six ELTs that would be relevant to tractor-trailer and commercial drivers (Table 12). Four of these focus on familiarizing the learner with specific controls of a truck/semi-trailer/bus. Generally, these ELTs guide learners through various exercises such as driving forwards and reversing, turning and cornering, manual shifting, monitoring alignment, docking, parking, and more. These ELTs are delivered via simulator systems of varying levels of cost, immersiveness, and realism of controls.

The other two ELTs train learners on the best practices to identify pre-trip safety hazards. Of these, one is delivered via VR headset, and the other is a complimentary app compatible with desktops, tablets, and smartphones.

Table 12. Experiential learning technologies that train the safe operations of tractor-trailers.

Task/ Topic Area	Developer(s)/Distributor(s)	Name of ELT
Truck Driving	Acreos	Heavy Group
	Advanced Training Systems LLC.	Fleetmaster
		Shiftmaster
		Transmaster
Pre-trip Inspection	Advanced Training Systems LLC.	Pre-trip Inspection
	Humulo Engineering	Pre-trip Inspection

3.2.3.5 Production Line Tool/Equipment Operation

Five ELTs trained safe operation of various tools/equipment found on a production line (Table 13). Process operators within food manufacturing, power, refinery, chemical, and liquid processes, and wood products may find one or more of these ELTs relevant.

Table 13. Experiential learning technologies for safe operation of tools/equipment that may be found on production lines.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Head Saw	Acreos	Head Saw
IS Machine	VR Inn	IS Machine Training
Lathe	Ulster University	Lathe Safety Simulator
Production line	Mimbus	Production Line Operator
Sawmill	Mimbus	Sawmill Operator

3.2.3.6 Railway

A series of nine ELTs developed by Heartwood would be relevant to railway car technicians and car persons (Table 14). Delivered through a desktop or mobile app, these ELTs cover topics and tasks such as air brake test, blue signal protection, daily inspection, pre-trip inspection and ventilation that aligns with various Code of Federal Regulations (i.e., CFR 215, 218, 229, 232, 238).

Table 14. Experiential learning technologies pertaining to locomotive cars and railways.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Air Brake Test	Heartwood	Air Brake Test (CFR 238) - Virtual Interactive Guide
		Air Brake Test (CFR232) - Virtual Interactive Guide
		Air Brake Test SIM (CRF 232)
Blue Signal Protection	Heartwood	Blue Signal Protection (CFR 218) - Interactive Simulation
Daily Inspection	Heartwood	Locomotive Daily Inspection (CFR 229) - Virtual Interactive Guide
Pre-trip Inspection	Heartwood	Pre-departure Inspection (CFR 215) - Interactive 3D Simulation
		Pre-departure Inspection (CFR 215) - Virtual Interactive Guide
		Railroad Locomotive Daily Inspection (CFR 229) - Interactive 3D Simulation
Ventilation (Locomotive)	Heartwood	Air Flow Simulation (CFR 232, 238)

3.2.3.7 Utilities

We identified ten ELTs relevant to gas and utilities (Table 15); those pursuing a career to become a gas technician may find these ELTs helpful. All ELTs within this category are delivered through VR headsets. Noteworthy, PIXO VR developed and distributes eight of the ten ELTs in this category; they have ELTs for facility locating and marking, gas handling, leak investigation, inside meter inspection, maintenance and repair, pipeline patrolling, and more.

Table 15. Experiential learning technologies pertaining to gas and utilities.

