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XR – state of play, market needs, training trends

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Alliance4XR

Innovation alliance to infuse Extended Reality skills into Higher education and Vocational Training



D1.1

XR – state of play, market needs, training trends



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Abstract (for dissemination)	<i>D1.1 focuses on the results of the desk study, the distributed questionnaire exploring the XR state and needs, as well as the interviews with industry and academia stakeholders. This report's focal point is to identify the state-of-play, market needs and training trends In the XR sector, focusing on the enhancement of green skills. The outcome of D1.1 will provide Input to the following deliverables D1.2 and D1.3.</i>

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Abbreviations

Term	Explanation
XR	eXtended Reality
VR	Virtual Reality
AR	Augmented Reality
MR	Mixed Reality
HEI	Higher Education Institution
VET	Vocational Education and Training
LMS	Learning Management Systems
WW	Wastewater
WWTP	Wastewater Treatment plant
UC	Use Case
TBD	To Be Determined
TBC	To Be Confirmed
3D	Three Dimensional
SATLE	Strategic Alignment of Teaching and Learning Enhancement Fund
GIS	Geographic Information System
BIM	Building Information Modeling
LM	Learning Material

Disclaimer

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EXECUTIVE SUMMARY

D1.1 offers a comprehensive analysis of the Extended Reality (XR) sector, aiming to assess the current state, identify market needs, and explore training trends, particularly focusing on the enhancement of green skills. This analysis is grounded in a comprehensive desk study, responses from a distributed questionnaire, and in-depth interviews with industry and academic stakeholders. The report identifies key trends, challenges, and opportunities in the XR landscape, emphasizing the importance of incorporating environmentally sustainable practices and green skills into training and professional development. The findings from D1.1 are crucial for shaping the strategic direction of subsequent deliverables, D1.2 and D1.3, which will provide frameworks and recommendations to further integrate these essential skills into the sector, thereby aligning XR industry growth with broader sustainability goals.

1 INTRODUCTION

In the realm of *Alliance4XR*, the emergence of XR technologies signifies a great advancement in facilitating profound and immersive human-digital interactions. This progress is chiefly attributed to recent strides in high-speed communication and computation, enabling unprecedented possibilities in the domains of education and training. Notably, the industry's transition towards open-source solutions, exemplified by platforms such as [Unreal](#) and [Unity](#) for XR creators, has ushered in a new era. This shift towards open-source game engines has substantially democratized the process of content creation, making the development of XR content more attainable and inclusive than ever before. As we embark on the incorporation of XR into education and training methodologies, the profound implications of these technological advancements and open-source solutions are duly acknowledged, shaping a future characterized by collaborative and accessible immersive learning experiences.

1.1 Project general objectives

The main target of the project is to design, develop and validate an innovative teaching and training approach, using XR technologies. A careful design requires a reflection on the status of the HEI, VET and key engineering sectors (structural engineering and construction, grids and energy, and maritime professions).

The investigation of the multiple uses of VR, AR and MR technologies in the field of education and training are key goals of the project. This investigation is closely related to the range of technical proficiency that you can allow for outputs, the skills of the end-users, and the financial resources available. This project will explore these aspects thereby investigating the feasibility and efficacy of XR technologies as pedagogical tools to cater to the varied needs of stakeholders in education and industry in engineering arenas.

The project implementation stage aims to be a revolutionary step and it calls for the creation of a strong Remote & Hybrid collaboration landscape. As the educational and work environments are changing, this is the foundational framework to facilitate communication and coordination between stakeholders. This strategic emphasis on remote and hybrid models reflects the contemporary

and global nature of connectivity, the urgent need for flexible learning solutions, and the necessarily deep penetration of formal education into civil society.

Ultimately, *Alliance4XR* is one example of how to foster the symbiosis of classicist educational and training methods and the frontier of new XR technologies. The idea is to work with engineering sectors and universities which will provide a scalable and flexible model for an enhanced learning experience resulting in sharing with the broader discussion on the integration of XR in education as well. The project ultimately aims to riff on this future by hacking its way into existence through research, iteration, and collaboration, where XR is woven into the fabric of pedagogy as a whole, enabling us to transcend disciplinary boundaries, enriching educational practices across disciplines of study.

1.2 Task objectives

WPI of the project deals with a gap analysis, where the need of the market is compared with the education offers being provided by the educational institutes. The scope of this report is the first part of this gap analysis, more precisely to describe the market needs and emerging professions, focusing on XR that at the same time enhance the green skills.

The survey for this deliverable is mostly limited to the consortium member's countries, mostly in Europe and the UK. But, outside Europe, there are several initiatives regarding XR-based learning.

The implications of XR have massive potential, and the United States has been one of the leaders when it comes to bringing these technologies into higher education. Universities are utilizing immersive technologies to support pedagogy in many areas. The University of Michigan developed a few XR applications, like "*Under the Skin*" and an "*XR Nuclear Reactor Laboratory*", to provide interactive experiences for students¹. Harvard University and the University of Iowa are also exploring 'metaversity' projects to test digital twin campus experiences.

Canadian universities are also adopting XR technologies to improve educational outcomes. Institutions such as the University of British Columbia and the University of Waterloo have programs that are actively working to streamline augmented

¹<https://www.educause.edu/research/community/2024/navigating-the-xr-educational-landscape-privacy-safety-and-ethical-guidelines/xr-adoption-in-higher-education>

reality into their training². For example, a study³ examined the potential of AR in Canadian higher education, highlighting its ability to enhance student engagement and learning.

Countries like China, Japan, and Korea are heavily investing in the development of learning solutions based on XR. China is deploying XR in its education system, driven by government programs to enhance learning results and train students for the digital economy. A study⁴ showed that the effectiveness of using VR in Chinese higher education could increase spatial ability and problem-solving skills.

While not yet mainstream, XR is making its way into African higher education, with some ambitious initiatives on the horizon. Organizations such as the African Virtual Reality Association are working to promote the adoption of XR technologies in African universities, addressing challenges such as infrastructure and accessibility. A study⁵ explored the potential of XR combined with AI within health professions education in southern Africa.

The focus of the project is on green skills within engineering, primarily within the marine, energy and construction sectors. The aim is to advance the integration of XR technologies into education and industry. The research involves collecting a comprehensive list of successful XR applications and use cases and is intended to guide future developments. By conducting semi-structured interviews with stakeholders in education and engineering, we hope to glean some insight into the impact, challenges, and opportunities of XR. On the one hand, the intention is to identify key factors for successful remote and hybrid learning in future. In addition, attention must be paid to the technical proficiency requirements of all learners. Finally, we must overcome adoption barriers in order that XR's place in education and training be more firmly established.

1.3 Achievement indicators

The pre-specified achievement indicators for this task are the following:

² <https://dearcanada.net/extended-reality-xr-adoption-in-higher-education/>

³ <https://www.cigionline.org/publications/facing-reality-canada-needs-to-think-about-extended-reality-and-ai/>

⁴ <https://heritagesciencejournal.springeropen.com/articles/10.1186/s40494-024-01217-1>

⁵ doi:[10.7196/AJHPE.2024.v16i2.1101](https://doi.org/10.7196/AJHPE.2024.v16i2.1101)

- Number of in-depth interviews: Target value is 10.
- Number of identified case studies, good practices and existing teaching and training material on XR: Target value is 5.

1.4 Structure of the document

The document is divided into six main sections. The first section describes the methodology followed for T1.1, extending from the desk study to the in-depth interviews and the survey. The next section aims at presenting the results from the desk study, extracting insights based on the use-cases and learning material from various sectors. In the next section, the results from the analysis of the in-depth interviews and the questionnaire are presented. Finally, the document concludes with the discussion and conclusion parts of the deliverable. In the annex section, the questionnaire, the guidelines for the in-depth interviews, as well as the description of the use cases and the learning material are presented.

2 METHODOLOGY

The objectives of this report is to describe the market needs and emerging professions, related to XR technologies which at the same time enhance green skills. To reach this objective, three different studies have been performed, namely

- A desk study aiming to identify current and potential future usages of XR technologies within the prioritised industry sectors (marine, energy and construction).
- In-depth interviews with key stakeholders, to describe the market needs in a more qualitative way.
- A questionnaire aiming to identify additional market needs not covered by the desk study and the interviews.

2.1 Current and potential future XR usage

The process of specifying successful XR use cases is a crucial step in understanding the current landscape of virtual, augmented, and mixed reality applications across various sectors. Desk research, a method of collecting and analyzing existing data from various sources, provides a structured approach to identifying and evaluating exemplary use cases. This section outlines the methodology for conducting desk research to compile a comprehensive list of successful XR applications.

The first step of this analysis was to define the general scope of the research. The sectors covered in this deliverable, that were defined by the *Alliance4XR* project, are the following:

- **Higher Education Institutions;**
- **Vocational Education and Training Institutions;**
- **Structural Engineering and Construction;**
- **Maritime Professions;**
- **Grids and Energy;**
- **Remote Collaboration;**

For analysis purposes, an additional category has been added, namely AR/VR/MR, that covers any additional use case that does not fit into any of the previous.

The next step was the data collection process. This process involves collecting information from various reliable sources, which include, but are not limited to:

- **Academic Journals and Conference Proceedings;**
- **Industry Reports;**
- **Company Websites;**
- **Technology Review Platforms;**
- **News Articles and Press Releases;**

To systematically compile the use cases, their information was gathered by the same template. The last step was to verify the credibility and pertinence of the obtained use cases, by cross-checking information among various resources and getting advice from experts whenever possible. This phase also entails an early-stage analysis to assess overall themes and common features in the use cases. The same procedure also applied to the collection of the learning material for the sectors.

2.2 In-depth interviews with industry and academia stakeholders

In order to gain insights from industry and academic experts regarding the state of the art and needs of XR technologies, in-depth interviews were conducted. At first, finding the candidates for the interviews was a crucial step of the process. This was achieved by addressing the consortium's extended network and colleagues. Based on the background of the candidates, the focal point was to have a fair

representation between industry and academia. Thus, we conducted **11 in-depth interviews** with the following respondents:

- Two Lecturers/Academics in Engineering;
- One Associate Professor in Electrical and Computer Engineering;
- One CEO of company related to XR;
- Two industry representatives in the field of Mechatronics;
- One Head of Department of Information Technology/University;
- One Chief Marketing Officer of a company related to XR;
- One Co-Founder of a spin-off company related to XR;
- One Innovation Manager;
- One representative of a company working with Aerospace applications;

At the next step, the questions needed to guide the conversation were defined. During the interviews, follow-up questions were asked in order to gain insight into the unique way of thinking of the experts. The consortium members who conducted the interviews also received the guidelines for the in-depth interviews. The full version of the guidelines can be found in the annexes section.

2.3 Questionnaire: eXtended Reality state and needs for Education & Training

In order to reach out also to organisations not covered by the desk study, a questionnaire was distributed to the partner's networks in order to capture the current state of XR technologies in industry and academia, and the needs of the sector. The questionnaire was distributed through LimeSurvey⁶, to ensure that it was user-friendly and accessible. As a first step, we identified the target audience for the survey. Our target audience included stakeholders in the sectors we are targeting and academic experts. The next step was the design of the questionnaire and ethical approval. The full version of the questionnaire, along with the privacy

⁶ <https://www.limesurvey.org/>

policy, can be found in the annexes section. As a next step, the questionnaire was distributed to various distribution channels, which include, but are not limited to:

- **Email:** Personalized emails to identified stakeholders with a link to the questionnaire.
- **Professional Networks:** Distribution through professional networks such as LinkedIn to reach a broader audience.
- **Industry Associations:** Collaboration with industry associations and professional bodies to distribute the questionnaire to their members.
- **Social Media:** Promotion of the questionnaire on the project’s social media platforms to increase reach and participation.

3 RESULTS

The objective of this chapter is to describe the results of the two different studies being performed, namely the desk study on use cases and a description of the learning materials being identified.

3.1 Insights and lessons learned from use cases

In this section, the collected use cases are presented, followed by an analysis. In Table 1, a summary of the use cases is presented by sector. The analysis of the use cases was conducted based on the gathered material and enhanced based on the experience of the authors. The images used to visualize the information are derived from a paid subscription and are copyright free.

Table 1 ALLIANCE4XR Use Cases

Use Case	Title	Sector	Location
UC-01	Bachelor of Engineering (Hons) in Mechanical and Manufacturing Engineering	Higher Education Institution	Table 3
UC-02	COMP47930 Augmented and Virtual Reality	Higher Education Institution	Table 3
UC-03	COMP3025J Augmented and Virtual Reality	Higher Education Institution	Table 3




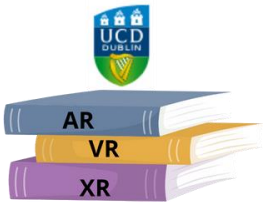


UC-04	Digital Construction (CVEN3006W)	Higher Education Institution	Table 3
UC-05	FLAME – Facilitated Learning with Animated Multi-media Engagement	Higher Education Institution	Table 3
UC-06	Micro-Credential - Introduction To XR: Applications And Technology (DPEEG-XRAT-1M01)	Higher Education Institution	Table 3
UC-07	Virtual Reality for Future Skills (IA20220) – Innovation Academy UCD	Higher Education Institution	Table 3
UC-08	Pulse XR - Virtual reality app for students training to be healthcare professionals.	Vocational Education and Training	Table 4
UC-09	Dual User Virtual Reality Welding Training Simulator	Vocational Education and Training	Table 4
UC-10	Training Wind Turbine Engineers using Virtual Reality Training Experiences	Vocational Education and Training	Table 4
UC-11	The Virtual Museum of STEM	Vocational Education and Training	Table 4
UC-12	Digital FabLab - Footwear virtual learning by doing - Transition from analogue practices to digital education	Vocational Education and Training	Table 4
UC-13	CSETIR - Construction Safety with Education and Training using Immersive Reality	Vocational Education and Training	Table 4
UC-14	DRINVET - Digital reality - the basis of skills training	Vocational Education and Training	Table 4
UC-15	GOA Bridge Management System – Bridge Intelligence (GOA.BI)	Structural Engineering and Construction	Table 5
UC-16	Augmented Reality to Increase Efficiency of MEP Construction: A Case Study	Structural Engineering and Construction	Table 5
UC-17	Hospital Nova – VR to involve staff in building design	Structural Engineering and Construction	Table 5
UC-18	Virtual reality application simulator of Wind Energy Turbine Direct Drive Generator	Structural Engineering and Construction	Table 5

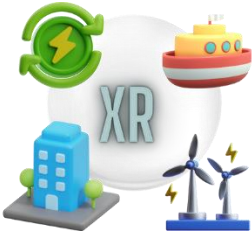


UC-19	VR models drive safe design in rail project signal sighting	Structural Engineering and Construction	Table 5
UC-20	Wärtsilä Voyage Solutions - Bridge Operations	Maritime Professions	Table 6
UC-21	BMT's REMBRANDT - Ship Handling Simulator	Maritime Professions	Table 6
UC-22	VSTEP - NAUTIS Maritime Simulators	Maritime Professions	Table 6
UC-23	Morild Ship & Bridge Simulator	Maritime Professions	Table 6
UC-24	K-Sim Maritime Simulation	Maritime Professions	Table 6
UC-25	Maritime Safety Education with VR Technology (MarSEVR)	Maritime Professions	Table 6
UC-26	Immersive Safe Oceans Technology: Developing Virtual Onboard Training Episodes for Maritime Safety	Maritime Professions	Table 6
UC-27	Application of VR tools in conceptual ship design	Maritime Professions	Table 6
UC-28	Virtual Reality Based Application for Safety Training at Shipyards	Maritime Professions	Table 6
UC-29	Application of VR Technology for Maritime Firefighting and Evacuation Training - A Review	Maritime Professions	Table 6
UC-30	VR-based Training on Handling LNG Related Emergency in the Maritime Industry	Maritime Professions	Table 6
UC-31	VR based training of Operators of Heavy Duty Cranes	Grids and Energy	Table 7
UC-32	GlobalSim - Cloud-based Crane Training Simulator	Grids and Energy	Table 7
UC-33	Nuclear Pump Room	Grids and Energy	Table 7
UC-34	MR remote training and assistance in Sub Stations operations	Grids and Energy	Table 7
UC-35	Equipment / Product Training Practical Assessment	Grids and Energy	Table 7
UC-36	To revolutionize workforce training in operations of Nuclear Facilities through Virtual Reality Immersive Rooms (VIROO)	Grids and Energy	Table 7
UC-37	Blue Deal Virtual Reality Educational Experience	Grids and Energy	Table 7

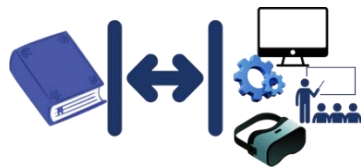
UC-38	VR Solar Farm Visualization Tool	Grids and Energy	Table 7
UC-39	ClassVR - Virtual Reality Technology for the Classroom	Remote Collaboration	Table 8
UC-40	EON Reality - Augmented and virtual reality technologies for education, training, and industry	Remote Collaboration	Table 8
UC-41	Labster - Virtual lab simulations for science education	Remote Collaboration	Table 8
UC-42	ZSpace - Immersive AR/ VR Learning Solutions	Remote Collaboration	Table 8
UC-43	MeetinVR - Virtual collaboration platform	Remote Collaboration	Table 8
UC-44	VIVERSE - Virtual collaboration platform	Remote Collaboration	Table 8
UC-45	Caldic VR experience	AR/VR/MR	Table 9
UC-46	DTEK VR training	AR/VR/MR	Table 9
UC-47	Industry 4.0 XR HUB	AR/VR/MR	Table 9
UC-48	MHP soft skills training	AR/VR/MR	Table 9
UC-49	Servier virtual training solution	AR/VR/MR	Table 9
UC-50	VictoryXR - Augmented and virtual reality technologies for education, training, and industry	AR/VR/MR	Table 9
UC-51	Equipment Maintenance	AR/VR/MR	Table 9
UC-52	Sewer inspection and cleaning (from BP Sewer inspection and cleaning)	AR/VR/MR	Table 9
UC-53	Public Services – Indication of a House Connection location (from BP Public Services – Management of permissions for sewers connections)	AR/VR/MR	Table 9
UC-54	Applied Research (from BP Academic sector – Applied research using AR technology)	AR/VR/MR	Table 9
UC-55	Procurement	AR/VR/MR	Table 9
UC-56	WWTP management	AR/VR/MR	Table 9
UC-57	Public Services – Wastewater (WW) Leakage Detection (from BP Public Services – Management of permissions for sewers connections)	AR/VR/MR	Table 9

3.1.1 Higher Education Institutions

Insights and Analysis




		
<p>HEI programs are incorporating XR to work with traditional learning methods and support immersive and interactive educational experiences across fields like engineering, digital construction, and creative media.</p>	<p>Programs like the Munster Technological University's Bachelor of Engineering and the Micro-Credential in XR focus on hands-on learning with XR tools, providing students with practical skills directly applicable in industry contexts.</p>	<p>Immersive learning environments created through XR technologies allow students to engage in realistic virtual scenarios. The Innovation Academy at UCD developed a VR module cultivating future skills that places learners within controlled simulations. This approach enables the development of transversal abilities in novel ways.</p>
		
<p>BDIC offers modules focused on Augmented and Virtual Reality covering cutting-edge advancements within the field of XR. Their courses prepare students to stay at the forefront of evolving XR technologies and expanding applications. By learning the latest developments, students gain expertise in developing immersive solutions for the future of learning and beyond.</p>	<p>The SATLE-funded FLAME project highlights the utilization of extended reality technologies to develop accessible, interactive 3D learning materials, addressing deficiencies in the availability and affordability of educational resources that have traditionally hindered certain student populations.</p>	<p>XR applications provide avenues for students in the Micro-Credential programs to create an original virtual or augmented reality learning environment as a part of their digital portfolio to showcase their technical expertise and creativity as teachers.</p>


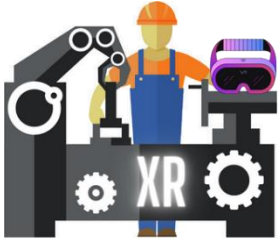

		
<p>XR technologies also encourage interdisciplinarity: one of the first modules was the Digital Construction of CDIC, with building information modelling tools designing a project management and digital model that improves the collaboration between architects and the planning and construction of a design.</p>	<p>An increasing number of degree programs are designed to focus on giving students practical skills and real-world experience to tackle the challenges of the next century by thoughtfully incorporating scenarios involving XR technologies into internship and professional placement with industry, making sure that graduates are ready to apply their skills when they enter an industry.</p>	<p>XR technologies are leveraged to supplement and enhance conventional pedagogical approaches, providing novel avenues for engaging students and cultivating more impactful learning through interactive and experiential education models reliant upon simulation and virtual experimentation.</p>



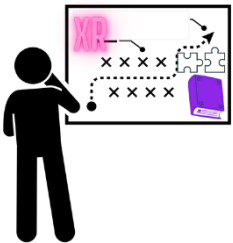
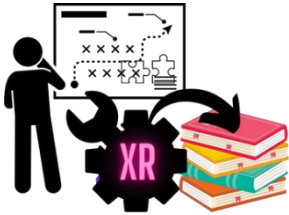

Projects like FLAME use education as a vehicle to address gaps in both the curricula and format of existing educational resources, enabling even populations in the most remote areas to design their interactive learning tools, bypassing the traditional financial and technical barriers to access that have excluded so many from using such tools in the past.


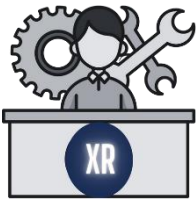

Gaps

		
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<p>The integration of XR technologies into the existing curriculum while aligning with traditional teaching methods and standards could pose a challenge.</p>	<p>Bringing XR tools to thousands of programs and institutions requires a big investment in hardware, software, and faculty training, which can be very resource-intensive.</p>	<p>A critical gap is that faculty and students possess limited knowledge and experience with XR technologies to be able to use them in the process of teaching and learning.</p>
		
<p>The initial costs for hardware, as well as for software and content development are high, which some of the institutions will find hard to fund.</p>	<p>Ensuring XR systems are functioning effectively and continuously requires ongoing technical support and system maintenance throughout its lifespan.</p>	<p>Standardized assessment methods to measure the effectiveness of XR-enhanced learning experiences and their impact on educational outcomes ought to be developed.</p>

Requested industry developments

		
<p>Develop strategies for the seamless addition of XR tech to traditional curricula in a manner that is in alignment with academic standards and then builds on traditional teaching methods</p>	<p>Develop a scalable plan for deploying XR tools into multiple programs that lean on efficient resource usage and cost-effective measures.</p>	<p>Provide faculty and students with training programs in XR technologies and learning use cases.</p>

		
<p>Identify low-cost solutions and cost-sharing and funding opportunities to leverage initial investment and long-term maintenance of XR technologies.</p>	<p>Provide a robust technical support structure to help manage and maintain our suite of XR tools.</p>	<p>Create evaluation frameworks for measuring the effect that XR-enhanced learning has on educational outcomes, establishing universal standards for evaluation.</p>

3.1.2 Vocational Education and Training

Insights and Analysis

		
<p>Pulse XR, VR Welding Simulator, ImTech Skills, CSETIR: Projects focusing on health care, welding, wind turbines, and construction, which is perfect for high-risk training environments with safety and practical skills implementations.</p>	<p>Interestingly, numerous foreign consortiums are supporting some of the projects, underlining a tendency towards an increase in collaboration in VET to uplift the standard and quality of training in all regions.</p>	<p>Projects like Digital FabLab and CSETIR showcase the potential for scalability and adaptability to different sectors, indicating a flexible approach to VET training.</p>
		

<p>Digital competences are a repeated basic requirement, further emphasizing the necessity of digital literacy in current VET programs.</p>	<p>Most of the projects will provide a detailed evaluation and feedback components that will ensure the desired learning outcomes. Conversely, Pulse XR has an activity assessment PDF, and the VR Welding Simulator measures and scores critical weld parameters.</p>	<p>The projects aim to improve the employability of the people by providing them with practical, critical thinking, and decision-making skills. For instance, the Pulse XR teaches clinical skills to healthcare students, and Digital FabLab enhances practical skills in footwear manufacturing.</p>
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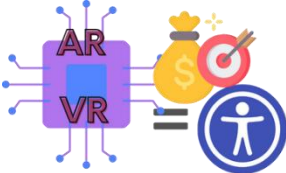

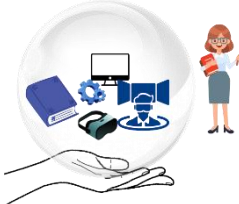
The main priority is to create an engaging and interactive user experience. Pulse XR and the VR Welding Simulator are both projects that use realistic simulations to recreate real-life scenarios, increasing learner engagement and comprehension.

Gaps

<p>There is a lack of standardized implementation models and certification processes for immersive technology-based training across different vocational disciplines.</p>	<p>Connecting VR/AR technologies to traditional training methods can also be difficult to implement, leading to potential gaps in comprehensive skill development.</p>	<p>Lack of affordability, as well as the often-high entry-point and advanced level of technological proficiency required, further restricts these training tools to only certain disciplines and universities, potentially excluding other institutions or student populations.</p>

	
<p>Minimal research to date has explored how immersive technology training may help or hinder employability and/or career progression.</p>	<p>Educators may lack preparation and support to educate with great exposure to innovation.</p>

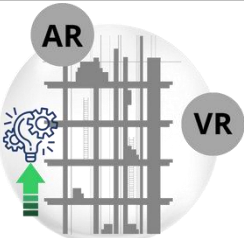
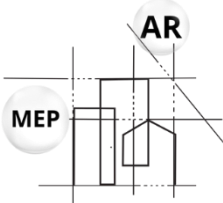



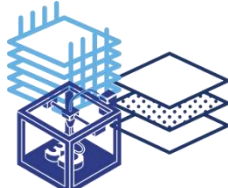
Requested industry developments



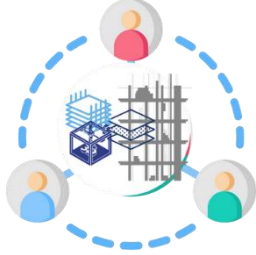

		
<p>Standardized curricula and certification processes that establish uniform recognition and meaning of the skills acquired through VR and AR training programs across employers.</p>	<p>Guiding principles for the beneficial incorporation of immersive technologies alongside traditional teaching methodologies for a continuous learning journey.</p>	<p>Creating affordable solutions and improving ease of access to VR & AR to promote its use in a variety of educational environments.</p>
		
<p>Conduct longitudinal studies to verify the effectiveness of VR and AR training and its</p>	<p>Offering VR/AR resources and professional development programs</p>	

<p>impact on students' employability and skill retention highlights the immense potential that remains in this field.</p>	<p>for teachers to use these tools in the classroom.</p>	
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3.1.3 Structural Engineering and Construction

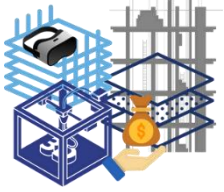

Insights and Analysis

		
<p>Reflecting a growing tendency for immersive solutions, most of the projects exploit VR or AR technology to improve training, maintenance, and design processes for structural engineering.</p>	<p>With projects like MEP Construction and VR Maintenance Simulator, the emphasis is on efficiency and accuracy; time and money are no longer spent on long processes that traditional methods offer.</p>	<p>Examples of this include projects that involve both real-time collaboration and feedback (e.g., GOA Bridge Management System and Hospital Nova) to bring stakeholders along for the journey to drive improved outcomes.</p>
		
<p>These demonstrated the possibilities of scalability and extension to other sectors and functions, with some examples being rail signal projects, VR Maintenance Simulator, etc.</p>	<p>VR Maintenance Simulator & Rail Signals - Highlights cost savings and improvements in training outcomes of the projects.</p>	<p>As an example of technology integration, many projects are built on BIM, CAD, and GIS data showing that new technologies should be merged into established systems for better results.</p>

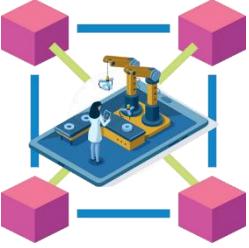


		
<p>The projects are additionally supported with detailed assessment and feedback mechanisms to enable effective learning and smart decision-making, such as the predictive maintenance management module in the GOA Bridge Management System.</p>	<p>Hospital Nova and VR Maintenance Simulator are examples of success cases, in terms of education, raising skills, and readiness of staff and trainees.</p>	<p>It is important to make sure the end users are engaging in the projects and having a positive experience, such as with the Hospital Nova (employee involved in the design process via VR tours) and the Rail Signal (interactive signal sighting VR).</p>
		
<p>The different phases of project implementation show that this is a field that is dynamic and changing. These technologies have diverse ownership, not restricted to research institutions, and are driving great interest and investment in them.</p>		



Gaps

		
<p>Combining these new immersive technologies can be difficult to integrate into their existing BIM, CAD, and</p>	<p>Immersive technologies have shown promise in pilots but scaling these solutions to full-scale,</p>	<p>While VR and AR tools can be immensely helpful, engineers and construction workers may not be trained to</p>

<p>GIS systems, ultimately affecting this interconnected and interdependent environment leading to inefficiencies and data silos.</p>	<p>real-world applications can be challenging.</p>	<p>properly apply these tools in their everyday tasks.</p>
		
<p>The initial costs and ongoing investment in using immersive technologies for structural engineering can be a hurdle to it being widely adopted.</p>	<p>Though VR and AR can enhance safety training, companies will need a fully integrated risk-management strategy to confront the possible safety hazards of using these technologies on-site.</p>	

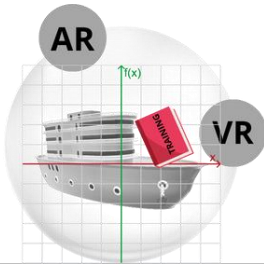

Requested industry developments

		
<p>Improving interoperability standards and solutions to extend the usability of existing engineering tools in a compatible form with the use of VR and AR.</p>	<p>Scalable VR / AR project examples; Successful use case studies with VR/AR in big engineering projects.</p>	<p>Designing training for professionals who want to gain skills in immersive technologies.</p>

	
<p>Creating comprehensive safety measures and management guidelines to introduce immersive technologies in engineering projects</p>	<p>Ensuring the delivery of cost-effective solutions that can be repaid, with identifying possible funding streams to support the uptake and maintenance of VR / AR technologies.</p>

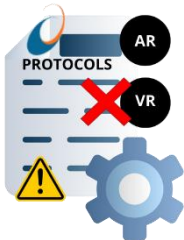
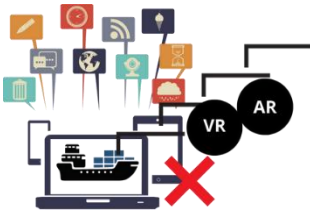
3.1.4 Maritime Professions

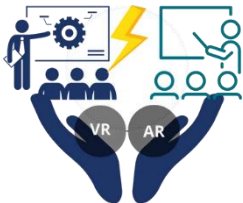



Insights and Analysis

	
<p>The widespread applications of VR and AR technologies serve to underscore a major priority for maritime training. This improves the experience and skills of maritime personnel starting in the bridge with Wärtsilä Voyage Solutions augmenting awareness in bridge operations through to K-Sim Maritime Simulation systems providing combined ship handling and emergency procedure training. These technologies offer high-fidelity simulations - they let trainees practice and hone their skills in a risk-free setting and minimize the risk of mistakes in the field.</p>	<p>Other such instances include the MarSEVR for maritime safety education, and VR-based safety training for shipyards, all of which point toward a cost-effective method of adopting VR solutions. In many instances, these applications can replace the need for physical resources such as fire extinguishers and can be utilized in a wide range of environments, from onboard vessels to land-based training facilities, thereby enabling more advanced training opportunities and minimizing the requirement for physical assets.</p>

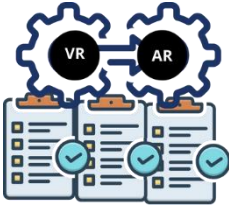

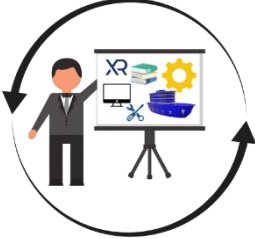

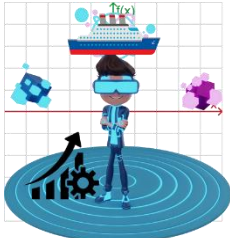

	
<p>Many applications (e.g., BMT's REMBRANDT or VSTEP's NAUTIS) underscore the importance of real-time feedback as well as an immersive sensorimotor experience. Trainees practice ship handling and emergency response in LNG-related emergencies, with immediate feedback and performance assessments. This hands-on strategy enables recruits to proceed through trial and error to develop their understanding of maritime dilemmas.</p>	<p>The use cases provided include training for navigation and ship handling, as well as emergency procedures and design of ships. For example, integrating VR into a conceptual ship design process enables naval architects to assess critical design parameters in a virtual space leading to better design results. For emergencies related to LNG, VR-based trainings address how to safely deal with dangerous substances and follow safety protocols step-by-step.</p>
	
<p>Certain use cases such as the Morild Ship & Bridge Simulator and the Immersive Safe Oceans Technology show how VR can be used in conjunction with existing training methods as well as a few different maritime scenarios. The goal of this integration is to augment traditional coaching techniques to make them more productive and animated.</p>	

Gaps

	
<p>An area lacking in skills is the integration of VR and AR technologies with marine systems and protocols. For example, the integration of the Wärtsilä BridgeMate AR system with existing navigational data sources, true real-time synchronization is still an issue. Likewise, figuring out how to bring VR-based training to shipyard safety</p>	<p>This solution's limitations stem from its numerous applications and diverse maritime environments that VR and AR can touch, making it difficult to scale - as illustrated by the white paper. For instance, global deployment of the K-Sim Maritime Simulation systems adds complexity to the infrastructure and</p>

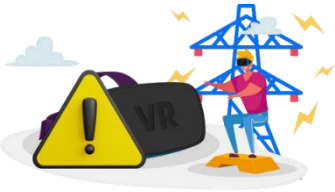



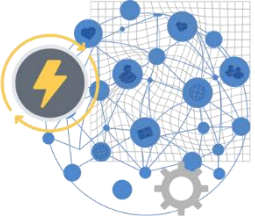
<p>policies can be messy - it must be finely tuned to align with physical reality.</p>	<p>maintenance, to ensure the level of training quality is consistent throughout all training facilities. Furthermore, these technologies also require optimization for different environmental conditions (e.g., offshore or coastal).</p>
	
<p>While the tools for VR and AR can lay the foundations for specialized training programs, more work is needed to address the current training incompatibility that exists at sea. These will be your VR equipment, how to get around the different simulation interfaces, and how to interpret the simulation results. The effectiveness of these immersive tools can be limited without proper user training.</p>	<p>Rollout of VR and AR applications like the Morild Ship & Bridge Simulator or VR inception projects for shipyard safety training means investing in hardware, software, and development upfront. Wider adoption hinges on the ability to justify this outlay through detailed cost-benefit analyses and potential funding streams.</p>
	
<p>They are still a long way off from making sure the virtual simulations have real-world characteristics like maritime needs. In addition, the VR application for safety training at shipyards will have little effect unless the shipyard hazards are accurately simulated. To bridge the gap between virtual training and real maritime operations, even more realistic and high-fidelity simulations.</p>	<p>While many VR applications provide real-time feedback, a limitation is the current lack of standardized methods to evaluate trainee performance between different simulations. For example, if it is needed to measure the efficacy of training in VR automobiles that are designed for both LPG emergency handling or maritime firefighting, standard performance metrics and assessment standards are required.</p>

Requested industry developments

		
<p>Creating seamless integrations into VR / AR systems to maritime systems with relevant maritime protocols. This will also involve making connections to navigational data feeds for the Wärtsilä BridgeMate AR system. Moreover, there is a need to integrate VR-based safety training applications with existing safety standards within shipyards.</p>	<p>Design scalable deployment strategies of VR and AR technologies that allow adaptation to various maritime scenarios. This means customizing those technologies for different types of ships, training environments, and geographical locations so that the training outcomes will be as consistent and effective as possible.</p>	<p>Introduce a holistic training program to ensure the workforce has the knowledge to use VR and AR tools correctly. Thus, these programs should instruct how to work with VR equipment, how to navigate simulation interfaces, and how to read and use the results of the training to get the most value out of immersive technologies.</p>
		
<p>Creation of economic realization plans that justify the initial cost for the adoption of VR and AR technologies. This involves in-depth cost-benefit modeling that potentially shows new sources of funding and demonstrates the long-term savings and improvements in operations that these technologies have to offer.</p>	<p>Further improvement of VR/AR simulations to increase their realism and fidelity. This involves the construction of robust physics-based models for maritime firefighting and evacuation training, as well as the accurate reproduction of shipyard hazards in VR safety training applications.</p>	<p>Developing universally applicable performance metrics and evaluation standards to measure how well a trainee performs on a VR or AR simulation. Such proof-of-concept deployment will provide consistent, objective measurements of the effectiveness of these immersive tools in developing maritime skills.</p>

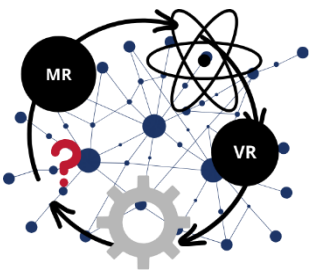
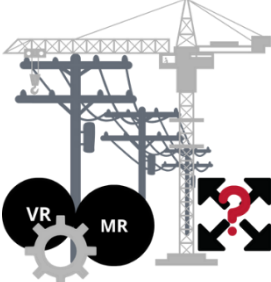


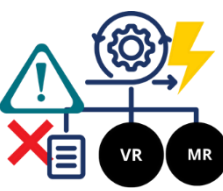

3.1.5 Grids and Energy

Insights and Analysis

		
<p>In several use cases, such as VR-Based Training of Heavy Duty Crane Operators, Exelon's Nuclear Pump Room, and MR-Based Remote Assistance in Sub-Stations, organizations train in dangerous environments without risking personnel. In addition to safety, it also provides them with ample preparation for the real operating conditions</p>	<p>Using VR and MR technologies creates a level of immersion that allows trainees to better understand the material as well as retain that knowledge longer than conventional methods. This has seen heavy-duty crane operator training duration reduce significantly and sub-station operations training become more efficient.</p>	<p>Several use cases including the Blue Deal Virtual Reality Educational Experience and VR Solar Farm Visualization Tool illustrate how immersive technology can be integrated with existing systems such as aerial 3D mapping data. The integration results in effective planning and visualization, giving stakeholders a real-life view of energy projects.</p>
		
<p>Applications in MR Based Remote Assistance in Sub-Stations Operations and Aggreko's Equipment/Product Training Practical Assessment are successful use-case scenarios where the system has been found to help learn real-time as the trainee is performing</p>	<p>The variety of purpose-built applications, from educating crane operators to simulating nuclear plant operations to exploring a solar farm demonstrates the broad field, that immersive technologies are surely set to occupy. These technologies can be used for a range of</p>	

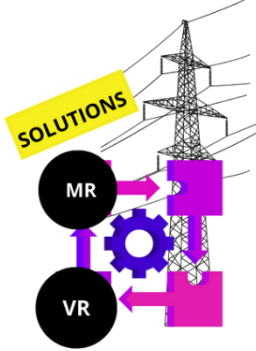
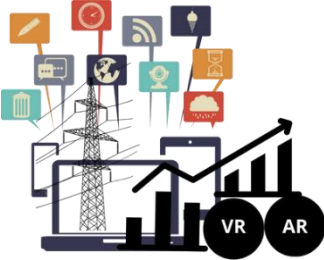
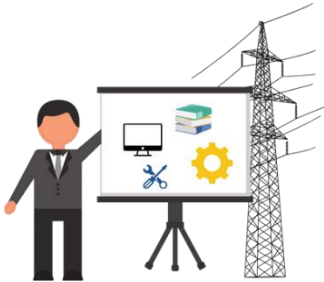



<p>tasks, mistakes can be made but they do not have any real-world consequences. This accelerates the learning process as it corrects the mistakes as they happen.</p>	<p>applications in the Grids and Energy sector supporting varied training and operational requirements.</p>
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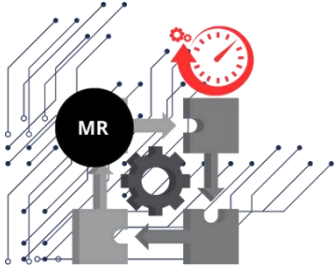
Gaps

		
<p>Integrating VR and MR systems with existing grid management tools, crane operation databases, and nuclear facility protocols is complex. There are challenges in ensuring that VR/MR environments are connected directly to the real-time data and operations of SCADA, GIS, and CAD.</p>	<p>The scale of the VR and MR applications (extending across significant areas or involving a large and varied number of objects, such as a complex power grid or multiple types of cranes), presents difficulties. Deploying these technologies at a global level or across different sub-station setups will need to be significantly improved.</p>	<p>Personnel in the energy sector are not specially trained to work with VR and MR systems. There is a gap in comprehensive training programs tailored to the unique needs of grid and energy operations.</p>
		
<p>The initial costs of deploying proprietary VR and MR systems (i.e., purchasing hardware, developing bespoke simulations, and integrating capability</p>	<p>There is a gap in developing multidimensional risk management frameworks for VR-MR simulations in the energy sector. These simulations</p>	<p>The robust remote collaboration relies on live MR workflows, involving the streaming of real-time data to ensure reliable data transmission.</p>

with infrastructure) are extremely high.	at-scale are	are required to realistically encompass hazards plausible to occur in the real-world and resources for mitigation training.	Improvements are required to accommodate complex multi-user interactions and long-distance remote monitoring and supervision.
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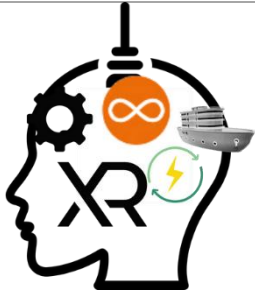

Requested industry developments




		
<p>Development of solutions that enable effective integration of VR and MR systems with existing grid management tools and protocols. This includes ensuring compatibility and real-time data synchronization with systems such as SCADA, GIS, and CAD to avoid data silos.</p>	<p>Creation of scalable VR and MR solutions that can handle large-scale and complex environments, including extensive power grids and diverse crane fleets. Optimization for varied conditions, especially for outdoor applications, is necessary to broaden the use of MR technologies.</p>	<p>Implementation of training programs tailored to the energy sector, focusing on the operation of VR/MR tools and interpretation of their outputs. These programs should aim to equip personnel with the necessary skills to use these technologies effectively.</p>
		