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Facility Locating & Marking	PIXO VR	Facility Locating & Marking
Gas Handling	PIXO VR	Gas Handling
Gas Leak Survey	Elite VR Training	Walking Gas Leak Survey
Inside Leak Investigation	PIXO VR	Inside Leak Investigation
Inside Meter Inspection	PIXO VR	Inside Meter Inspection
Maintenance and Repair (Utilities)	PIXO VR	Operator Qualification
Natural Gas Leak	PIXO VR	Natural Gas Leak
Outside Leak Investigation	PIXO VR	Outside Leak Investigation
Pilot Lighting	NextWave Safety Solutions, Inc.	Pilot Light Technician
Pipeline Patrolling	PIXO VR	Pipeline Patrolling

3.2.4 ELTs for skilled trades in the automotive sector

Nine ELTs specific to training workers in the automotive sector were identified (Table 16). Of these, eight focused on the safe maintenance and repair of cars, while one was specific to tractor-trailers. Occupations within the automotive sector that may find these ELTs helpful include alignment and brakes technicians, auto body and collision damage repairers, auto body repairers, automotive glass technicians, automotive service technicians, motive power machinists, tire wheel and rim mechanics, transmission technicians, truck and coach technicians, and truck-trailer service technicians. Automotive painters may benefit from the ELTs identified in [3.2.2.5 Painting](#).

Table 16. *Experiential learning technologies for automotive maintenance and repair.*

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Assemble/Disassemble Automotive Parts	zSpace; Shenzhen GTA Education Tech Ltd.	VR Automotive Expert
		VR Automotive Mechanic
		VR Electric Automotive Mechanic
		VR Hybrid Automotive Mechanic
Maintenance and Repair (Car)	Red Dot Games	Car Mechanic Simulator 2021
	TRANSFR, Inc.	Automotive Maintenance Fundamentals
	zSpace; Shenzhen GTA Education Tech Ltd.	VR Automotive Diagnostics
	Missing Digit	Wrench
Maintenance and Repair (Tractor-Trailers)	Technology and Maintenance Council	TMC Supertech



3.2.5 ELTs for skilled trades in the service sector

Although many of the skilled trade occupations in the service sector may benefit from the generic OSH-related ELTs (e.g., emergency preparedness, first aid, fire safety, hazard awareness, PPE, etc.), there were three ELTs that were specific to occupations in the service sector.

3.2.5.1 Residential Appliances

We identified two ELTs that may be relevant for appliance service technicians (Table 17). In *Appliance Inspection*, delivered through VR headset, users perform a multi-step appliance safety inspection before re-lighting and turning it on. *Appliance Inspection* covers several customer-owned appliances, including gas ranges, gas dryers, water heaters, gas furnaces, and hot water boilers; in this ELT, trainees learn to inspect gas piping, shut-off valves, vent piping, combustion, boiler pressure, discharge pipe, safety valves, etc. The other ELT, *Electrical Control VR Instruction*, delivered through a 3D projector system, helps students understand electrical controls through animations of model parts. *Electrical Control VR Instruction* provides exploded and perspective views of each component and includes control circuit building tasks.

Table 17. *Experiential learning technologies for inspecting, maintaining, and repairing residential appliances.*

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Assemble/Disassemble (Electrical Control in low-voltage electrical appliances)	zSpace; Fun2	Electrical Control VR Instruction
Appliance Inspection	PIXO VR	Appliance Inspection

3.2.5.2 Meat Cutting

We identified a poultry-cutting ELT relevant to cooks, chefs, institutional cooks, and retail meat cutters (Table 18). This ELT teaches users to cut the appropriate parts of the chicken, sort the pieces of meat, and sharpen the knife at the right time.

Table 18. *Experiential learning technology for meat cutting.*

Task/Topic	Developer(s)/Distributor(s)	Name of ELT
Poultry Cutting	Mimbus	Poultry Cutting

4. DISCUSSION

In this environmental scan, we identified 288 off-the-shelf OHS-related ELTs that support skilled trades trainees in learning OSH and safe work processes. We identified the delivery mechanisms available for these ELTs and presented our findings based on the OSH-related tasks and topics covered. Our analysis of the ELTs allowed us to better understand the landscape of OHS-related ELTs that are currently available for skilled trades occupations, the feasibility of implementing ETL in skilled trade education, and the opportunities for further development.

4.1 Landscape of OHS-related ELTs

Although it is unlikely that ELTs will replace classroom learning in the skilled trades, ELT are increasingly becoming a common element for applying OSH training in the trades. In this report, we identified several ELTs that focused on developing skills for general OSH topics covered within the Ontario College of Trades Curriculum Training Standards including confined spaces, emergency preparedness, fall safety/working at heights, fire safety, hazards identification and lockout/tagout, manual materials handling, and personal protective equipment. Most of these ELTs are delivered through VR headsets, meaning that there are ELTs available to give trainees general knowledge and skills in various aspects of OSH given they have access to a VR headset. Also noteworthy is that many of these are relevant for acute injuries; we did not find any ELTs that showed the long-term health consequences of hazardous exposures. For example, except for three mobile apps related to manual materials handling, we did not find any ELTs that focus specifically on ergonomics and the prevention of musculoskeletal disorders (MSD). Given the high rates of MSD in skilled trade occupations, more ELTs on ergonomic hazards and controls are needed. Further, a concurrent gap analysis comparing the existing OHS training components with WSIB injury data reported significant gaps in training related to fall safety, personal protective equipment, and hazards identification training (13). ELTs may be useful in supplement the training.

ELTs designed for trades-specific occupations (n=192) often focused on the safe work processes and practices of a given task (e.g., painting, welding, machine operations, gas leak inspection) with the integration of OSH concepts. These were often tasks and topics that were resource intensive to physically simulate (e.g., use of expensive/inaccessible



location, equipment, or materials) or had severe consequences if proper safety protocols were not followed. Noteworthy, over 93% (180/192) of the ELTs were designed for either the construction (65%; 126/192) or industrial (28%; 54/192) sector. ELTs for the automotive and service sectors were limited. We hypothesize that occupations within the automotive and service sector involve fine motor skills that are difficult to simulate in an ELT. Additionally, ELTs may not be needed in these industries because providing experiential learning may be already accessible (e.g., cooking or working on a real car) and the associated risks and health consequences are low.

Furthermore, we learned that some forms of delivery mechanisms are more commonly used for teaching specific tasks/topics. For example, teaching the safe operation of heavy machinery is mainly delivered via simulator systems where trainees can become familiar with the configuration, feel, and operation of the machine's controls. Fall safety, on the other hand, was often delivered via VR headsets to immerse trainees into an elevated work environment and give trainees a sense of falling if their fall arrest system is not appropriately secured. Procedural knowledge, such as maintenance and repair of appliances, was also commonly delivered via VR. Lanzotti et al. found that simulations are effective in teaching standard operating procedures that are usually difficult or dangerous to simulate in a real work scenario, without stopping production (12).

4.2 Feasibility of Implementing ETLs in Skilled Trades-Related Programs

ELTs are already being used in skilled trades training and certification. There were even some standalone programs where most of the content is taught through ELTs. For example, we found three comprehensive HVAC-related ELTs (i.e., Skillcatapp, Skillmill, and Tauris Tech) aimed to prepare trainees to write a certification exam upon completion (i.e., EPA 608 certification). Furthermore, ELTs have also been used as an assessment tool for certification. The [VR Construction Hazard ID Assessment](#) and the [MEWP VR Simulator](#) are examples of ELTs used as an assessment tool for nationally recognized certifications. Most of the ELTs, however, may be used as a complementary teaching aid to provide virtual hands-on experience as well as individualized real-time feedback for trainees. Depending on how a training institution wants to implement ELTs, there was a wide range of ELTs identified to suit various models of implementation.

For training institutions and trainees that have restricted resources, we identified over 50 complimentary ELTs that can be delivered via highly accessible platforms such as desktops or smartphones. Instructors can direct trainees to these ELTs for additional information and practice on a given OSH topic or skill. Being able to access ELTs outside the classroom provides trainees with an engaging means to practice and reinforce skills and knowledge on their own time until they are confident in the material. Many of these ELTs are developed in collaboration with and/or funded by government bodies, universities, trade associations, and/or unions which gives the ELTs a level of credibility.