<p>Strategies to ensure these technologies are accessible to all workforce levels, including those in remote or less technologically advanced areas.</p>	<p>Development of cost-effective strategies and potential funding sources to support the initial investment and ongoing maintenance of VR and MR technologies. Detailed cost-benefit</p>	<p>Formulation of comprehensive risk management strategies and safety protocols for using VR and MR technologies in training environments. These frameworks should</p>

	<p>analyses can help justify these investments by demonstrating long-term savings and operational improvements.</p>	<p>address the simulation of real-world hazards and provide effective risk mitigation training specific to the energy sector.</p>
		
<p>Enhancement of MR capabilities to support complex real-time interactions, including multi-user environments and remote supervision of simultaneous tasks. Improvements in network reliability and bandwidth, particularly in remote or industrial areas, are needed to support these functionalities effectively.</p>		




3.1.6 Remote Collaboration




Insights and Analysis

		
<p>The use cases demonstrate various applications of XR technologies for education, training, and business collaboration. ClassVR and zSpace focus on enhancing educational outcomes through VR/AR experiences, while Labster provides virtual lab simulations for scientific learning. EON Reality supports both education and industrial training with VR/AR tools, and MeetinVR and</p>	<p>XR technologies are effectively used to enhance learning outcomes and practical skills development. Platforms like ClassVR and Labster provide interactive experiences that improve student engagement and understanding of complex concepts. Similarly, EON Reality and zSpace offer tools for creating immersive educational content,</p>	<p>MeetinVR and VIVERSE for Business are pivotal in facilitating remote collaboration through VR meetings, providing tools for effective communication and interaction in virtual environments. These platforms address the challenges of remote work by offering immersive meeting experiences, enhancing team collaboration and decision-making.</p>


<p>VIVERSE for Business facilitate enterprise meetings in VR, emphasizing remote collaboration and communication.</p>	<p>promoting active learning.</p>	
		
<p>Successful implementation of these XR tools requires comprehensive integration with existing systems and support for users. Ensuring proper setup, training, and maintenance is essential for maximizing the effectiveness of these technologies in various settings.</p>	<p>XR tools offer scalability and flexibility, allowing them to be adapted to different educational, training, and business contexts. This adaptability is crucial for addressing diverse user needs and expanding the applications of XR technologies.</p>	<p>All platforms emphasize user engagement through interactive and immersive interfaces, ensuring that participants remain active and involved in their learning or collaborative activities.</p>

Gaps

		
<p>Integrating XR tools with traditional educational and business systems can be complex, requiring alignment with existing workflows and practices.</p>	<p>Scaling these XR solutions to accommodate large user groups or extensive use cases can present challenges in terms of hardware availability, user management, and performance.</p>	<p>Ensuring all users are proficient in using XR technologies requires comprehensive training programs and ongoing support.</p>

		
<p>Implementing XR solutions involves substantial initial costs for hardware, software, and content development, posing financial challenges for some organizations.</p>	<p>Providing ongoing technical support and maintaining XR systems to ensure their effective functioning throughout their lifecycle is essential.</p>	<p>Developing standardized methods to assess the effectiveness of XR-enhanced learning or collaboration experiences and their impact on outcomes is necessary.</p>

Requested industry developments


		
<p>Develop streamlined integration solutions to align these XR tools with existing workflows and systems used by educational and business organizations.</p>	<p>Create scalable plans for deploying XR tools across various applications, ensuring efficient resource allocation and minimizing costs.</p>	<p>Implement comprehensive training programs and resources to build proficiency in using XR technologies and incorporating them into educational and collaborative practices.</p>
		

<p>Identify cost-effective solutions and funding sources to support the initial investment and ongoing maintenance of XR technologies.</p>	<p>Establish robust technical support systems to ensure the effective functioning and maintenance of XR tools in different contexts.</p>	<p>Develop frameworks for assessing the impact of XR-enhanced learning and collaboration on outcomes, providing consistent metrics for evaluation.</p>
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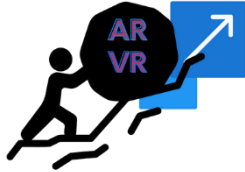


3.1.7 AR/VR/MR



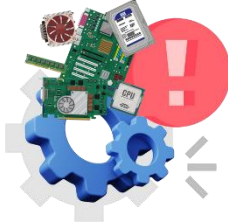

Insights and Analysis

		
<p>DTEK VR Training, Servier Virtual Training Solution, and VictoryXR are just a few examples of their successful use in training use cases. VR/AR technology provides a more interactive, real-life environment for users practice complex skills, learn safety protocols, or simply interact with learning resources to promote knowledge retention and practical skill development.</p>	<p>Examples of user engagement applications, such as CALDIC VR EXPERIENCE and Industry 4.0 XR HUB, also serve to underline the importance of VR and AR for their capability of allowing realistic and interactive experiences. Users can interact with these applications to explore environments, complete tasks, or manipulate simulations, which engages users and helps them better understand complex systems or procedures.</p>	<p>Equipment maintenance, public services, and WW leakage detection are a few of the use cases that can make maintenance operations more agile, efficient, and cost-effective using AR. By providing real-time guidance and visualization, AR can enhance the accuracy of maintenance tasks, leading to fewer errors and downtime.</p>
		


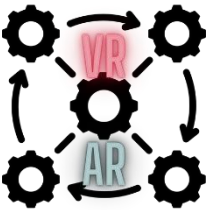


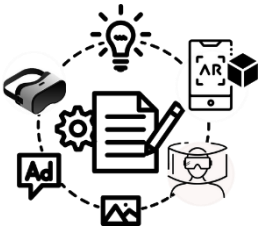

<p>Industry 4.0 XR Hub and Procurement showcase how XR technologies are dynamic and able to cater to different industrial requirements. These solutions are fully customizable to showcase not only different equipment but entirely different operational processes or scenarios to serve as versatile training, maintenance, and operational management tools.</p>	<p>Using the DTEK VR Training use case, haptic feedback is provided by the TeslaSuit, offering a novel approach in training by allowing users to feel the impact of their actions. This amplifies the authenticity of the training experience and can significantly improve learning outcomes.</p>	<p>Solutions like the Servier Virtual Training Solution and Applied Research using AR, also highlight the use of data collection and analysis. The primary purpose of these use cases is to capture detailed performance metrics that can be used to assess the effectiveness of training, measure progress, and identify areas for development.</p>
		
<p>With the Industry 4.0 XR HUB use case, users can even collaborate with others in shared virtual environments with multiplayer interaction. This feature can enhance teamwork and provide a more engaging learning or training experience.</p>		

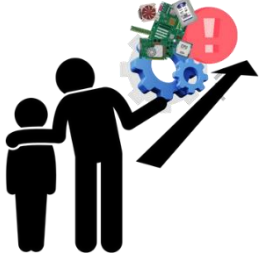

Gaps

		
<p>Implementing VR/AR technologies on a larger scale remains a challenge. Organizations often struggle to transition from pilot projects to full-scale deployments due to technical limitations,</p>	<p>Ensuring seamless integration between VR/AR systems and existing organizational infrastructure can be problematic. Compatibility with various hardware and software platforms is</p>	<p>Effective use of VR/AR technologies requires proper training for users. Many use cases, such as DTEK VR Training and VictoryXR, depend on users' familiarity with the technology. Without adequate training and</p>

<p>integration issues, and cost constraints. For example, while Industry 4.0 XR HUB and Applied Research using AR demonstrate promising applications, scaling these solutions across multiple facilities or departments can be complex and resource-intensive.</p>	<p>necessary for effective deployment. Use cases like Equipment Maintenance highlight the need for AR solutions that can easily integrate with current maintenance management systems.</p>	<p>support, users may face difficulties, leading to suboptimal outcomes and reduced engagement.</p>
		
<p>The high initial cost of VR/AR equipment and ongoing maintenance expenses can be a barrier to adoption. Projects like DTEK VR Training and CALDIC VR EXPERIENCE require significant investment in hardware and software, which may deter smaller organizations or those with limited budget from adopting these technologies.</p>	<p>Creating relevant and high-quality VR/AR content tailored to specific use cases is essential but can be resource-intensive. Use cases such as MHP Soft Skills Training and Servier Virtual Training Solution need custom content development, which requires expertise and can be costly.</p>	<p>Technical challenges, including hardware malfunctions, software bugs, or connectivity issues, can hinder the effectiveness of VR/AR solutions. Use cases like Sewer inspection and cleaning and Public Services – WW Leakage Detection need reliable AR software and hardware to ensure smooth operation and accurate performance during maintenance or inspection tasks.</p>
		
<p>Adhering to industry-specific regulations and standards is crucial for VR/AR applications, especially in sectors like healthcare and industrial maintenance. Ensuring compliance with regulatory requirements can be complex and requires ongoing monitoring and updates to the VR/AR solutions used, as seen in Servier Virtual Training Solution and Procurement.</p>		

Requested industry developments

		
<p>Developing frameworks and guidelines for scaling VR/AR solutions across various organizational levels is crucial. This includes standardized integration protocols, deployment strategies, and support mechanisms to facilitate widespread adoption, as seen in the need for scalability in Industry 4.0 XR HUB.</p>	<p>Establishing interoperability standards for VR/AR systems can facilitate smoother integration with existing infrastructure. This includes creating compatibility guidelines for hardware and software platforms to ensure seamless functionality, as highlighted in the Equipment Maintenance use case.</p>	<p>Providing comprehensive training programs and support resources for users of VR/AR technologies is essential. This includes developing user-friendly training modules, ongoing support, and resources to ensure users can effectively operate and benefit from these technologies, as needed in DTEK VR Training.</p>
		
<p>Identifying and developing cost-effective VR/AR solutions that provide value without requiring significant financial investment is critical. This includes exploring affordable hardware options, open-source software, and</p>	<p>Developing robust content creation tools and platforms for VR/AR applications can streamline the process of generating relevant and high-quality content. This includes providing templates, development frameworks, and</p>	<p>Building reliable technical support infrastructure and ensuring the availability of maintenance services for VR/AR systems is essential. This includes providing quick troubleshooting, regular updates, and ensuring</p>

<p>scalable solutions to make these technologies accessible to a broader range of organizations, as seen in VictoryXR.</p>	<p>collaboration tools for creating immersive experiences tailored to specific use cases, as highlighted in MHP Soft Skills Training.</p>	<p>the robustness of hardware and software used, as necessary for Public Services – WW Leakage Detection.</p>
		
<p>Offering guidance and tools to ensure VR/AR solutions comply with industry regulations and standards can facilitate their adoption in regulated sectors. This includes developing compliance checklists, monitoring tools, and resources to navigate regulatory landscapes, as seen in the Servier Virtual Training Solution.</p>	<p>Implementing mechanisms to collect user feedback and continuously improve VR/AR solutions based on real-world usage can enhance their effectiveness. This includes integrating feedback loops, user satisfaction surveys, and iterative development processes to refine these technologies, as needed in Sewer inspection and cleaning.</p>	

3.2 Analysis of missing learning outcomes and curricula gaps

In the following section, the collected learning materials are presented, following their analysis. In Table 2, a summary of the learning material is presented by sector. The analysis of the learning material was conducted based on the gathered material and enhanced based on the experience of the authors.

Table 2 ALLIANCE4XR Learning Material




Learning Material	Title	Sector	Location
LM-01	FLAME – Facilitated Learning with Animated Multi-media Engagement	Higher Education Institution	Table 10
LM-02	Training Wind Turbine Engineers using Virtual Reality	Higher Education Institution	Table 10

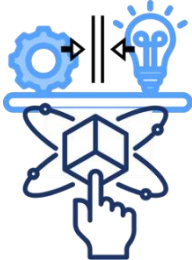

	Training Experiences (WMC Galway)		
LM-03	Virtual Reality Welding Training Simulator (Dundalk Institute of Technology)	Higher Education Institution	Table 10
LM-04	Innovation Academy UCD: Virtual Reality for Future Skills	Higher Education Institution	Table 10
LM-05	UCD School of Computer Science: Augmented and Virtual Reality (COMP3025J)	Higher Education Institution	Table 10
LM-06	Pulse XR (Education Training Board – Ireland)	Vocational Education and Training	Table 11
LM-07	BodySwaps	Vocational Education and Training	Table 11
LM-08	Gadgeteer	Vocational Education and Training	Table 11
LM-09	Virtual Shoe Fablab	Vocational Education and Training	Table 11
LM-10	VM STEM	Vocational Education and Training	Table 11
LM-11	Principles of Augmented Reality Technologies	Vocational Education and Training	Table 11
LM-12	From spatial data to Augmented Reality	Vocational Education and Training	Table 11
LM-13	Visualisation of underground utility networks in Augmented Reality	Vocational Education and Training	Table 11
LM-14	Putting AR in operation	Vocational Education and Training	Table 11
LM-15	Outdoor AR application for site instruction and real-scale anchoring	Structural Engineering and Construction	Table 12
LM-16	In door AR application for bridge design	Structural Engineering and Construction	Table 12
LM-17	Design and construction of zero-emission vessels	Maritime Professions	Table 13
LM-18	Engine Room Operations	Maritime Professions	Table 13

LM-19	Shore Side Electricity (Cold-Ironing)	Maritime Professions	Table 13
LM-20	Energy3D	Grids and Energy	Table 14
LM-21	VR Vision	Grids and Energy	Table 14
LM-22	ThingLink - Fingrid example	Grids and Energy	Table 14
LM-23	ITI VR CRANE SIMULATOR	Remote Collaboration and AR/VR/MR	Table 14
LM-24	SimX	Remote Collaboration and AR/VR/MR	Table 14
LM-25	Industry 4.0 VR Hub	Remote Collaboration and AR/VR/MR	Table 14




3.2.1 Higher Education Institutions



Insights and Analysis

		
<p>FLAME and Training Wind Turbine Engineers demonstrate the integration of XR technologies to enhance the learning experience by providing interactive 3D models and immersive VR environments. FLAME allows educators to create online 3D interactive materials, while Training Wind Turbine Engineers uses VR for training scenarios relevant to renewable energy sectors, offering practical and engaging</p>	<p>Virtual Reality Welding Training Simulator and Innovation Academy UCD: Virtual Reality for Future Skills emphasize practical, hands-on training using XR. The Welding Training Simulator provides realistic simulations of welding processes, aiding skill acquisition for engineering students. Similarly, the Innovation Academy's VR module helps students develop transversal skills such as critical thinking, problem-solving, and decision-making in simulated workplace settings.</p>	<p>Courses like UCD School of Computer Science: Augmented and Virtual Reality (COMP3025J) focus on educating students about the fundamental techniques and recent developments in VR/AR technologies. This course covers a range of topics from display technologies and tracking systems to the creation of AR/VR applications, providing a solid foundation in XR for computer science students.</p>






<p>ways to understand complex concepts.</p>		
		
<p>Principles of Augmented Reality Technologies and From Spatial Data to Augmented Reality bridge the gap between theoretical knowledge and practical application. These courses delve into computer vision, AR techniques, and spatial database management, equipping students with the skills to implement AR in various fields.</p>	<p>Virtual Reality for Future Skills and FLAME illustrate the shift towards using XR to foster innovative learning strategies. These applications create interactive and immersive environments that enhance student engagement and practical understanding, promoting a more dynamic learning process.</p>	

Gaps

		
<p>The reliance on VR headsets like Meta Quest 2 or 3 for applications such as Virtual Reality Welding Training Simulator and Innovation Academy UCD: Virtual Reality for Future Skills presents</p>	<p>There's a lack of standardized guidelines for effectively integrating XR tools into existing curricula, making it challenging to align XR applications like Training Wind Turbine Engineers and Gadgeteer with</p>	<p>Many educators lack the training necessary to effectively utilize XR technologies in their teaching practices, limiting the potential benefits of tools like FLAME and Virtual Shoe Fablab.</p>

<p>accessibility challenges due to the high cost and limited availability of these devices.</p>	<p>traditional educational frameworks.</p>	
		
<p>XR content may not always align with the specific needs of diverse educational fields or adapt well to different cultural contexts, as seen in applications like VM STEM and Principles of Augmented Reality Technologies.</p>	<p>Existing evaluation methods may not adequately measure learning outcomes in XR environments, highlighting the need for improved assessment tools for applications like Gadgeteer and BodySwaps.</p>	






Requested industry developments

		
<p>Develop cost-effective XR solutions to improve accessibility for applications such as Pulse XR and Virtual Reality Welding Training Simulator, ensuring broader adoption and use.</p>	<p>Create detailed guidelines to facilitate the integration of XR technologies into traditional educational curricula, as required for Training Wind Turbine Engineers and Gadgeteer.</p>	<p>Implement comprehensive training programs to equip educators with the skills needed to effectively use XR technologies, as needed for applications like FLAME and Virtual Shoe Fablab.</p>
		

<p>Develop XR content that is adaptable to various languages and educational standards, addressing the need for more customized learning experiences in applications like VM STEM and From Spatial Data to Augmented Reality.</p>	<p>Develop advanced assessment tools specifically designed for XR learning environments to provide detailed performance insights and effective feedback, as indicated by the gaps in Gadgeteer and BodySwaps.</p>	
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3.2.2 Vocational Education and Training

Insights and Analysis

		
<p>Applications like Pulse XR and Virtual Shoe Fablab highlight how XR technology facilitates realistic simulations for skill training in VET. For example, Pulse XR provides a virtual hospital environment for healthcare students to practice clinical skills and decision-making without patient risk. Virtual Shoe Fablab enables hands-on practice in footwear manufacturing using AR, enhancing real-world skill application.</p>	<p>Tools such as BodySwaps and VM STEM increase engagement through interactive scenarios and virtual environments. BodySwaps offers VR-based simulations for soft skills training, like interviews and conflict resolution. VM STEM engages students with a virtual museum showcasing STEM exhibits, fostering immersive exploration of scientific concepts.</p>	<p>Applications like Gadgeteer and Training Wind Turbine Engineers offer specialized training in engineering principles and disaster response. Gadgeteer uses VR to teach mechanical engineering through Rube-Goldberg machine simulations, while Training Wind Turbine Engineers prepares students for wind turbine maintenance with VR disaster scenarios.</p>
		

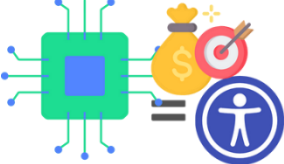

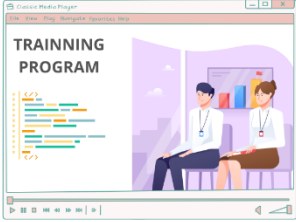


<p>Tools such as Pulse XR and VM STEM integrate XR content with LMS platforms like Moodle, supporting comprehensive educational strategies and tracking student progress. These integrations provide analytics for monitoring engagement and outcomes.</p>	<p>XR applications like Principles of Augmented Reality Technologies and Gadgeteer focus on building technical skills and competencies. They expose learners to advanced XR technologies and prepare them for future roles requiring tech proficiency.</p>	
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Gaps

		
<p>High costs and limited availability of VR headsets like Meta Quest 2 or 3 restrict use, as seen in Pulse XR and BodySwaps.</p>	<p>There is a lack of clear guidelines for incorporating XR tools into traditional VET curricula, creating integration challenges for applications like Gadgeteer and Training Wind Turbine Engineers.</p>	<p>Many educators lack the technical skills to effectively use XR technologies, limiting the potential benefits of tools like Virtual Shoe Fablab and Principles of Augmented Reality Technologies.</p>
		
<p>XR content may not always meet the specific needs of various vocational fields or adapt well to different cultural contexts, as noted in VM STEM and From Spatial</p>	<p>There is a need for effective evaluation tools for XR learning, as current tools may not adequately assess performance in XR environments, seen in</p>	




Data to Augmented Reality.	Gadgeteer and BodySwaps.
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Requested industry developments






		
<p>Develop more affordable XR solutions to overcome hardware accessibility challenges noted in Pulse XR and BodySwaps.</p>	<p>Create comprehensive guidelines to assist with integrating XR into VET curricula, aligning with Gadgeteer and Training Wind Turbine Engineers.</p>	<p>Implement robust training programs to equip educators with technical skills for XR use, as needed by Virtual Shoe Fablab and Principles of Augmented Reality Technologies.</p>
		
<p>Develop diverse and localized XR content that adapts to different languages and educational standards, addressing gaps in VM STEM and From Spatial Data to Augmented Reality.</p>	<p>Create tailored assessment tools for XR-based learning to provide detailed performance insights and effective feedback, as indicated by Gadgeteer and BodySwaps.</p>	

3.2.3 Structural Engineering and Construction

Insights and Analysis

		
<p>Through interaction with 3D models and real-scale simulations using technologies like Unity and Azure Spatial Anchoring, students gain practical skills that are crucial for their professional development in structural engineering.</p>	<p>These applications simulate site conditions and design changes, enabling students to practice real-world tasks such as assembly and dimension checks in a controlled virtual environment. This exposure helps bridge the gap between theoretical knowledge and practical application.</p>	<p>AR and MR technologies foster a more engaging learning environment by allowing students to interact with 3D content, participate in simulations, and collaborate on structural design tasks, thus promoting a deeper understanding of complex engineering concepts and teamwork.</p>

Gaps

		
<p>The lack of integration with Learning Management Systems (LMS) like Moodle or Brightspace limits the ability to streamline content delivery, monitor student progress, and centralize educational resources and assessments.</p>	<p>The absence of built-in accessibility features in these applications restricts their usability for students with disabilities, highlighting a need for features such as text-to-speech, screen readers, and adjustable display settings to ensure inclusivity.</p>	<p>Dependence on specific hardware (e.g., Microsoft HoloLens) and software (e.g., Unity game engine and MRTK) can be prohibitive for institutions with constrained budgets or resources, necessitating the exploration of more affordable or alternative solutions.</p>
		

<p>Current applications are specifically tailored to bridge engineering scenarios and may not easily adapt to other areas within structural engineering and construction. Expanding content to cover a broader range of disciplines and scenarios would enhance their utility.</p>	<p>The absence of integrated evaluation tools and feedback mechanisms within the AR applications hinders the ability to assess student performance, provide constructive feedback, and track skill development effectively.</p>
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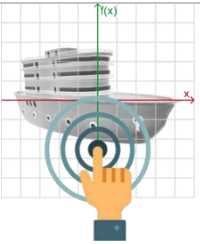
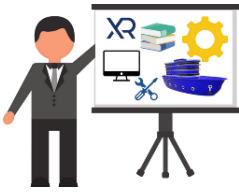

Requested industry developments

		
<p>Incorporating LMS support would facilitate the distribution of educational materials, allow for better tracking of student progress, and offer a platform for assessments and feedback, thus improving overall learning management.</p>	<p>Developing and implementing accessibility features would make the applications more inclusive, accommodating students with diverse needs and ensuring equal access to learning resources.</p>	<p>Exploring more cost-effective hardware and software options or developing flexible applications that do not rely on high-end equipment would make these technologies more accessible to a wider range of educational institutions.</p>
		
<p>Creating versatile content that can be adapted to various structural engineering and construction scenarios would extend the educational value of these applications, making them useful for a broader audience.</p>	<p>Implementing tools for evaluating student performance, providing feedback, and tracking progress within the AR applications would enhance learning outcomes by enabling targeted skill development and</p>	

	identifying areas for improvement.
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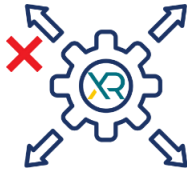
3.2.4 Maritime Professions

Insights and Analysis






		
<p>The use cases, including Design and Construction of Zero-Emission Vessels, Engine Room Operations, and Shore Side Electricity (Cold-Ironing), demonstrate the significant role of XR technologies in maritime professions. They enhance practical understanding by providing immersive, interactive experiences that replicate real-world scenarios without actual risks. These applications are particularly valuable for training in high-stakes environments such as zero-emission vessel design and engine room operations.</p>	<p>Pulse XR and Engine Room Operations highlight the effectiveness of XR in developing clinical and technical skills. By simulating real-world environments and tasks, students can practice and refine their abilities in a controlled setting, improving their readiness for real-world applications.</p>	
		
<p>The interactive elements in these use cases, such as the Virtual walkthroughs of zero-emission vessels and Simulation of engine operation, offer deep engagement and learning by allowing users to explore complex systems and scenarios. This approach not only</p>	<p>The focus on industry-specific skills and knowledge, such as those required for Shore Side Electricity and Engine Room Operations, ensures that training is aligned with current industry standards and practices. This alignment helps in bridging the gap</p>	<p>Effective integration with LMS platforms, as seen in all use cases, facilitates tracking of learner progress, provides access to assessments, and supports a seamless educational experience. This integration enhances the learning process by combining immersive experiences</p>

aids in understanding but also in problem-solving and decision-making processes.	between academic learning and professional application.	with structured educational frameworks.
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Gaps



		
While XR applications excel in technical training, there is a noticeable gap in addressing non-technical skills such as leadership, teamwork, and communication, which are critical in maritime operations but are not thoroughly covered.	There is a general lack of comprehensive accessibility features across the use cases, making it difficult for shore-based professionals with disabilities to fully engage with the content. Enhancements in accessibility, such as more robust support for screen readers and alternative navigation options, are needed.	Current XR applications may not fully accommodate the diverse learning paces of students. There is a need for more adaptive learning features that allow for personalized learning experiences based on individual progress and understanding.
		
There is limited integration of real-time data or live simulations in the current XR tools, which could enhance the realism and applicability of the training modules by providing up-to-date scenarios and dynamic learning environments.	Some XR applications may face challenges in scalability, particularly in terms of hardware requirements and the need for high-speed internet, which could limit their use in resource-constrained environments or regions with less technological infrastructure.	

Requested industry developments

		
<p>Development of XR modules that focus on soft skills, including leadership, crisis management, and effective communication, to complement technical training and provide a more holistic educational experience.</p>	<p>Implementation of comprehensive accessibility features to ensure that all shore-based professionals, including those with disabilities, can fully engage with XR learning materials.</p>	<p>Incorporation of adaptive learning technologies that can adjust the complexity and pace of training modules based on individual learner performance and feedback.</p>
		
<p>Integration of real-time data and live simulations to provide more dynamic and current learning experiences that reflect the latest industry conditions and challenges.</p>	<p>Development of scalable solutions that can be effectively implemented in various educational settings, including those with limited access to high-end technological infrastructure, to broaden the reach and impact of XR training tools.</p>	



3.2.5 Grids and Energy

Insights and Analysis




		
<p>The XR applications in this sector offer a range of training experiences, from designing</p>	<p>These applications effectively leverage XR to simulate real-world scenarios. Energy3D</p>	<p>ThingLink helps in reducing the need for physical travel to remote sites for training and</p>

<p>renewable energy systems in Energy3D to practical, hands-on training for technicians through VR Vision. ThingLink is used for site safety training, providing immersive virtual environments to familiarize employees with power station settings.</p>	<p>focuses on simulating energy systems for educational purposes, allowing users to visualize and analyze the performance of renewable energy installations. VR Vision offers interactive simulations for various energy sector roles, enhancing the practical skills of technicians through realistic training scenarios.</p>	<p>orientations, cutting down on time and environmental impact. This is particularly useful for energy companies managing geographically dispersed infrastructure, as it allows employees to virtually explore and understand site layouts and safety protocols without being on-site.</p>
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Gaps

	
<p>There is a lack of comprehensive integration with Learning Management Systems (LMS) across the XR applications, which hinders seamless incorporation into existing educational and training programs. Only Energy3D and ThingLink have some form of integration or potential for integration with LMS platforms, while VR Vision does not explicitly support it.</p>	<p>There are minimal accessibility features across these XR applications, such as text-to-speech or adjustable font sizes, which could limit usability for individuals with disabilities.</p>

Needs

		
<p>There is a need for improved integration with LMS platforms to facilitate tracking of learner progress and to incorporate XR training more effectively into formal education and training curricula.</p>	<p>Incorporating more accessibility features, such as screen readers and customizable user interfaces, would make these applications more inclusive and user-friendly for a broader audience.</p>	<p>Enhanced real-time data tracking and analytics within the XR applications could provide more detailed insights into user interactions and learning outcomes, which would be valuable for both</p>

	educators and industry professionals.
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3.2.6 Remote Collaboration and AR/VR/MR

Insights and Analysis




		
<p>The ITI VR Crane Simulator and SimX demonstrate the effective use of VR for simulating real-world training scenarios in machinery operation and healthcare, respectively. They highlight how VR can create immersive, realistic environments for practicing complex tasks and decision-making without the associated risks of real-world practice.</p>	<p>Industry 4.0 VR Hub offers an innovative approach to educating users about modern manufacturing, circular economy, and robotics through immersive VR experiences. This use case emphasizes the integration of Industry 4.0 concepts into training to enhance understanding and skills in automation and modern production processes.</p>	<p>All applications leverage interactive elements to enhance user engagement. From handling machinery in simulated environments (ITI VR Crane Simulator) to practicing patient care (SimX) and configuring factory layouts (Industry 4.0 VR Hub), these applications show how interactivity in VR/AR/MR can improve learning outcomes by providing hands-on, experiential learning opportunities.</p>
		
<p>The integration with Learning Management Systems (LMS) varies across applications. SimX and Industry 4.0 VR Hub provide options for</p>	<p>While accessibility features are minimal across these applications, Industry 4.0 VR Hub incorporates audio guides and visual</p>	

exporting session data for performance analysis, enabling a more data-driven approach to training and assessment.	hints, showing some consideration for accessibility, though overall improvement in this area is needed.
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Gaps

		
Most applications lack comprehensive accessibility features, such as alternative input methods for those with disabilities, screen reader support, and closed captions for videos.	The integration with LMS is not uniformly available or optimized across all applications. More seamless integration and better tracking of user progress within LMS platforms could enhance the overall utility and effectiveness of these training tools.	There is a need for more robust real-time collaboration features. While Industry 4.0 VR Hub supports multiplayer interactions, similar capabilities are lacking in the ITI VR Crane Simulator and SimX, which could benefit from enhanced collaborative learning and teamwork functionalities.

Requested industry developments

		
Development of comprehensive accessibility options, including text-to-speech, adjustable interfaces, and compatibility with	Improved and more seamless LMS integration to facilitate tracking, assessment, and reporting of user performance, which is	Inclusion of more advanced real-time collaboration tools to enable simultaneous participation and interaction among users,

assistive technologies, to ensure inclusivity.	critical for academic and professional training environments.	which is particularly useful for remote teams and educational settings.
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4 ANALYSIS

In this section, the analysis of the in-depth interviews and the questionnaire are presented. The insights derived from these methodologies provide a comprehensive understanding of the current landscape and future potential of XR technologies across various sectors.

4.1 In-depth interviews with industry and academia stakeholders

In the following section, the answers to the in-depth interviews are presented in short paragraphs. Those paragraphs represent only the views of the respondents, were based on their answers, and were expanded with the follow-up questions that were asked. The questions are presented in such a way that the anonymity of the respondents can be preserved.

4.1.1 Documentation of the interviews

At first, the interviews started with simple Yes/No questions, and then the analysis of the short answer questions will take place.

What are the priorities in terms of XR tools for teaching, learning and training?

Assembly task training Yes: 9 responses, No: 1 response, I don't know: 1 response

Perception of Physical or Biological phenomena to learn/understand some scientific models Yes: 8 responses, No: 2 responses, I don't know: 1 response

Manipulating virtual or augmented objects because such proprioception can help memorisation Yes: 11 responses

Tools to Implement XR based collaborative environments for such application:

To allow Immersion and better awareness of learners and teachers, in a co-located or remote learning context Yes: 10 responses, No: 1 response

To manage, automatically or in advising the teacher, the Engagement and Attention of learners Yes: 8 responses, No: 3 responses

Regarding Creating XR experiences, where are the needs to reduce the usability gap in teaching, learning and training:

Ready-to-use platform for XR content creation systems for such applications

Yes: 11 responses

XR methodology to follow for designing such applications (from classical Curricula up to design and implement XR experiment required) Yes: 10

responses, No: 1 response

Regarding collaborative environments for teaching, learning and training

Does everything have to take place as an immersive XR experience? Yes: 6

responses, No: 5 responses

In the case of remote collaboration, do you want to mix conventional teleconference with XR one? Yes: 9 responses, No: 2 responses

How do you envision XR technologies transforming the landscape of operational and/or training purposes within your sector?

Over the next 10 years, XR technologies will transform operational and training use cases in the engineering sector, with a significant percentage of impact reserved for increasing safety due to real-world dangerous areas where learning is imminent. Its promise has been evident for some time, but the onset of COVID-19 appears to have accelerated its deployment as well as embedding in training. However, leading consultancies like Accenture and PwC and companies like TRANSFR are utilizing VR to offer cost-effective and continuous training solutions. VR, however, has a strong business case in B2B scenarios where mature platforms exist to provide improved understanding and retention of complex operations. But that too will take some time before the benefits can be fully balanced, as XR technologies have high costs that must be managed. This enables the visualization and correction of processes in a virtual environment, resulting in an innovative learning experience. While XR seems best suited to training in industries that need a visual, hands-on approach (like designing and simulating lightning protection systems), the reconfiguration of company landscapes through its use is likely to be a slow burn. However, content creation is still complex and expensive, and most of the technology is overshadowed by AI. That said, immersive training is a major part of the formative process, with 2D simulations and VR as an evolutionary next phase.

As software and hardware components continue to advance, "people need to see some examples first" but XR tech will grow comprehensively.

How do you think XR technologies can address the diverse learning needs of trainees within your sector?

The benefits of XR-based education can solve the varied learning requirements of trainees from multiple domains by providing personalized experiences and adaptive feedback. Some of the benefits XR provides are its ability to be customized, as well as accessibility features, and adaptive learning experiences. This customization and level of personalization in VR platforms as well as AR applications are also driven by digital assistants enabled through large language models. A good example of this is how Legal Place has shown that it can be deployed to train based individual learners' careers, publications, and preferences using AI assistants. We are still in the early stages regarding personalization enabled by XR.

For application purposes, XR can project instructions directly onto machines as well, which then allow learners to go at their own pace and keep reiterating some points when they feel the necessity. This not only leads to the trainer's independence but also gives the teacher a very good idea of how well a kid understands through programmed questions. When combined with AI, XR technologies can offer customized content according to the users' learning abilities and break language barriers, so no learners feel left behind in a session.

On the other hand, XR can be used for technical training by showing a first-person view of equipment and technology in manufacturing to help users visualize. This can provide a more complete training experience across levels of employees as they are trained in real-world settings, ensuring comprehensive training experiences. VR training tools are configurable, so all necessary requirements, like realism and haptics, can be adapted accordingly. As content is crucial, producing engaging and relevant content for trainees is essential to maximize the benefits of XR technologies.

How do you believe XR technologies can contribute to fostering collaboration and interdisciplinary learning within your sector?

XR technologies can foster collaboration and interdisciplinary learning in different sectors to provide better learning experiences. Such technologies can improve

existing processes by facilitating plant and machinery supplier connectivity on a remote basis, reducing travel requirements, and thereby enabling immediate problem-solving. An example is digital twins, which enable diverse technical experts to work in a common virtual space, modelling changes affecting the production line or manipulating devices and predicting outcomes. This feature is particularly valuable for enterprise-level companies.

In manufacturing, XR technologies can engage users in operational activities and offer enhanced experiential learning experiences by interacting with virtual objects. They can also be used in the field of lightning protection of cultural heritage sites. This combination of immersive and remote capabilities allows XR technologies to raise awareness about the problem they address, as well as provide tools for interaction and sharing materials easily in a collective space.

Design reviews provide a potential platform where colleagues with different majors and from various departments can solve problems and invariably increase productivity within collaborative virtual environments. These models can be used as guidelines for setting up similar XR applications effectively. This capability is what makes XR an invaluable tool for interdisciplinary learning and working, changing the way teams collaborate on projects to meet the demands set by a rapidly evolving landscape of new challenges.

Are there any concerns or reservations you have regarding the ethical or security implications of integrating XR technologies into operational/training environments?

Applying XR technologies for operational and training use cases introduces important ethical as well as security considerations. Key concerns include privacy and reluctance to use new modules. With these new modalities, data security is a significant concern, as expanding the scope of cyber-attack agents increases the potential for people to access sensors and cameras used in XR setups. The implications of privacy safeguards and how personal information and interactions can be protected require significant thought. The concept of identity also becomes complex with XR, as multiple avatars and digital replicas could have long-term implications on personal data and identity representation.

Although some respondents appear to be ethically neutral, especially the ones in the engineering sector, others see clear ethical dangers. For instance, XR's

attractiveness could create a "Wow effect," potentially leading to a mystified perception of reality. Moreover, safety issues should be managed appropriately and grounded in standards in order to protect users.

The security concerns continue when it comes to how XR devices are managed within machines too, which have to be properly handled and not in violation of NDAs. There are also ethical considerations when mixing XR with AI since this sort of fusion could invade one's privacy and most intimate aspects via surveillance. There is also one respondent asking for open standards and software to keep student data within the EU, which addresses a broader local concern over the citizens' privacy rights.

Nonetheless, most respondents remain convinced that the teaching improvements offered by XR will be integrated and the focus should be on developing robust security measures.

From your perspective, what role do you see XR technologies playing in preparing employees and trainees for future career opportunities in engineering sectors?

XR technologies are viewed by most respondents as a way to help prepare employees and trainees for the engineering careers of tomorrow. At first, XR will probably supplement rather than replace physical experiences as a training tool. Eventually, and depending on the nature of a job, 100% of the training could take place in a virtual environment.

XR is compelling for many because it immerses trainees in realistic workplace environments, offering perspectives and experiences that are difficult to obtain otherwise. This hands-on learning enables trainees to learn from the best how their industries are changing and using new tech, arming them with invaluable knowledge of proven processes that also include fundamental tools in today's rapidly moving technological world.

Simulation environments in XR are a key milestone on our way to use them more significantly for training. Although XR is considered a great innovation, there are still those who claim that it may not be necessary for all industries. It has a special application in the machining design or visual thinking, and for training people to work in hostile environments that have inherent health risks.

XR technology has different levels of maturity; some industries view it as a must-have for training, but its capabilities are too primitive today to be useful in many others. For jobs that involve improving communication skills, XR is critical and can even help in the interview itself while underlining non-verbal signals.

Moreover, traditional training techniques are expected to work complementarily with traditional training methods. Training young people in XR using these tools (since they are more familiar with the technology) can help to make it less foreign when incorporating it into training systems. However, the innovativeness of XR in training and education towards an engineering future cannot be underestimated.

What strategies do you suggest for overcoming potential barriers to the adoption of XR technologies in operational and training settings?

This complexity requires a multi-faceted approach to address potential barriers to the adoption of XR technologies in both operational and training use cases. Addressing the high costs through limited-time pilot projects can help build a strong business case, demonstrating the benefits and justifying the investment. Moreover, involving stakeholders, especially end-users, in the design and implementation process is crucial. This will facilitate the acceptance of proposed solutions as well as provide end-users with more relevant tools to work on real needs. Technical improvements like increased hardware quality and better content creation are also likely to drive adoption. Educating users on the advantages and providing training on using XR devices will help overcome resistance to change. Additionally, ensuring applications are accessible and systems are robust can address skepticism, particularly among older employees.

How can XR technologies be effectively integrated into existing activities without disrupting the process?

One proposed way to integrate XR technologies will be through strategic deployment, starting with pilots that integrate with existing activities and cause no disruption. These first tests help organizations validate use cases, test feasibility, and refine goals with feedback from real-world users. Pilot projects are critical for detecting possible obstacles and implementing adaptations early enough to support a seamless transition without any substantial disruption of regular activities.

Leadership plays a pivotal role in successful XR adoption. Effective managers do more than just support innovation; they help their teams make the change, showing in real terms how XR adds value to processes and operations. They create a culture that is open to new technologies and supports constant change, all while making sure the correct reception mechanisms are in place so XR technology projects match with business purposes.

In addition, the emphasis should always be on the user experience. Keeping XR solutions simple, intuitive, and easy to use can help overcome barriers to disruption while streamlining their adoption by staff or workers through peer-to-peer training. Providing adequate training and support further enhances adoption rates and ensures that individuals feel comfortable using XR tools in their daily tasks. Companies can also maximize the benefits of XR technologies while reducing disruption to their operations and training environments by adopting user-centric designs with a focus on accessibility.

What are the potential drawbacks or limitations of XR technologies in operational/training contexts, and how can they be mitigated?

First, the cost of acquiring equipment is a challenge for schools, especially with how quickly technology changes and older hardware becomes obsolete after just a few years. Apart from this, organizations can explore leasing options or technology partnerships with providers for entry-level-priced solutions and invest in scalable ones that allow progress in adoption and upgrade.

Users may also experience motion sickness because there is a lack of standardized approaches across platforms. Enterprises such as the Metaverse Standards Forum work to foster interoperability, a critical factor in ensuring XR experiences are more accessible and comfortable. Providing alternative access points through apps or web links can also broaden accessibility, accommodating users who may struggle with immersive environments.

Moreover, there is a disparity in access to XR technologies, with the developed world having access to XR technologies more easily compared to developing countries. There is going to be a necessity for initiatives that build infrastructure and educational strategies in order to democratize XR tools. This includes fostering experimentation opportunities in educational settings and ensuring that global

education agendas prioritize digital literacy alongside traditional skills, thereby equipping students worldwide for future technological landscapes.

In addition to these technological and accessibility challenges, there is a need to carefully manage change within organizations. Valid concerns such as resistance to new technologies, perceived distractions, and the time it takes for adaptation can be addressed with robust change management strategies. These plans need to include effective communication strategies, combined with training and the gradual integration of XR technologies within current operational and training workflows that offer minimal disruption for all while reaping the benefits.

How do you foresee the role of XR technologies evolving in operations and/or training over the next decade?

XR technologies will soon become mainstream in several industries, including an evolution and integration of their role within operations and training over the next decade. These include XR solutions transforming how training happens today by providing remote assistance, augmented reality instruction, and easy content creation tools like Microsoft Guides and Remote Assistance. In the short term, we expect to see XR for professional training becoming commoditized and routine, offering immersive, interactive experiences that will accelerate learning outcomes at scale.

In addition, its role in the wider integration of remote and collaborative working will continue to grow. This ability is especially useful for industries that must handle difficult processes where any errors could have expensive or even hazardous consequences, such as the mechanical and electrical sectors. This movement toward remote and collaborative usage will not only simplify processes but also make training the onboarding process for employees much faster, giving them an easier understanding of intricate workflows and practices.