Other ELTs identified would require institutional investment into the software and its associated hardware. However, that is not to say that such ELTs would not be feasible. Within the past five years, many institutions have invested into infrastructure and hardware, such as VR studios and headsets. For example, Northern Ontario College, Saskatchewan Polytechnic, and Mohawk College have recently purchased new virtual reality equipment for their training programs (14). Access to such equipment allows for implementing several ELTs delivered via VR headset, regardless of the topic area, task, or trade. Saskatchewan Polytechnic.

4.3 Opportunities for Further Development

This project aims to develop a toolbox/database of skilled trade- and OSH-related ELTs to support instructors in identifying relevant ELTs that can be used to supplement training for achieving the desired learning outcomes. To further the usefulness of the toolbox, instructors should know the efficacy of the ELT in achieving its learning outcomes. For now, many ELT developers refer to the fact that ELTs are generally more effective than traditional teaching methods, with no evidence, other than testimonies, that their specific ELT(s) is/are effective. Many of the ELTs that have undergone scientific program evaluation are proof of concept studies and not direct evaluations of the ELT that is commercially available (7,12,15). The studies found advantages with VR training for maintaining trainees' attention and concentration (7), learning the task, and memorizing critical points (12). Another area for further development is to create ELTs using Canadian safety laws and regulations. Most of the ELTs identified were created by developers in the USA, which refers to safety laws and regulations in the USA. More ELTs need to be developed in Canada or have options of customization to Canadian safety laws and regulations.

5. CONCLUSION

In this environmental scan, we systematically searched and identified 288 off-the-shelf OHS-related ELTs that support skilled trade trainees in learning OSH and safe work processes. The ELTs were presented based on the OSH-related tasks and topics they covered. The various delivery mechanisms of the ELTs were also described. Findings from this report will be used to develop a toolbox/database of skilled trade- and OSH-related ELTs to support instructors in identifying relevant ELTs that can be used to supplement training to achieve desired learning outcomes.





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APPENDIX A. AVAILABLE DELIVERY MECHANISMS FOR EACH IDENTIFIED EXPERIENTIAL LEARNING TECHNOLOGY (SORTED BY DEVELOPER/DISTRIBUTOR).

Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
3M											
3M Fall Protection Harness Inspection	\$				✓						
3M Fundamentals of Fall Protection VR Pro	\$				✓						
3M Working at Heights Awareness	\$				✓						
3M Welding Demonstration	\$				✓	✓					
Acreos											
Backhoe Loader	\$			✓							
Crawler Crane	\$			✓							
Mobile Crane	\$			✓							
Ship to Shore Container Crane	\$			✓							
Tower Crane	\$			✓							
Bulldozer	\$			✓							
Articulated Dump Truck	\$			✓							
Dumper	\$			✓							
Excavator	\$			✓							
Mining Excavator with Shovel Bucket	\$			✓							
Milling Machine	\$			✓							
Motor Grader	\$			✓							
Straddle Carrier	\$			✓							
Telehandler	\$			✓							
Heavy Group	\$			✓							
Mining Wheel Loader	\$			✓							
Wheel Loader	\$			✓							
Head Saw	\$			✓							
Forklift Truck	\$			✓							
Mining Excavator with Backhoe Bucket	\$			✓							
Advanced Training Systems LLC.											
Fleetmaster	\$			✓							
Shiftmaster	\$			✓							
Transmaster	\$			✓							
Pre-trip Inspection	\$									✓	
Arcadicus											
HVAC Virtual Simulation					✓						
Archvirtual											
ASSP Fall Protection VR Experience	\$				✓						
Astragon Entertainment GmbH											
Construction Simulator 3	\$							✓		✓	
Bit Space Development Ltd.											
Flagpersons Safety Training									✓	✓	
MCSC Framers										✓	