As XR technologies continue to reach a wider audience, we can expect broader applications and interactions with AI. Complementing XR experiences, this integration will use AI-driven data to serve as a powerful offering in aiding the personalization of training modules and simulation-based scenarios so that the trainees will get effective real-time feedback on their performance. Faster haptic feedback technology has been reported to advance on predictions, allowing for

users to be able to not just visually but also touch the feel of virtual objects, adding yet another layer between AR and VR ecosystems.

At last, while XR seems unlikely to become ubiquitous across all sectors in the next ten years, its ongoing cost reduction and quality/versatility improvements will drive large-scale adoption, at least within manufacturing and engineering as well as healthcare industries. This transformation will change the ways that businesses perform employee training, work together across regions, and develop new products using immersive experiences.

What opportunities do you see for interdisciplinary collaboration and knowledge sharing facilitated by XR technologies within your sector?

Most respondents agree that XR technologies present profound opportunities for interdisciplinary collaboration among different sectors. Leveraging XR technologies, people across different disciplines can interface more naturally and efficiently using immersive environments. XR enables professionals to visualize complex concepts and simulations together within a shared virtual space, improving comprehension and enabling more effective interdisciplinary collaboration.

Moreover, experts from diverse locations and regions may specifically convene in digital environments to collaborate on projects, share insights, and solve complex problems in real-time. Not only does it broaden the team of experts, but this also accelerates innovation by integrating diverse perspectives and approaches.

In addition, XR technologies facilitate cross-collaboration across technical expertise and social sciences. The integration of anthropologists, sociologists, and philosophers in XR projects helps to assess the impact of technologies on society. The interdisciplinary nature of this work is necessary for addressing ethical, societal, and inclusive design problems, addressing considerations beyond technical functionalities.

What strategies do you recommend for evaluating the effectiveness of XR technologies in enhancing training outcomes?

In order to develop a clear understanding of how XR technologies might be improving training outcomes or not, the organization must initially devise some defined KPIs that will be measurable and that are consistent with their own

established goals. These KPIs should be capable of measuring specific goals (e.g., improving knowledge retention or skill acquisition, operational efficiency in task completion, etc., or user satisfaction with training experience). These metrics must be defined in partnership with relevant stakeholders and leadership to align priorities and the expected results from XR implementation.

The success of XR-enhanced training programs can also be measured by user feedback and satisfaction. Conducting user surveys, interviews, or usability tests to evaluate how learners experience produced XR content provides continuous feedback throughout the process. These feedback mechanisms diagnose usability failures, comprehension levels and highlight focal points that need improvement. By including tools such as QR codes for immediate feedback or post-training evaluation procedures that encourage users to provide optional comments and ratings with their domain-specific knowledge on various aspects of the assessment process. This consolidated user experience collection method enables organizations to continuously iterate on experience design improvements in XR technologies according to specific requirements.

Another suggested method of evaluation is the comparative analysis between XR training and traditional methods. Organizations can measure metrics like task completion times, error rates, and retention of learned material by conducting side-by-side comparisons. These practical evaluations and simulations only serve to compound the evidence that XR training will effectively begin transferring these same skills into real-world situations. Using these methods is a way to measure the incremental value of XR technologies on learning outcomes and operational efficiencies, thus delivering empirical evidence needed for sustaining training investments in time as well as fine-tuning digital learning strategies.

What steps can organizations take to ensure equitable (inclusive) access to XR technologies for all?

At first, addressing the financial aspect is crucial to the respondents. Subsidies and grants for XR equipment can make the technology more accessible to less privileged groups, such as employees from low-income backgrounds. Organizations may want to explore funding opportunities in order to reach a broader demographic. Partnering with financial institutions or technology

providers for bulk purchases can also lower costs per unit, making it feasible for more individuals to acquire XR devices.

Enhancing awareness and education about XR technologies is essential for the respondents. Providing comprehensive information sessions, demos, and training opportunities can demystify these technologies and highlight their potential benefits across various domains, from professional development to personal wellness. This approach not only fosters interest but also ensures that users understand how to effectively utilize XR tools.

Moreover, creating a wide variety of consumer-friendly content is an important step in expanding the reach and usefulness of XR technologies. Finally, as a vehicle for personal growth, XR applications should include exercise and meditation, along with social engagement opportunities. As a result, different user requirements are addressed, and XR tools become more relatable and engaging. Organizations can further their ability to develop and adopt applications and benefits of these technologies by allowing users to experiment with them, thereby creating a culture of innovation.

At last, ensuring that XR experiences are user-friendly and accessible is critical. Intuitive user interfaces and accessibility for persons with disabilities should be integrated in by organizations. XR technologies must be designed in accordance with the universal design principle, so that all people can take advantage of them irrespective of their physical capacities and level skill using technology. Focus marketing efforts on raising public awareness of what XR can do and how it works, as opposed to just trying to sell an experience. Designing an inclusive environment that strengthens the experience created by XR technologies for all users can be achieved through these strategies.

How do you envision the future integration of XR technologies into mainstream operational/training practices within your sector?

Future integration of XR technologies into mainstream operational and training practice within the electrical and mechanical sectors seems inevitable. As these technologies continue to converge with AI, 5G/6G, and cloud computing, we are seeing the creation of a new web where 3D formats become standard. This convergence makes XR technologies easy to use across various platforms, from headsets and smart glasses to AR and 3D digital worlds in web browsers or game

consoles. The 3D exploration focus will greatly improve training and operational capabilities within these industries.

The reining element of XR adoption on a large scale will be the balance between cost and benefit. With XR technologies proving to be less expensive and providing training effectiveness, they will become more democratized and widely used. Simulation software will be utilized to help assemble mechanical tools, providing hands-on training practice without the use of physical materials. Not only will it cut costs, but the training programs will also be more accessible and safer. The interesting new insight or viewpoint is that such proven tools apply to mature XR artifacts already moving out of pure prototyping and proof-of-concept phases into operational commercial solutions being used on a daily basis.

Although the future looks bright, there are still obstacles to be faced. As XR technologies progress, safety and privacy remain big concerns too. In order to protect user safety and the confidentiality of business data, organizations will need to develop robust protocols to ensure user safety and protect sensitive information. There are also logistical issues faced due to educational settings, where hygiene concerns associated with VR helmets must be managed. Providing enough helmets for everyone to use individually or taking the time necessary to sanitize them periodically could alleviate these problems. And, as educators and trainers further adopt XR technologies into their curricula or training regimens and these tools continue to prove effective, XR will become a mainstream part of operational and training practices in the electrical and mechanical sectors.

How do you see XR technologies contributing to environmental sustainability and green initiatives, particularly in terms of reducing carbon footprints or promoting eco-friendly practices?

Based on the answers of the respondents, XR technologies have a huge potential to help limit environmental harm and promote the green industry as carbon emissions are reduced, all of which could aid eco-friendly practices. A key way XR can help with this is by reducing the demand for physical travel. Using XR as a tool for remote conferences, training sessions, and collaborative work can replace many in-person meetings and trips, thereby reducing the carbon emissions related to air or ground transportation.

On top of that, XR can make an important contribution to sustainability by offering the possibility of prototyping in a digital environment that reduces the need for physical materials and resources. By creating and testing virtual models, organizations can cut down on the waste generated from producing and discarding physical prototypes. This approach is not only better for the environment, but it also means we can get through work faster and with fewer delays in project delivery.

Moreover, the ecological costs of XR technologies should be taken into account along with their environmental benefits. The computing power required to create and sustain digital twins, virtual environments, and AR experiences is significant. Though quantum computing offers a long-term solution, the current consumption of energy by XR's is high and will continue to hold back any possible technological advancement. Accordingly, we need to devise practical measures that provide energy-efficient computing and other ecological means of supporting XR applications so that, in paperless ecosystems, such data centers are able to process but do not leave any carbon footprint.

Can you discuss any specific features or developments in XR technology that prioritise environmental sustainability, such as energy-efficient hardware, recyclable materials, or virtual collaboration tools that reduce the need for travel?

A key focus based on the answers of the respondents is lightweight hardware XR devices, with manufacturers aiming at building more power-efficient experiences. One example is how companies such as NVIDIA are making new, more efficient graphics processors that can lower the rendering and real-time collaboration computing power. Smaller, more efficient chips will help improve XR devices to deliver better results with less energy. Some XR devices are even being designed to run on alternative and renewable sources of energy, like solar power, in order to reduce their environmental impact further.

Recyclable materials are another essential innovation. More manufacturers are using eco-friendly materials in the production of their XR devices. This entails the use of recyclable, biodegradable elements too, in an effort to reduce its total environmental footprint. Enterprises are looking at modular designs that allow for

easy upgrades and repairs, which will increase the product lifecycle of these devices. This will assist to reduce electronic waste as new components can be implemented rather than replacing entire products outright.

Virtual collaboration tools play a strategic part in raising awareness for sound environmentally responsible behaviors. Virtual meetings, training sessions, or collaborative workspaces can engage participants in an effective way without their physical presence using XR technologies. This decreases carbon emissions from travel and saves time and resources. For example, a machinery supplier can use XR to provide virtual training and support to clients, eliminating the need for on-site visits and reducing the associated carbon footprint.

Similar energy-efficient solutions are being implemented for the data centers and XR cooling systems as well. Inefficient cooling technologies requiring a great deal of energy are being replaced or further supplemented with other types of resources to supply the additional power. That also lowers the global energy demand and makes the environmental impact of the currently required infrastructure that powers XR applications lower.

Another benefit of XR is the reduction of peripheral devices. Transitioning from traditional setups that require multiple peripherals (like keyboards, mice, and monitors) to a single XR headset reduces the production and disposal of electronic devices. Interaction through gestures and voice commands eliminates the need for many traditional input devices, further conserving resources.

What steps or initiatives do you believe organisations should take to ensure that the adoption and use of XR technologies align with broader environmental goals and contribute positively to a greener future?

Based on the answers of the respondents, to help ensure XR technologies contribute positively to environmental sustainability, organizations will need a multifaceted approach. First, regulatory standards need to be established. These should include energy efficiency, recyclable materials, and sustainable manufacturing practices for XR hardware. By doing that, organizations will minimize the environmental impact of XR technologies across their life cycle.

Secondly, working with hardware manufacturers and technology providers is important. By collaborating with these stakeholders, organizations can encourage the development of energy-efficient XR devices and promote sustainable practices in production processes.

Moreover, it is important to integrate XR within wider corporate sustainability strategies. This includes mapping XR initiatives to sustainability targets, tracking reductions in carbon footprints, and highlighting how the reduced need for travel can be met through virtual reality.

At last, public advocacy for XR, such as universal standards and public relations campaigns, is an important media event to raise awareness of the industry. This will involve informing stakeholders on the environmental positives of XR, advocating for supportive policies, and promoting research into greener forms of this technology. The measures reiterated above help to maintain a balance where XR technologies not only boost operational efficiency but also drive us towards an environment-friendly future.

When hiring new employees, is knowledge and skills in XR technologies an asset?

When it comes to recruiting, views on the advantages and potential necessity of knowledge and skills in XR technologies are mixed between the respondents. Some believe that while XR knowledge can be acquired quickly, its value lies more in the specific applications and ongoing learning mindset rather than static knowledge. They emphasize the importance of continuous updates and adaptability in utilizing XR effectively within evolving technological landscapes.

Others see XR skills as already valuable in their sector, particularly when employees come from non-technical backgrounds, suggesting it enhances cross-disciplinary collaboration and innovation. This viewpoint highlights XR's potential to bridge gaps between traditional education and practical application, underscoring the need for relevant content alongside technological tools.

Moreover, some responses indicate a more cautious approach, mentioning that XR technology's integration into hiring criteria is still under evaluation through pilot projects. They emphasize the importance of foundational knowledge over specific

tool proficiency, implying a need for comprehensive understanding before broad adoption.

At last, while many agree that XR skills can be beneficial, especially within certain sectors or for younger candidates adept at learning new technologies, there's also recognition that its true value lies not just in initial proficiency but in the ability to continuously adapt and innovate within rapidly evolving technological landscapes.

Do you see any need for a new type of professionals related to XR, for instance “XR designer” or similar?

Opinions are divided on whether there is a need for a distinct new type of professional like an XR designer. Some argue that existing interaction designers possess the necessary skills to develop user experiences and user interfaces for immersive environments. They emphasize that while XR entails novel interaction methods like biometric inputs (voice commands, gestures), the foundational principles of interaction design remain central.

Conversely, others acknowledge the evolving nature of XR interfaces and advocate for specialized training in XR design aspects. They suggest that while it might not necessitate entirely new professions, XR-specific skills are becoming increasingly important for existing roles, such as designers adapting to new technological demands.

There's also recognition that while the tools themselves may become more user-friendly for non-XR experts, the complexity and potential for innovation in XR may indeed create new avenues for specialized competencies.

Which barriers do you consider to be the most important ones, limiting your usage of XR technologies?

Cost: Perhaps the biggest barrier to the entry of XR technologies is cost, both in terms of hardware, software, and infrastructure. That means all the up-front costs of getting XR equipment and then the ongoing costs associated with keeping them current.

Resistance to Change: This is the biggest challenge with users and organizations resisting new XR-tech, as they are not familiar with or skeptical of their benefit or utility, and also because it might disrupt the existing workflow.

Infrastructure and Access: To deploy XR technologies efficiently, there must be robust infrastructure available that includes high-speed internet and compatible devices. The availability of appropriate hardware and software platforms also influences the adoption rate.

Proving Value and Generating Buy-In: Stakeholders need hard evidence of the benefits and return on investment (ROI) from using XR applications. Key Performance Indicators (KPIs) setting, and their effective implementation are considered the mandatory preliminary requirements to be fulfilled.

Regulatory and Content Challenges: Regulatory environments, as well as the creation content for XR applications, carry additional barriers. The respondents highlighted potential issues such as adhering to standards, ensuring data security, and navigating evolving regulatory frameworks.

Technological Complexity: The complexity of XR technologies, including integration with existing systems and ensuring interoperability, can pose hurdles. This complexity also extends to issues like data protocols and compatibility across different platforms.

How do you envision Alliance4XR supporting trainers in leveraging XR technologies to create inclusive and accessible training experiences for all?

A respondent's recommendation for Alliance4XR was to adopt a more holistic approach around aiding trainers in implementing XR technology into the learning process. Initially, we would need to emphasize vast awareness campaigns and literacy opportunities for people. This material should come in user-friendly manuals, detailed courses, and online content tailored to creating easy usage and adoption of XR tools. Providing clear technical direction and promoting safe usage, Alliance4XR can greatly demystify the learning curve for novice immersive technology trainers. In addition, highlighting ethical considerations of using XR would protect that gender reflective integrity within and from our educational

space when we use these technologies, embedding in educators and stakeholders a positive perception.

Also, it would be beneficial to develop robust skills certification programs tailored for XR. They should not only target educators and trainers, but they must also be presented as true educational projects to certify knowledge about the management of XR projects (technical and budget) and educational content. Alliance4XR, in turn, can certify the trainers that they are competent to use XR for training, so it is assured that employers or educational institutions will gain the most from their investment. Certifications will help global interoperability and encourage individuals to trust anyone around the world in relation to XR for education.

Additionally, supporting educators to be able to teach in 3D environments should be a priority based on one respondent. While not an end-to-end solution, Alliance4XR should offer some introductory steps and tools to help it along the way with methods of what has worked well for others in XR education. By enabling this shift, educators can be more willing to adopt XR technologies in their teaching models and improve student engagement as well as learning outcomes.

Finally, showcasing compelling case studies and scenarios related to XR-based learning in training or education would also be very helpful. The purpose of these examples is to serve as a clear representation of the benefits of XR within education and employ cases where it has helped improve learning outcomes, drive engagement levels, and make content attainable by learners. Through detailing those successful applications, Alliance4XR should be able to provide models that teachers and policymakers can use more broadly for educational advancement via XR technologies.

4.1.2 Analysis of the findings and insights

The findings of the in-depth interviews can be summarized in the following topics:

Transformation of Operational and Training Purposes: The respondents in industries like education and engineering see XR as having the most significant impact on how we train or operate. In education, where immersive learning environments are a major focus, helps enhance student engagement and comprehension with interactive simulations. Engineering professionals note that

XR facilitates virtual prototyping and simulations, enabling designers to save time on designs and costs from physical prototypes. Likewise, in the medical industry, XR technologies are expected to increase the efficiency of training for surgeries and patient care by creating more realistic simulations of those cases. XR has the ability to send learning further down that continuum because it is designed and optimized for simulating real-world experiences.

Challenges and Barriers: Although the potential was observed to be huge, it was noted that some challenges could stop XR from becoming mainstream. One big barrier is cost, especially for smaller organizations and educational institutions with limited budgets. XR adoption was also restricted by the resistance to change and the need for cultural shifts in enterprises. Further comments were made about the need for fine-tuned integration to make XR systems easier-to-use for end-users that come with several software and hardware development complexities, also requiring a specialized skill set, reflecting common hurdles seen in adopting those technologies.

Inclusivity and Accessibility: There is a growing recognition between our respondents, regarding the importance of inclusivity and accessibility in XR applications. It was clear that respondents are looking for XR solutions to provide varied options, from accessible tools that could be used by people with disabilities to learners with specific learning requirements. The value of standards and guidelines in ensuring XR is accessible to everyone was discussed, echoing a call for universal design principles and user-centered approaches during the development process.

Environmental Impact: Discussions around XR's environmental impact revealed contrasting views. Although XR enables carbon footprint reduction by avoiding travel through virtual collaboration and training, it was noticed that energy use, especially in data processing and server infrastructure essential to powering these XR technologies, is high. These issues will require breakthroughs in energy-efficient hardware as well as best practices for green XR throughout the lifecycle of these new technologies.

Skills and Workforce Development: As XR technologies are evolving, there is also a need for an organized workforce to make effective use of resources in training

and assessing them. Most of the respondents agree on the importance of specific roles, such as XR designers who comprehend specialized requirements within immersive environments. Further, the need for lifelong learning and upskilling is key to keeping pace with technological advancements and realizing the potential that XR has to offer across sectors.

4.2 Questionnaire: eXtended Reality state and needs for Education & Training

The main objective of the questionnaire is to identify additional market needs not covered by the desk study and the interviews. The questionnaire is primarily addressed to existing XR practitioners and is aiming to identify market needs at a more detailed level. The questions covered by this survey include:

- Are the respondents representatives of the target group?
- Are XR technologies efficient and effective?
- How do you foresee the future of XR technologies?
- What are the main barriers for implementing XR technologies?
- Which contributions can XR technologies provide to the development of the green deal?

In the following section, the statistics, and the analysis of findings of the questionnaire are presented. In total, *the survey collected 89 answers* from industry and academia stakeholders. In 4.2.1, the statistics of the questionnaire for Likert scale (1= Not at all, 5=Extremely) or Yes/No questions are presented. In 4.2.2, the open-ended questions are presented.

4.2.1 Statistics of the questionnaire

How familiar are you with eXtended Reality (XR) technologies and their usage in your sector/domain?

Arithmetic mean: 3.79 Standard deviation: 1.29

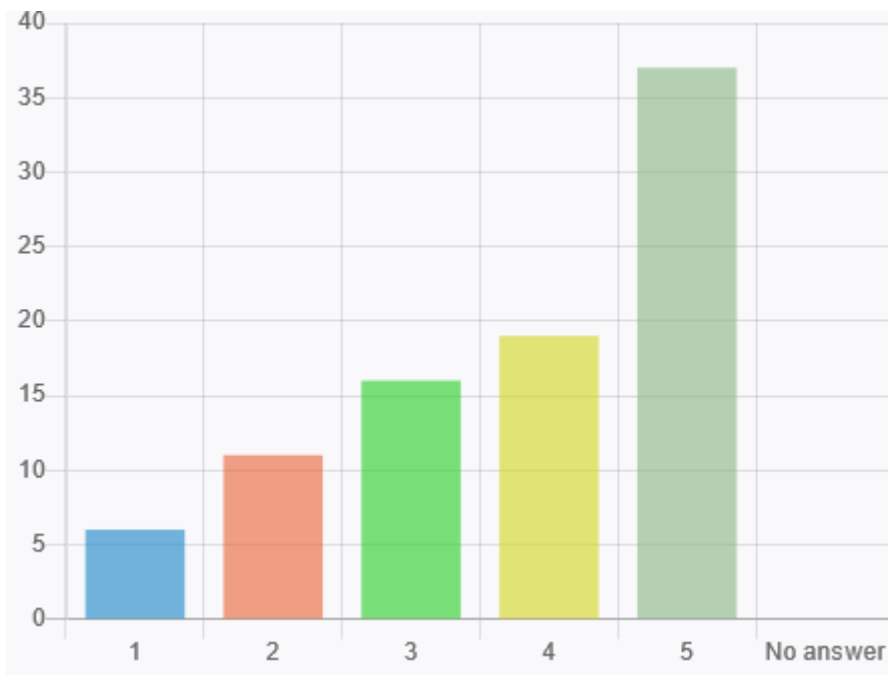


Figure 1 How familiar are you with eXtended Reality (XR) technologies and their usage in your sector/domain?

What is your current sector/occupation or what industrial sector do you target?

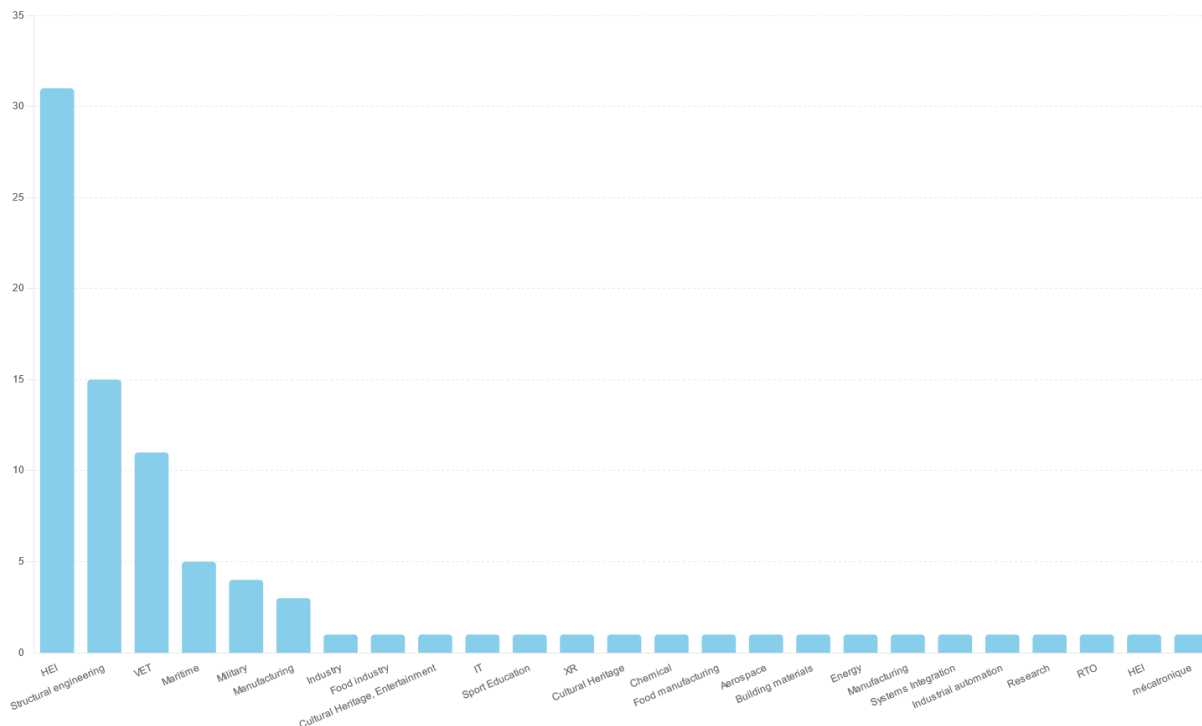


Figure 2 What is your current sector/occupation or what industrial sector do you target?

How familiar are you with game engines such as Unity and/or Unreal?

Arithmetic mean: 3.27 Standard deviation: 1.59

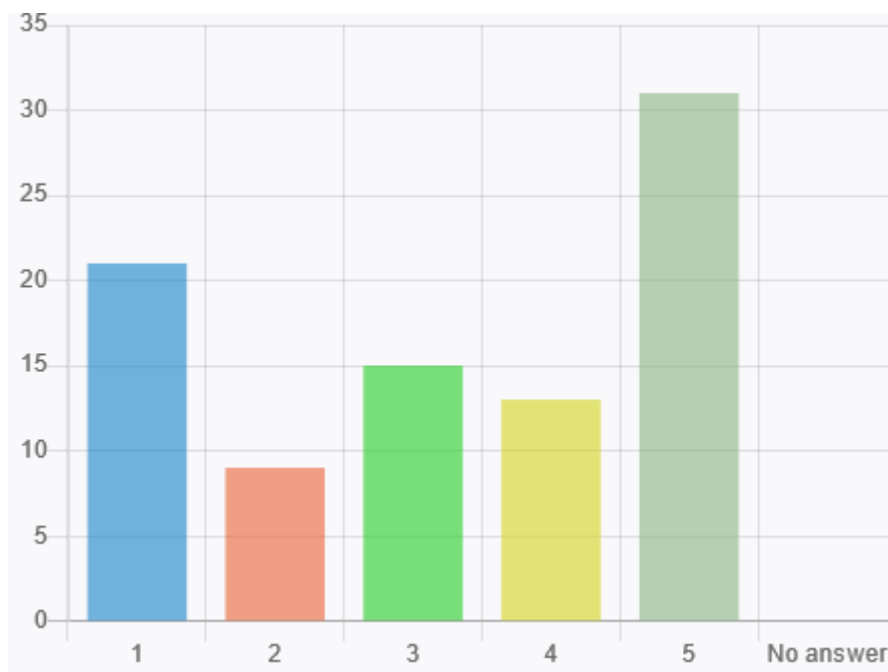


Figure 3 How familiar are you with game engines such as Unity and/or Unreal?

Do you have any programming and/or 3D modeling skills?

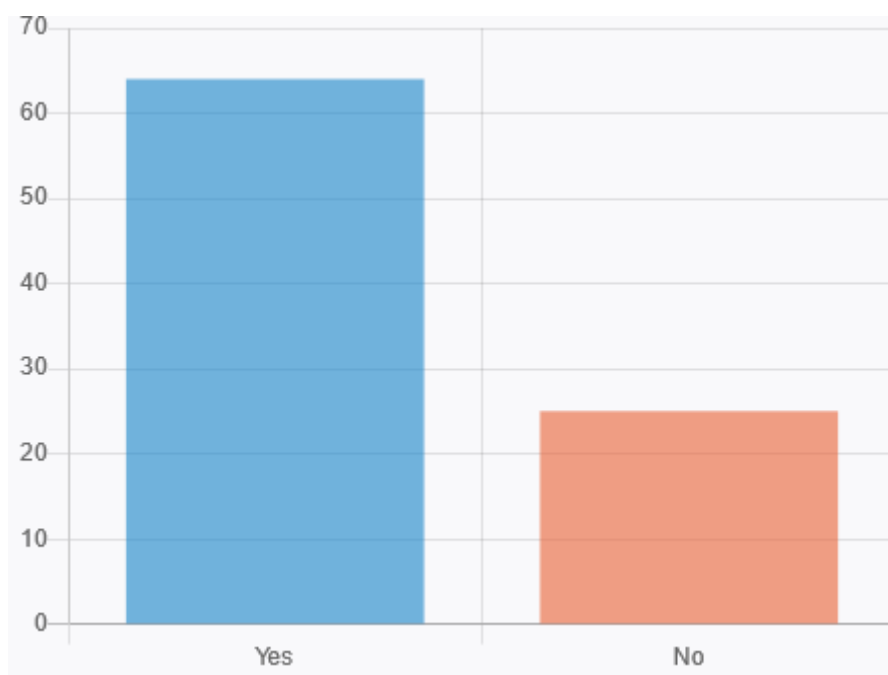


Figure 4 Do you have any programming and/or 3D modeling skills?

How familiar are you with the cost of software and hardware for an XR installation?

Arithmetic mean: 3.31 Standard deviation: 1.53

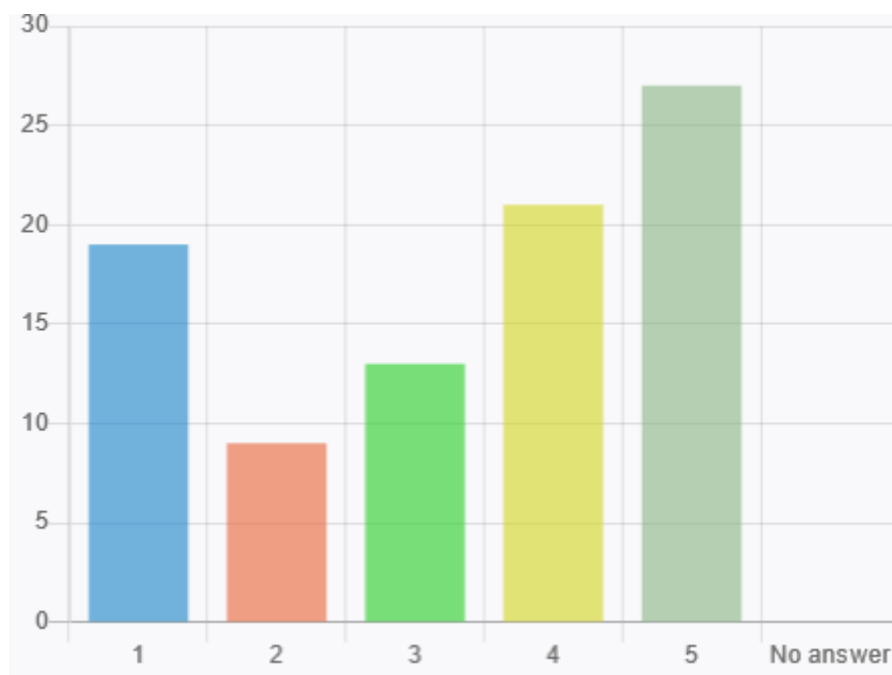


Figure 5 How familiar are you with the cost of software and hardware for an XR installation?

To what extent has your institution integrated XR technologies into operational and training activities?

Arithmetic mean: 2.79 Standard deviation: 1.33

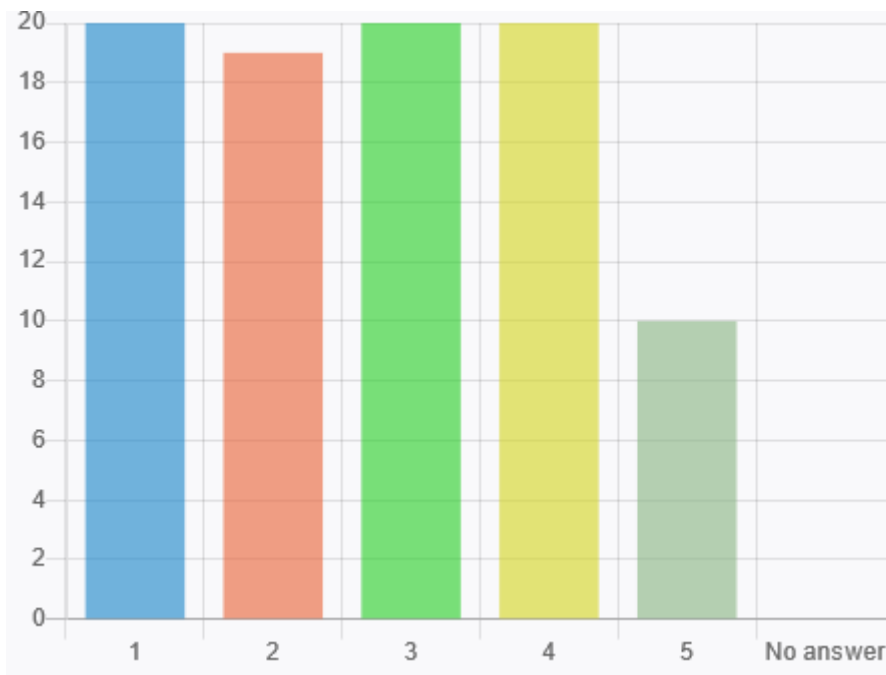


Figure 6 To what extent has your institution integrated XR technologies into operational and training activities?

To what extent has your institution integrated XR technologies into other activities (e.g. hiring process, demonstrations, experimental design)?

Arithmetic mean: 2.56 Standard deviation: 1.31

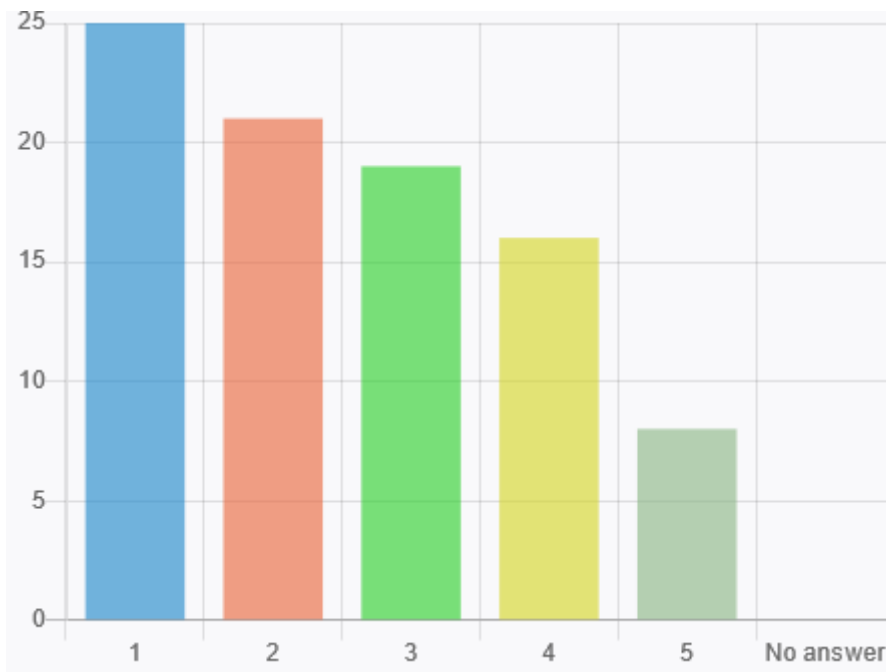


Figure 7 To what extent has your institution integrated XR technologies into other activities (e.g. hiring process, demonstrations, experimental design)?

Based on your experience, how effective do you observe XR technologies are in the enhancement of operational and training activities?

Arithmetic mean: 3.81 Standard deviation: 1

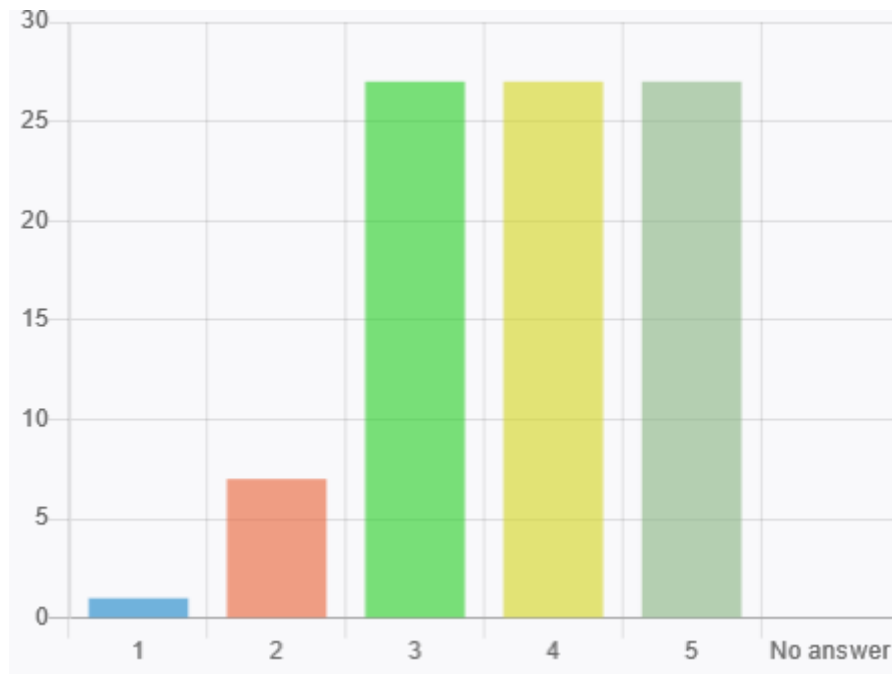


Figure 8 Based on your experience, how effective do you observe XR technologies are in the enhancement of operational and training activities?

How effective do you believe or envision XR technologies to be in the enhancement of operational and training activities?

Arithmetic mean: 4.27 Standard deviation: 0.69

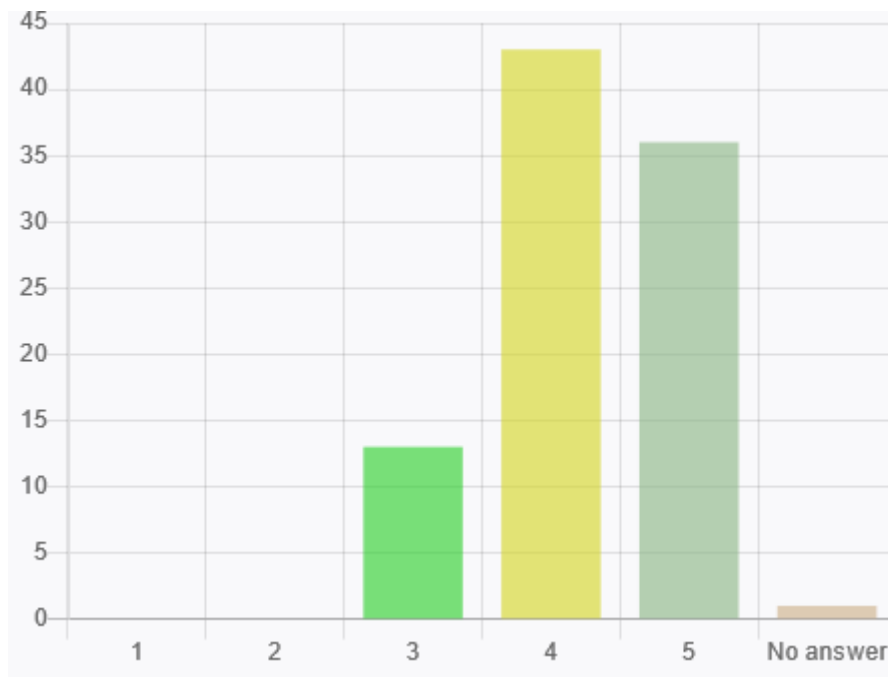


Figure 9 How effective do you believe or envision XR technologies to be in the enhancement of operational and training activities?

How skilled are you with XR technologies to estimate their potential to support co-localized and/or remote collaborative activities?

Arithmetic mean: 3.6 Standard deviation: 1.26

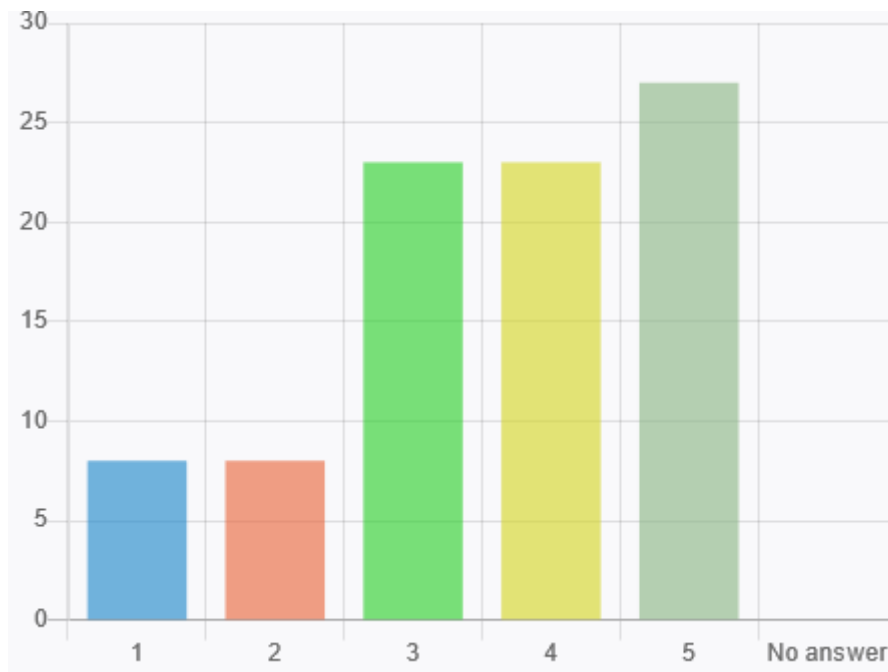


Figure 10 How skilled are you with XR technologies to estimate their potential to support co-localized and/or remote collaborative activities?

How likely is your institution to incorporate XR technologies into its operations and training programmes in the near future?

Arithmetic mean: 3.44 Standard deviation: 1.08

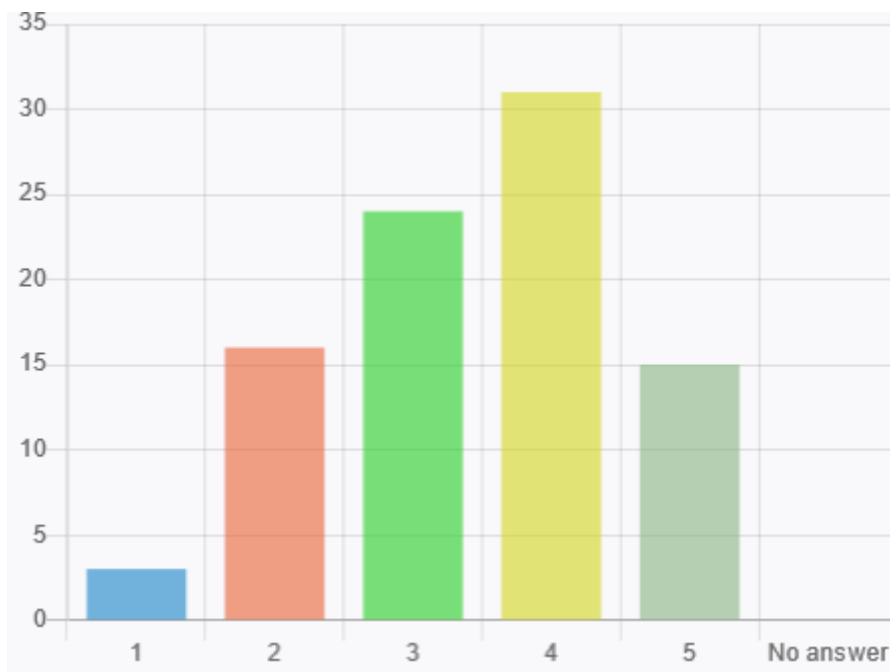


Figure 11 How likely is your institution to incorporate XR technologies into its operations and training programmes in the near future?