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
IBEW Safety VR					<	<					
IBEW Slips Trips & Falls						<			<	<	
CSAM/RMP/MHCA PPE Course Companion										<	<
MHBA Confined Space Virtual Reality										<	<
MHBA Fall Protection App										<	<
MHBA Scaffolding Safety Awareness App										<	
United Association Safety 360					<	<					
Cat® Safety VR	\$				<						
Cat® Construction Simulator	\$		<	<							
Cat® Mining Simulator	\$		<	<							
Virtual Reality Training for Forklifts						<			<		
OSHA Safety Simulator	\$				<						
Feeder Protection Relay Training					<						
Transformer Oil Sampling in VR					<						
Ditch Witch HDD VR Simulator	\$		<				<				
Fire Extinguisher Training	\$				<						
Experience the Energy: Take the Challenge					<	<			<	<	
VR Forklift Simulator (Stand Up Reach/ CB)	\$				<		<				
Tower Crane	\$		<								



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
Forklift	\$		✓								
Forklift University											
Premium Virtual Forklift Simulator	\$		✓								
Virtual Forklift Mobile	\$						✓				
Hard Hat VR											
Hard Hat VR Training Toolbox	\$				✓						
FreeRangeXR											
Confined Spaces	\$				✓						
Fall Protection	\$				✓						
Fire Suppression	\$				✓						
AED Education	\$				✓						
CPR Education	\$				✓						
Lockout Tagout	\$				✓						
FreeRangeXR; Raymond											
Forklift Virtual Reality Simulator	\$	✓	✓								
Groove Jones; IVRY Technologies											
Virtual Electrical Training	\$				✓						
Groove Jones; Toyota											
Prevent the Fall										✓	
Heartwood											
Air Brake Test (CFR 238) - Virtual Interactive Guide (VIG)	\$								✓	✓	
Air Brake Test (CFR232) - Virtual Interactive Guide (VIG)	\$								✓	✓	
Air Brake Test SIM (CRF 232) - Interactive Simulation	\$								✓	✓	
Blue Signal Protection (CFR 218) - Interactive Simulation	\$								✓	✓	
Locomotive Daily Inspection (CFR 229) - Virtual Interactive Guide (VIG)	\$								✓	✓	
Lockout-Tagout (LOTO)	\$								✓	✓	
Pre-departure Inspection (CFR 215) - Interactive 3d Simulation	\$								✓	✓	
Pre-departure Inspection (CFR 215) - Virtual Interactive Guide (VIG)	\$								✓	✓	
Railroad Locomotive Daily Inspection (CFR 229) - Interactive 3D Simulation	\$								✓	✓	
Air Flow Simulation (CFR 232, 238)	\$								✓	✓	
Humulo Engineering											
Confined Spaces	\$				✓						
Fall Safety	\$				✓						
Fall Safety: Communication Towers	\$				✓						
Fall Safety: Ladders	\$				✓						
Scaffolding Safety	\$				✓						
Fire Safety	\$				✓						
General Hazard Recognition	\$				✓						



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
Underground Utilities	\$				<						
Lock-out/Tag-out	\$				<						
Forklift Fundamentals Training	\$				<						
Pre-trip Inspection	\$				<						
Rigging: Mobile Towers and Cranes	\$				<						
Trench Safety	\$				<						
Immersive Technologies											
Worksite VR Quest	\$				<		<		<		
Mine Training Standards	\$				<						
Autonomous and Remote Equipment	\$			<					<		
Pre-start Inspection	\$								<		
ITI Industrial Training											
VR Construction Hazard ID Assessment	\$				<						
ITI Industrial Training; Serious Labs											
Boom Truck VR Simulator	\$						<				
Carry Deck Crane VR Simulator	\$						<				
Down Cab Rough Terrain Simulator	\$		<				<				
Heavy Lift Crawler VR Simulator	\$		<				<				
Lattice Boom Crawler Crane Operator Simulator	\$		<				<				
Overhead Bridge Crane VR Simulator	\$		<				<				
Polar Crane Simulator	\$		<				<				
Rough Terrain Mobile Crane Operator Simulator	\$		<				<				
Tower Crane Operator Simulator	\$		<				<				
JLG											
Access Ready Fusion XR	\$		<								
Lennox											
Lennox VR & WebVR Training	\$				<				<		
Lincoln Electric											
VRTEX 360	\$		<								
VRTEX Engage	\$			<							
VRTEX Transport	\$						<				
Melcher Studios; Virtual Reality Training Solutions											
VR Fall Arrest	\$		<								
VR Fire Extinguisher Training	\$		<						<	<	
VR Snowplow Training	\$		<						<		
Mimbus											
Electrical Qualification	\$				<						
Scaffolding Safety	\$				<						
Worksite Safety	\$				<						
Electrical Maintenance	\$				<						
Mimbus (cont.)											
Poultry Cutting	\$				<						
Refrigerant Accreditation	\$				<						



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)Smartphone +VR	gogglesDesktop+Accessories/VR	Video Game Console Desktop or	Web Browser	Tablet or Smartphone	3D Projection System
Production Line Operator	\$									
Sawmill Operator	\$									
WOOD-ED	\$									
Mimbus; VRSim, Inc										
SimSpray/ SimSpray Go	\$		✓							
Mimbus; zSpace										
Wave NG Welding	\$									
Mindgames Media										
Workplace Sim								✓	✓	
Missing Digit										
Wrench	\$				✓			✓		
NextWave Safety Solutions, Inc										
Fall Prevention	\$				✓					
Scaffold Safety	\$				✓					
Construction Site Safety	\$				✓					
General Industry safety	\$				✓					
Lockout-Tagout (LOTO)	\$				✓					
Forklift Operator	\$				✓					
Pilot Light Technician	\$				✓					
Norcat										
FIAR	\$			✓					✓	
Oberon Technologies										
Titania® Fire Equipment Training	\$				✓					
Virtual Reality Training for Hazardous or Dangerous Environments	\$				✓					
Titania® Warehouse Hazard Recognition Training	\$				✓					
Titania® Lockout / Tagout Procedure Training	\$				✓					
Titania® PPE Protocol Training	\$				✓					
OSHA's Hazard Identification Training Tool								✓		
VR Evacuation Training	\$				✓					
Driving Safety	\$				✓			✓		
Line of Fire	\$				✓			✓		
Safe Mechanical Lifting	\$				✓			✓		
Energy Isolation	\$				✓			✓		



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
PIXO VR											
Low Voltage Rescue	\$				✓						
Pole Top Rescue	\$				✓						
Facility Locating & Marking	\$				✓						
Fall Protection	\$				✓						
Gas Handling	\$				✓						
Stand-by Activities	\$				✓						
Hazard Recognition	\$				✓						
Inside Leak Investigation	\$				✓						
Inside Meter Inspection	\$				✓						
Operator Qualification	\$				✓						
Natural Gas Leak	\$				✓						
Outside Leak Investigation	\$				✓						
Appliance Inspection	\$				✓						
Pipeline Patrolling	\$				✓						
PIXO VR; Aviation Virtual											
Fire Extinguisher Training	\$				✓						
PIXO VR; Buzzark											
Electrical Substation Maintenance	\$				✓						
PIXO VR; Inside Technologia											
Working at Heights Training - Oil and Gas Platform	\$				✓						
PIXO VR; ITT											
Fire Prevention - Construction Site	\$				✓						
Housekeeping Safety Rules - Construction Site	\$				✓						
Hazard Recognition (Construction)	\$				✓						
PIXO VR; Vectre											
Confined Spaces	\$				✓						
Lockout/Tagout	\$				✓						
Purdue University											
Fall Safety VR Training Simulator	Ⓜ				✓	✓			✓	✓	
Realityworks											
guideWELD VR Simulator	\$			✓							
Really Virtual											
Real-Forklift Simulator	\$		✓				✓				
Red Dot Games											
Car Mechanic Simulator 2021	\$				✓			✓	✓		
Redlab Engineering											
Redsafe	\$				✓						
Redweld	\$		✓								
Sentient Computing											
Working at Heights VR Training	\$				✓						
Fire Extinguisher Safety VR Training	\$				✓						
Hazard Recognition VR Training	\$				✓						
Serious Labs											