Has your institution sufficient resources to integrate XR technologies into your operational and training practices?

Arithmetic mean: 3.3 Standard deviation: 1.16

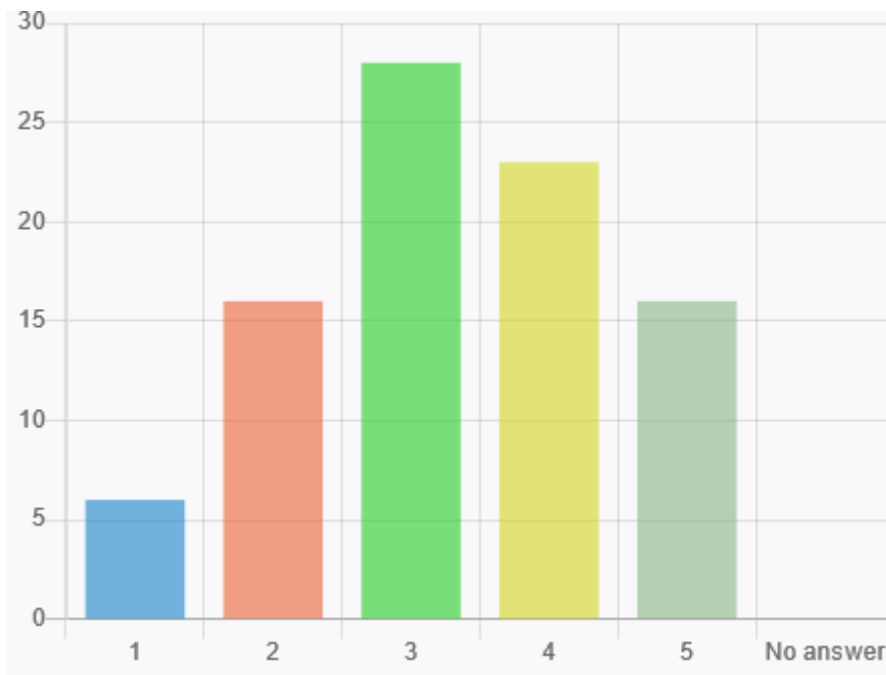


Figure 12 Has your institution sufficient resources to integrate XR technologies into your operational and training practices?

Rate the usability of XR content creation tools (e.g., Unreal, Unity) for trainers

Arithmetic mean: 3.12 Standard deviation: 1.19

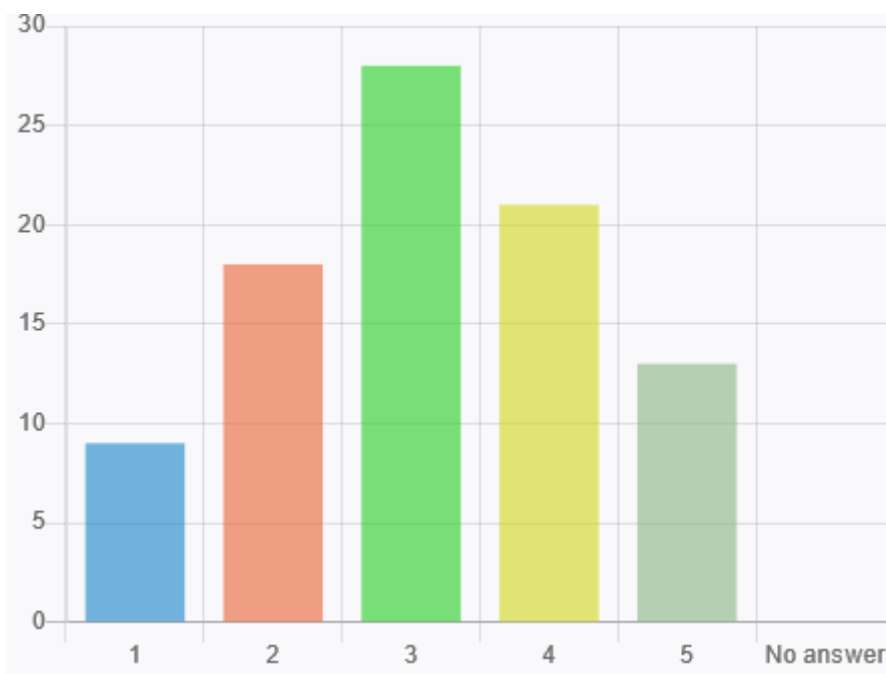


Figure 13 Rate the usability of XR content creation tools (e.g., Unreal, Unity) for trainers

Rate the level of internal and/or external to your institution support and resources available for implementing XR technologies in training programmes.

Arithmetic mean: 2.93 Standard deviation: 1.13

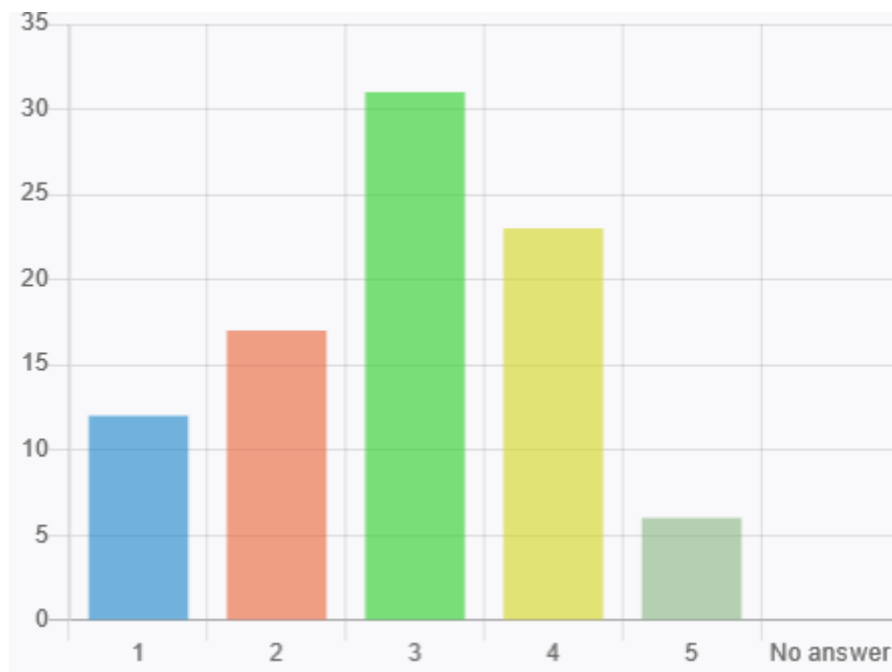


Figure 14 Rate the level of internal and/or external to your institution support and resources available for implementing XR technologies in training programmes.

How satisfied are you with the ongoing professional development opportunities related to XR technologies?

Arithmetic mean: 3.01 Standard deviation: 1.03

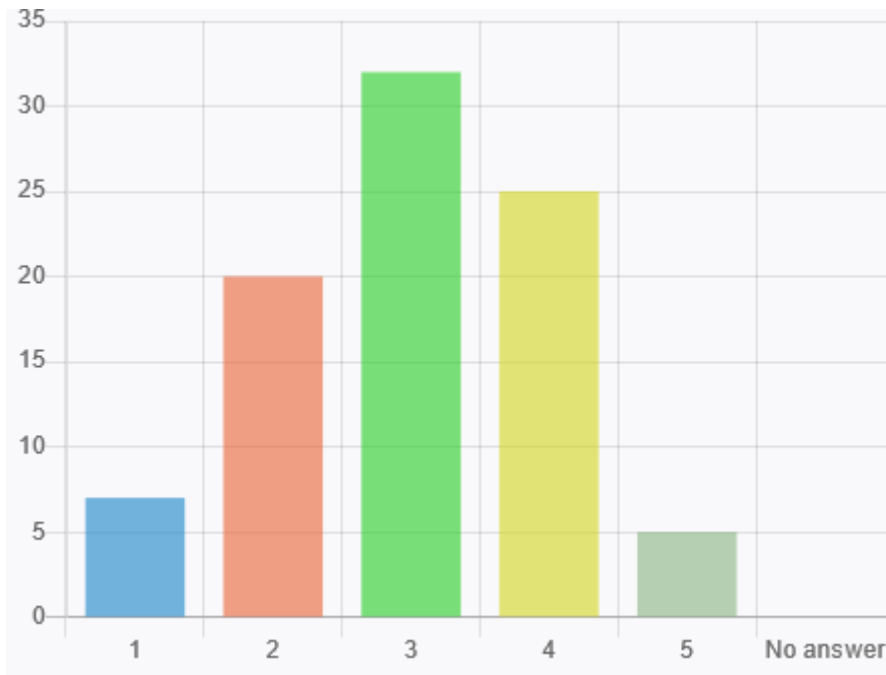


Figure 15 How satisfied are you with the ongoing professional development opportunities related to XR technologies?

How likely are you to seek out professional development opportunities to improve your understanding and proficiency in XR technologies?

Arithmetic mean: 3.33 Standard deviation: 1.13

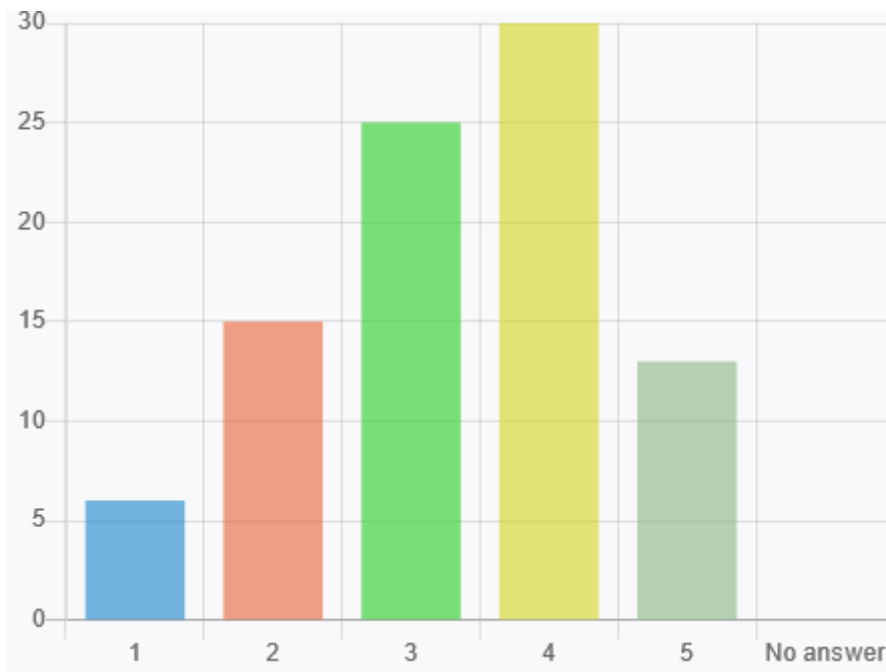


Figure 16 How likely are you to seek out professional development opportunities to improve your understanding and proficiency in XR technologies?

To what extent do you believe XR technologies can enhance practical skill development in operational and training contexts?

Arithmetic mean: 4.27 Standard deviation: 0.72

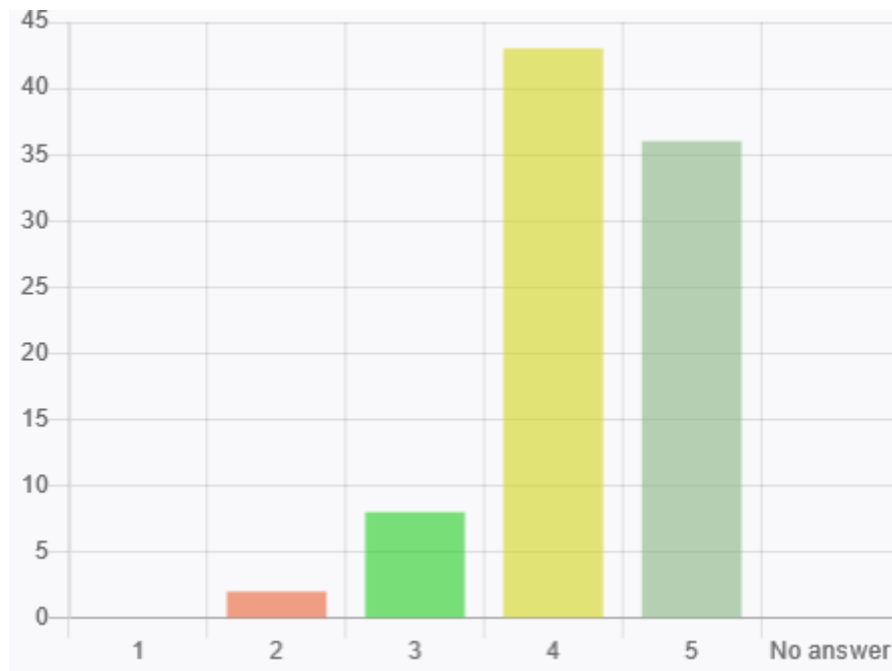


Figure 17 To what extent do you believe XR technologies can enhance practical skill development in operational and training contexts?

To what extent do you believe XR technologies can enhance validation of skills and evaluation processes for the hiring process in operational contexts?

Arithmetic mean: 3.64 Standard deviation: 1.01

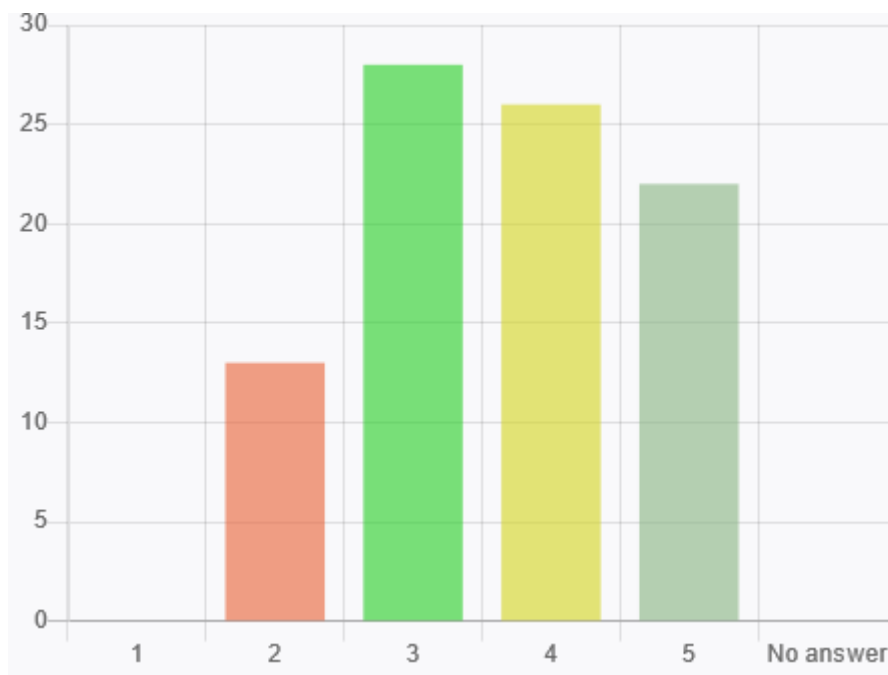


Figure 18 To what extent do you believe XR technologies can enhance validation of skills and evaluation processes for the hiring process in operational contexts?

Rate the scalability of XR technologies for operational and training purposes

Arithmetic mean: 3.85 Standard deviation: 0.94

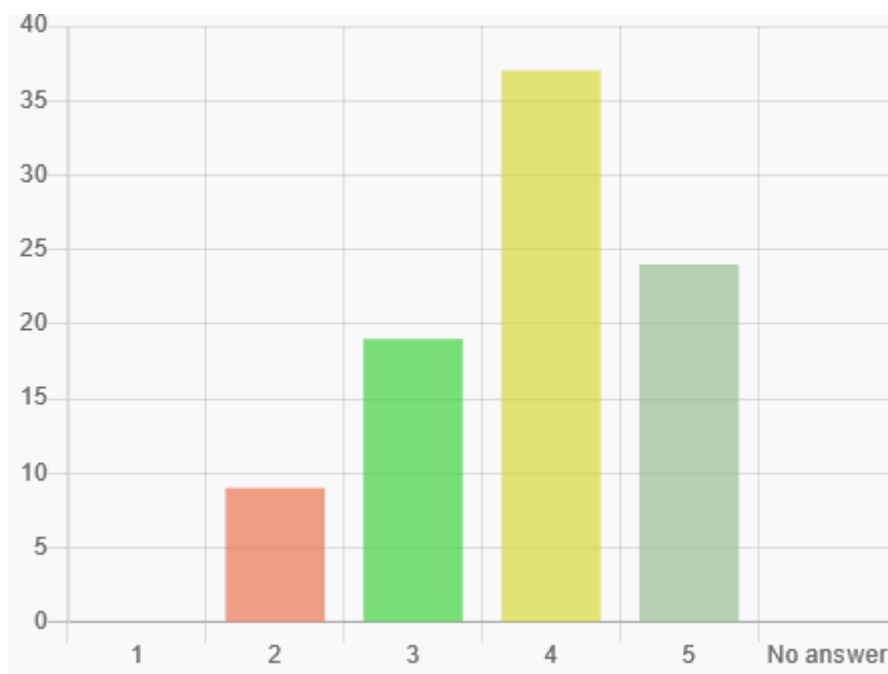


Figure 19 Rate the scalability of XR technologies for operational and training purposes

How satisfied are you with the level of data privacy and security measures implemented within XR technology platforms used for operational and training purposes?

Arithmetic mean: 2.94 Standard deviation: 0.88

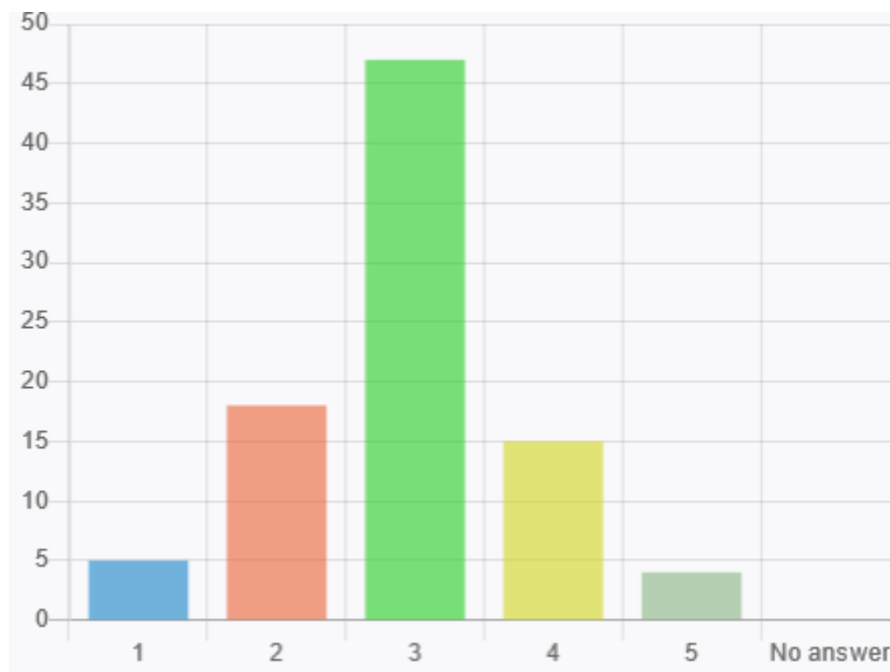


Figure 20 How satisfied are you with the level of data privacy and security measures implemented within XR technology platforms used for operational and training purposes?

Rate the degree of customisation and personalisation options available in XR learning experiences.

Arithmetic mean: 3.26 Standard deviation: 1.04

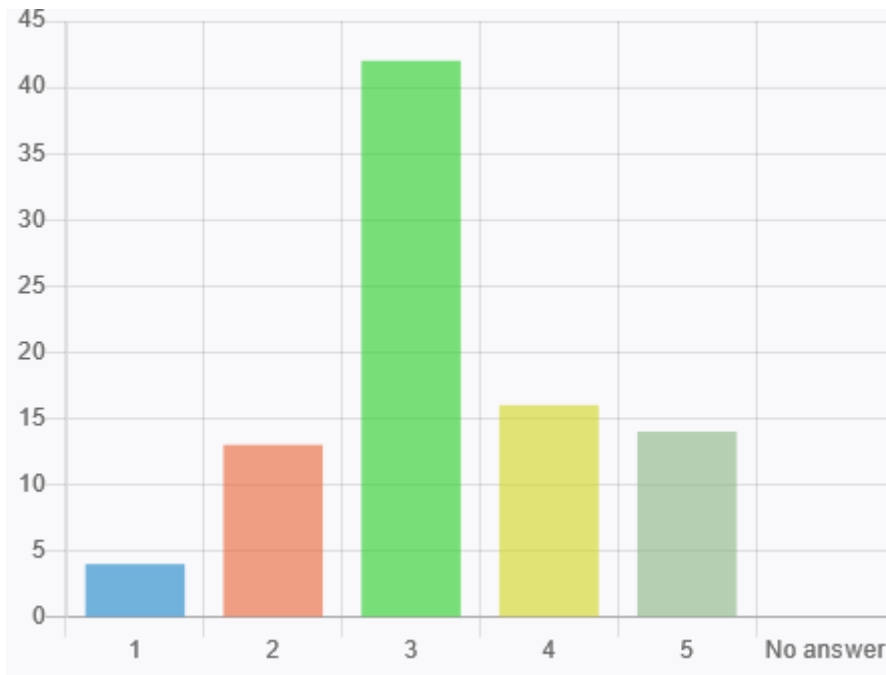


Figure 21 Rate the degree of customisation and personalisation options available in XR learning experiences.

How would you rate the usability of XR technologies for trainers with varying levels of technical expertise?

Arithmetic mean: 3.07 Standard deviation: 0.99

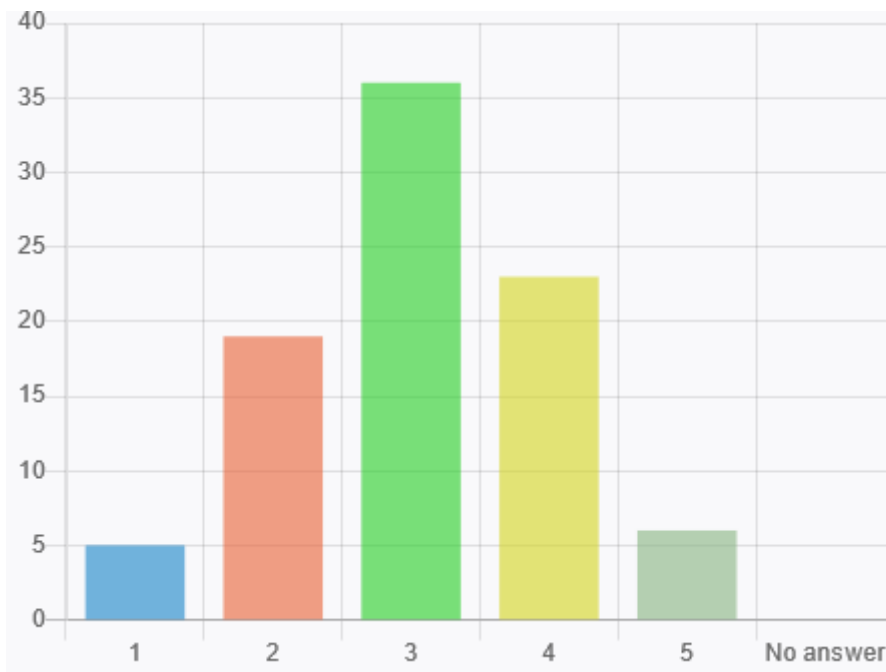


Figure 22 How would you rate the usability of XR technologies for trainers with varying levels of technical expertise?

How would you rate the effectiveness of XR technologies in facilitating real-world simulations for industrial training purposes?

Arithmetic mean: 4.04 Standard deviation: 0.89

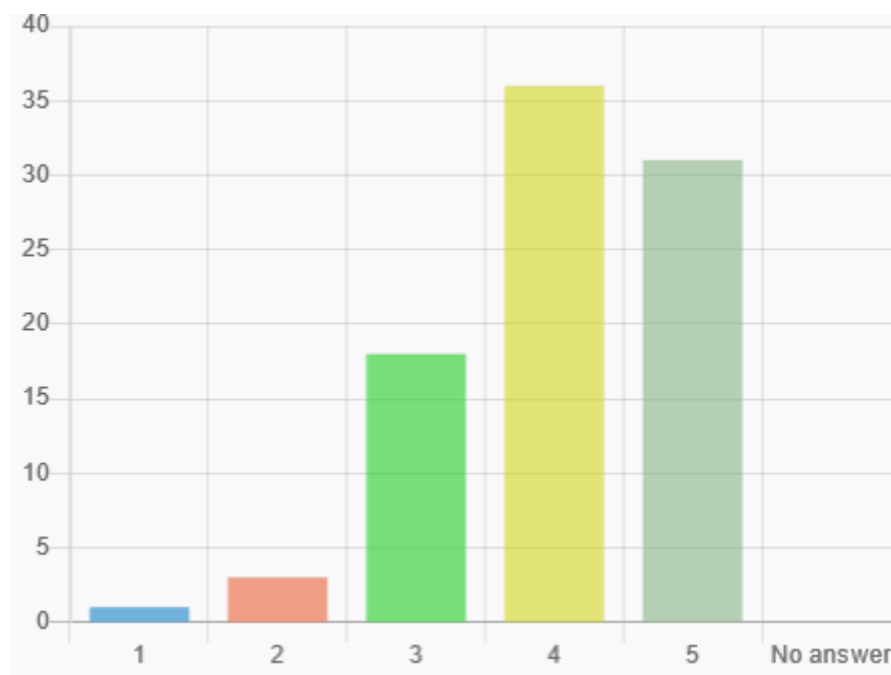


Figure 23 How would you rate the effectiveness of XR technologies in facilitating real-world simulations for industrial training purposes?

Rate the overall impact of XR technologies on the quality of training delivered within your institution/organisation.

Arithmetic mean: 3.2 Standard deviation: 1.24

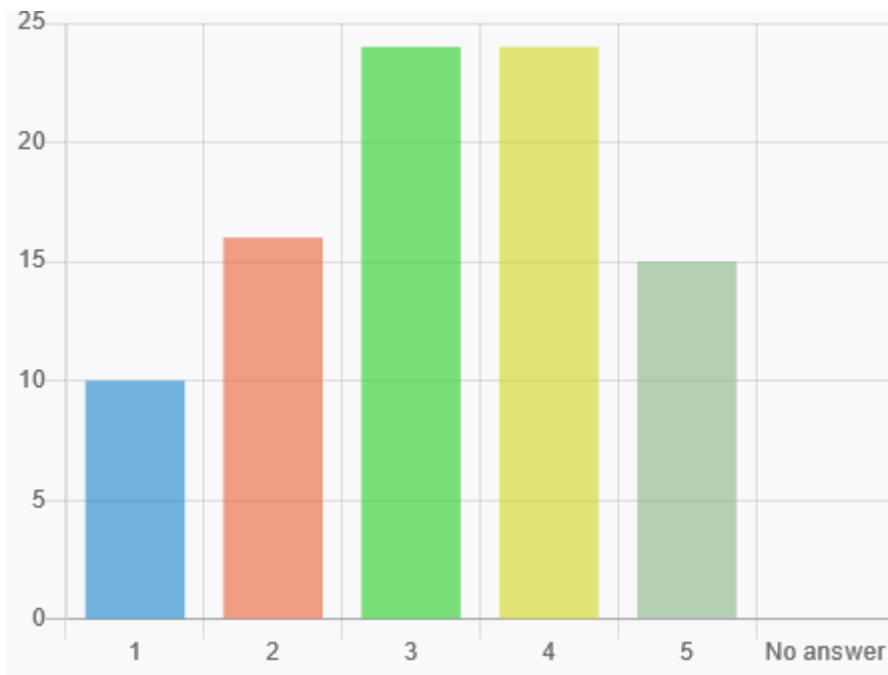


Figure 24 Rate the overall impact of XR technologies on the quality of training delivered within your institution/organisation.

Are you aware of any companies within your sector using VR/AR as a training/operations platform?

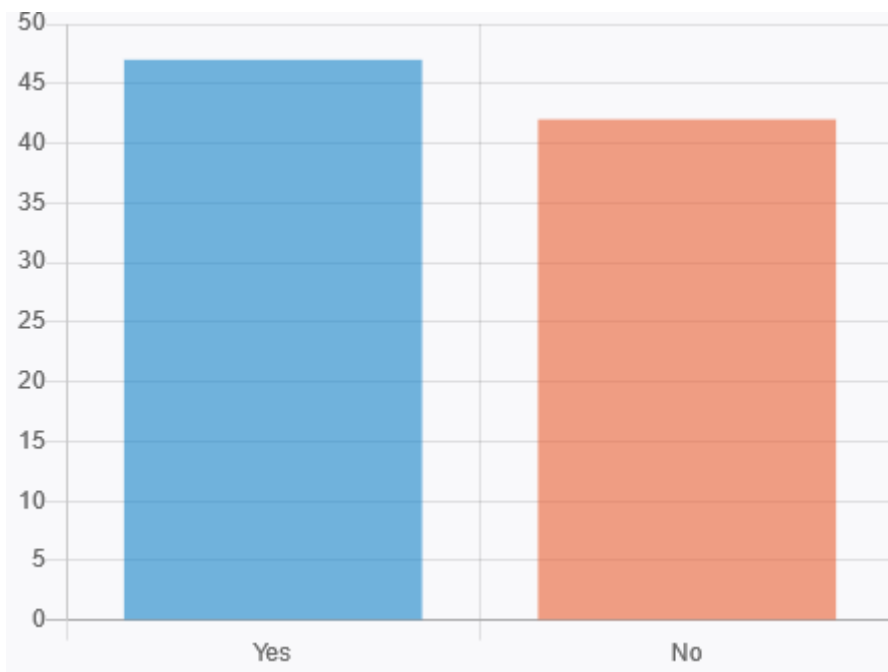


Figure 25 Are you aware of any companies within your sector using VR/AR as a training/operations platform?

Are you aware of any operations at your department that already use XR tools?

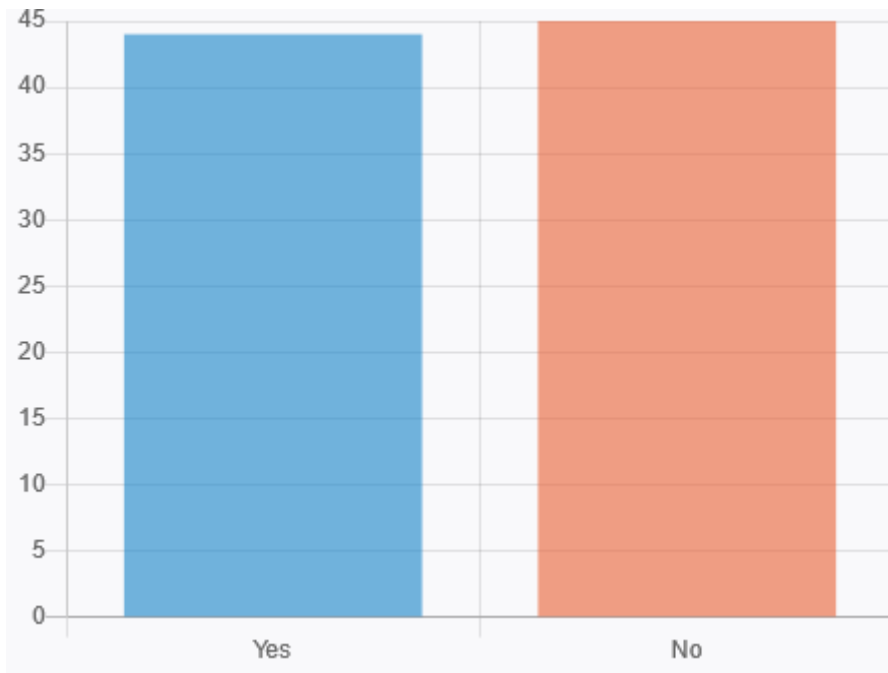


Figure 26 Are you aware of any operations at your department that already use XR tools?

Are you aware of companies using XR training enhanced-learning experiences to train new hires or upskill experienced technicians?

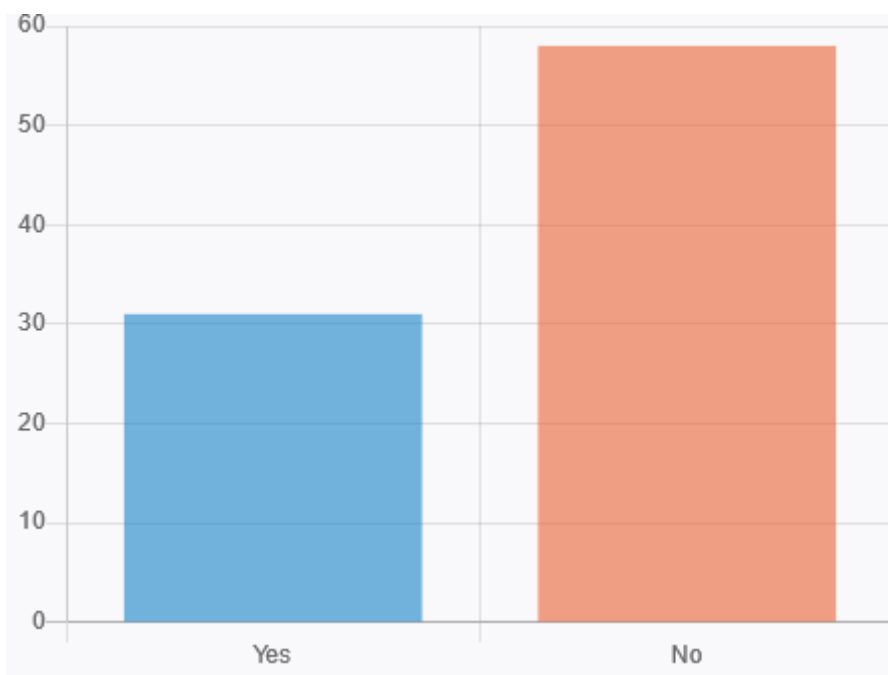


Figure 27 Are you aware of companies using XR training enhanced-learning experiences to train new hires or upskill experienced technicians?

Would you be interested in a solution that adopts XR technologies in your professional sector?

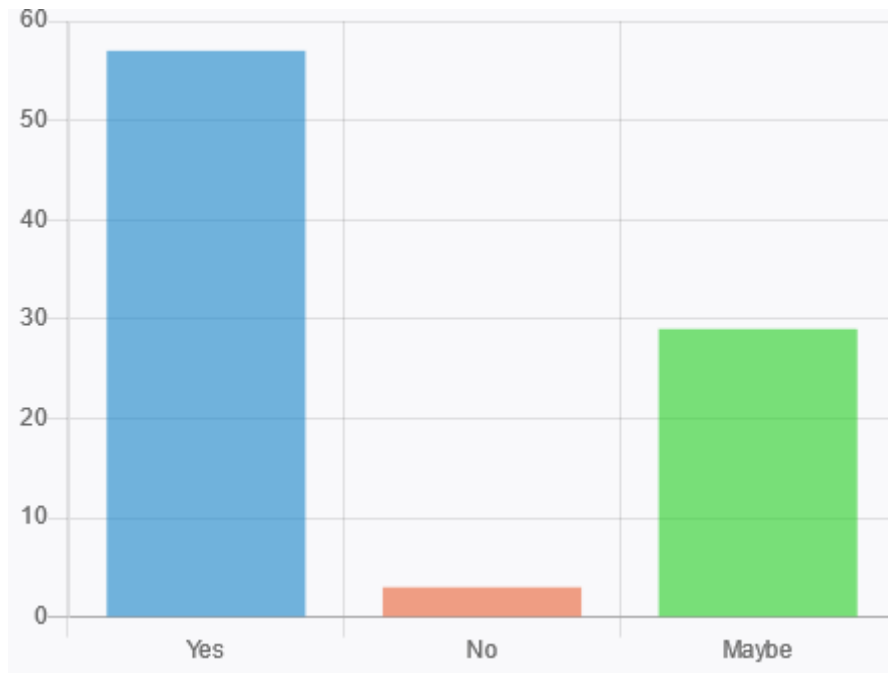


Figure 28 Would you be interested in a solution that adopts XR technologies in your professional sector?

How confident would you feel in using XR technology at your workplace?

Arithmetic mean: 4 Standard deviation: 0.98

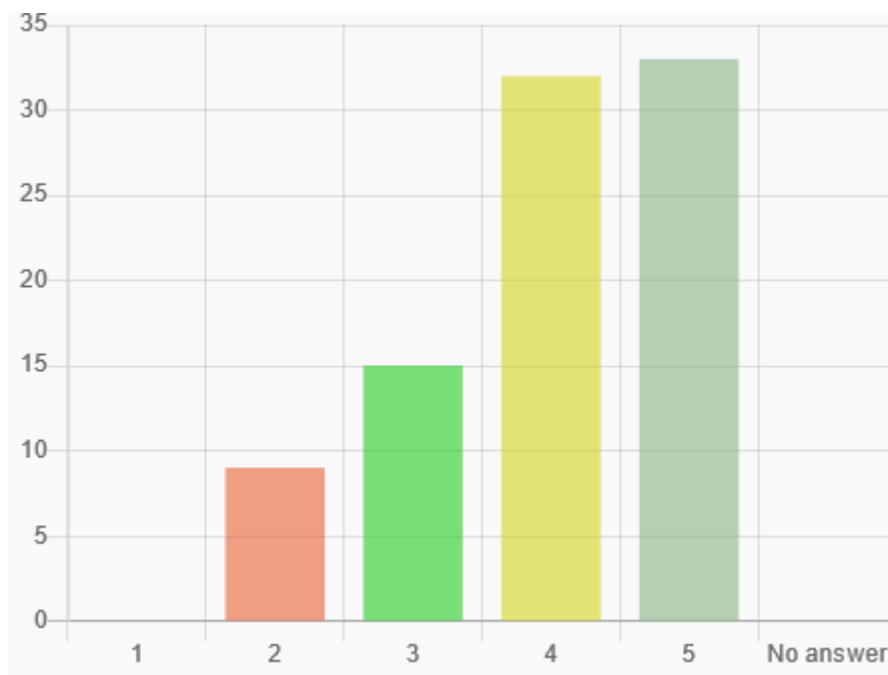


Figure 29 How confident would you feel in using XR technology at your workplace?

Are you familiar with the EU policy about green skills included in the “European Green Deal”?

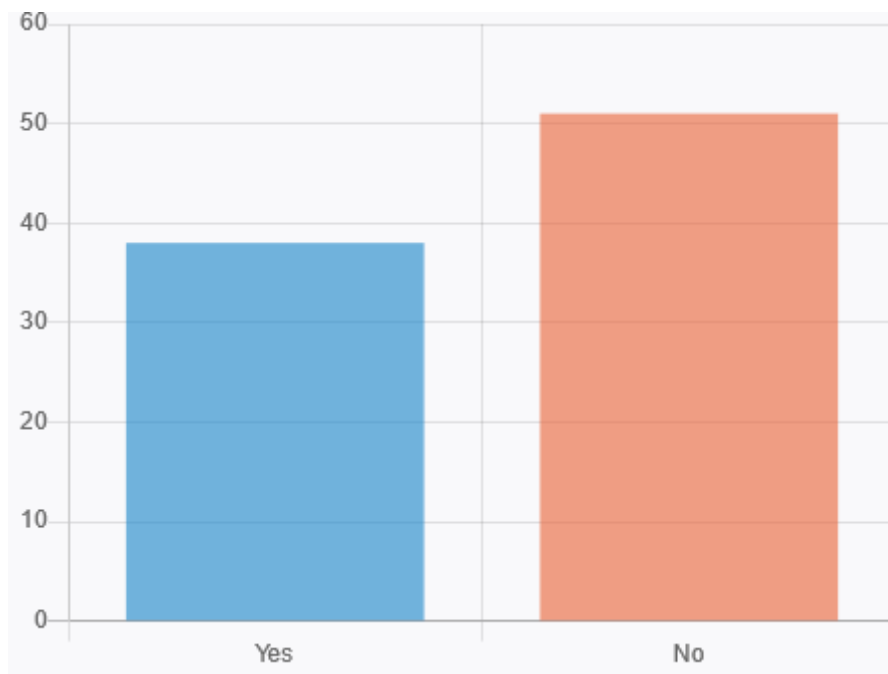


Figure 30 Are you familiar with the EU policy about green skills included in the “European Green Deal”?

Are you familiar with the EU policy about digital skills included in the “EU Digital Decade”?

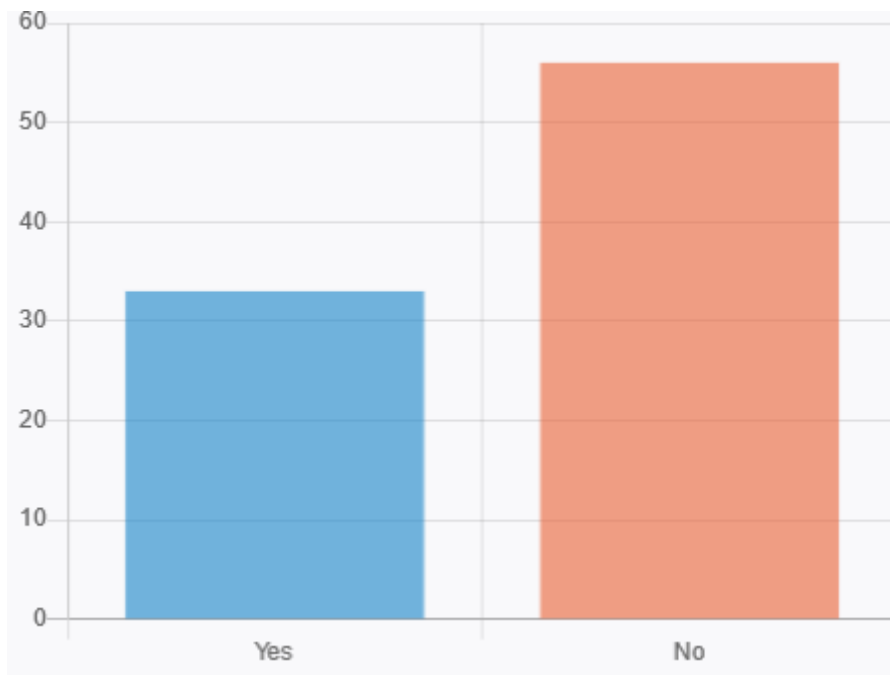


Figure 31 Are you familiar with the EU policy about digital skills included in the “EU Digital Decade”?

Have you noticed any impact from the utilisation of XR technologies in decreasing carbon footprint and CO2 emissions?

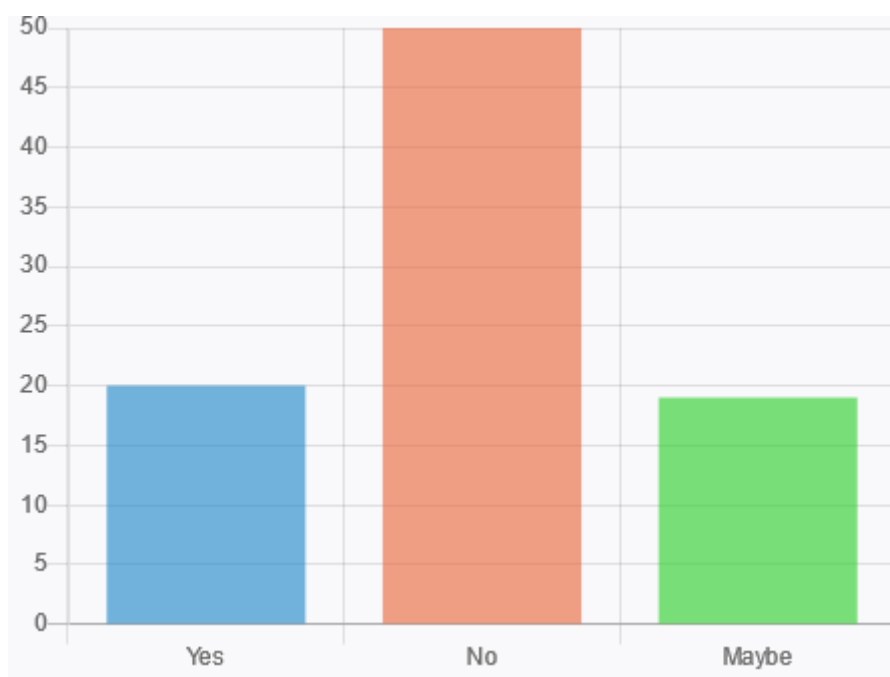


Figure 32 Have you noticed any impact from the utilisation of XR technologies in decreasing carbon footprint and CO2 emissions?

Have you observed any influence of employing XR technologies in mitigating carbon footprint and CO2 emissions?

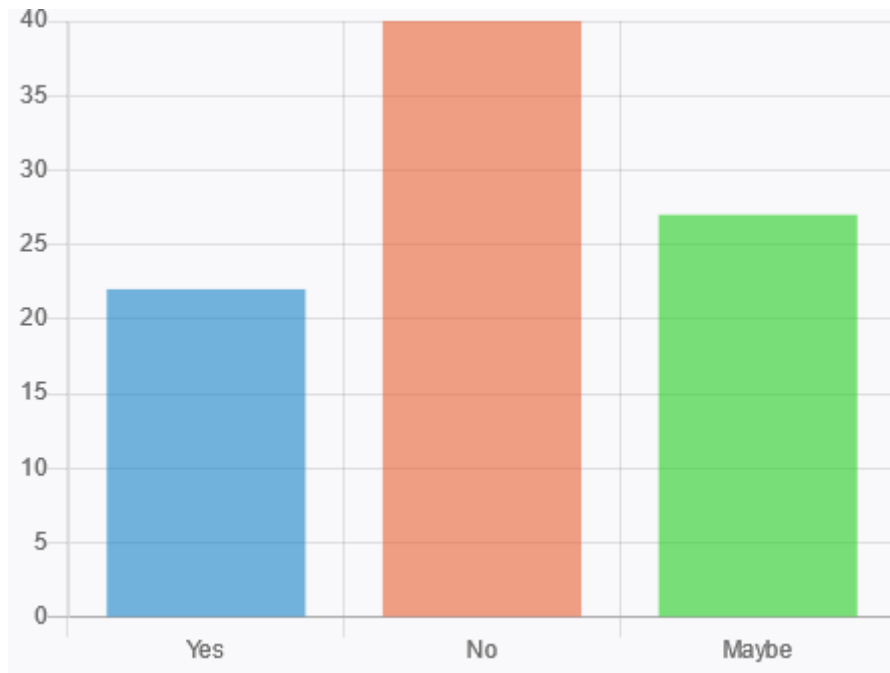


Figure 33 Have you observed any influence of employing XR technologies in mitigating carbon footprint and CO2 emissions?

In your opinion, how significant do you believe it is for a candidate to possess fundamental XR skills during the hiring process?

Arithmetic mean: 3.21 Standard deviation: 0.99

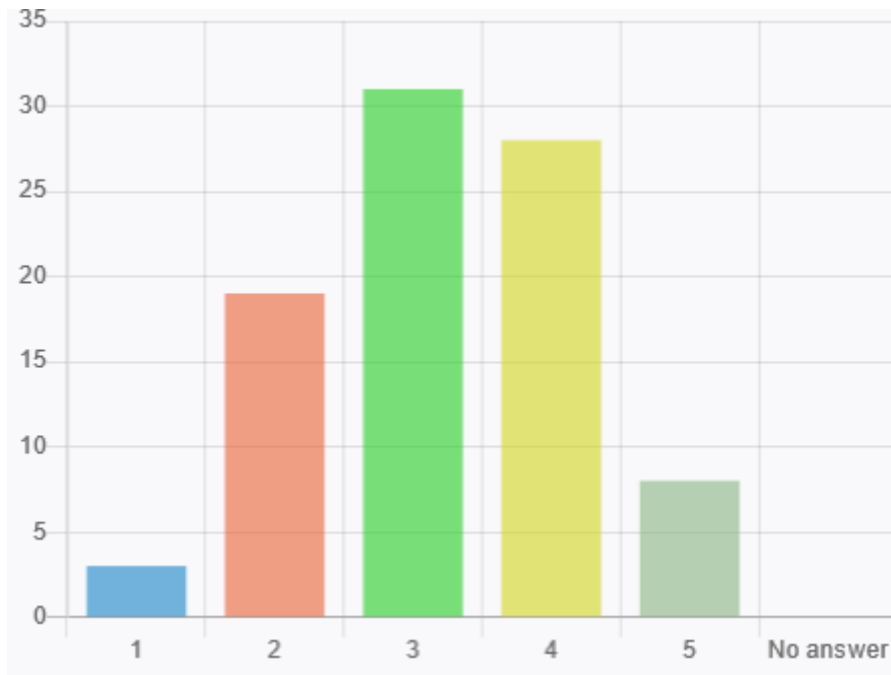


Figure 34 In your opinion, how significant do you believe it is for a candidate to possess fundamental XR skills during the hiring process?

How important is competence in XR technologies within the next 5 years for your institution?

Arithmetic mean: 3.71 Standard deviation: 1.18

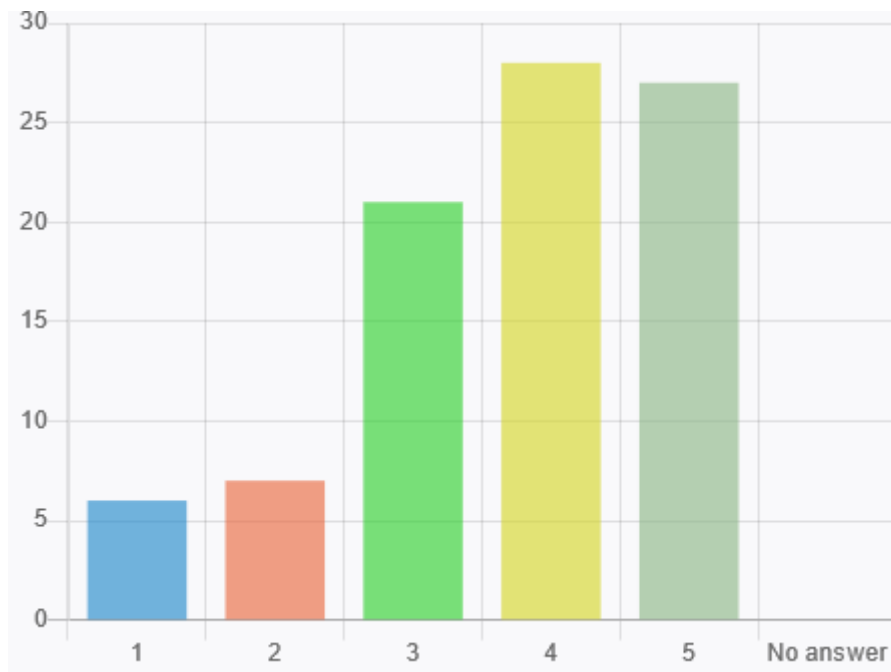


Figure 35 How important is competence in XR technologies within the next 5 years for your institution?

What gender do you identify as?

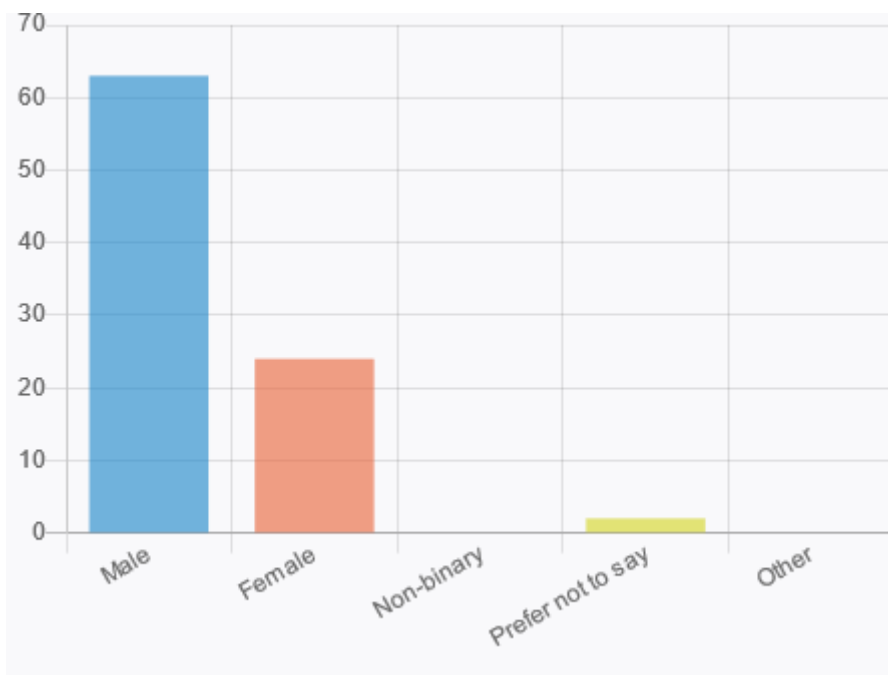


Figure 36 What gender do you identify as?

What is your age?

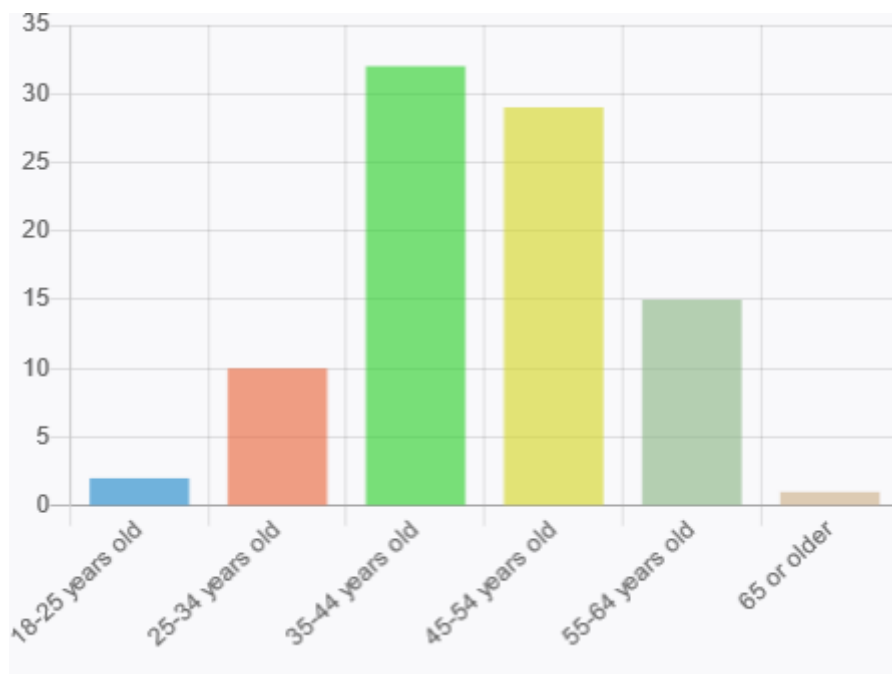


Figure 37 What is your age?

What is the highest degree or level of education you have completed?

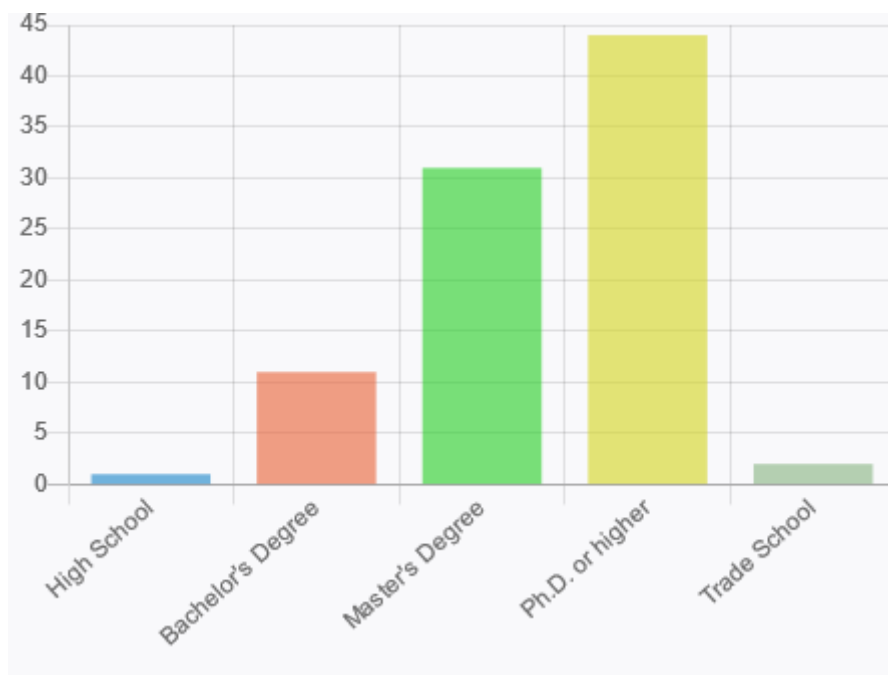


Figure 38 What is the highest degree or level of education you have completed?

What is your current employment status?

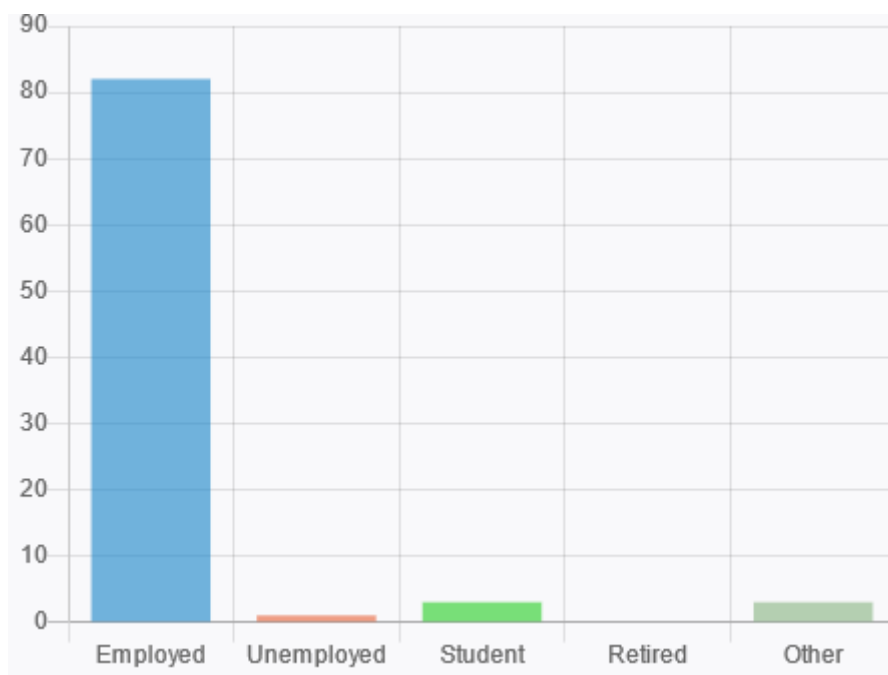


Figure 39 What is your current employment status?

In which country are you currently living?

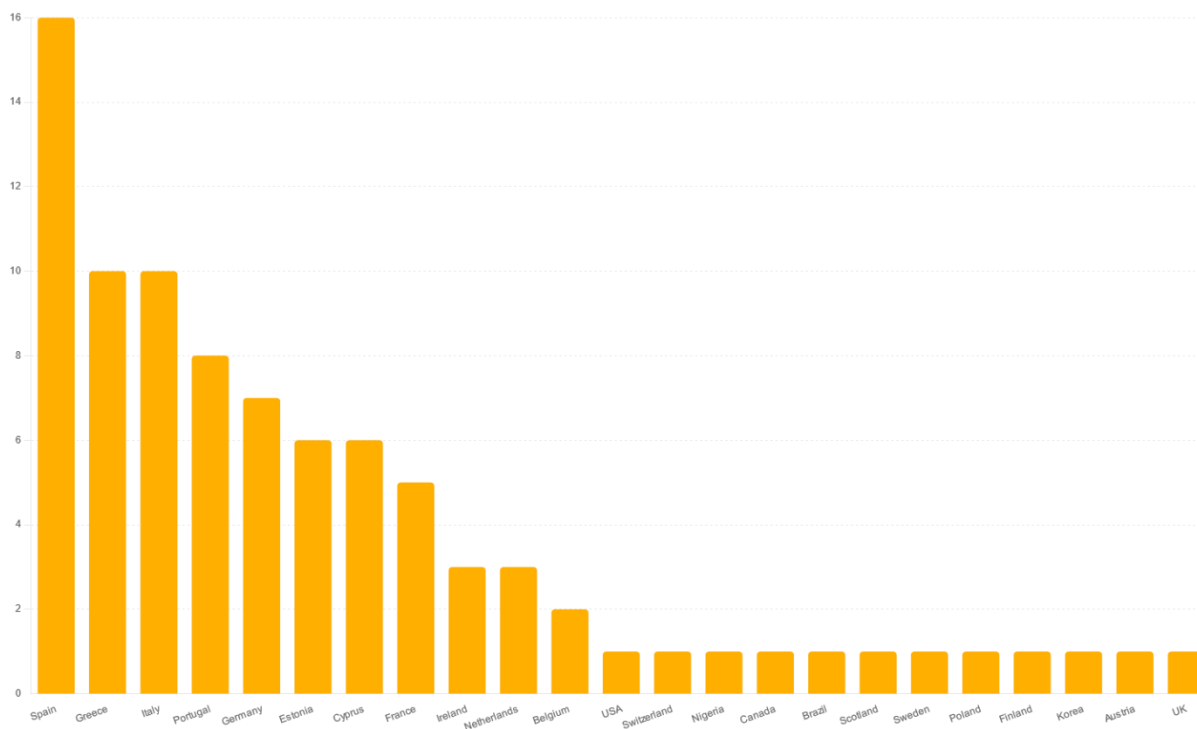


Figure 40 In which country are you currently living?

4.2.2 Analysis of the findings the insights

Are you aware of any companies within your sector using VR/AR as a training/operations platform? If yes, can you name the companies?

This question contained several answers, such as “Betar, CCG, IP, Spotlite”, “BasisSoft”, “Valmet Automation, Varcus (maritime-related)”, “Flens, Kommun, Strängnäs”, “BMW”, “Siemens”, and “Volkswagen”.

Are you aware of companies using XR training enhanced-learning experiences to train new hires or upskill experienced technicians? If yes, can you name the companies?

This question contained several answers, such as “CCG”, “Walmart”, “Trimble”, “KLM”, “Boeing”, “SAAB”, “Wärtsilä”, “Airbus”, and “Meta”.

In your opinion, what are the key factors that contribute to the successful adoption of XR technologies in operational or training programmes?

This question contained several answers, and the common suggestions can be summarized in the following bullets:

- ***Clear objectives*** and alignment with organizational goals.

- **User engagement** through realistic and interactive content.
- **Proper training** and support for educators and users.
- **Usability** and accessibility to ensure broad adoption.
- **Technological infrastructure** that supports versatile and scalable solutions.
- **Financial feasibility** with clear cost-benefit analysis.
- **Demonstrated value** through measurable outcomes.
- **Data security** to protect sensitive information.
- **Organizational culture** that embraces innovation.
- **Collaboration** with experienced partners.
- **Innovation** in applications to maintain interest and relevance.
- **Environmental considerations** for sustainable practices.

What are the main barriers for a successful implementation of XR technologies in your organization?

This question contained several answers, and the common suggestions can be summarized in the following bullets:

- **High costs** and budget limitations hinder widespread adoption.
- **Hardware and compatibility** issues complicate implementation.
- **Insufficient training** and expertise in XR technologies.
- **Resistance to change** and cultural inertia.
- **Difficulty and cost** of developing high-quality **content**.
- **Challenges** in integrating XR with existing systems.
- **Infrastructure limitations** and scalability concerns.
- **Ensuring data privacy** and security.
- **Limited awareness** and perceived relevance of XR.
- **Ergonomic issues** and non-user-friendly devices.

Do you think XR can enhance green skills? If so, how?

This question contained several answers, and the common suggestions can be summarized in the following bullets:

- **Virtual Prototyping and Sustainable Design.**
- **Interactive and Immersive Training** for green technologies and practices.
- **Remote Collaboration** reducing travel and resource use.
- **Raising Awareness** and promoting sustainable behaviors.

- **Efficient Data Visualization** aiding in environmental decision-making.

What challenges do you foresee in integrating XR technologies into existing operational or training methodologies?

This question contained several answers, and the common suggestions can be summarized in the following bullets:

- **High costs** for acquisition, maintenance, and content development.
- **Compatibility, performance**, and infrastructure requirements.
- **Need for skilled professionals** and extensive training.
- **Overcoming cultural resistance** and health concerns.
- **Complexity and resource intensity** of developing quality content.
- **Robust internet**, processing power, and physical space.
- **Ensuring data privacy** and regulatory compliance.
- **Scaling solutions** and achieving standardization.
- **Smooth integration** with existing systems.
- **Assessing impact** and ROI.
- **Compliance** with regulations and administrative procedures.

Can you provide examples of successful implementations of XR technologies in operations or training that you've encountered?

This question contained several answers, and the common suggestions can be summarized in the following bullets:

Companies: Boeing, Volkswagen, Ford, Skasnka, IKEA, BP, US Army, Shell, Iscte, TNO, Fundtec.

1. **Healthcare:** Enhanced medical training and procedural simulations.
2. **Aviation:** Improved pilot and maintenance training with VR.
3. **Manufacturing:** AR and VR for assembly, maintenance, and design processes.
4. **Construction:** VR for project planning and virtual walkthroughs.
5. **Retail:** AR for better customer visualization and decision-making.
6. **Military:** VR combat simulations for training and readiness.
7. **Energy:** VR safety training and emergency response simulations.
8. **Education:** XR for interactive learning and engagement.
9. **Emergency Services:** VR training for firefighters and paramedics.

10. **Automotive and Construction:** Use of digital twins and VR for design and training.

Familiarity and Skills

- The average familiarity is moderately high (3.79), but the standard deviation (1.29) indicates varied levels of familiarity among respondents.
- There is moderate familiarity with game engines like Unity and Unreal (3.27) with a high variability (1.59), suggesting significant differences in individual experiences.
- Respondents have moderate awareness of the costs associated with XR installations (3.31), with a notable variability (1.53).

Institutional Integration and Effectiveness

- The integration level is relatively low (2.79), with high variability (1.33). Similarly, integration in other activities is also low (2.56), indicating limited adoption.
- Respondents observe XR as effective in enhancing operational and training activities (3.81) and envision even higher effectiveness (4.27) with lower variability (0.69).

Institutional Readiness and Support

- Institutions are moderately likely to incorporate XR technologies in the near future (3.44) with a moderate degree of variability (1.08).
- There is moderate agreement on having sufficient resources (3.3), with variability (1.16) indicating some institutions may face resource constraints.
- The support level is moderate (2.93) with a moderate variability (1.13), suggesting inconsistent availability of support across institutions.

Usability and Satisfaction

- The usability is moderate (3.12) with variability (1.19), indicating mixed experiences among trainers.
- Respondents are moderately satisfied (3.01) with available professional development opportunities, showing some room for improvement.

Potential and Customization

- High belief in XR's potential for skill enhancement (4.27) and moderate belief for validation in hiring processes (3.64).
- XR technologies are perceived as moderately scalable (3.85) and offer moderate customization options (3.26).

Data Privacy and Security

- Respondents are moderately satisfied (2.94) with the current measures, indicating an area for improvement.

Overall Impact and Interest

- The perceived impact on training quality is moderate (3.2) with high variability (1.24).
- High interest in adopting XR solutions (4.0), and respondents feel moderately confident in using XR technologies (4.0).

Findings and Gaps

1. There is a significant range in familiarity and technical skills related to XR technologies, indicating a need for tailored training programs.
2. Low current integration levels highlight a gap in the adoption of XR technologies in operational and training activities.
3. There is a discrepancy between the perceived potential and actual integration, suggesting barriers to implementation.
4. Moderate to low ratings on resource sufficiency and support indicate gaps in institutional readiness and external assistance.
5. Mixed experiences in usability and customization suggest a need for more user-friendly and adaptable XR tools.
6. Moderate satisfaction with data privacy and security measures points to a need for enhanced security protocols.

Needs and Recommendations

1. Develop and provide comprehensive training programs to bridge the knowledge gap and improve technical skills among users.
2. Increase investment in resources and provide better institutional support to facilitate XR technology integration.

3. Focus on developing more intuitive and customizable XR tools to cater to users with varying levels of technical expertise.
4. Implement robust data privacy and security measures to build trust and ensure the safe use of XR technologies.
5. Promote the benefits and effectiveness of XR technologies through pilot projects and success stories to encourage wider adoption.

Highly Significant Positive Correlations (> 0.7)

1. **Familiarity with game engines vs. Familiarity with the cost of software and hardware for XR installation**

Correlation: 0.81

This very high correlation suggests that individuals who are familiar with game engines are also highly knowledgeable about the costs of XR installations. This is intriguing because it implies a deep level of engagement with both the technical and financial aspects of XR technologies, which are often handled by different roles within an organization.

2. **Familiarity with game engines vs. Skill with XR technologies to estimate their potential for collaborative activities**

Correlation: 0.76

The strong correlation indicates that familiarity with game engines is closely tied to the overall skill in using XR technologies. This might suggest that mastering game engines is a key factor in becoming proficient with XR technologies, which could be a valuable insight for developing training programs.

3. **Familiarity with the cost of software and hardware for XR installation vs. Skill with XR technologies to estimate their potential for collaborative activities**

Correlation: 0.77

4. **Effectiveness of XR technologies in enhancing operational and training activities vs. Belief in XR's potential to enhance practical skill development**

Correlation: 0.73

This high correlation highlights a strong belief in the practical applications of XR technologies. It is surprising in the sense that it shows a direct and strong link between current effectiveness and future potential, indicating that experiences with XR are overwhelmingly positive and influential in shaping expectations.

5. **Skill with XR technologies to estimate their potential for collaborative activities vs. Confidence in using XR technology at the workplace**

Correlation: 0.74

6. **Familiarity with EU policy about green skills vs. Familiarity with EU policy about digital skills**

Correlation: 0.70

The correlation between awareness of these two distinct policy areas suggests that individuals who are informed about one policy are very likely to be informed about the other, hinting at a potentially well-informed respondent group or effective dissemination of related policy information.

7. **Noticing impact from XR utilization in reducing carbon footprint vs. Observing influence of XR in mitigating carbon footprint**

Correlation: 0.74

The strong correlation highlights a consistent perception among respondents that XR technologies have environmental benefits. This suggests that the environmental impact of XR technologies is a well-recognized and potentially motivating factor for adoption.

Significant Positive Correlations (0.5 - 0.7):

1. **Belief in XR effectiveness in enhancing operational and training activities vs. XR's potential to support co-localized and/or remote collaborative activities**

Correlation: 0.54

There are no significant negative correlations with an absolute value greater than 0.5. This indicates that the variables in the dataset do not exhibit strong inverse relationships.

5 DISCUSSION

5.1 Interpretation of results and their implications

First, the respondents of the questionnaire and the in-depth interviews seem to be the representatives of the target group. They shared insights spanning construction, healthcare, manufacturing, energy, education, emergency services, and more. Experiences and examples call for direct engagement with XR technologies, making their feedback pertinent and comprehensive.

Moreover, various sector representatives have realized the potential benefits that XR technologies can provide. VR training for pilots and AR assisting assembly processes from Boeing, Volkswagen, and the Cleveland Clinic's HoloAnatomy platform show that XR can improve learning outcomes, decrease error rates, and be a more engaging way to learn while just adding up efficiencies. These various successful use cases demonstrate the capability of XR to enhance operational efficiencies and training outcomes.

As the technology matures and its accessibility increases, we will probably see wider adoption in more industries. Macrotrends, some being AI integration for better content creation and experiences, rising accessibility with cheaper yet intuitive systems, more scalability thanks to infrastructure refinements, along with advanced training and simulation in support of real immersive environments, as well as remote collaboration work tools, are something that would shape AR/VR usage ahead.

Based on the outcome of the survey and the in-depth interviews, the main barriers to implementing XR technologies include high initial costs for hardware, software, and content development, technical complexity in integrating XR with existing systems and ensuring compatibility, user resistance and lack of expertise, the need for high-quality and engaging content, infrastructure requirements such as robust internet and processing power, health and safety concerns like eye strain and motion sickness, and data privacy and security issues in handling sensitive information.

Lastly, XR technologies can also contribute to the development of the green deal, largely reducing travel through remote collaboration and virtual meetings, hence leading to a reduction in carbon emissions caused by travel. This means they can train in an efficient way that requires fewer physical materials and, thus, less space for training areas or simulators, resulting in reduced resource consumption. XR also enables sustainable design and manufacturing with virtual prototyping, which can reduce waste while nearly touching on all the resources used in a product. On the other hand, XR might enable direct interactive environmental education alongside immersive telepresence to raise awareness of the environment and sustainability. Virtual simulations can also aid in the design of more energy-efficient industry processes and systems in sectors like construction or manufacturing.

5.2 Broader contributions of XR in education and training

The introduction of XR technologies in education and training has enabled the next generation of immersive, hands-on learning, capitalizing on authentic 3D-based resources, and also balancing the education sector and industrial sector, making them reach the current demands and trends from each other. XR enables VR, which is an artificial environment created with software; AR, which is the blending of virtual reality and real-life; and MR, which involves combining elements of both AR and VR⁷.

The most significant contribution XR has brought to education is enhancing student engagement and motivation. By creating immersive environments, XR allows learners to experience subjects in a more interactive and engaging manner⁸. For example, in subjects like history or science, students can take a tour of historical sites or visualize biological processes in 3D, making abstract concepts tangible and easier to understand. The students are more engaged in the learning process, they actively participate and therefore retain and comprehend what is studied much better.

XR in VET gives students a safe place to learn, practice and hone their skills. Simulations of hazardous tasks, such as those in medical, military, or industrial

⁷<https://op.europa.eu/en/publication-detail/-/publication/f242f605-a82e-11ed-b508-01aa75ed71a1>

⁸ doi: [10.11113/humentech.v1n2.27](https://doi.org/10.11113/humentech.v1n2.27)

training, allow trainees to gain experience without the associated risks⁹. Medical students can perform virtual surgeries, and firefighters can practice emergency scenarios. This experiential learning not only builds competence but also enhances confidence and preparedness for real-world applications.

XR also supports personalized learning paths by adapting to individual learning styles and paces¹⁰. With XR, educators can create customized training modules that cater to the specific needs of each student, ensuring that learners receive the most relevant and effective instruction. This adaptability is particularly beneficial in diverse classrooms where students may have varying levels of prior knowledge and skills.

Moreover, collaboration and teamwork are critical skills in today's professional landscape, and XR fosters these competencies through collaborative virtual environments. Students and trainees can work together in shared virtual spaces, regardless of their physical locations. This capability is especially valuable in globalized education and training programs, where cross-cultural collaboration and communication are essential.

The development of XR technologies is also more cost-effective and resource-efficient for education and training use cases. Traditional methods often require physical materials, equipment, and travel, which can be cumbersome, expensive to use, and logistically difficult. By enabling virtual labs, simulations, and field trips via XR, resource costs are heavily reduced as the same level of training can be provided with fewer physical resources.

XR also brings the possibility of democratization in education, which means giving everyone access to high-quality learning. This means that the same immersive and interactive content can be experienced by students in remote or underserved areas as the ones at universities with large research capacities¹¹. This inclusionary practice builds pathways to education and promotes universal learning among all.

Lastly, the use of XR in education and training aligns with the principles of lifelong learning. As industries and technologies evolve, continuous education and

⁹ <https://doi.org/10.1177/00178969231198955>

¹⁰ doi: [10.4018/IJWLTT.286743](https://doi.org/10.4018/IJWLTT.286743)

¹¹ doi: [10.1063/5.0127818](https://doi.org/10.1063/5.0127818)

upskilling become necessary. XR facilitates ongoing professional development by providing flexible, on-demand training solutions that professionals can access throughout their careers.

6 CONCLUSION

6.1 Summary of major conclusions

XR technologies are perceived as being extremely transformative across a broad spectrum of industries, particularly in the areas of education, engineering, and maritime. In addition, XR can also be used to improve operations and indulge in

learning and skill-development activities by providing immersive experiences through virtual training environments while allowing for the creation of realistic prototypes and simulations.

Although the potential is recognized, there are numerous challenges and barriers impeding a broader adoption of different types of XR technologies. These include high costs, resistance to change, integration complexities, and the need for specialized technical skills.

There is increased awareness about the necessity of ensuring XR applications are inclusive catering for many user needs, as well as accessible. It is important that XR applications are developed using universal design principles and user-centered approaches.

The environmental impact of XR technologies is a mixed topic, with both positive and negative aspects. While XR can decrease carbon footprints through virtual collaboration and training, the high energy use of data processing and infrastructure is a concern that requires further advancements in energy-efficient hardware and green XR practices.

The adoption of XR technologies necessitates the development of a specialized workforce with skills in areas such as XR design, development, and assessment. Continuous learning and upskilling will be essential to keep pace with the technological advancements in the XR field.

The analysis of correlations revealed several strong positive relationships, such as the link between familiarity with game engines and cost awareness, as well as the connection between XR effectiveness and the belief in its potential for practical skill development. These insights can inform the design of targeted training and support programs.

6.2 Future directions and recommendations

The rise of XR technologies in the future will present transformative opportunities for various sectors. Some of the key trends are improved hardware performance, increased accessibility, advancements in sensing and tracking technologies, and seamless integration of multimodal interactions. These technological

advancements will enable more immersive and intuitive XR experiences, driving broader adoption.

In the future, as technology advances, we can expect XR to disrupt education and training with highly personalized, interactive, and engaging learning experiences. In the healthcare sector, XR will have a significant role in medical training, remote patient monitoring, and therapeutic intervention. In the same way, XR will enhance the shopping experience in retail and e-commerce, re-shape design and maintenance processes in manufacturing and engineering, and redefine the boundaries by creating new worlds for immersive storytelling or gaming.

Moreover, the convergence of spatial computing and artificial intelligence (AI) will be a driving force behind the next wave of XR innovation. AI-powered spatial mapping and reconstruction will enable more seamless integration of virtual content with the physical world, while AI-driven adaptive interfaces and personalized content will enhance the user experience and engagement. Additionally, AI-powered virtual agents and assistants will facilitate more natural and intuitive interactions within XR environments.

As XR technology becomes more pervasive, it is crucial to prioritize user-centric design and address ethical considerations. Providing inclusive and accessible XR experiences, resolving privacy issues, and responsible development and deployment of XR technology are needed to limit negative impacts on society. To capitalize on the future potential of XR, various stakeholders, including educators, industry leaders, policymakers, and technology providers, should collaborate to drive innovation, enhance user experiences, and unlock new opportunities across diverse sectors.

7 ANNEX

7.1 APPENDIX 1 Introductory text and privacy policy of the questionnaire

[Alliance4XR](#) is set on co-creating and testing a well-tailored teaching and training methodology and material for empowering universities, vocational and training

centers to successfully address the challenge of XR digital skills mismatch with a focus in engineering.

Project Coordinator:

Mr. **Konstantinos Smagas**, Project Manager, GEOIMAGING LIMITED

Email: kostas@geoimaging.com.cy

Principal Investigator:

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Dr. **Patrick Bourdot** Research Director at CNRS Founder of the VENISE V&AR team (<https://www.limsi.fr/venise/>) Université Paris-Saclay, LISN, Orsay (France)

Email: patrick.bourdot@universite-paris-saclay.fr

Survey location and procedure:

You have been invited by email to participate in a survey called “**eXtended Reality state and needs for Education & Training**”, and before starting, to fill and sign electronically a consentment agreement by ticking the boxes in the last part of this page. Answers collected during the survey will stay fully anonymous.

Goal of the study:

The study focuses on understanding the current status (state) and requirements (needs) concerning eXtended Reality (XR) technology in the context of education and training. By eXtended Reality (XR) we target a set of technologies from Virtual Reality (VR) to Mixed Reality (MR) including Augmented Reality (AR), according to the [reality–virtuality continuum conceptualized by Milgram, Takemura, Utsumi, and Kishino \(1994\)](#). More specifically, with VR technology users may experiment immersive interaction within environments fully composed of virtual content,

while with AR or MR technologies users experiment such interaction in an environment blending virtual elements in the real world.

What we are expecting from you:

The full duration to answer the questions of this survey is about 10 minutes. Some answers will be simple Yes/No, some will be to scale a rating, and some others will expect synthetic descriptions of examples (about 2-3 sentences, maximum).

If you face any issues or if you need additional information, you can contact info@alliance4xr.eu

Participation cost: There is no cost for the participant for the involvement in this study.

How will your data be used?

Your data will be used solely for research purposes to assess how XR is currently being used, what its potential applications are, and what specific needs or challenges exist in integrating XR into educational and training settings. The data obtained will be confidential. Each participant will be assigned a unique identifier preserving their anonymity. The data automatically captured during the experiment will be linked to this unique identifier and cannot be linked directly to your identity.

How will your confidentiality and privacy be protected?

The personal data specified in this document will be kept in a secure location in order to guarantee your rights of withdrawal and rectification. Only the Principal Investigator and the Scientific Supervisors will have access to it. Although statistics on all participants may use the specified age and gender information in the aggregate, your identity will not be used or communicated in any way. In accordance with the provisions of the Data Protection Act, you may exercise your rights of access, rectification or deletion of data concerning you by simple request to the scientific manager of the project.

Benefits of the study: Discovery of XR technologies state, needs and use cases scenario for Learning and Training

Possible risks of the study: no risk

Diffusion/Dissemination:

The results of this study will be presented in some reports as official deliverables of the Alliance4XR project to the ERASMUS+ program and at the European Commission. Moreover, it may be presented in academic conferences or symposia, and published in academic journal articles and conference proceedings.

Rights to ask questions:

You can ask questions about the research before and after your participation by contacting by email the Principal Investigator and/or the Scientific supervisors of this survey.

Right to refuse or withdraw:

Your participation is not forced. You can stop the research at any time if you wish. Consent is provided for 6 months until it is revoked by sending an e-mail to the Principal Investigator or the Scientific Supervisors or by sending the application form enclosed at the end of this document to the address of the coordinator of the research/scientific. The right to withdraw consent at any time does not affect the lawfulness of the processing based on the consent given before its withdrawal.

Data managing:

The data collected within the survey will be stored for six (6) months after the completion of the study, and followed by their permanent deletion. The processing of your personal data is based on consent to this processing for a specific purpose. Your personal data will be codified and saved at computers in accordance with appropriate technical and organizational measures. You have the right to access to or rectification or erasure of your personal data or restriction of processing concerning your data or to object to processing as well as the right to data portability. For such request or any enquiry or guidance regarding your rights, you could send an email to the Principal Investigator or the Scientific Supervisors. Any change in your personal data will take place within 30 days of your communication with the Principal Investigator.

Consent to Participation:

By signing the consent form, you certify that you have read and understood the information above, that the Principal Investigator has answered your questions

satisfactorily and that she has informed you that you are free to withdraw your consent or withdraw from this survey at any time, without prejudice.

Questionnaire:

Section A:

A1. How familiar are you with eXtended Reality (XR) technologies and their usage in your sector/domain?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A2. What is your current sector/occupation or what industrial sector do you target?

You can select at least one or several sectors

- Vocational Education and Training (VET)
- Higher Education Institution (HEI)
- Structural engineering
- Energy
- Maritime
- Other

Other

A3. How familiar are you with game engines such as Unity and/or Unreal?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A4. Do you have any programming and/or 3D modeling skills?

Yes

No

A5. How familiar are you with the cost of software and hardware for an XR installation?

1 = Not at all, 5 = Extremely

1

2

3

4

5

A6. To what extent has your institution integrated XR technologies into operational and training activities?

1 = Not at all, 5 = Extremely

1

2

3

4

5

A7. To what extent has your institution integrated XR technologies into other activities (e.g. hiring process, demonstrations, experimental design)?

1 = Not at all, 5 = Extremely

1

2

3

4

5

A8. Based on your experience, how effective do you observe XR technologies are in the enhancement of operational and training activities?