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
MEWP VR Simulator	\$										
Simcoach Games											
Harness Hero											
Harness Hero - Bridge Edition											
Site Coach: Ladder Safety											
Future Road Builders											
Excavator Game (CAWP Arcade)											
Reinforcers (CAWP Arcade)											
Best Built Plans: Manual Materials Handling											
Lift Coach: Plan Your Route											
Lift Coach: Plan Your Lift											
Traffic Control (CAWP Arcade)											
Simcoach Games (cont.)											
Road Builder Blitz											
Ground Up Construction											
Hooked: A Tower Crane Game											
Dig In: A Dozer Game											
Dig in: An Excavator Game											
Construction Crane Signals											
ICRA for Construction											
Electric Protector											
Site Coach: Fall Hazards											
Site Coach: Start Smart											
Future Construction Managers											
Future Construction Inspectors											
Construction Crane Rigging											
SIMLOG											
Backhoe Loader Personal Simulator	\$										
Mobile Crane Personal Simulator (Advanced Edition)	\$										
Tower Crane Personal Simulator	\$										
Drill Jumbo Personal Simulator	\$										
Bulldozer Personal Simulator	\$										
Hydraulic Excavator Personal Simulator (Version 2.5)	\$										
Forklift Personal Simulator (Version 2.0)	\$										
Reach Lift truck Personal Simulator	\$										
Forwarder Personal Simulator	\$										
Harvester Personal Simulator	\$										
Mining Truck Personal Simulator (Version 2.0)	\$										
Off-Highway Truck Personal Simulator	\$										
Electric Rope Shovel Personal Simulator	\$										
Skid Steer Loader Personal Simulator	\$										



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
Wheel Loader Personal Simulator (Version 2.0)	\$			✓			✓				
Wheeled Material Handler Personal Simulator	\$			✓			✓				
Skillcatapp											
Skillcat					✓				✓	✓	
SkillMill											
Personal Interplay Learning Subscription	\$								✓	✓	
Skillveri											
Skillveri Chroma® Spray Painting Simulators	\$		✓		✓						
Skillveri AURA® Z+ Welding Simulator	\$		✓		✓						
SQLearn											
Fire in the Engine Control Room	\$				✓				✓		
Lifeboat Launching Procedure VR course	\$				✓				✓		
Strata Tech											
OcuWeld	\$				✓						
Streamline Simulations											
3-D Forklift (Standard or Customizable)	\$			✓						✓	
Tauris Tech											
HVAC Basics / Heat Pump Installation (Course)	\$								✓		
Technical Laboratory Systems, Inc											
V/R Workplace Safety Training Program	\$				✓						
V/R Industrial Safety Training Programs	\$				✓						
Technology and Maintenance Council											
TMC Supertech										✓	
Tecknotrove Systems (1) PVT Ltd.											
TecknoSIM Backhoe Loader Simulator	\$		✓	✓							
TecknoSIM Dozer Simulator	\$		✓	✓							
TecknoSIM Dumper Truck Simulator	\$		✓	✓							
TecknoSIM Tipper Simulator	\$		✓	✓							
TecknoSIM Excavator and Shovel Simulator	\$		✓	✓							
TecknoSIM Forklift Simulator	\$		✓	✓							
TecknoSIM Truck Driving Simulator and Heavy Vehicle Training Simulator	\$		✓	✓							
Texas Mutual											
Safety in a Box 2.0										✓	
Texas Safety Solutions LLC; Peak Activity LLC											
Hazards AR Training System (H.A.R.T.S)										✓	
Thoughttec Simulation											
CYBERMINE Full Mission Mining Simulators	\$			✓							
CYBERQUIP Full Mission Simulators	\$			✓							
Tradiebot											
SprayVIS	\$		✓								
TrainPOINT											
Fall Protection - Harness Inspection	\$				✓				✓		