1 = Not at all, 5 = Extremely

1

2

3

4

5

A9. How effective do you believe or envision XR technologies to be in the enhancement of operational and training activities?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A10. How skilled are you with XR technologies to estimate their potential to support co-localized and/or remote collaborative activities?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A11. How likely is your institution to incorporate XR technologies into its operations and training programmes in the near future?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A12. Has your institution sufficient resources to integrate XR technologies into your operational and training practices?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A13. Rate the usability of XR content creation tools (e.g., Unreal, Unity) for trainers

1 = Very low level, 5 = Very high level

- 1
- 2
- 3
- 4
- 5

A14. Rate the level of internal and/or external to your institution support and resources available for implementing XR technologies in training programmes.

1 = Very low level, 5 = Very high level

- 1
- 2
- 3
- 4
- 5

A15. How satisfied are you with the ongoing professional development opportunities related to XR technologies?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A16. How likely are you to seek out professional development opportunities to improve your understanding and proficiency in XR technologies?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A17. To what extent do you believe XR technologies can enhance practical skill development in operational and training contexts?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A18. To what extent do you believe XR technologies can enhance validation of skills and evaluation processes for the hiring process in operational contexts?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A19. Rate the scalability of XR technologies for operational and training purposes

1 = Very low level, 5 = Very high level

- 1
- 2
- 3
- 4
- 5

A20. How satisfied are you with the level of data privacy and security measures implemented within XR technology platforms used for operational and training purposes?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A21. Rate the degree of customisation and personalisation options available in XR learning experiences.

1 = Very low level, 5 = Very high level

- 1
- 2
- 3
- 4
- 5

A22. How would you rate the usability of XR technologies for trainers with varying levels of technical expertise?

1 = Very low level, 5 = Very high level

- 1
- 2
- 3
- 4
- 5

A23. How would you rate the effectiveness of XR technologies in facilitating real-world simulations for industrial training purposes?

1 = Very low level, 5 = Very high level

- 1
- 2
- 3
- 4
- 5

A24. Rate the overall impact of XR technologies on the quality of training delivered within your institution/organisation.

1 = Very low level, 5 = Very high level

- 1
- 2
- 3
- 4
- 5

A25. Are you aware of any companies within your sector using VR/AR as a training/operations platform?

Yes

	No <input type="checkbox"/>
A26. If yes, can you name the companies?	<div style="border: 1px solid black; height: 100px; width: 100%;"></div>
A27. Are you aware of any operations at your department that already use XR tools?	Yes <input type="checkbox"/> No <input type="checkbox"/>
A28. Are you aware of companies using XR training enhanced-learning experiences to train new hires or upskill experienced technicians?	Yes <input type="checkbox"/> No <input type="checkbox"/>
A29. If yes, can you name the companies?	<div style="border: 1px solid black; height: 100px; width: 100%;"></div>
A30. Would you be interested in a solution that adopts XR technologies in your professional sector?	Yes <input type="checkbox"/> No <input type="checkbox"/> Maybe <input type="checkbox"/>
A31. How confident would you feel in using XR technology at your workplace?	<i>1 = Not at all, 5 = Extremely</i> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/>

<p>A32. In your opinion, what are the key factors that contribute to the successful adoption of XR technologies in operational or training programmes?</p> <div style="border: 1px solid black; height: 100px; width: 100%;"></div>
<p>A33. What are the main barriers for a successful implementation of XR technologies in your organization?</p> <div style="border: 1px solid black; height: 100px; width: 100%;"></div>
<p>A34. Are you familiar with the EU policy about green skills included in the “European Green Deal”?</p> <p style="text-align: right;">Yes <input type="checkbox"/></p> <p style="text-align: right;">No <input type="checkbox"/></p>
<p>A35. Are you familiar with the EU policy about digital skills included in the “EU Digital Decade”?</p> <p style="text-align: right;">Yes <input type="checkbox"/></p> <p style="text-align: right;">No <input type="checkbox"/></p>
<p>A36. Have you noticed any impact from the utilisation of XR technologies in decreasing carbon footprint and CO2 emissions?</p> <p style="text-align: right;">Yes <input type="checkbox"/></p> <p style="text-align: right;">No <input type="checkbox"/></p> <p style="text-align: right;">Maybe <input type="checkbox"/></p>
<p>A37. Have you observed any influence of employing XR technologies in mitigating carbon footprint and CO2 emissions?</p> <p style="text-align: right;">Yes <input type="checkbox"/></p> <p style="text-align: right;">No <input type="checkbox"/></p> <p style="text-align: right;">Maybe <input type="checkbox"/></p>

A38. In your opinion, how significant do you believe it is for a candidate to possess fundamental XR skills during the hiring process?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A39. Do you think XR can enhance green skills? If so, how?

A40. How important is competence in XR technologies within the next 5 years for your institution?

1 = Not at all, 5 = Extremely

- 1
- 2
- 3
- 4
- 5

A41. What challenges do you foresee in integrating XR technologies into existing operational or training methodologies?

A42. Can you provide examples of successful implementations of XR technologies in operations or training that you've encountered?

A43. What gender do you identify as?

Male

Female

Non-binary

Prefer not to say

Other

Other

A44. What is your age?

18-25 years old

25-34 years old

35-44 years old

45-54 years old

55-64 years old

65 or older

A45. What is the highest degree or level of education you have completed?

High School

Bachelor's Degree

Master's Degree

Ph.D. or higher

Trade School

A46. What is your current employment status?

Employed

	Unemployed	<input type="checkbox"/>
	Student	<input type="checkbox"/>
	Retired	<input type="checkbox"/>
	Other	<input type="checkbox"/>

Other

A47. In which country are you currently living?

	Germany	<input type="checkbox"/>
	France	<input type="checkbox"/>
	Italy	<input type="checkbox"/>
	Spain	<input type="checkbox"/>
	Netherlands	<input type="checkbox"/>
	Belgium	<input type="checkbox"/>
	Sweden	<input type="checkbox"/>
	Greece	<input type="checkbox"/>
	Poland	<input type="checkbox"/>
	Ukraine	<input type="checkbox"/>
	Other	<input type="checkbox"/>

Other

7.2 APPENDIX 2 Guidelines for the in-depth interviews

Duration: Approximately 30-45 minutes to answer 20 questions

Target group: Trainers, IT professionals, decision-makers, end-users (trainees), XR technology providers, and industry specialists.

Profile of Individuals to be Approached: Individuals with experience or interest in XR technologies, innovative training methodologies, and a willingness to explore new operational and training tools.

Before the questions: Make sure you are taking notes for the interview

Introduction and Background: 1) Asking for permission for voice recording 2) Starting by introducing yourself, the purpose of the interview, the Alliance4XR project, and briefly explain XR technologies for context. 3) Asking the interviewee about the sector, maybe some XR related projects he/she is currently working on.

Potential pitch: “Hello, I'm [], and I'm thrilled to explore the dynamic world of XR technologies with you. Our interview today aims to uncover the multifaceted impact of XR across various industries, from enhancing operational efficiencies to fostering innovative learning experiences.

XR, short for eXtended Reality, encompasses a range of immersive technologies like Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). These technologies are revolutionising the way we interact with digital content, offering immersive simulations, virtual environments, and interactive experiences. We are currently working on the *Alliance4XR ERASMUS+* project, which is set on co-creating and testing a well-tailored teaching and training methodology and material for empowering universities, vocational and training centres to successfully address the challenge of XR digital skills mismatch with a focus in engineering.

Throughout our discussion, we'll delve into how XR technologies are reshaping industries by improving training methodologies, streamlining operations, and unlocking new levels of creativity and collaboration. Additionally, we'll touch upon the exciting potential of XR in contributing to environmental sustainability and green initiatives.

I'm excited to dive deep into these topics and discover how XR is not only transforming industries but also paving the way towards a more sustainable and connected future.”

Understanding Current Use: Inquire about the current use of XR technologies in the industry or sector of interest. Explore specific applications, success stories, and challenges faced.

Potential Transformations: Discuss how XR technologies are expected to transform operations, training, or other relevant areas. Explore potential benefits, such as improved efficiency, safety, or learning outcomes.

Questions and Comments for interviewers:

1. **What specific resources or support would trainers require to effectively integrate XR technologies into their training modules?**

Inquire about the resources and support trainers would need to effectively integrate XR technologies into their training modules. This may include training programs, technical support, and access to XR hardware and software.

To help answering this question, what is your opinion on the following items (several answers are authorised):

- a. **What are the priorities in terms of XR tools for teaching, learning and training:**

- i. **Tools for Creating XR experiences for such application (including immersion and sensorimotor feedback) to support:**

1. Assembly task training: **yes/no?**
2. Perception of Physical or Biological phenomena to learn/understand some scientific models: **yes/no?**
3. Manipulating virtual or augmented objects because such proprioception can help memorisation: **yes/no?**
4. **Other needs:** please give some examples

- ii. **Tools to Implement XR based collaborative environments for such application:**

1. To allow Immersion and better awareness of learners and teachers, in a co-located or remote learning context: **yes/no?**
2. To manage, automatically or in advising the teacher, the Engagement and Attention of learners: **yes/no?**
3. **Other needs:** please give some examples

- b. **Regarding Creating XR experiences, where are the needs to reduce the usability gap in teaching, learning and training:**

- i. Ready-to-use platform for XR content creation systems for such applications: **yes/no?**
- ii. XR methodology to follow for designing such applications (from classical Curricula up to design and implement XR experiment required): **yes/no?**

- c. **Regarding collaborative environments for teaching, learning and training:**

- i. Does everything have to take place as an immersive XR experience: **yes/no?**
- ii. In the case of remote collaboration, do you want to mix conventional teleconference with XR one: **yes/no?**

2. How do you envision XR technologies transforming the landscape of operational and training purposes within your sector?

Discuss how XR technologies are expected to transform operational and training practices within the sector. Focus on specific examples of how XR can improve efficiency, safety, and learning outcomes.

3. How do you think XR technologies can address the diverse learning needs of trainees within your sector?

Explore how XR technologies can cater to diverse learning needs among trainees. Discuss the potential for customization, accessibility features, and adaptive learning experiences offered by XR.

4. How do you believe XR technologies can contribute to fostering collaboration and interdisciplinary learning within your sector?

Explore how XR technologies can foster collaboration and interdisciplinary learning within the sector. Discuss the potential for remote collaboration, simulation-based learning environments, and knowledge sharing platforms enabled by XR.

5. Are there any concerns or reservations you have regarding the ethical or security implications of integrating XR technologies into operational/training environments?

Address concerns or reservations regarding the ethical and security implications of integrating XR technologies into operational and training environments. Discuss privacy issues, data security, and ethical use of XR simulations.

5. From your perspective, what role do you see XR technologies playing in preparing employees and trainees for future career opportunities in engineering sectors?

Discuss the role of XR technologies in preparing employees and trainees for future career opportunities in engineering sectors. Explore how XR can bridge the gap between theoretical knowledge and practical skills.

6. What strategies do you suggest for overcoming potential barriers to the adoption of XR technologies in operational and training settings?

Discuss strategies for overcoming potential barriers to the adoption of XR technologies in operational and training settings. This may include addressing cost concerns, technical challenges, and resistance to change.

8. How can XR technologies be effectively integrated into existing activities without disrupting the process?

Explore strategies for effectively integrating XR technologies into existing activities without disrupting the process. Discuss phased implementation, pilot programs, and gradual adoption strategies.

9. What are the potential drawbacks or limitations of XR technologies in operational/training contexts, and how can they be mitigated?

Discuss potential drawbacks or limitations of XR technologies in operational/training contexts and strategies to mitigate them. This may include addressing issues such as motion sickness, equipment reliability, and content relevance.

10. How do you foresee the role of XR technologies evolving in operations and training over the next decade?

Envision how the role of XR technologies is expected to evolve in operations and training over the next decade. Discuss emerging trends, technological advancements, and potential new applications of XR.

11. What opportunities do you see for interdisciplinary collaboration and knowledge sharing facilitated by XR technologies within your sector?

Explore opportunities for interdisciplinary collaboration and knowledge sharing facilitated by XR technologies within the engineering sector. Discuss how XR can bridge gaps between different engineering disciplines and promote cross-functional collaboration.

12. What strategies do you recommend for evaluating the effectiveness of XR technologies in enhancing training outcomes?

Discuss strategies for evaluating the effectiveness of XR technologies in enhancing training outcomes. This may include measuring learning outcomes, user satisfaction, and performance improvements.

13. What steps can organisations take to ensure equitable access to XR technologies for all?

Discuss steps organisations can take to ensure equitable access to XR technologies for all employees and trainees. This may include providing subsidies, offering training programs, and promoting diversity in XR adoption.

14. How do you envision the future integration of XR technologies into mainstream operational/training practices within your sector?

Envision the future integration of XR technologies into mainstream operational and training practices within the engineering sector. Discuss

potential barriers to overcome, industry trends, and the role of innovation in driving XR adoption.

15. **How do you see XR technologies contributing to environmental sustainability and 'green' initiatives, particularly in terms of reducing carbon footprints or promoting eco-friendly practices?"**

Encourage the interviewee to discuss aspects such as reduced carbon footprints, eco-friendly practices, and overall positive environmental impact.

16. **Can you discuss any specific features or developments in XR technology that prioritise environmental sustainability, such as energy-efficient hardware, recyclable materials, or virtual collaboration tools that reduce the need for travel?**

Focusing on any specific features or developments within XR technology that prioritise environmental sustainability. Encourage the interviewee to elaborate on any advancements or innovations aimed at reducing environmental impact.

17. **What steps or initiatives do you believe organisations should take to ensure that the adoption and use of XR technologies align with broader environmental goals and contribute positively to a 'greener' future?**

Ask for practical recommendations or best practices that organisations can implement to maximise the positive environmental impact of XR technologies. This could include guidelines for sustainable procurement, lifecycle assessments, or carbon offsetting strategies.

18. **When hiring new employees, is knowledge and skills in XR technologies an asset?**

19. **Do you see any need for a new type of professionals related to XR, for instance "XR designer" or similar?**

20. **Which barriers do you consider to be the most important ones, limiting your usage of XR technologies?**

We are close ending this interview organised within the framework of the Alliance4XR ERASMUS+ project. As said before this project is set on co-creating and testing a well-tailored teaching and training methodology and material for empowering universities, vocational and training centres to successfully address the challenge of XR digital skills mismatch with a focus in engineering. For instance, we plan to draft guidelines and to provide content resources to support trainers, and any other initiative to support trainers in leveraging XR technologies.

Moreover we want Alliance4XR to take initiative to follow the European Green deal as well as European people inclusive policy. Therefore our last question is:

21. How do you envision Alliance4XR supporting trainers in leveraging XR technologies to create inclusive and accessible training experiences for all?

Inquire about the role of Alliance4XR in supporting trainers to leverage XR technologies for creating inclusive and accessible training experiences. Discuss initiatives, guidelines, or resources provided by Alliance4XR for this purpose.

Well, thank you very much for taking the time to do this interview. Your contribution with those of a number of other interviewed people will be analysed and compiled within a report that will be published in a couple of months, and that you will receive an issue. In between, we kindly invite you to follow-up the Alliance4XR ERASMUS+ project on its website: <https://alliance4xr.eu/>

7.3 APPENDIX 3 Detailed description of use cases

Table 3 ALLIANCE4XR Use Cases for Higher Education Institutions

UC-01	Munster Technological University
Title	Bachelor of Engineering (Hons) in Mechanical and Manufacturing Engineering
Description	<p>The REEdI (Rethinking Engineering Education in Ireland) BEng (Honours) in Mechanical and Manufacturing Engineering is a blended degree that brings in the best of manufacturing and mechanical engineering, culminating in flexible and adaptable engineers to meet industry needs. The REEdI student engineer will learn about the design and development of processes whilst also gaining an equally strong knowledge of the design, development and operation of products and equipment.</p> <p>Students will learn “just-in-time” not “just-in-case”. The course will be delivered using cutting edge technologies such as augmented and virtual reality. In addition, students get to learn from top lecturers in the field, study and work with emerging technologies, work with world-class companies, learning using a blended approach, through classroom-based, as well as hands-on experience. The goal of the REEdI programme is to turn curious, creative, innovative and adaptable people into the engineers of the future.</p>

	<p>Our Bachelor of Engineering (Hons) in Mechanical and Manufacturing Engineering student engineers at MTU Kerry Campus get to experience first-hand these emerging technologies. They use virtual reality (VR) and augmented reality (AR) technologies as standard tools throughout the modules they study on the programme. Every student on this programme gets an Oculus Quest 2 VR headset to allow them to work on engineering projects in VR anytime, anywhere. Our student engineers also have access to Microsoft HoloLens AR glasses. They are currently using the HoloLens to improve and streamline mock production processes as part of a module called “production engineering”, which they study in Semester 2 on the programme.</p> <p>The Bachelor of Engineering (Hons) in Mechanical and Manufacturing Engineering at MTU Kerry Campus (CAO Code: MT834) was designed as part of the REEdI- Rethinking Engineering Education in Ireland project. The REEdI Project is funded through the Higher Education Authorities Human Capital Initiative (HCI) Pillar 3 fund. The goal of this project is to reinvent the way that engineering education is designed and delivered in Ireland. Our agile and innovative engineering programme is the first of its kind in Ireland and the world. We use XR technologies as key learning tools throughout the programme. Student Engineers will spend 2 years on campus in Tralee, County Kerry and then have a choice of world class manufacturing companies to go to for 2 years paid work placement. Our student engineers will bring their XR knowledge and skills with them to our partner companies. Also, we are proud of the support structures we have in place for our student engineers. These include many things-for example- extra maths support, mentoring, online learning supports and access to engineers in residence (who have industry expertise and help prepare our student engineers for their work placement).</p>
Primary Actor	Dr Fiona Boyle, Head of Department, STEM/Director of the REEdI Project at MTU
Preconditions	Requisite CAO points
Postconditions	None
Main Success Scenario	<p>Graduates of this programme will be able to:</p> <ul style="list-style-type: none"> • Demonstrate technical, soft skill and transversal skill competencies work effectively and professionally as an individual or within multidisciplinary teams

	<ul style="list-style-type: none"> • Apply acquired skills and knowledge required to solve problems and collaborate with subject matter experts (SMEs) • Research and develop potential solutions to problems • Interpret engineering drawings, SI units, specifications, engineering standards, regulatory requirements • Demonstrate implementation of principles and application of the concepts involved in operational excellence and lean 6-sigma • Demonstrate an in-depth knowledge of digital / immersive technology and identify opportunities to utilise these effectively in industry • Recognise good leadership attributes and look for continuous professional development (CPD) opportunities to develop these • Demonstrate awareness of the UN Sustainable Development Goals (SDGs) and the importance of the engineer's role in society
Extensions	Formal work placement (2 years) is an integral element of the course and takes place in years three and four. MTU will secure work placement for students, working with industry partners to ensure specific projects are ready for students to prepare for prior to going on placement which they will then work on whilst on placement.
Frequency of Use	Annual degree programme
Status	Ongoing
Owner	MTU
Priority	TBD
UC-02	BDIC(UCD) Beijing Master's Degree
Title	COMP47930 Augmented and Virtual Reality
Description	The course will act as an introduction to the field of Augmented and Virtual Reality, which is traditional in academic circles referred to as Mixed Reality. In much of the current popular media it is normally referred to as XR, Extended Reality The course aims to allow students to develop applications and understand the concepts behind with this novel field, and its potential future as the final medium for human computer interaction. As such it covers recent developments in the field and teach the fundamental foundations of Mixed Reality.
Primary Actor	Dr Abey Campbell
Preconditions	Undergraduate degree
Postconditions	None

Main Success Scenario	<p>Learning Outcomes:</p> <p>The student will acquire knowledge of fundamental techniques to produce Virtual and Augmented Reality applications.</p> <p>The student will be able to develop VR/AR applications using modern techniques.</p> <p>The student will have knowledge of the latest developments in VR/AR and competence to improve on this understanding in the future.</p>
Extensions	<p>Indicative Module Content:</p> <ol style="list-style-type: none"> 1. History of Augmented and Virtual Reality (AR/VR) / Display technologies to produce AR/VR environment (Reality-Virtuality continuum) 2. 3D Fundamentals 3. XR Game Engines 4. Tracking technologies (Active / Passive) 5. 3D Reconstruction / 3D Printing / 3D photogrammetry 6. Metaverses 7. Mobile XR 8. HMD based XR 9. NON-HMD XR Environments 10. Tele-presence: A Surrogate future 11. Future VR/AR Programming techniques including Augmented Reality Agents (AuRA's) and VR Learning Objects.
Frequency of Use	Autumn Trimester
Status	Ongoing
Owner	Beijing-Dublin International College (BDIC), founded in 2012, is a joint international college established in collaboration between University College Dublin (UCD) and Beijing University of Technology (BJUT).
Priority	TBD
UC-03	BDIC(UCD) Beijing
Title	COMP3025J Augmented and Virtual Reality
Description	The course will cover recent developments in the field and teach the fundamental foundations of Mixed Reality which combines both fields.
Primary Actor	Dr Soumyabrata Dev
Preconditions	<p>Requirements, Exclusions and Recommendations</p> <p>Learning Recommendations:</p> <p>Review of Comp3033J over the summer before taking course or any introduction Computer Graphics course.</p> <p>Reading Virtual Reality by Howard Rheingold</p>

	<p>Reading Rainbows End by Vernor Vinge Module Requisites and Incompatibles</p> <p>Required: BDIC1047J - English for Uni Studies BDIC, BDIC1048J - English Gen Acad Purposes BDIC, BDIC2007J - English for Spec Acad Purposes, BDIC2015J - Acad Wrt & Comm Skills</p> <p>Additional Information: This module is delivered overseas and is not available to students based at the UCD Belfield or UCD Blackrock campuses.</p>
Postconditions	None
Main Success Scenario	<p>Learning Outcomes: The student will acquire knowledge of fundamental techniques to produce virtual reality (VR) and augmented reality (AR) applications. The student will have knowledge of the latest developments in VR/AR and the competence to improve on this understanding in the future. They will also be exposed to the fundamental concepts of image processing used in VR/AR applications.</p>
Extensions	<p>The course material includes:</p> <ul style="list-style-type: none"> - History of Augmented and Virtual Reality (AR/VR) - Display technologies to produce AR/VR environment (Reality-Virtuality continuum) - Tracking technologies - 3D Reconstruction - 3D Printing - VR/AR Game Engines - Mobile AR/VR - CAVE VR Environments - VR HMD - 3D photogrammetry - Computer vision fundamentals - Case study on Medical VR/AR applications - Case study on Educational VR/AR applications
Frequency of Use	Autumn Trimester
Status	Ongoing
Owner	Beijing-Dublin International College (BDIC), founded in 2012, is a joint international college established in collaboration between University College Dublin (UCD) and Beijing University of Technology (BJUT).
Priority	TBD
UC-04	CDIC
Title	Digital Construction (CVEN3006W)

Description	<p>This module introduces digital modelling and information management in construction projects. The module provides a range of theory and technical concepts associated with projects based on nD modelling. Students will evaluate and improve the management of construction projects by adopting Building Information Modelling (BIM) tools.</p> <p>Note: This module is for CDIC students only.</p>
Primary Actor	Dr Seong mok Paik
Preconditions	Civil Engineering Degree
Postconditions	None
Main Success Scenario	<p>Learning Outcomes:</p> <ul style="list-style-type: none"> ● Define the concepts and process of information management and understand the difference between 3D modelling ● Investigate and practice BIM tools associated with the construction project stages ● Describe qualitative and quantitative construction management techniques, their uses, benefits and limitations ● Apply appropriate sources of information in construction projects and explain proper techniques to manipulate data in assessing the projects ● Evaluate the benefits of various management and technique skills by Performing a BIM case study
Extensions	<p>Indicative Module Content:</p> <ol style="list-style-type: none"> 1. Introduction to Innovative Information Management <ul style="list-style-type: none"> - Digital Twin Technologies 2. Building Information Modelling and Concurrent Engineering 3. Standards (ISO 19650) and Regulations 4. Digital Tool Practice 1 <ul style="list-style-type: none"> - Revit tools and functions - Revit user interface - Revit basic tasks - Project management with Revit 5. Digital Tool Practice 2 <ul style="list-style-type: none"> - Navisworks tools and functions - Navisworks user interface - Navisworks essential skills - Project management with Navisworks 6. Design Check and Clash Detectives 7. Digital Collaboration <ul style="list-style-type: none"> - Autodesk Construction Cloud 8. Information Management Practice: nD Modelling

	<ul style="list-style-type: none"> - MS Project, P3, Revit, Navisworks - Revit, Vico, CostX - Blockchain Technology and Smart Contracts <p>9. Performance Analysis and Simulation</p> <p>10. SMART City</p>
Frequency of Use	As required for self-directed professional development.
Status	Ongoing, Spring Trimester Module
Owner	Chang'an Dublin International College of Transportation (CDIC) is a joint international college established in collaboration between University College Dublin (UCD) and Chang'an University (CHD). Students are awarded degrees by both Chang'an University (CHD) and University College Dublin.
Priority	TBD
UC-05	SATLE funded project - FLAME
Title	FLAME – Facilitated Learning with Animated Multi-media Engagement
Description	FLAME aims to empower educators to create online 3D interactive material to support learning rather than accept limited materials burdened by fees and vendor lock-in (e.g. 3DEXPERIENCE, Jigsawspace, H5P). A clear gap exists in terms of the availability, accessibility, and cost of interactive learning materials.
Primary Actor	Lecturers in engineering in higher level education.
Preconditions	Some prior knowledge of where 3D modelling will enhance the teaching and learning of engineering concepts.
Postconditions	None
Main Success Scenario	<p>Student outcomes:</p> <p>Enhanced learning for complex concepts.</p> <p>Facilitating equality, diversity, and inclusion in online learning materials through the use of Inclusive Design in interactive components with W3C Accessibility Standards.</p> <p>Enabling greater critical assessment of unvouched media.</p> <p>Greater visual learning to overcome language barriers (CDIC and BDIC).</p> <p>Improved practical aspects of laboratory sessions with pre and post lab 3D/AR materials.</p> <p>Empower students to participate in the co-creation of 3D materials for challenging topics.</p>
Extensions	<p>The key deliverables for the project are:</p> <ol style="list-style-type: none"> 1. A new Brightspace module to teach deployment of interactive 3D media.

	<ol style="list-style-type: none"> 2. Establish the Digital Library. 3. Physical artefacts to link online learning to physical touch. 4. Establish and disseminate effectiveness of produced material to a wider educator audience.
Frequency of Use	As required for self-directed professional development.
Status	Launched 2023
Owner	Dr Kevin Nolan – UCD – SATLE funded project
Priority	TBD
UC-06	Micro-Credential - Introduction To XR
Title	Micro-Credential - Introduction To XR: Applications And Technology (DPEEG-XRAT-1M01)
Description	<p>This micro-credential is being offered to creative media professionals, musicians, composers, visual artists; those looking to upskill in the development of interactive environments using Unity software and apply their audio, 3D visual and interactive media skills in Virtual Reality and Augmented Reality.</p> <p>This micro-credential will give learners a broad but deep overview of the Unity3D software and how it can be used to develop Virtual and Augmented reality applications. The focus of these developments will be applications in a variety of areas, from art and music to health and training.</p> <p>Learners will show their design and development skills, in the Unity software, by creating two portfolio-standard XR projects. The first half of this micro-credential introduces learners to a broad range of topics in Unity3D that will allow them to develop an interactive VR environment. This ranges from the workspace, adding 3D visuals and audio to making the world interactive. It also provides a brief introduction to programming in Unity3D.</p> <p>The second part is focused on developing environments for Augmented Reality applications using an AR engine. The course will appeal to creative media professionals, musicians, composers, visual artists; those looking to upskill in the development of interactive environments using Unity software and apply their audio, 3D visual and interactive media skills in Virtual Reality and Augmented Reality.</p>
Primary Actor	Dr. Fionnuala Conway
Preconditions	Experience with the fundamentals of audio and visual production is highly desirable, but not necessary, for this micro-credential. CV.
Postconditions	None

Main Success Scenario	<ul style="list-style-type: none"> • In this micro-credential you will attend weekly 2-hour lectures. These will be classroom based but will be live streamed and recorded for those that prefer online delivery. These lectures will introduce you to the development of interactive environments using the software Unity3D, that can be designed for Virtual or Augmented Reality applications. • There is a particular focus on the development of creative and innovative uses and application of these environments. • Two of the lectures will be dedicated to showcasing and reviewing the body of work created by the learners. • You will create 2 applications that can be used for portfolio and write a report on the design and development of each piece.
Extensions	<p>How is this Micro-credential assessed?</p> <p>It is assessed through 2 practical assessments, worth 40% and 60% respectively.</p> <ul style="list-style-type: none"> • Assignment 1 (40%) Focuses on the development of an original interactive environment in, that could be experienced as VR and shows the learner's ability to think creatively about the application and use of the interactive environment. • Assignment 2 (60%) has 2 parts: Part 1 requires the learner to create a video trailer of Assignment 1. Part 2 requires learners to develop an original interactive Augmented Reality application, to be experienced using a mobile phone (or another AR device they may have access to).
Frequency of Use	Each January
Status	Ongoing
Owner	Daniel Wearen ¹²
Priority	TBD
UC-07	Innovation Academy UCD
Title	Virtual Reality for Future Skills (IA20220)
Description	This module utilises Virtual Reality (VR) to develop and practise transversal skills. Participants progress through a multi-stage immersive VR experience completing tasks, making decisions, and exercising their critical faculties in a virtual workplace. The VR experience replicates a real-world enterprise, allowing participants to identify their areas of

¹² Email: wearend@tcd.ie

	strength and tackle realistic workplace challenges in a safe environment.
Primary Actor	Ms Eleanor Kelly, Lecturer / Co-Lecturer
Preconditions	None
Postconditions	None
Main Success Scenario	<p>Learning Outcomes:</p> <p>On completion of this module, students should be able to:</p> <ul style="list-style-type: none"> • Identify and articulate their own strengths and character qualities • Appreciate how their and others' strengths and character qualities can be leveraged in a range of contexts, including the workplace • Develop the ability to make reasoned decisions in complex and ambiguous situations • Effectively communicate with others, including justifying decisions made • Practise personal reflection as a tool for continuous self-improvement • Confidently navigate learning and working in a VR environment
Extensions	<p>Indicative Module Content:</p> <ol style="list-style-type: none"> 1. Virtual Reality Experience 2. Typical business start-up activities e.g. product development, customer discovery, building a team, data analysis 3. Pitching and presenting 4. Reflective practice
Frequency of Use	Autumn and Spring Trimester (separate)
Status	Ongoing
Owner	Mr Maurice Knightly
Priority	TBD

Table 4 ALLIANCE4XR Use Cases for Vocational Education and Training

UC-08	Pulse XR (Education Training Board – Ireland)
Title	Virtual reality app for students training to be healthcare professionals.
Description	Pulse XR offers an immersive experience that transports healthcare assistance students into a virtual hospital setting. Here, they encounter a variety of patient care scenarios, each designed to hone their clinical skills, critical thinking, and decision-making abilities. The VR environment replicates the

	sights, sounds, and the stress of a real-world clinical setting, but without the risk of harm to actual patients.
Primary Actor	A student training to be a healthcare professional completes several tasks in a VR environment.
Preconditions	Some knowledge of anatomy and healthcare tools are needed before the learning experience is launched.
Postconditions	Healthcare tasks have been properly carried out.
Main Success Scenario	<p>Success Scenario:</p> <p>The tasks are carried out by a student using a 6DOF virtual reality headset.</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Before starting the learning module, a safe boundary zone is created for students. 2. The experience has two modes including self-guided and training mode. 3. An understating of the necessary procedure is required before the training module starts. This includes for instance finding PPE and cleaning hands. If required, instructions of how to use the equipment can also be displayed by the app. For each healthcare scenario the following activities are carried out. 4. With the help of a virtual tablet, students' progress through several patient care scenarios. Each scenario includes tasks where the emphasis is on the student actively engaging with a patient. <p>The closing of the maintenance operations consists of the following activities:</p> <ol style="list-style-type: none"> 5. When the healthcare scenarios are finalized, an activity assessment PDF document is sent to the student.
Extensions	The main scenario is based on the usage of a 6DOF virtual reality headset. The usage of the headset is motivated by the need of using both hands during the scenario. Students can decide to explore the scenario in explore mode or training mode. AR capabilities are not included in any scenario.
Frequency of Use	Weekly
Status	Launching March 2024
Owner	Wicklow and Waterford Education and Training Board
Priority	TBD
UC-09	Virtual Reality Welding Training Simulator (Advanced Manufacturing Training Centre of Excellence) - Ireland
Title	Dual User Virtual Reality Welding Training Simulator
Description	Virtual reality welding trainers for dual users simulates welding for hands on welding training for two students at a

	time on one machine.
Primary Actor	A student training to be a welder follows instructions through specially created VR goggles and welder tool.
Preconditions	Some knowledge of welding tools is needed before the learning experience is launched.
Postconditions	Six welding tasks have been properly carried out.
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a student using a 6DOF virtual reality headset and interactive welder tools.</p> <p>Welding Environment: Realistic puddle and actual welding sound helps welders learn to respond and adjust welding technique. Simulates sparks, slag, grinding and weld cooling. Welding discontinuities appear when improper welding technique is used. Virtual bend test provides results instantly and reveals what causes a weld to pass or fail.</p> <p>Reinforcement for Students: Replicates proper machine set-up using a Welding Procedure Specification. Students must select gas type, process, gas flow, amperage/voltage and wire-feed speed in the system. Tracks and scores key weld parameters including work angle, travel angle, travel speed, distance and position. Demos of successful welds.</p> <p>Features</p> <ul style="list-style-type: none"> • Dual stands allow for training two students at the same time on one machine, each independently performing welds using different processes, coupons, joints and Welding Procedure Specifications (WPS). • Retractable SMAW stick stinger, GMAW/FCAW gun and GTAW TIG torch, filler metal and adaptive foot pedal devices realistically simulate the look, feel and action of actual guns and torches. • Extremely realistic weld puddle is visually and audibly responsive to operator behavior, helping welders learn when to adjust welding technique. Welding discontinuities appear when improper technique is used. • Tracks and scores key weld parameters including work angle, travel angle, travel speed, distance and position. • Tracks and scores key weld parameters including work angle, travel angle, travel speed, distance and position. • Virtual bend test provides results instantly and reveals what causes a weld to pass or fail.
Extensions	The main scenario is based on the usage of a 6DOF virtual reality headset. Demo, Replay& Lesson Mode mode helps

	instructors and welders identify what went wrong or well. The usage of the headset is motivated by the need of using both hands during the scenario. Students can decide to explore the scenario in explore mode or training mode. AR capabilities are not included in any scenario.
Frequency of Use	Weekly
Status	Launched 2022
Owner	Advanced Manufacturing Training Centre of Excellence (AMTCE)
Priority	TBD
UC-10	IMMERSIVE TECHNOLOGY SKILLS TRAINING (Education Training Board – Ireland)
Title	Training Wind Turbine Engineers using Virtual Reality Training Experiences
Description	<p>Immersive Technology Skills” (ImTech Skills) – aims to develop a strategic approach, in collaboration with stakeholders and businesses, to support the development of ImTech Training specifically for the Renewable Wind Energy sector. The aim of this project is to create fresh opportunities for training and upskilling the existing workforce using high-quality enhanced-learning skills embedded into state-of-the-art Virtual Reality imaging tools.</p> <p>Initially, the focus will be on the training requirements for Wind Turbine Engineers as it is relevant to both the onshore and offshore renewable wind energy generation. The ImTech Training developed will have applicability across other renewable energy disciplines and technologies as well as the potential for deployment across other industries and sectors in the future.</p>
Primary Actor	A wind turbine engineer.
Preconditions	Knowledge of wind turbines and maintenance processes.
Postconditions	Maintenance tasks have been properly carried out.
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a student using a 6DOF virtual reality headset.</p> <p>For each maintenance scenario the following activities are carried out.</p> <p>The experience offers an in-depth look into the application and understanding of the types of personal protective equipment needed to ascend and carry out work on a wind</p>

	<p>turbine. Each element is based on real world equipment, these include: climbing compliant helmet, safety glasses, gloves, climbing harness, work positioning lanyard, fall arrest lanyard and fall arrest device.</p> <p>The training is centred on reacting to a disaster relief in a confined space. The user is given a choice to react on the spot to a potential life-threatening fire. The unique pathways implemented into the scenario allows the user to make their own decisions in a safe environment. The experience is guided by a voiceover to ensure they can be fully immersed in and focused on the experience, looking around and learning in a natural way – just like it would happen in the real world.</p>
Extensions	The main scenario is based on the usage of a 6DOF virtual reality headset. The usage of the headset is motivated by the need of using both hands during the scenario. AR capabilities are not included in any scenario.
Frequency of Use	TBC
Status	TBC
Owner	Mayo, Sligo and Leitrim Education and Training Board
Priority	TBD
UC-11	VMSTEM
Title	The Virtual Museum of STEM
Description	<p>The first European virtual museum for STEM education at secondary level, that is including the needs of students with learning disorders.</p> <p>It is offering an experience that is immersive, interactive, and engaging. As in a real museum, the students are able to go and see what they wish, and to spend as much time exploring the notions and elements presented. To make sure it is useful for school education, it comes with supporting material to help teachers make the most of the tools provided, and guidance to link what it presented in the museum with the STEM programs. The Museum is accessible from a regular web browser and not limited to virtual reality to make sure it is usable by most.</p>
Primary Actor	A Virtual Museum of STEM ¹³
Preconditions	General digital competences
Postconditions	Necessary content and platform updates
Main	The usage and incorporation of virtual reality exhibitions into

¹³ <https://www.vmstem.eu/>

Success Scenario	the curricular programs. The project includes 60 collections related to STEM in secondary education related to 4 main areas: a) The Science Exhibition; b) the Exhibition of Technological Advancements; c) the Contemporary Engineering Collections; d) the Exhibition of Hidden Mathematics. All the resources are available in 5 languages: English, French, Greek, Portuguese, and Croatian.
Extensions	No AR/XR components are used. Translations to other languages.
Frequency of Use	Decision on the use frequency to be determined by the teachers.
Status	TBD
Owner	Erasmus+ Consortium: CEPROF, CIP, SREDNJA SKOLA IVANEC, LOGOPSYCOM, YUZUPULSE.
Priority	TBD
UC-12	Digital FabLab
Title	Footwear virtual learning by doing - Transition from analogue practices to digital education
Description	<p>This project aimed at responding to the emergent needs in education/training towards a specific economic sector – the footwear which employs more than 278.000 people in more than 21.000 companies, mainly SMEs - as a consequence of the digitalisation and adoption of new practices of teaching/learning, which was intensified by the covid-19 pandemic, and respond to the TCLF Pact4 Skills objectives. The project objectives were posed at the follow various levels:</p> <ol style="list-style-type: none"> 1. To prepare VET providers and HE providing VET and their correspondent staff, including trainers, teachers and coaches, to implement comprehensive digital strategies for the learning-by-doing in Footwear Manufacturing, including approaches, methodologies and autonomy in the development of contents. 2. To extend and consolidate an EU network of VET providers and HE providing VET and lead it to excel in the digital delivering of practical training, toward the development of the practical skills, in footwear manufacturing. 3. To create of a free complete digitally environment for training/teaching/leaning of practical skills in Augmented reality and correspondent contents in Footwear manufacturing – and example of a traditional

	<p>sector that pioneers the most advance technology and state-of-the-art practices in their activities, and will also lead practices in education training.</p> <p>4. To create a joint international digital training/education product – a course – and conduct it to a certification at National level, and a recognition at EU level, for the development of practical skills in Footwear manufacturing.</p>
Primary Actor	An immersive virtual Shoe Fab Lab using AR ¹⁴
Preconditions	General digital competences
Postconditions	Necessary content and platform updates
Main Success Scenario	<ul style="list-style-type: none"> • Create a free, entirely digital FabLab using Augmented Reality to teach and learn practical footwear manufacturing skills. • Elaborate a joint international digital course, certified at National level and recognised at EU level for the development of practical skills in footwear manufacturing. • Train VET teachers, trainers and coaches on how to implement digital learning-by-doing strategies to guarantee that such tools are well-understood and blended into learning programmes to their full capacity. • Establish a network of European VET providers committed to delivering the most advanced digital practical training in footwear manufacturing.
Extensions	Possibility of adapting the lab to different sectors. Translations to other languages.
Frequency of Use	TBD
Status	TBD
Owner	Erasmus+ Consortium: CTCP, CEC, Hearthand Solutions, TUIASI, Politecnico Calzatureiro, CTCR, Institute of Leather Industry.
Priority	TBD
UC-13	CSETIR
Title	Construction Safety with Education and Training using Immersive Reality
Description	Construction sites are dynamic and complex environments, making them difficult to control and monitor. Construction safety prevents people from dying or becoming incapacitated.