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
Construction Hazard Identification	\$				<				<		
Outdoor Hazardous Conditions	\$				<				<		
Atomic Energy Hazard Identification	\$				<				<		
Factory Hazard Identification	\$				<				<		
Warehouse Hazard Identification	\$				<				<		
TRANSFR, Inc.											
Blueprint Reading	\$				<						
Construction Safety	\$				<						
Plant Safety	\$				<						
Automotive Maintenance Fundamentals	\$				<						
Mechatronics	\$				<						
Paint Robot Trouble Shooting	\$				<						
Precision Measurement	\$				<						
Ulster University											
Lathe Safety Simulator					<						
University of Idaho VTD; University of Washington DEOHS CEP											
Permit-Required Confined Space Entry									<		
VARtech LLC											
OSHA Portable Ladder Safety VR						<				<	
Varwin											
Varwin Rigging VR Lab Virtual Training Simulator	\$				<						
VR Direct											
Enviro - Safety Construction Training									<		
VR Inn											
IS Machine Training	\$				<						
WorkSafeBC											
The Ladder Challenge Game									<		
zSpace; Fun2											
Electrical Control VR Instruction	\$										<
Advanced Manufacturing Hydraulics	\$										<
Advanced Manufacturing Mechanical	\$										<
Advanced Manufacturing Pneumatics	\$										<
zSpace; Labtech											
HVAC Fundamentals	\$										<
HVAC Residential	\$										<
zSpace; Shenzhen GTA Education Tech Ltd.											
VR Automotive Expert	\$										<
VR Automotive Mechanic	\$										<
VR Electric Automotive Mechanic	\$										<
VR Hybrid Automotive Mechanic	\$										<
Industrial Robotics Mechanic	\$										<
Industrial Robotics Expert	\$										<
VR Automotive Diagnostics	\$										<



Name of ELT	Access	System +VR	Simulator System +VR	Simulator System	VR headset (w/ controllers)	Smartphone +VR goggles	Desktop+Accessories/VR	Video Game Console	Desktop or Web Browser	Tablet or Smartphone	3D Projection System
zSpace; VIVED VIVED Carpentry	\$										↩

APPENDIX B. SOFTWARE DEVELOPERS THAT ONLY OFFERED CUSTOMIZED ELT SOLUTIONS.

Developers for Only Custom ELT Safety Training	Technology	Country
Accenture	XR	Global
Arch Virtual	VR	USA
Attensi	Simulation	Norway
Austin Visuals	XR	USA
Designing Digitally	VR; mobile apps	USA
e-learning studios	VR; AR	UK
ForgeFX	VR; AR; Simulations	USA
Future Visual	XR	UK
Golder's Medialab	VR	Global
Jasoren	VR	USA
Khora	VR; AR	Denmark
Lumeto	VR/AR	Canada
MojoApps	XR	Switzerland
Motive	VR	Canada
MR studios	XR	Czech Republic
MX Reality	XR systems	UK
NNTC	VR	United Arab Emirates
Norcat Studios	XR	Canada
OutHere	XR	Sweden
PaleBlue	XR	Norway
Program-ace	XR	Cyprus
Progress Software Corporation	VR	USA
Ramboll	VR; mobile app	Denmark
Real Serious Games	XR	Australia
Servreality	XR	Ukraine
Simulated Training Solutions 3D	VR	South Africa
St. Engineering Antycip	XR systems	UK
Strivr Labs, Inc.	VR	USA
Tengo Interactive	VR	Netherlands
Totem Learning	VR; Simulations	UK
Upskill	AR	USA



Vector Form	XR	USA
Virmode	VR	Istanbul
Virtual Reality Ireland	VR	Ireland
Virtual Reality Machine Training	VR	UK
VisionThree	XR	US
Vitro	VR	Canada
VR OWL	XR	Netherlands
VR Vision Group	XR	Canada
VTM Digital	XR	Hong Kong
WeAR Studio	XR	Ukraine
Yeppar	XR	India

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