¹⁴ <https://www.digitalfablab.eu/>

	<p>It is a socially relevant issue that persists despite several initiatives. To cope with the pressure of avoiding accidents development, safety can no longer rely on traditional accident preventions measures.</p> <p>The project (CSETIR – Construction Safety with Education and Training using Immersive Reality, co-funded by the Erasmus+ Programme of the European Union - http://csetir.civil.auth.gr/) arises from the synergy between higher education institutions and construction company provider to implement the use of smart technologies in proper training. The digital tools allow the creation of instruments that simulate construction scenarios allowing the identification and prevention of risks for teachers, technicians, and engineers. This approved project aims at enhancing knowledge exchange between representatives of three sectors to innovate the accident prevention approaches through effective collaboration between researchers in the virtual reality field and construction companies. The project will develop innovative and interactive VR/AR (Virtual and Augmented Reality) solutions based on BIM modelling capacities to prevent accidents and train workers. The project intends to create usable tools for teachers, technicians, and engineers that will be used in any construction project. Project also aims at offering training sessions online on an online platform (project website, wiki) to grant learners and trainees access to interactive material and resources. These tools will range from applications to be used on smartphones to virtual reality contexts depending on the needs of training.</p>
Primary Actor	VR/AR (Virtual and Augmented Reality) solutions based on BIM modelling capacities to prevent accidents and train workers.
Preconditions	General digital competences
Postconditions	Necessary content and platform updates
Main Success Scenario	<p>CSETIR is an international project comprising several types of HEI and methods of training and teaching prevention in construction. The participation of a construction company to involve stakeholders from construction sites will allow the interpretation and feedback from those that are most affected by the construction accidents. At the construction company level, each enterprise and official regulatory agencies have their own construction safety regulations and guidelines, different construction techniques, different construction culture and educational backgrounds of the academic and engineering staff. This diversity will be handled during the</p>

	<p>simulations while ensuring training that is independent from local characteristics allowing possibilities of adaptation to the actual scenarios.</p> <p>The tools will be interactive relying on the particular diversity to provide the adequate answers. This will allow that the several HEI, construction companies and training entities to implement interactive strategies regardless of regional policies, construction habits and H&S guidelines. The repository of case studies obtained from the application of the tools will facilitate the adaptation for different scenarios and situations. The European cooperation may strengthen the collaboration and cooperation between the companies, the teaching and training organizations and the students, workers, engineers and technicians with shared case studies and examples. This cooperation may also be helpful to raise awareness about solutions to eliminate or decrease the risks in construction. One of the the added values of these learning/teaching/training activities will be the possibility of different participants in different countries with different construction cultures to be in touch with each other and to experience sharing in a digital platform. Since all materials will be digital the access by all interested in the tools will be easy and cheap.</p> <p>Different configurations for learning and training materials and metods will be tested, leading to a virtual information repository that can be accessed by any interested participant. This may allow materials, tools and techniques to be compared with different scenarios. The validation of the results will also be done with participation of international organizations in the area of training for construction safety (AECEF) and in the area of construction safety coordinators professionals (ISHCCO). It is expected that CSETIR project will provide efficient and effective tools to be used by the different stakeholders to reduce accidents in construction sites and to progress towards a Zero Vision transformed in reality.</p>
Extensions	Possibility of adapting to different sectors. Translations to other languages.
Frequency of Use	TBD
Status	TBD
Owner	Erasmus+ Consortium: UPorto, AUTh, Technical University Kosice, UZagreb, Kamgrad
Priority	TBD

UC-14	DRINVET
Title	Digital reality - the basis of skills training
Description	<p>DRinVET is a project aimed at introducing Digital Reality (VR, AR, MR and XR) in Vocational Education and Training. It is a step that will help resolve crisis situations, especially in practical training and assessment, which we still encounter today.</p> <p>Objectives:</p> <ol style="list-style-type: none"> 1. Promote Digital Reality (DR) technologies (AR, VR, MR and XR) in education, especially in Vocational Education and Training (VET) 2. Promote the application of simulators (DR) in learning and skills training in VET 3. Promote a constructivist and collaborative approach in the teaching process 4. Learn how to learn using technology in teams consisting of teachers and students 5. Enable teachers and students to work/learn in crisis situations (e.g., pandemics).
Primary Actor	DRinVET ¹⁵ project consortium
Preconditions	General digital competences
Postconditions	Necessary content and platform updates
Main Success Scenario	<p>Development of a relevant pedagogy and methodology for the use of DR tools, as well as tools that will raise teachers and trainers' competences and enable teaching processes to lead safely towards learning outcomes needed for the labour market.</p> <p>DRinVET will have an immediate and long-term impact on target groups because it will deliver tools that will provide the foundations for further personal development of teachers and students as well as the development of educational organizations and institutions in which they operate and learn.</p>
Extensions	Possibility of adapting the lab to different sectors. Translations to other languages.
Frequency of Use	TBD
Status	TBD
Owner	Erasmus+ Consortium: STRUKA, VIRSABI, IOS, EWF, UCV, ATS, LVE.
Priority	TBD

¹⁵ <https://drinvet-project.eu/results.html>

Table 5 ALLIANCE4XR Use Cases for Structural Engineering and Construction

UC-15	POCI-01-0247-FEDER-06964
Title	GOA Bridge Management System – Bridge Intelligence (GOA.BI)
Description	<p>The project aims to introduce a new philosophy in the context of transport infrastructure maintenance. It is intended to develop new data acquisition equipment and provide a mobile platform for inspectors. All the collected information will be converted into Bridge Information Models, which will serve as a basis for the application of new predictive and decision-making algorithms, in order to support the maintenance strategy. All work is supported on an existing database.</p> <p>The following list summarizes all the main objectives of the project:</p> <ul style="list-style-type: none"> • Development of a new web-based platform, modular and scalable, that can be continuously upgraded with new features and modules; • Development of an intelligent interface platform to be used in the field by the in-situ inspectors' team; • Development of new inspecting equipment taking advantage of existing commercial tools (e.g. commercial drones, cameras, etc.) and algorithms/methods on the computer vision and deep learning field; • Development of mixed reality tools to manage bridges information with Visual Analytics and Augmented Reality techniques; • Development of algorithms to be used in information exchange between new inspecting equipment sensors and BRIM models; • Development of digital image correlation algorithms to post-process inspection measurements; • Development of predictive maintenance management module, which will help in defining priorities for maintenance works; • Development of decision-making module, which will help in defining the type of intervention to be taken, considering the associated cost-benefit ratio.
Primary Actor	Bridge Managers; Researchers; Decision Makers
Preconditions	1. Availability of existing bridge management system (GOA)

	<ol style="list-style-type: none"> 2. Availability of digital model (BIM) for existing bridges 3. Availability of opensource game engines and mixed reality toolkits
Postconditions	<ol style="list-style-type: none"> 1. Enhanced understanding of holographic computing application 2. Improved stakeholder engagement for AR technology 3. Streamlined planning and decision-making process remotely
Main Success Scenario	<ol style="list-style-type: none"> 1. Users can remotely access and manage the bridge model through mobiles, web-based or AR devices. 2. Users can collaborate work by real-time access and interact with the AR model. 3. The office manager/engineer can remotely instruct the site labor/inspector for real-time inspection tasks 4. The developed mixed reality tools allow to manage bridges information with Visual Analytics and Augmented Reality techniques,
Extensions	Needs of developing real-scale outdoor AR application
Frequency of Use	On demand
Status	Project finished since 2023
Owner	R&D projects (PT2020), National Innovation Agency (ANI)
Priority	N/A
UC-16	MEP Construction
Title	Augmented Reality to Increase Efficiency of MEP Construction: A Case Study
Description	<p>Mechanical, Electrical, and Plumbing (MEP) play a crucial role in civil construction projects. MEP is characterized by various interdisciplinary and interconnected activities of multiple trades. Augmented reality (AR), in combination with building information modelling (BIM), is one of the emerging technologies that support providing information in real-time, on-demand, and location-based ways. Using a multistorey apartment building as a case study, we compared the performance of conventional MEP practices and the support with an AR head-mounted display. The study results showed measurable benefits in terms of significant reductions in execution time. However, potential negative effects, such as increased work accident risks, were also recognized. The results are further discussed in a SWOT analysis that examines the AR application in terms of performance inhibitors and enhancers in both internal and external settings. Future research activities should consist of developing a standardized implementation model to best exploit the benefits of AR also</p>

	within other construction trades.
Primary Actor	MEP engineers; Researchers;
Preconditions	<ol style="list-style-type: none"> 1. Availability of existing MEP BIM models. 2. Availability of AR device and indoor testing site. 3. Availability of opensource game engines and mixed reality toolkits
Postconditions	<ol style="list-style-type: none"> 1. BIM and AR integration in construction 2. MEP works on-site are characterized by budget, time constraints, complex management of multiple simultaneous processes and stakeholders
Main Success Scenario	<p>A medium-sized multi-apartment building in Northern Italy with five apartments on three levels was chosen. It was selected according to the following criteria: i) manageable size, which is not too complex and not too big for the tests on-site; ii) identical apartments on the ground and first floor being able to compare the work processes with and without AR support. An initial analysis was carried out to identify suitable work processes for AR support. As a result, the MEP company decided to use AR to support the marking works for the installation of heating and sanitation tubes (HVS) as well as the underfloor heating (UFH) in the apartments and electrical pipes. The traditional way of marking works consists of 2D drawings, measuring tape, and spray to indicate where the tubes should be placed on-site. Consequently, the marking activities with and without AR were compared:</p> <ul style="list-style-type: none"> • In summary, the accuracy level increases with the number of measurements for the carried-out markings. The greatest accuracy was achieved with AR in complex areas where the operator traditionally needs to seek out plans and drawings and take numerous measurements. • The average accuracy of the marking works with the AR HMD amounts to 3.68 cm for the UFH, 7.34 cm for the HVS, and 2.67 cm for the electric works. Therefore, it can be concluded that the AR HDM reached an accuracy level in X and Y axis between 2 and 8 cm.
Extensions	The main results of the case study application are summarized in a Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis to form the practical insights.
Frequency of Use	On demand
Status	Online since 2021

Owner	Source: ISARC 2021 ¹⁶
Priority	N/A
UC-17	Hospital Nova
Title	Hospital Nova – VR to involve staff in building design
Description	<p>Innovative processes were used in the co-design of Finland's new Hospital Nova, which used BIM models and involved more than 350 staff.</p> <p>As the first completely new hospital to be built in the Central Finland Healthcare District since the 1970s, Hospital Nova aims to be one of the most modern and efficient hospitals in Europe. With a planned opening in late 2020, the project is an entirely new building type and concept compared to traditional hospitals, with a target to cut traditional operating costs by 10%.</p> <p>Due to the challenging nature of the project, the project team wanted to involve staff in the design of the hospital to ensure it would meet everyone's needs. Inviting the hospital's staff to pre-visit the building virtually enables early-stage sharing of new designs, collaboration with the building's future users and gathering vital feedback for the design process.</p>
Primary Actor	The Central Health Care; Researchers; public service operators
Preconditions	<ol style="list-style-type: none"> 1. Availability of existing BIM models. 2. Availability automated service to process the architect's BIM files into 3D interactive models. 3. The VR solution involved building a hospital demonstration space next to the construction site for both the staff and the public to visit. Facilities included a virtual space where staff could use VR goggles to explore the future hospital and an auditorium where others could follow the virtual experience on a large screen.
Postconditions	<ol style="list-style-type: none"> 1. The response from staff was impressive 2. Design feedback
Main Success Scenario	<p>Staff's response: More than 350 registered to be involved in the design process, and many are using the virtual model. At the height of its use, several visitor groups per day, including members of the public interested in seeing what the hospital would look like, visited the showroom. In 2019 alone, more than 3,000 visitors visited the showroom.</p> <p>Design feedback: Staff have been able to explore future buildings using the virtual model and provide feedback in the early design stages. Various clinical and operational teams</p>

¹⁶ https://www.iaarc.org/publications/fulltext/061_ISARC_2021_Paper55.pdf

	<p>were able to make plans for new facilities based on their virtual visits, as the model helped people to understand the design and if space was adequate for the planned functions. Gathering feedback from so many different groups who would be using the building was invaluable in helping shape its design. Changes were made to the architect's plans based on feedback. The result is an improved hospital which avoids any expensive alterations once the hospital is complete.</p> <p>With construction now in its final stages and a planned opening in late 2020, the virtual model is currently being used by staff to test the hospital signage and ensure the smooth flow of different users around the site. This will allow further cost savings to be made as any changes can easily be done in the design phase. Staff are also becoming familiar with the new premises even before entering the building.</p>
Extensions	BIM-to web-publishing: Hospital Nova is now starting to publish the 3D model to mobile devices via the web, which will help communicate the design to additional stakeholders. The hospital is also planning on using the virtual model throughout its lifecycle in facilities management.
Frequency of Use	On demand
Status	Project online since 2020
Owner	The Central Finland Health Care District (source: BimPlus ¹⁷)
Priority	N/A
UC-18	VR maintenance simulator
Title	Virtual reality application simulator of Wind Energy Turbine Direct Drive Generator
Description	<p>Training in the maintenance of large installations such as wind generators is costly. The delivery of staff to the workplace and the training on a real installation is not just a time cost but also a significant financial one since the installation can be done remotely. An alternative is training on individual units of the installation in the classroom. However, this option also does not provide complete training for the correct sequence of actions. As an alternative to the training approach, a virtual reality simulator is developed that provides a complete immersion of the trainee and significantly saves money for training the enterprise staff.</p> <p>The purpose of developing this VR simulator was to teach service personnel the correct procedure for inspecting and</p>

¹⁷<https://www.bimplus.co.uk/case-study-how-finlands-hospital-nova-used-vr-invo/#:~:text=With%20construction%20now%20in%20its,different%20users%20around%20the%20site.>

	replacing the nodes of a wind turbine with direct drive and the proper behavior in an emergency.
Primary Actor	Maintenance trainer; Researchers; Project managers
Preconditions	<ol style="list-style-type: none"> Availability of Team: 3D Designer, two 3D Animators, UX/UI Designer, two Unreal Engine Developers, Sound Engineer, Quality Assurance Specialist, and Project Manager Availability of Tools: Maya, 3D Studio Max, UE4 (C++)
Postconditions	<p>During the development, the following tasks are solved:</p> <ul style="list-style-type: none"> Creation of a 3D model of a wind turbine with all its key elements Creation of a system of interaction in virtual reality with elements of a wind turbine and auxiliary tools Animation of a system's nodes and elements. Animation of interaction with nodes and elements of the wind generator system Application programming
Main Success Scenario	<p>Key features</p> <ul style="list-style-type: none"> Using high-polygonal models: The environment, such as the nodes and elements of the wind generator, was created using highly polygonal graphics. Real shadows and lighting: The project was implemented using the Unreal Engine development environment. This allowed us to create the most realistic environment, which contributed to maximum immersion. The human factor: Considering the human factor, we maximally simulated the possible trainee mistakes and their consequences. <p>The implementation results of this simulator include the following:</p> <ul style="list-style-type: none"> Training time of engineers was reduced by 20% and more. Direct costs associated with training on real equipment were reduced by 70%. Employees of the client's company highly appreciate this simulator and plan to increase additional functionality in the application.
Extensions	As interaction with virtual objects was crucial to accomplishing all the tasks the client had set, the project was implemented as a desktop VR application for the HTC Vive device.
Frequency of Use	On demand
Status	Online

Owner	JASOREN (source: VR simulator of Wind Energy Turbine Generator Jasoren ¹⁸)
Priority	N/A
UC-19	Rail signal
Title	VR models drive safe design in rail project signal sighting
Description	When designing new structure installations and buildings on or near the rail line (including alterations to existing structures and buildings), whether permanent or temporary, it is essential to consider the potential impact on signal sighting compliance. VR models, driven by CAD and GIS data, are being used to ensure safety in the design of rail projects, particularly for signal sighting. The rail industry uses signal sighting assessment to confirm that train operators can reliably read, interpret and respond to signals at the lineside.
Primary Actor	Railway and train operators; Researchers; Decision Makers
Preconditions	<ol style="list-style-type: none"> 1. Availability of existing CAD and GIS data 2. Availability of VR platform
Postconditions	<ol style="list-style-type: none"> 1. Design feedback 2. Train operators can reliably respond to signals at the lineside
Main Success Scenario	<p>The TrueSight VR platform, using CAD and GIS data, has been developed by True North Rail and provides multi-angle videos of signal positioning. The system enables the most commonly required changes to be implemented 'in-game' live in a signal sighting review session. This significantly reduces the review timescales and rework compared with other methods, True North Rail said.</p> <p>The example in the main image above is the driver's view as they approach a station. At this point, the driver's view of the signal is blocked by the other train. The image below shows a few mouse clicks after the signal has been repositioned in the model, revealing that the driver can now see the signal despite the other train.</p>

¹⁸ <https://www.jasoren.com/portfolio/vr-maintenance-simulator/>

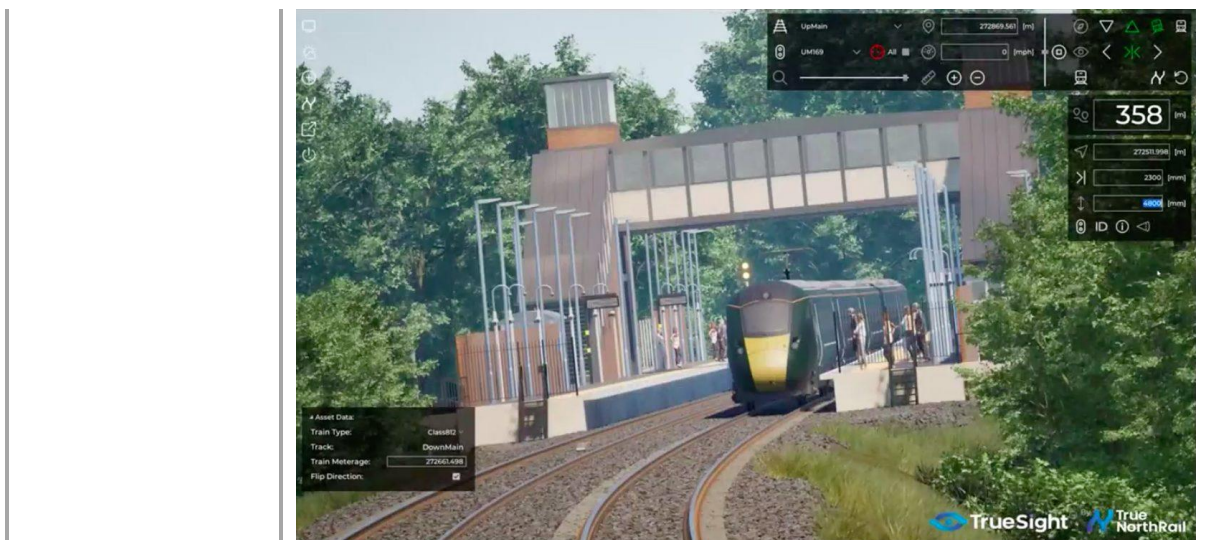


Figure 41 Rail Signal screenshot

Extensions	<p>According to James Furlong, co-director at True North Rail, TrueSight was used recently to achieve “approval on all required signaling changes for two new stations, eliminating the need for two signal banner repeaters. This not only expedited the project, but also generated substantial savings of approximately £500,000.” True North Rail was formed in 2018 by rail engineers who wanted to bring the technology used in computer gaming to the rail sector. After a period of research and development, the business secured its first competitive tender to deliver the signal sighting model for a major re/signaling scheme. In 2022, True North Rail secured its largest project to date, in partnership with WSP, to provide the signal sighting VR model and driver route learning package for the Network Rail Crewe program.</p>
Frequency of Use	On demand
Status	Project online since 2022
Owner	True North Rail (source: True North Rail CGI Rail Visualisation ¹⁹)
Priority	N/A

Table 6 ALLIANCE4XR Use Cases for Maritime Professions

UC-20	Wärtsilä Voyage Solutions
Title	Wärtsilä Voyage Solutions - Bridge Operations
Description	<p>Wärtsilä is a leading provider of marine technology and has developed the Wärtsilä BridgeMate system, which utilizes augmented reality (AR) to enhance bridge operations. The system overlays critical navigation information onto the real-world environment, improving situational awareness for</p>

¹⁹ <https://www.truenorthrail.com/>

	bridge officers and enabling more informed decision-making during navigation.
Primary Actor	The bridge officers or navigational personnel who use the system to enhance their navigation and situational awareness on ships.
Preconditions	<ol style="list-style-type: none"> 1. The system hardware and software are properly installed and operational on the ship's bridge. 2. Relevant navigational data sources (e.g., GPS, radar) are integrated and functioning correctly. 3. Bridge officers are trained to use the system effectively.
Postconditions	<ol style="list-style-type: none"> 1. Enhanced situational awareness for bridge officers. 2. Accurate and efficient navigation of the vessel. 3. Improved decision-making capabilities during navigation.
Main Success Scenario	<ol style="list-style-type: none"> 1. Accessing the system interface. 2. Viewing overlaid navigational information on the AR display. 3. Interacting with the system to adjust settings or display options. 4. Using the system to navigate safely and efficiently.
Extensions	<ol style="list-style-type: none"> 1. Loss of GPS signal or other navigational data sources. 2. System malfunctions or errors requiring troubleshooting. 3. Emergency situations requiring rapid response and adaptation of system functionality.
Frequency of Use	This depends on factors such as the duration and frequency of vessel operations, the navigational complexity of routes, and the reliance on the system for navigation assistance.
Status	"Operational" or "In Use"
Owner	Wärtsilä - BridgeMate - seakeeping, storm avoidance and more with the mobile app by Wärtsilä ²⁰
Priority	The priority for the Wärtsilä BridgeMate system tool may be determined based on factors such as safety implications, regulatory compliance, customer demand, and strategic business objectives.
UC-21	BMT's REMBRANDT
Title	BMT's REMBRANDT - Ship Handling Simulator
Description	BMT is a leading international design, engineering, science, and risk management consultancy, and has developed REMBRANDT, which is a ship handling simulator that integrates virtual reality (VR) technology. REMBRANDT provides highly realistic simulations of ship handling

²⁰ <https://www.wartsila.com/>

	scenarios, allowing maritime professionals to train for various maneuvers and emergency situations in a safe and controlled environment.
Primary Actor	Maritime professionals, such as ship captains, officers, or pilots, who use the simulator for training and skill development in ship handling and navigation.
Preconditions	<ol style="list-style-type: none"> 1. The simulator hardware and software are properly installed and operational. 2. Training scenarios and simulation environments are set up according to the intended training objectives. 3. Trainees have completed any necessary prerequisite training or familiarization with the simulator interface.
Postconditions	<ol style="list-style-type: none"> 1. Trainees have gained experience and improved skills in ship handling and navigation. 2. Performance data and feedback from simulation sessions are recorded for assessment and analysis. 3. Trainees receive debriefing and feedback from instructors or evaluators based on their performance.
Main Success Scenario	<ol style="list-style-type: none"> 1. Launching the simulator and selecting the desired training scenario. 2. Performing ship handling manoeuvres and navigation tasks within the simulation environment. 3. Receiving real-time feedback and guidance from instructors. 4. Completing the training session and reviewing performance metrics and debriefing.
Extensions	<ol style="list-style-type: none"> 1. Equipment malfunction or technical issues with the simulator requiring troubleshooting. 2. Emergency scenarios introduced by instructors to assess trainee responses. 3. Requests for additional training or practice on specific maneuvers or scenarios.
Frequency of Use	Depends on factors such as the training requirements of maritime personnel, the availability of simulation facilities, and the frequency of training programs conducted by maritime organizations or training institutions.
Status	May vary depending on factors such as the availability of the simulator for training, ongoing development or updates to the simulation software, and the scheduling of training sessions or programs utilizing the simulator.
Owner	BMT REMBRANDT: digital forensics and S-100 ENC platforms ²¹
Priority	High, given its critical role in training maritime professionals

²¹ <https://www.bmt.org/innovations/bmt-rembrandt/>

	and enhancing their skills in ship handling and navigation. Priority may be determined based on factors such as safety considerations, regulatory compliance, and the importance of maintaining proficiency among maritime personnel.
UC-22	VSTEP
Title	VSTEP - NAUTIS Maritime Simulators
Description	VSTEP is a provider of simulation and virtual training solutions for maritime professionals and offers the NAUTIS suite of maritime simulators. NAUTIS simulators utilize VR and AR technologies to replicate realistic maritime environments, enabling immersive training experiences for ship handling, navigation, and emergency response scenarios. The content and functionality packages include solutions in Navigation, Towage, Inland operations, Naval, GMDSS and Fishing.
Primary Actor	The trainee maritime professionals or instructors who use the simulator for training purposes.
Preconditions	<ol style="list-style-type: none"> 1. Availability of the NAUTIS Maritime Simulator hardware and software. 2. Proper setup and calibration of simulator components. 3. Availability of trained instructors to facilitate simulation sessions. 4. Access to relevant training scenarios and exercises within the simulator.
Postconditions	<ol style="list-style-type: none"> 1. Trainees gaining practical experience and skills in ship handling, navigation, and emergency procedures. 2. Assessment and evaluation of trainee performance based on simulation outcomes. 3. Feedback provided to trainees for improvement and learning.
Main Success Scenario	<ol style="list-style-type: none"> 1. Accessing the simulator interface and selecting a training scenario. 2. Interacting with simulated ship controls, navigation instruments, and communication systems. 3. Responding to simulated scenarios such as maneuvering in different weather conditions, navigating through busy waterways, or handling emergency situations. 4. Receiving feedback and debriefing from instructors based on simulation performance.
Extensions	<ol style="list-style-type: none"> 1. Simulated equipment failures or malfunctions requiring troubleshooting and corrective action. 2. Changes in environmental conditions or vessel behaviour that affect the course of the simulation. 3. Emergency scenarios such as collision avoidance,

	grounding, or fire drills.
Frequency of Use	Depends on various factors such as the training schedule, the number of trainees, and the availability of simulation resources. NAUTIS Maritime Simulators may be used regularly as part of maritime training programs, with sessions scheduled daily or weekly depending on training needs.
Status	It may be "Operational" if it is actively used for training, "Under Maintenance" if maintenance or upgrades are being performed, or "Offline" if it is temporarily unavailable.
Owner	VSTEP - NAUTIS Home - Ship Simulator ²²
Priority	High, especially for organizations and institutions that rely on it for maritime training and education. Ensuring its proper functioning and availability would be crucial to delivering effective training and preparing maritime professionals for real-world scenarios.
UC-23	Morild Ship & Bridge Simulator
Title	Morild Ship & Bridge Simulator
Description	Morild Ship & Bridge is developed by Morild Interaktiv and is a full mission simulator system built for Virtual Reality (VR) Technology. It offers the possibility for an unlimited number of users to train together in the same scenario. The training areas include navigation, ship handling, maneuvering, bridge resource management, piloting and combined operations.
Primary Actor	The primary actors are trainee maritime professionals or students undergoing training in ship handling, navigation, and bridge operations.
Preconditions	<ol style="list-style-type: none"> 1. Availability of the Ship & Bridge Simulator hardware and software. 2. Proper setup and calibration of simulator equipment, including bridge consoles, controls, and visual displays. 3. Access to training scenarios, exercises, and simulation modules within the simulator. 4. Presence of trained instructors or operators to facilitate simulation sessions. 5. Trainees' familiarity with maritime procedures and equipment.
Postconditions	<ol style="list-style-type: none"> 1. Trainees gaining practical skills and knowledge in ship handling, navigation, and bridge operations. 2. Assessment and evaluation of trainee performance based on simulation outcomes. 3. Feedback provided to trainees for improvement and learning.

²² <https://www.vstepsimulation.com/nautis-simulator/nautis-home/>

	4. Documentation of simulation sessions and trainee progress.
Main Success Scenario	<ol style="list-style-type: none"> 1. Trainees accessing the simulation interface and selecting a training scenario. 2. Interacting with simulated ship controls, navigation instruments, and communication systems. 3. Responding to simulated scenarios such as maneuvering in different weather conditions, navigating through challenging waterways, or handling emergency situations. 4. Receiving feedback and debriefing from instructors based on simulation performance.
Extensions	<ol style="list-style-type: none"> 1. Simulated equipment failures or malfunctions requiring troubleshooting. 2. Changes in simulation parameters or scenarios based on trainee performance or instructor intervention. 3. Additional training exercises or scenarios introduced to address specific learning objectives or skill gaps.
Frequency of Use	Depends on factors such as the training schedule, the number of trainees, and the availability of simulation resources. The Ship & Bridge Simulator may be used regularly as part of maritime training programs, with sessions scheduled daily, weekly, or as needed based on training requirements.
Status	It may be "Operational" if actively used for training, "Under Maintenance" if updates or maintenance are being performed, or "Offline" if temporarily unavailable.
Owner	Morild Interaktiv AS Ship & Bridge Simulator System — Morild Interaktiv AS ²³
Priority	High, especially for organizations and institutions relying on it for maritime training and education. Ensuring its proper functioning and availability is crucial for delivering effective training and preparing maritime professionals for real-world scenarios.
UC-24	K-Sim
Title	K-Sim Maritime Simulation
Description	The K-Sim Maritime Simulation systems are developed by Kongsberg Digital and offer both full-scale realistic bridge simulation and cloud-based training for various maritime operations. The K-Sim Maritime Simulation systems cover a diverse array of training areas, including ship handling, navigation, engine room operations, cargo handling, bridge resource management, and emergency procedures.

²³ <https://www.morildinteraktiv.no/morild-navigator>

Primary Actor	The primary actors for the K-Sim Maritime Simulation systems are trainee maritime professionals, instructors, and simulation operators who interact with the simulation for training and educational purposes.
Preconditions	<ol style="list-style-type: none"> 1. Availability of the K-Sim Maritime Simulation hardware and software. 2. Proper setup and calibration of simulation equipment, including consoles, controls, and visual displays. 3. Access to the K-Sim Maritime Simulation scenarios and exercises. 4. Trained instructors or operators to facilitate simulation sessions. 5. Trainees' familiarity with maritime procedures and equipment.
Postconditions	<ol style="list-style-type: none"> 1. Trainees acquiring practical skills and knowledge in ship handling, navigation, and emergency procedures. 2. Assessment and evaluation of trainee performance based on simulation outcomes. 3. Feedback provided to trainees for improvement and learning. 4. Documentation of simulation sessions and trainee progress.
Main Success Scenario	<ol style="list-style-type: none"> 1. Trainees accessing the simulation interface and selecting a training scenario. 2. Interacting with simulated ship controls, navigation instruments, and communication systems. 3. Responding to simulated scenarios such as maneuvering in different weather conditions, navigating through challenging waterways, or handling emergency situations. 4. Receiving feedback and debriefing from instructors based on simulation performance.
Extensions	<ol style="list-style-type: none"> 1. Simulated equipment failures or malfunctions requiring troubleshooting. 2. Changes in simulation parameters or scenarios based on trainee performance or instructor intervention. 3. Additional training exercises or scenarios introduced to address specific learning objectives or skill gaps.
Frequency of Use	Depends on factors such as the training schedule, the number of trainees, and the availability of simulation resources. K-Sim Maritime Simulation systems may be used regularly as part of maritime training programs, with sessions scheduled daily, weekly, or as needed based on training requirements.
Status	The status may be "Operational" if actively used for training,

	"Under Maintenance" if updates or maintenance are being performed, or "Offline" if temporarily unavailable.
Owner	Kongsberg Digital ²⁴
Priority	High, especially for organizations and institutions relying on this simulation tool for maritime training and education. Ensuring its proper functioning and availability is crucial for delivering effective training and preparing maritime professionals for real-world scenarios.
UC-25	MarSEVR
Title	Maritime Safety Education with VR Technology (MarSEVR)
Description	<p>It is well known that about 60-80% of the accidents are attributed to human error (directly or indirectly). Generally, each operator or seafarer must undergo training before starting professional work. In recent decades, emphasis on operator training has increased resulting in advance training simulators with several features like immersivity, stereoscopic sounds, hydraulics, and even use of different odors. However, the design of training methodologies can have a significant impact on the skill acquisition of trainees. The growth of integration of technology in existing systems as well as newer systems is much higher than that of improvement in training methods. The increase of complexity in process and maritime industries was higher than that of improvement/ upgradation of the training methods. This resulted into an evident gap between training needs and demands of operators, some of which are lack of:</p> <ol style="list-style-type: none"> 1. Realism in training (e.g., immersive environments, virtual reality) 2. Simulated abnormalities and accidents 3. Team training 4. Objective performance assessment 5. Integration of technological tools to aid training/learning phenomena 6. Non-technical staff training 7. Generation of data from training simulators 8. Scenarios imitating abnormalities and malfunctions. 9. Integration of results and research from other domains where safety and training are relatively more developed (for instance, process, nuclear and aviation industries) <p>The first prototype version of the MarSEVR virtual training technology for maritime safety training is presented in this</p>

²⁴ <https://marsim.kongsbergdigital.com/>

	paper. Emphasis was given on the concept of a portable training system which is cost effective and able to be used in on-board, training centers or even office environments. This system can consist of various learning chapters either as individual training scenarios or as continuous episodes part of a training curriculum / program.
Primary Actor	Maritime Safety Trainee or Student
Preconditions	<ol style="list-style-type: none"> 1. MarSEVR application is installed and properly functioning on the VR device. 2. The VR equipment (headset, controllers, etc.) is in working condition. 3. The trainee has basic knowledge of operating the VR equipment. 4. Curriculum or training modules are loaded and accessible within the MarSEVR platform.
Postconditions	<ol style="list-style-type: none"> 1. Trainee completes the designated maritime safety education module or scenario. 2. Progress and performance data are recorded and saved within the MarSEVR platform
Main Success Scenario	<ol style="list-style-type: none"> 1. Trainee selects a specific maritime safety education module or scenario. 2. MarSEVR environment loads, immersing the trainee in the selected scenario. 3. Trainee successfully completes safety tasks or protocols within the VR environment. 4. Feedback or assessment is provided based on the trainee's performance. 5. Trainee's progress is saved, and they are returned to the main menu or provided with the option to select another module.
Extensions	<ol style="list-style-type: none"> 1. If the trainee struggles to complete safety tasks, additional guidance or tutorials may be provided within the VR environment. 2. Technical issues (e.g., VR equipment malfunction) may require troubleshooting steps or session restarts.
Frequency of Use	Frequency of use depends on the training schedule and requirements of maritime safety education programs, varying from periodic to regular usage.
Status	Operational
Owner	Evangelos Markopoulos, Jenny Lauronen, Mika Luimula, Pihla Lehto, Sami Laukkanen - Maritime Safety Education with VR Technology (MarSEVR) ST Engineering Antycip ²⁵

²⁵ <https://steantycip.com/blog/maritime-safety-education-with-vr-technology-marsevr/>

Priority	High, considering the critical importance of maritime safety education and the potential impact of VR technology in enhancing training effectiveness.
UC-26	Immersive Safe Oceans Technology
Title	Immersive Safe Oceans Technology: Developing Virtual Onboard Training Episodes for Maritime Safety
Description	A paper focusing on the development of virtual reality-based onboard training episodes aimed at enhancing maritime safety. The study explores the innovative use of VR technology to simulate realistic maritime scenarios, providing effective training for crew members. Through immersive experiences, trainees engage in fire drills, emergency procedures, and more, fostering improved safety awareness and preparedness.
Primary Actor	Maritime Crew Member or Trainee
Preconditions	<ol style="list-style-type: none"> 1. Access to the Immersive Safe Oceans Technology (ISOT) virtual onboard training platform. 2. Availability of VR equipment (headset, controllers, etc.). 3. Familiarity with basic operation of VR equipment and software. 4. Understanding of maritime safety protocols and procedures.
Postconditions	<ol style="list-style-type: none"> 1. Completion of virtual onboard training episodes within the ISOT platform. 2. Increased awareness and proficiency in maritime safety procedures. 3. Potential reduction in maritime accidents and incidents.
Main Success Scenario	<ol style="list-style-type: none"> 1. The maritime crew member or trainee accesses the ISOT virtual onboard training platform. 2. Relevant training episodes or scenarios, such as fire drills or man overboard situations, are selected within the VR environment. 3. The crew member engages with the virtual environment, which simulates onboard maritime scenarios. 4. Safety protocols and emergency procedures are demonstrated and practiced within the VR environment. 5. The crew member successfully completes the training episodes and receives feedback on their performance. 6. Upon completion, the crew member demonstrates improved readiness and competency in maritime safety procedures.
Extensions	<ol style="list-style-type: none"> 1. If the crew member encounters challenges in

	<p>executing certain safety procedures, additional guidance or tutorials may be provided within the VR environment.</p> <p>2. Integration with real-world training exercises or simulations may enhance the effectiveness of the virtual onboard training episodes.</p>
Frequency of Use	Frequency of use may vary depending on the training schedule and requirements of maritime crew members, ranging from periodic drills to regular training sessions.
Status	Operational
Owner	Markopoulos, E. and Luimula, M., 2020. Immersive safe oceans technology: Developing virtual onboard training episodes for maritime safety. Future Internet, 12(5), p.80.
Priority	High, given the critical importance of maritime safety training and the potential of immersive VR technology to simulate realistic scenarios and enhance training outcomes.
UC-27	VR tools in conceptual ship design
Title	Application of VR tools in conceptual ship design
Description	Using VR for simulating critical ship operations at the conceptual design stage to evaluate the likely implications of set design parameters and to understand how external factors such as environmental conditions impact the concept design solution.
Primary Actor	Naval Architect or Ship Designer
Preconditions	<ol style="list-style-type: none"> 1. Access to the virtual reality (VR) tools for ship design. 2. Necessary hardware and software for VR design are available and properly configured. 3. Data and specifications relevant to the ship design project are accessible. 4. Familiarity with basic principles of ship design and VR technology.
Postconditions	<ol style="list-style-type: none"> 1. Completion of ship design tasks or objectives within the VR environment. 2. Generation of design concepts or prototypes for further evaluation and refinement. 3. Documentation of design decisions and iterations for future reference.
Main Success Scenario	<ol style="list-style-type: none"> 1. The naval architect or ship designer loads the VR design environment. 2. Relevant ship design parameters and constraints are input into the VR tool. 3. The designer explores and manipulates the virtual ship model using VR controllers or interface. 4. Iterative design changes are made within the VR

	<p>environment, considering factors such as hydrodynamics, stability, and aesthetics.</p> <ol style="list-style-type: none"> 5. Design iterations are evaluated in real-time, with feedback provided through visualizations and simulations. 6. Upon completion, the designer generates documentation or reports detailing the final design concepts or prototypes.
Extensions	<ol style="list-style-type: none"> 1. If design constraints or requirements change during the process, the designer adjusts the parameters accordingly within the VR environment. 2. Collaboration with other stakeholders, such as engineers or clients, may involve sharing the VR design environment or exporting design data for review and feedback.
Frequency of Use	Frequency of use may vary depending on the stage of the ship design project, ranging from occasional to regular usage during the conceptual design phase.
Status	Operational
Owner	Agis, J.G., Brett, P.O., Ebrahimi, A. and Kramel, D., 2020. The potential of virtual reality (VR) tools and its application in conceptual ship design. In Proceedings of the 19th International Conference on Computer Applications and Information Technology in the Maritime Industries (COMPIT'20), Pontignano (pp.123-134).
Priority	High, given the potential impact of VR tools in enhancing the efficiency and effectiveness of ship design processes.
UC-28	Safety Training at Shipyards
Title	Virtual Reality Based Application for Safety Training at Shipyards
Description	The implementation of safety training is conducted to provide knowledge on the importance of safety for its employees. However, the implementation of safety training requires many consumable things such as a lot of Portable Fire Extinguishers (PFE) that increase the operational cost and trigger the environmental pollution. This research aims to design a safety simulation based on VR (virtual reality) to provide an immersive experience for safety training and reduce the training costs. It was obtained that the application of VR technology requires two main devices namely HMD (Head-Mounted Display) and controller. Observations were conducted in the training of conventional safety and health at shipyards and training institutes.
Primary Actor	Shipyards Worker or Trainee

Preconditions	<ol style="list-style-type: none"> 1. Access to the virtual reality-based safety training application. 2. Availability of necessary VR equipment (headset, controllers, etc.). 3. Familiarity with basic operation of VR equipment and software. 4. Safety protocols and procedures relevant to shipyard operations are understood.
Postconditions	<ol style="list-style-type: none"> 1. Completion of safety training tasks or modules within the VR environment. 2. Increased awareness and understanding of safety protocols and procedures. 3. Potential reduction in workplace accidents and incidents.
Main Success Scenario	<ol style="list-style-type: none"> 1. The shipyard worker or trainee accesses the virtual reality-based safety training application. 2. Relevant safety training modules or scenarios are selected within the VR environment. 3. The trainee engages with the virtual environment, which simulates various shipyard hazards and safety protocols. 4. Safety procedures and responses to hazards are demonstrated and practiced within the VR environment. 5. The trainee successfully completes the safety training tasks and receives feedback on their performance. 6. Upon completion, the trainee demonstrates improved awareness and understanding of safety procedures in shipyard environments.
Extensions	<p>If the trainee struggles to understand certain safety concepts or procedures, additional guidance or tutorials may be provided within the VR environment.</p> <p>Integration with real-world safety training exercises or simulations may enhance the effectiveness of the VR-based safety training application.</p>
Frequency of Use	Frequency of use may vary depending on the onboarding process for new workers, periodic safety refresher training, or in response to specific safety concerns or incidents at the shipyard.
Status	Operational
Owner	Wahidi, S.I., Pribadi, T.W., Rajasa, W.S. and Arif, M.S., 2022. Virtual reality-based application for safety training at shipyards. In IOP Conference Series: Earth and Environmental Science (Vol. 972, No. 1, p. 012025). IOP Publishing.

Priority	High, given the critical importance of safety training in shipyard environments and the potential of VR technology to enhance training effectiveness and reduce workplace accidents.
UC-29	Maritime Firefighting and Evacuation Training
Title	Application of VR Technology for Maritime Firefighting and Evacuation Training - A Review
Description	Firefighting and evacuation training are important tasks in maritime education and training, especially for crews working on large passenger ships, to ensure the safety of the vessel, cargo and passengers. With the evolution of virtual reality (VR) technology and the introduction of wearable hardware, a change in paradigm has happened in firefighting and evacuation training where these new technologies are being introduced. This paper serves as a review on the use of VR technology in maritime firefighting and evacuation training, trying to answer the following questions: what is the current state of using VR technology, and what are the research gaps that need to be addressed to further accelerate the implementation of VR? Research shows that other industries have adopted the use of VR technology relatively quickly, but the maritime industry still seems reluctant. As for the research gaps, the physics-based modelling of fire spread is discussed along with two other topics: the lack of immersive solutions for evacuation and the potential for developing search and rescue scenarios onboard a ship.
Primary Actor	Maritime Firefighter or Trainee
Preconditions	<ol style="list-style-type: none"> 1. Access to the virtual reality (VR) technology for firefighting and evacuation training. 2. Availability of VR equipment (headset, controllers, etc.). 3. Familiarity with basic operation of VR equipment and software. 4. Understanding of basic firefighting procedures and evacuation protocols.
Postconditions	<ol style="list-style-type: none"> 1. Completion of firefighting and evacuation training scenarios within the VR environment. 2. Enhanced knowledge and skills related to maritime firefighting and evacuation procedures. 3. Potential improvement in response time and effectiveness during actual emergencies.
Main Success Scenario	<ol style="list-style-type: none"> 1. The maritime firefighter or trainee accesses the VR-based firefighting and evacuation training application. 2. Relevant training scenarios, such as shipboard fires or emergency evacuations, are selected within the VR

	<p>environment.</p> <ol style="list-style-type: none"> 3. The trainee engages with the virtual environment, which simulates maritime fire and emergency situations. 4. Firefighting techniques, evacuation procedures, and safety protocols are demonstrated and practiced within the VR environment. 5. The trainee successfully completes the training scenarios and receives feedback on their performance. 6. Upon completion, the trainee demonstrates improved proficiency and readiness in maritime firefighting and evacuation procedures.
Extensions	<ol style="list-style-type: none"> 1. If the trainee encounters difficulty in executing certain firefighting techniques or evacuation procedures, additional guidance or tutorials may be provided within the VR environment. 2. Integration with real-world training exercises or simulations may further enhance the effectiveness of the VR-based firefighting and evacuation training.
Frequency of Use	Frequency of use may vary depending on the training schedule and requirements of maritime firefighting and emergency response teams, ranging from periodic drills to regular training sessions.
Status	Operational
Owner	Vukelic, G., Ogrizovic, D., Bernecic, D., Glujic, D. and Vizentin, G., 2023. Application of VR technology for maritime firefighting and evacuation training—A review. <i>Journal of marine science and engineering</i> , 11(9), p.1732.
Priority	High, given the critical importance of effective training for maritime firefighting and emergency response, and the potential of VR technology to simulate realistic scenarios and enhance training outcomes.
UC-30	Handling LNG Related Emergency in the Maritime Industry
Title	VR-based Training on Handling LNG Related Emergency in the Maritime Industry
Description	Presents a VR-based training solution designed to enhance the preparedness of maritime personnel in handling LNG-related emergencies. The paper outlines the development and implementation of virtual reality simulations tailored to simulate realistic LNG emergency scenarios. Through immersive experiences, trainees engage in LNG leak detection, fire response, and other critical emergency procedures, fostering improved safety awareness and response capabilities in the maritime industry.

Primary Actor	Maritime Personnel or Trainees
Preconditions	<ol style="list-style-type: none"> 1. Access to the VR-based training platform for handling LNG-related emergencies. 2. Availability of VR equipment (headset, controllers, etc.). 3. Familiarity with basic operation of VR equipment and software. 4. Understanding of LNG (Liquefied Natural Gas) properties and safety protocols.
Postconditions	<ol style="list-style-type: none"> 1. Completion of VR-based training modules on handling LNG-related emergencies. 2. Increased proficiency and readiness in responding to LNG-related incidents. 3. Potential reduction in accidents and incidents involving LNG in the maritime industry.
Main Success Scenario	<ol style="list-style-type: none"> 1. The maritime personnel or trainee accesses the VR-based training platform for LNG-related emergencies. 2. Relevant training modules, such as LNG leak detection or fire response, are selected within the VR environment. 3. The trainee engages with the virtual environment, which simulates LNG-related emergency scenarios. 4. Safety protocols and emergency response procedures specific to LNG handling are demonstrated and practiced within the VR environment. 5. The trainee successfully completes the training modules and receives feedback on their performance. 6. Upon completion, the trainee demonstrates improved readiness and competency in handling LNG-related emergencies in the maritime industry.
Extensions	<ol style="list-style-type: none"> 1. If the trainee encounters challenges in executing certain emergency response procedures, additional guidance or tutorials may be provided within the VR environment. 2. Integration with real-world training exercises or simulations may enhance the effectiveness of the VR-based training on LNG-related emergencies.
Frequency of Use	Frequency of use may vary depending on the training schedule and requirements of maritime personnel involved in LNG operations, ranging from periodic drills to regular training sessions.
Status	Operational
Owner	Liu, Y., Lan, Z., Tschoerner, B., Viridi, S.S., Li, F., Cui, J., Sourina, O., Zhang, D. and Müller-Wittig, W., 2021, September. VR-based Training on Handling LNG Related Emergency in the Maritime

	Industry. In 2021 International Conference on Cyberworlds (CW) (pp. 159-165). IEEE.
Priority	High, given the critical importance of safety in LNG operations and the potential of VR technology to enhance training outcomes and reduce risks associated with LNG handling in the maritime industry.

Table 7 ALLIANCE4XR Use Cases for Grids and Energy

UC-31	VR Based Training of Heavy Duty Crane Operators
Title	VR based training of Operators of Heavy Duty Cranes
Description	<p>Conventionally, training of operators of heavy construction plant and machinery such as heavy-duty cranes is a gradual and long drawn process starting with exposure of trainees to basic principles and design / configuration details of the construction equipment using operations manuals and drawings, which is then followed by demonstration of the operation by experienced personnel before trainees are involved in operation of the machines. In most cases trainees are also required to be certified by some authorized agencies before being deployed on jobs.</p> <p>Construction safety is an important consideration and therefore it is required to be specifically incorporated in the contents of the conventional training programs for operation of construction plant & machinery.</p> <p>The objective of VR based training of heavy-duty crane operators is to provide complete understanding of design/ configuration / control and safety aspects of the machine and impart operations training through an immersive virtual experience. This permits trainees to develop necessary proficiency in operating this critical machine without supervision, so that the trainee can start performing this operation independently on the actual job within a short period of time.</p>
Primary Actor	Equipment / Product Training
Preconditions	VR based training of operators of construction plant and machinery has proved to be effective due to the immersive nature of training, permitting trainees to get real like experience and high level of knowledge retention. This method is also cost effective since it does not involve expensive physical assets and can be repeated several times without major extra cost, also permitting purposeful mistakes by trainees which impresses upon them the implications of these mistakes.

Postconditions	<p>Improvements observed:</p> <ol style="list-style-type: none"> 1. Conversion of a long-drawn training process requiring 30 day's activity based on a 120-page manual into a crisp 30-minute VR based activity for the trainees. 2. Significant increase in trainees' comprehension of crane operations.
Main Success Scenario	<p>Functionalities:</p> <ul style="list-style-type: none"> • Explanation of crane configuration, various components such as boom, crane operator cabin and controls, slings / hook, drive mechanism • Specifications such as lifting capacity, boom radius, boom angle / Crane Make / Model • Description of operational controls • Safety precautions and procedures • Rigging plan, Lifting and installation operations, controlling the swing and other critical aspects • Crane dismantling details and transportation
Extensions	Enhanced awareness of consequences of dangerous / hazardous situations and the means to avoid / mitigate the same.
Frequency of Use	On demand
Status	N/A
Owner	American Fuel & Petrochemical Manufacturers, Houston, TX ExxonMobil, Baytown, TX / Brightline Interactive, Washington DC
Priority	N/A
UC-32	GlobalSim
Title	Cloud-based Crane Training Simulator
Description	<p>Goal: Crane Training Simulator</p> <p>The Cloud simulator allows trainers to introduce students to the equipment and familiarize them with the basic movements and procedures. Students can also prepare for certification by using the Cloud simulator.</p> <p>Each lesson is recorded in full 3D so instructors and students can review performance together with the After-Action review module. Students can practice operating a variety of construction cranes, industrial overhead cranes, and port cranes. Additionally, instructors can create an unlimited number of custom lessons with the GlobalSim built-in scenario editor.</p>
Primary Actor	Equipment / Product Training
Preconditions	The Cloud simulator works with any high-definition display,

	with a VR headset
Postconditions	Improvement observed: reduced time to certification, Reduced the time for employees' access to customer sites/locations.
Main Success Scenario	<ul style="list-style-type: none"> • The software offers a subscription making simulator training more accessible and affordable. • GlobalSim's Cloud includes 10 different crane models of Construction Cranes, Industrial Cranes, Port Cranes • The Cloud simulator can be accessed online, and customers can run the software on their own computer.
Extensions	N/A
Frequency of Use	On demand
Status	N/A
Owner	GlobalSim ²⁶
Priority	N/A
UC-33	Exelon Corporation
Title	Nuclear Pump Room
Description	<p>Goal: simulations of the pump room for practicing in a safe environment</p> <p>The protocols and activities employees must perform in plants are specific, and performing them in the proper sequence is critical. When employees are performing these operations within the plant they may be exposed to radiation, so training is paramount to making sure employees work at maximum efficiency.</p> <p>To train employees, Exelon developed a series of VR simulations and created model equipment so employees could practice in a safe environment the actions they would need to perform quickly in the pump room within their plant.</p>
Primary Actor	Equipment / Product Training
Preconditions	To recreate the vast and complex pump room with a high degree of accuracy. The virtual environment would need to bring together simulations of all the protocols employees would need to follow, the tasks they would need to perform, the equipment they would need to interact with, and the potential hazards they could encounter in the environment.
Postconditions	Improvement observed: eliminated radiation exposure to employee during training and reduced radiation exposure

²⁶<https://www.globalsim.com/globalsim-announces-release-of-cloud-based-crane-training-simulator/>

	during repair through efficiency improvements
Main Success Scenario	<p>Functionalities:</p> <ul style="list-style-type: none"> • Replication of complex pump room and equipment in true-to-life virtual environment • Train in hazardous environment without any risk or radiation exposure • Full scale experience of representative nuclear facility and exact pump replications • Follow critical lockout/tagout protocols • Dismantle and reassemble pumps in proper sequence • Enable spatial awareness and positioning • Conduct specific, random, or rare scenarios • Simulate defects which would be difficult to reproduce in real-world scenarios • Randomize issues with pumps and repair procedures required to address the issue • Create hazardous scenarios without risk to personnel (e.g. fire, explosion, accidental pressure release, falling equipment, etc.) • Trainees are prompted to select appropriate personal protective equipment (PPE) and tools necessary to complete the tasks
Extensions	<p>Future applications in development include the creation of complete exact plant replications for location awareness, hazard recognition, foreign material exclusion, in situ component identification, and various other training scenarios.</p> <p>Training courses to include Line-of-Fire, Seismic Walkdown, Fuel Moves, and Active Shooter and other threat scenarios.</p>
Frequency of Use	On demand
Status	N/A
Owner	Exelon Corporation USA ^{27 28}
Priority	N/A
UC-34	MR Based Remote Assistance in Sub-Stations Operations
Title	MR remote training and assistance in Sub Stations operations
Description	One of the key challenges FactualVR is looking to address is the electric utility workforce that is rapidly retiring and the significant loss of institutional knowledge which has created a vulnerability in the United States electric grid, especially during widespread power outages.

²⁷ https://oberontech.com/wpcontent/uploads/2020/07/Exelon_CaseStudy_OBERON.pdf

²⁸ <https://oberontech.com/solutions/vr-training/>

	To mitigate this challenging problem, FactualVR is developing the HyperTunnel® platform under a U.S. Department of Energy Phase II SBIR award for Advanced Grid Technologies which leverages a limited number of experienced electric utility field personnel to train and/or supervise a larger workforce using a mixed reality remote collaboration system.
Primary Actor	Equipment / Product Training
Preconditions	Enabling field technicians to summon an expert or supervisor for side-by-side guidance and oversight through a shared immersive digital twin, by “teleporting” the expert as a real-time avatar to mimic operations on a shared virtual workspace. This grants the supervisor the ability to observe and understand the actions performed, as well as provide real-time demonstrations to field technicians.
Postconditions	<p>Improvements observed:</p> <ol style="list-style-type: none"> 1. Economic – Cost savings from eliminating traveling time and reduced operational risk from avoiding co-location requirements 2. Commercial – Reduce down-time by leveraging scarce supervisors or experts across multiple remote worksites 3. Technical – Improved quality and efficiency of repairs and upgrades 4. Societal – Faster response during major outages
Main Success Scenario	<p>Functionalities:</p> <ol style="list-style-type: none"> 1. Scanning a remote work site – Leverages input from 3D scanners, cameras and other sensors available through the AR devices at the remote worksite 2. Creating a Digital Twin at HQ – Captured data is used to reproduce an immersive digital twin of the worksite at a central office location 3. Matching and Enhancing the Shared Scenes – Remote worksites and immersive digital twins are synched and enhanced by Computer Vision and Artificial Intelligence 4. Annotating and Demonstrating – Users can interact with simulated components, provide guidance and demonstrate actions in the shared virtual space
Extensions	N/A
Frequency of Use	On demand
Status	N/A

Owner	Large Electric Utility in the North East USA / FactualVR ^{29 30}
Priority	N/A
UC-35	Aggreko and SGAS & LOGIC UK
Title	Equipment / Product Training Practical Assessment
Description	<p>Goal: To virtualize entry level Gas Safety Program</p> <p>Augmented Reality Aggreko created a life size holographic duplicate of the Gas Rig assembly including piping, flanges, gauges and relevant pressures under specific conditions. Using this multiple scenarios could be created with different faults/failures for each scenario that would need to be identified within the experience. This experience is also enabled by Remote “LIVE” session where the student and instructor can communicate over VoIP and the instructor can has a “See what I see” view of what the student is doing</p>
Primary Actor	Equipment / Product Training
Preconditions	To enable online instruction and assessments to be conducted with a trained instructor/ assessor
Postconditions	Improvement observed: reduced time to certification, Reduced the time for employees access to customer sites/locations.
Main Success Scenario	<p>Offers Functionalities such as:</p> <ul style="list-style-type: none"> ● User Management & Single Sign On ● Experience & Audience Grouping & Assigning ● Codeless Authoring & Publishing Tool ● Spatial Positioning ● Live Streamed Session (Experience, Video & Audio) ● Instructor/Assessor in Experience Interactions ● 3D Animations & Interactions ● Step tracking for individual activities in experience ● Available in Holographic view
Extensions	Deployed for Gas Safety Programs and planning further programs for inclusion
Frequency of Use	On demand
Status	N/A
Owner	Aggreko and SGAS & LOGIC UK
Priority	N/A
UC-36	Workforce training through VR Rooms
Title	To revolutionize workforce training in operations of Nuclear Facilities through Virtual Reality Immersive Rooms (VIROO)

²⁹ <https://youtu.be/Qsq9lkck6c0>

³⁰ <https://factualvr.com/demos/>

Description	<p>Current practice: The current practice for workforce training is a physical process of training professionals on the Fuel Movement (FM) Simulator. This physical process is replaced by Virtual Reality Immersive Rooms (VIROO).</p> <p>The objective of FM simulator is to improve capabilities of professionals through intensive training and contribute to the reduction of both costs and risks. The FM VR simulator replicates the complex process permitting multiple users collaborating in 1:1 scale VR nuclear environment. The simulator replicates the process with tactile and haptic feedback. A physical replica of the refuelling mast is connected directly to the virtual environment, so users carry out virtual fuel movement operations as if they were doing so in reality.</p>
Primary Actor	Equipment / Product Training
Preconditions	<p>To train the workforce to help implementation of significant savings opportunities in the most efficient manner. The specific process identified is fuel movement operations, a complex and highly skilled activity requiring high expertise and training, as well as outstanding coordination between the different parties involved during the fuel movement process.</p>
Postconditions	<p>Improvement observed:</p> <p>Due to the strong regulatory controls, nuclear training suppliers normally are limited to traditional OEM companies and a small number of enterprises with nuclear pedigree. On this backdrop, the subject application addresses and avoids following issues which under normal procedures lead to increased costs of this training:</p> <ol style="list-style-type: none"> 1. Necessity of complex mockups which are expensive to be maintained. 2. Physical mockups integrity limits the scope of training (efficiency vs contingency) 3. Training necessities are very specific, sometimes linked to specific site conditions. 4. Mockups are not deployable and consequently training has associated high T&L expenses <p>This initiative improves the capabilities of professionals through intensive training and contribute to the reduction of both costs and risks. In addition, these systems will help nuclear customers to have just-in-time bespoke training solutions on site that will contribute to the reduction of operational costs associated with training and quality issues.</p>
Main Success	<p>Functionalities:</p> <ol style="list-style-type: none"> 1. Replication of all functions of FM Simulator into Virtual

Scenario	<p>Environment.</p> <ol style="list-style-type: none"> 2. Continuous presence of training session manager console with the ability to introduce unplanned failures to challenge the trainees to improve their capability. 3. Provide reply to standard problems faced by trainees during the fuel movement. 4. Ability to reproduce different refuel floor configurations along with a live view station to let the audience and the instructor monitor and supervise the training in real time. <p>These functionalities are incorporated on VIROO Platform which manages the equipment and streamlines the workflow to generate and launch the VR content. This software allows the immersive room to be managed centrally thanks to the following functionalities, any organizations to generate VR content.</p>
Extensions	The solution addresses the ability to be located in strategic hubs around the world interconnected for remote collaboration especially with the threat of restricted travel and social distancing in pandemic situations. The fuel movement VR simulator is part of a new generation of simulators that GE Hitachi in alliance with Virtualware will release for operation during the coming years, not only for the Boiling Water Reactor technology but Pressurized Water Reactor and Decommissioning and Dismantlement as well.
Frequency of Use	On demand
Status	N/A
Owner	General Electric Hitachi Nuclear Energy / Virtualware ^{31 32 33}
Priority	N/A
UC-37	Blue Deal Virtual Reality Educational Experience
Title	Blue Deal Virtual Reality Educational Experience
Description	The Blue Deal Virtual Reality (VR) Educational Experience aims to provide stakeholders in the energy sector with an immersive learning environment to explore and understand Blue Energy technologies. Through a fully 3D virtual world, users can engage with landscapes, ocean systems, and detailed 3D models of Blue Energy technologies, including wind turbines, oscillating buoys, and seabed-based buoys. The user can wear the VR headset and take a look at the Blue

³¹ https://youtu.be/8xJ_qK0nbW0

³² <https://youtu.be/DAaL7hc-75w>

³³ <https://www.virtualwareco.com/news/the-vr-center-university-retono-unveiled/>

	<p>Energy technologies within candidate areas, interact with the environment and listen to information.</p> <p>Goal: The primary goal of the Blue Deal VR Educational Experience is to enhance stakeholders' knowledge and decision-making capabilities regarding Blue Energy technologies by providing a realistic and interactive visualization of their installation and visual impact.</p>
Primary Actor	Energy Sector Professionals, Researchers, Decision Makers
Preconditions	<ol style="list-style-type: none"> 1. Availability of VR headsets and compatible hardware. 2. Access to the Blue Deal VR Educational Experience application. 3. Basic familiarity with VR technology and navigation.
Postconditions	<ol style="list-style-type: none"> 1. Increased understanding of Blue Energy technologies and their visual impact. 2. Enhanced decision-making capabilities regarding the adoption and implementation of Blue Energy projects.
Main Success Scenario	<ol style="list-style-type: none"> 1. User wears the VR headset and enters the Blue Deal VR Educational Experience. 2. User starts the experience on a virtual boat near the Blue Energy Park. 3. Using hand tracking, the user activates narration to learn about the installed technologies. 4. The user boards a virtual hot air balloon for an aerial view of the park, gaining perspective on visual impact. 5. During the flight, the user receives additional information about the technologies and consults the area map. 6. User concludes the experience with a comprehensive understanding of Blue Energy technologies and their visual implications.
Extensions	<ol style="list-style-type: none"> 1. Additional Blue Energy technologies and installation scenarios. 2. Integration of interactive quizzes and assessments to reinforce learning objectives. 3. Expansion of educational content to cover broader energy sector topics and challenges.
Frequency of Use	On demand
Status	Online since 2022
Owner	Blue Deal Med ³⁴

³⁴ <https://bluedealmed.eu/visual-tools>

Priority	N/A
UC-38	VR Solar Farm Visualization Tool
Title	VR Solar Farm Visualization Tool
Description	<p>The VR Solar Farm Visualization Tool is a virtual reality application developed to facilitate the planning and visualization process of solar energy project, particularly the design and assessment of solar farms. Leveraging aerial 3D mapping data and real-time rendering technology, the tool allows stakeholders to explore and interact with virtual solar farm environments in immersive VR simulations, see the potential and observe the visual impact.</p> <p>Useful for:</p> <ul style="list-style-type: none"> • Survey and analyze potential solar farm sites using aerial 3D mapping data. • Optimize solar panel placement for maximum energy efficiency and minimal visual impact. • Visualize the proposed solar farm from various viewpoints and assess its visual impact on surrounding areas. • Facilitate community engagement and gain planning permission by demonstrating the proposed project's appearance in a realistic virtual environment.
Primary Actor	Energy Sector Professionals, Researchers, Decision Makers
Preconditions	<ol style="list-style-type: none"> 1. Availability of VR headsets and compatible hardware. 2. Access to the VR Solar Farm Visualization Tool application. 3. Aerial 3D mapping data of the solar farm site.
Postconditions	<ol style="list-style-type: none"> 1. Enhanced understanding of solar farm design and placement optimization. 2. Improved stakeholder engagement and community acceptance of proposed solar energy projects. 3. Streamlined planning and decision-making process for solar energy projects.
Main Success Scenario	<ol style="list-style-type: none"> 1. User wears the VR headset and launches the VR Solar Farm Visualization Tool. 2. User selects the desired solar farm site and loads the aerial 3D mapping data. 3. Using intuitive VR controls, the user navigates through the virtual environment and explores the terrain 4. The user simulates sunlight exposure and shadow movement to optimize solar panel placement for maximum energy yield.

	<ol style="list-style-type: none"> 5. Virtual tours and interactive simulations allow the user to visualize the solar farm from different viewpoints and times of the day. 6. Based on feedback and analysis, adjustments are made to the solar farm design to address concerns and optimize project feasibility.
Extensions	N/A
Frequency of Use	On demand
Status	Online since 2023
Owner	Private Customer
Priority	N/A

Table 8 ALLIANCE4XR Use Cases for Remote Collaboration

UC-39	ClassVR
Title	Virtual Reality Technology for the Classroom
Description	ClassVR is an open platform, supporting virtual and augmented curriculum content, as well as allowing students and teachers to create, upload and share their own content, creating a collaborative community of global educational resources.
Primary Actor	Students of all ages
Preconditions	<ol style="list-style-type: none"> 1. ClassVR Headset 2. Training and support for the headset features
Postconditions	Enhanced learning outcomes and practical skills development for users across various subjects
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a student using ClassVR Headset.</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Headset set up, including device being charged 2. Installation of ClassVR software 3. Lesson planning and student training on the usage of the equipment <p>For each session scenario the following activities are carried out.</p> <ol style="list-style-type: none"> 4. Students interact with objects related to the field of lesson 5. Students perform virtual experiments in science classes 6. Virtual field trips in areas and landmarks of interest 7. Students work on real world scenarios and get guidance through problem-solving activities using virtual reality tools and resources

	<p>The closing of the maintenance operations consists of the following activities:</p> <ol style="list-style-type: none"> 8. Equipment inspection, cleaning and charging 9. User training on on how to properly use and care for ClassVR equipment, including guidelines for hygiene, safety, and maintenance 10. Update inventory records to reflect any materials or supplies used during the session
Extensions	N/A
Frequency of Use	Weekly
Status	In business since 2017
Owner	Avantis Education
Priority	N/A
UC-40	EON Reality
Title	Augmented and virtual reality technologies for education, training, and industry
Description	Virtual Reality-based experience creation for education and industry as well as the creators of the Knowledge Metaverse
Primary Actor	Students of all ages
Preconditions	<ol style="list-style-type: none"> 1. Environment and hardware setup 2. Training and support for the app features
Postconditions	Enhanced learning outcomes and practical skills development for users across various subjects
Main Success Scenario	<p>Success Scenario: The tasks are carried out by students using either VR technology (headset and controller or Desktop/mobile)</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Equipment set up, including devices being charged (if needed) 2. Installation of EON Reality software 3. Lesson planning and student training on the usage of the equipment and software features 4. Guidance on proper use of any devices and guidelines for breaks and rest periods to prevent discomfort or fatigue 5. Content Selection and environment set up <p>For each session scenario the following activities are carried out.</p> <ol style="list-style-type: none"> 6. Students interact with objects related to the field of lesson 7. Students perform virtual experiments in science classes

	<p>8. Virtual field trips in areas and landmarks of interest</p> <p>The closing of the maintenance operations consists of the following activities:</p> <p>9. Equipment inspection, cleaning and charging</p> <p>10. User training on how to properly use and care for VR/AR equipment (if used), including guidelines for hygiene, safety, and maintenance</p> <p>11. Update inventory records to reflect any materials or supplies used during the session</p>
Extensions	N/A
Frequency of Use	Daily
Status	In business since 1999
Owner	Dan Lejerskar
Priority	N/A
UC-41	Labster
Title	Virtual lab simulations for science education
Description	Labster is a company that develops virtual lab simulations for science education. These simulations allow students to conduct experiments and explore scientific concepts in a realistic, interactive virtual environment.
Primary Actor	Students of the science field, learning through virtual labs
Preconditions	Students need to be aware of the “in-lab” processes and rules
Postconditions	Scientific tasks in lab have been properly carried out.
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a student using a virtual reality headset or through typical web browsers.</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Introducing Labster and why it was chosen 2. Visualize key scientific concepts 3. Prepare for lab experiments using simulations and lab manuals 4. Focus on specific concepts using adapted simulations. <p>For each session scenario the following activities are carried out.</p> <ol style="list-style-type: none"> 5. Student collaboration using editable lab manuals and lab reports. 6. Groups work on organizing and labeling 2D images <p>The closing of the maintenance operations consists of the following activities:</p> <ol style="list-style-type: none"> 7. When the sessions are finalized, students complete a lab report as a post-simulation activity.

	<ol style="list-style-type: none"> 8. Students create a scientific poster to demonstrate understanding. 9. Automatic grading & instructor dashboard allows instructors to provide students detailed feedback
Extensions	N/A
Frequency of Use	Weekly
Status	In business since 2011
Owner	Michael Bodekaer Jensen
Priority	N/A
UC-42	ZSpace
Title	Immersive AR/ VR Learning Solutions
Description	zSpace is a technology that combines elements of virtual and augmented reality in a computer. zSpace mostly provides AR/VR technology to the education market
Primary Actor	Middle schools and higher education students
Preconditions	<ol style="list-style-type: none"> 1. Compatible hardware 2. Training and support on educators for the platform’s features
Postconditions	Enhanced learning outcomes and practical skills development for users across various subjects
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a student using zSpace’s hardware or compatible device.</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Environment setup: Compatibility check, software setup 2. Training on the features and proper use 3. Engagement strategies to promote student participation and collaboration during the session 4. Have technical support resources readily available to troubleshoot any issues that may arise during the session. <p>For each session scenario the following activities are carried out.</p> <ol style="list-style-type: none"> 5. Students interact with objects related to the field of lesson 6. Students perform virtual experiments in science classes 7. Data visualization in order for students to gain insights <p>The closing of the maintenance operations consists of the following activities:</p> <ol style="list-style-type: none"> 8. Use of assessment tools to evaluate student

	<p>understanding</p> <p>9. Feedback from participants regarding their experience during the session, including any technical issues encountered, suggestions for improvement.</p> <p>10. Update inventory records to reflect any materials or supplies used during the session</p>
Extensions	N/A
Frequency of Use	Weekly
Status	In business since 2007
Owner	Paul Kellenberger
Priority	N/A
UC-43	MeetinVR
Title	Virtual collaboration platform
Description	Enterprise meetings in Virtual Reality
Primary Actor	Members of organization/ project/ business
Preconditions	<ol style="list-style-type: none"> 1. Internet connection 2. Familiarity with the platform 3. Being assigned as member of project
Postconditions	Colleagues connect for a remote Virtual meeting
Main Success Scenario	<p>Success Scenario: Colleagues and team members successfully carry out a VR Meeting either with a VR headset, or via PC/ Mac</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Connecting to the internet 2. Logging in the platform (if already signed in) 3. Prepare/ upload any sharable documents <p>For each session scenario the following activities are carried out:</p> <ol style="list-style-type: none"> 4. Participants share task related documents 5. During the session participants make use of (virtual) white board 6. Participants take notes (virtually), related to the meeting's subject
Extensions	N/A
Frequency of Use	Weekly
Status	In business since 2016
Owner	VR Owl Group
Priority	N/A
UC-44	VIVERSE for Business
Title	Virtual collaboration platform
Description	Enterprise meetings in Virtual Reality

Primary Actor	Members of organization/ project/ business
Preconditions	<ol style="list-style-type: none"> 1. Internet connection 2. Familiarity with the platform 3. Being assigned as member of project
Postconditions	Colleagues connect for a remote Virtual meeting
Main Success Scenario	<p>Success Scenario: Colleagues and team members successfully carry out a VR Meeting either with a VR headset, or via PC/ Mac</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Connecting to the internet 2. Logging in the platform (if already signed in) 3. Prepare/ upload any sharable documents <p>For each session scenario the following activities are carried out:</p> <ol style="list-style-type: none"> 4. Participants share task related documents 5. Presentation and/ or training on business related product takes place, with 3D object manipulation 6. Colleagues communicate in the platform with additional Speech-to-Text transcription & translation
Extensions	N/A
Frequency of Use	Weekly
Status	In business since 2022
Owner	Cher Wang
Priority	N/A

Table 9 ALLIANCE4XR Use Cases for AR/VR/MR

UC-45	CALDIC VR EXPERIENCE
Title	Caldic VR experience
Description	The goal of the project is to demonstrate the production and innovation site of the company at the exhibitions, to employees, partners and clients. Work: 360 video shooting, 360 video production, 3D modelling, programming, project management, etc ³⁵ .
Primary Actor	Visitors of the exhibition, employees, partners, clients
Preconditions	No
Postconditions	Users know more about the production and innovation site
Main Success Scenario	Success Scenario: The tasks are carried out by a user using a Meta Quest 2 / 3 virtual reality headset.

³⁵ <https://clutch.co/profile/sensorama#review-268540>

	<p>Scenario:</p> <ol style="list-style-type: none"> 1. Onboarding for new users of VR hardware 2. 360 video of the greetings from CEO 3. 360 video of safety instructions 4. 360 video from the laboratory 5. 360 video from the warehouse 6. 360 video from the drone 7. Interactive part of making and ice cream
Extensions	The main scenario is based on the usage of a Meta Quest 2 / 3 virtual reality headset. AR capabilities are not included in any scenario.
Frequency of Use	Daily usage
Status	Active
Owner	Caldic Europe
Priority	TBD
UC-46	DTEK VR training
Title	DTEK VR training
Description	<p>VR DTEK Training Simulator³⁶ allows to educate newcomers to how to maintain electrical equipment and switchgear. The factory facilities and tools have been accurately reconstructed with the help of 3D modeling. Training also integrated with TeslaSuit haptics feedback; the application enables employees to literally feel every mistake made during the training.</p> <p>Key facts:</p> <ul style="list-style-type: none"> • 3D scanning of equipment and environments • 3D modeling • Instructor interface • Haptic design for full body haptic suit
Primary Actor	Electricians at the company
Preconditions	N/A
Postconditions	Electricians practice virtually how to work with equipment
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a user using a Meta Quest 2 / 3 virtual reality headset.</p> <p>Scenario:</p> <ol style="list-style-type: none"> 1. Onboarding for new users of VR hardware 2. VR training in repair work 3. Exam in VR in repair work

³⁶ <https://youtu.be/xn8q6jNr0hY>

	<ol style="list-style-type: none"> 4. Haptic feedback suit integration 5. Instructor is managing trainings and exams in separate web application 6. Statistics of trainings and exams is demonstrated in web dashboard
Extensions	The main scenario is based on the usage of a Meta Quest 2 / 3 virtual reality headset. The usage of the headset is motivated by the need of using both hands during the scenario. AR capabilities are not included in any scenario.
Frequency of Use	Daily usage
Status	Active
Owner	DTEK
Priority	TBD
UC-47	INDUSTRY 4.0 XR HUB
Title	Industry 4.0 XR HUB
Description	The goal of the project is to demonstrate the possibilities of the circular economy, to conduct a virtual demonstration of the capabilities of the equipment, to have the flexibility to configure production lines virtually to save resources and time, to take virtual tours of geographically remote factories, to conduct training on the use of various equipment and processes, all this with the help of a qualified instructor ³⁷ .
Primary Actor	Visitors of the industrial parks where the system is installed
Preconditions	N/A
Postconditions	Users know more about the circular economy
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a user using a Meta Quest 2 / 3 virtual reality headset.</p> <p>Scenario:</p> <ol style="list-style-type: none"> 1. Onboarding for new users of VR hardware 2. 360 videos gallery 3. Virtual exhibition hall with equipment from different suppliers, including media materials 4. VR training for replacing the battery in an electric car 5. VR training for the robot launch 6. Factory configurator 7. Multiplayer interaction
Extensions	The main scenario is based on the usage of a Meta Quest 2 / 3 virtual reality headset. The usage of the headset is motivated by the need of using both hands during the scenario. AR capabilities are not included in any scenario.

³⁷ https://youtu.be/BUBOZxtU_EE

Frequency of Use	Daily usage
Status	Active
Owner	IT Technologies, EU supported project
Priority	TBD
UC-48	MHP soft skills training
Title	MHP soft skills training
Description	<p>MHP SE, short for Myronivsky Hliboproduct, is a leading Ukrainian agricultural company primarily focused on the production of poultry and the cultivation of grains. It is known for being one of the largest poultry producers in Ukraine, with significant operations extending into international markets.</p> <p>Sensorama developed a VR application for Meta Quest and a mobile version for Android aimed at improving the soft skills of the salespersons at the stores. This training included a realistic 3D environment of the store and a simulation of dialogue with different customer personas. Trainees were prompted to talk to the customers using voice recognition technology. The project encompassed training and exam mode where users would get points if they talked to the customers correctly ^{38 39}.</p>
Primary Actor	Sellers at branded stores
Preconditions	N/A
Postconditions	Sellers learn and pass a virtual exam on communication skills with customers on sales skills.
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a user using a Meta Quest 2 / 3 virtual reality headset.</p> <p>Scenario:</p> <ol style="list-style-type: none"> 1. Onboarding for new users of VR hardware 2. Demonstration in VR of correct interactions with clients 3. Soft skills VR training session 4. Results of the VR training session
Extensions	The main scenario is based on the usage of a Meta Quest 2 / 3 virtual reality headset. The usage of the headset is motivated by the need of using both hands during the scenario. AR capabilities are not included in any scenario.
Frequency of Use	Daily
Status	Active

³⁸ <https://youtu.be/ClklspNmNjw>

³⁹ https://clutch.co/profile/sensorama?sort_by=date_desc#review-274571

Owner	MHP
Priority	TBD
UC-49	Servier virtual training solution
Title	Servier virtual training solution
Description	The goal was to create a platform that would help with educating medical staff in a faster and more efficient way. We've created an application that allows us to conduct consultations both offline and online with a virtual human being that has specific medical indicators within a clinical case. Therefore, the virtual patient has to be consulted together with a speaker (moderator) and prescribe a treatment ⁴⁰ .
Primary Actor	Medical staff at the training sessions
Preconditions	N/A
Postconditions	Medical staff practice virtually to conduct consultations for a virtual human being that has specific medical indicators within a clinical case.
Main Success Scenario	<p>Success Scenario: The tasks are carried out by a user using web and mobile versions of the product.</p> <p>Scenario:</p> <ol style="list-style-type: none"> 1. Admin customizes virtual consultation 2. Admin adds users to the CMS 3. User receives invitation to virtual consultation 4. User is logging in to the system 5. User goes through virtual consultation 6. Statistics are collected and demonstrated in the dashboard
Extensions	The main scenario is based on the usage of a web based and mobile (android, iOS) versions of the solution.
Frequency of Use	Daily
Status	Active
Owner	Servier
Priority	TBD
UC-50	VictoryXR
Title	Augmented and virtual reality technologies for education, training, and industry
Description	Learn through virtual and augmented reality
Primary Actor	Students of all ages
Preconditions	<ol style="list-style-type: none"> 1. Environment and hardware setup

⁴⁰ <https://clutch.co/profile/sensorama#review-41867>

	2. Training and support for the app features
Postconditions	Enhanced learning outcomes and practical skills development for users across various subjects
Main Success Scenario	<p>Success Scenario: The tasks are carried out by students using either VR technology (headset and controller or Desktop/mobile)</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Equipment set up, including devices being charged (if needed) 2. Installation of VictoryXR software 3. Lesson planning and student training on the usage of the equipment and software features 4. Training and support for educators to effectively use VR technology in the classroom 5. Content Selection and environment set up <p>For each session scenario the following activities are carried out.</p> <ol style="list-style-type: none"> 6. Students interact with objects related to the field of lesson 7. Students perform virtual experiments in science classes 8. Virtual field trips in areas and landmarks of interest <p>The closing and the maintenance operations consists of the following activities:</p> <ol style="list-style-type: none"> 9. Emphasis on device cleaning and sanitization 10. Specialized training and support for educators 11. Documentation related to educational outcomes and curriculum integration
Extensions	N/A
Frequency of Use	Daily
Status	In business since 2016
Owner	Steve Grubbs
Priority	N/A
UC-51	Equipment Maintenance
Title	Equipment Maintenance
Description	The objective is to carry out maintenance operations at facilities according to a maintenance plan. The facility may for instance be a pumping station and the maintenance operations may for instance be to lubricate some components.
Primary Actor	A maintenance operator (MO), for instance a network operator

	or a person from security services (watchmen).
Preconditions	According to the maintenance plan, maintenance operations shall be carried out on some equipment at the facility being visited.
Postconditions	Maintenance operations have been properly carried out.
Main Success Scenario	<p>The maintenance operations are carried out by a MO, by the support of a tablet and an app, see figure 1.</p> <p>The preparatory session consists of the following activities</p> <ol style="list-style-type: none"> 1. Before going on the mission, the MO loads necessary data (BIM models, instructions, maintenance schedule, maintenance report forms etc.) on the tablet. 2. When arriving to the facility, the maintenance operator (MO) enters the facility and checks on an app which maintenance operations are scheduled for this site. 3. Necessary equipment to be used for maintenance is to be localized. This includes for instance finding a grease gun and suitable grease for lubrication. If required, instructions of how to use the equipment can also be displayed by the app. 4. Localization of item to be maintained. A tablet is mounted on a tripod and the camera is switched on. The AR software is aligning the image from the camera with a BIM model of the facility (registration). The item to be maintained is marked on top of the integrated camera / BIM model. 5. If needed, the tripod may be repositioned for better visibility of the item to be maintained. In such a case, a new registration of the tablet needs to be calculated. 6. When proper item to be maintained is localized, the maintenance operations starts. If required, instructions can be visualized on the tablet. <p>The closing of the maintenance operations consists of the following activities</p> <ol style="list-style-type: none"> 7. When the maintenance operations are finalized, a maintenance report is filled in, supported by an activity log file.
Extensions	The main scenario is based on the usage of a tablet with AR software. The usage of a tripod is motivated by the need of using both hand during the maintenance operations. Another option is to use AR glasses. In such a case, the procedure for registration is different. It is also not investigated to what

	<p>extent the AR glasses can be used for displaying instructions. In case the registration is not accurate or reliable enough, the MO should be notified about that and new registration procedure should be initiated.</p> <p>In case instructions, forms or other information is missing, there should be an option of downloading such data on site. The use case requires a BIM for registration of the tablet. If no suitable BIM is available, it must be established. The simplest way to do that may be to focus only on registration points required for the AR and measure them using indoor surveying methods (total stations, intersection from two theodolites etc). This process may be described as another use case.</p>
Frequency of Use	Once a week
Status	Requirement analysis not yet started
Owner	Anders Östman for requirement analysis
Priority	TBD
UC-52	Sewer inspection and cleaning
Title	Sewer inspection and cleaning (from BP Sewer inspection and cleaning)
Description	<p>The aim of this process is the execution of physical works done on a site, finalized to make again fully operational a part of the sewer network. It implies inspections through camera and cleaning.</p> <p>Sewer Inspection and Cleaning request comes from the BP Field Interventions Management as well as from the BP Real Time Network Management.</p>
Primary Actor	WW Network Manager, WW Network Operator
Preconditions	According to the procedures for sewer network management plan, operations shall be carried out on some equipment at the facility being visited.
Postconditions	Network operations have been properly carried out and sewer networks work properly again
Main Success Scenario	<p>Each task starts from a WO (work order – issued by the “BP field interventions management” or “BP Real Time Network Management”) and finishes either by the completion of the job or a report explaining the reasons why it was not possible to complete the job.</p> <p>Field interventions are carried out by WW Network operators, under the supervision of WW Network Manager, by the support of camera for video inspections, a tablet accessing the Network Information System of the utility company.</p>

	<p>The preparatory session consists of the following activities</p> <ol style="list-style-type: none"> 1. Request of intervention by the Process Control Technician, having noted a failure in the drainage system or by WW Network Manager as ordinary maintenance 2. Preparation of the team for field interventions and of the needed equipment 3. Before going on the field, the WW Network Operator loads on the tablet necessary data from the Network Information System, in case they were not accessible via web services. 4. When arriving on site, the WW Network Operator analyses the situation of the network and surrounding area and looks for the problem, as communicated by the BP Real Time Network Management. 5. Positioning of the equipment in manholes and pipes (e.g. video camera) for inspection and to collect data on drain conditions. Network Information System supports the operator providing data on the network and its main components. 6. Report about network conditions, accompanied with a video, where it is detailed the state of the sewer inspected, with a list of the malfunctions detected, its description and position in the sewer. 7. Planning of maintenance interventions, according to the failure detected with the inspection and supported by the NIS 8. Field intervention of network cleaning, which involves a hydrojet vehicle for undertaking remedial and preventive works: cleaning, draining, pumping out sewerage systems. If needed cleaning of manholes from insects and spraying to prevent. <p>The closing of the maintenance operations consists of the following activities</p> <ol style="list-style-type: none"> 9. Network works properly. This process can also report abnormalities found in installations, for which structural field interventions are needed.
<p>Extensions</p>	<p>The main scenario is based on the usage of a tablet with AR software. AR software is useful to support video inspection and to visualize hidden parts of the network.</p> <p>The usage of a tripod is motivated by the need of using both hand during the maintenance operations. Another option is to use AR glasses. In such a case, the procedure for registration is</p>

	<p>different. It is also not investigated to what extent the AR glasses can be used for displaying instructions.</p> <p>In case the registration is not accurate or reliable enough, the Network Operator should be notified about that and new registration procedure should be initiated. In case instructions, forms or other information is missing, there should be an option of downloading such data on site.</p>
Frequency of Use	Once/ Twice a week
Status	Requirement analysis not yet started
Owner	GISIG for requirement analysis
Priority	TBD
UC-53	Public Services – Indication of a House Connection location
Title	Public Services – Indication of a House Connection location (from BP Public Services – Management of permissions for sewers connections)
Description	<p>The aim of this process is the indication of a House Connection Location when it is not possible via a conventional process. When localization of a HC is finalized the works of connecting a premise with the main sewer network can be executed.</p> <p>Indication of a HC location request comes from the BP Public Services – Management of permissions for sewers connections.</p>
Primary Actor	WW Network Manager, WW Network Operator
Preconditions	According to the procedures for sewer network management plan, the premise must be visited and localization of a HC must be carried out.
Postconditions	The HC of the visited premise has been located and works of connecting the premise with the main network can be executed.
Main Success Scenario	<p>Each task starts from a WO (work order – issued by the “BP Public Services – Management of permissions for sewers connections”) and finishes either by the completion of the job or a report explaining the reasons why it was not possible to complete the job.</p> <p>Field interventions are carried out by WW Network operators, under the supervision of WW Network Manager, by the support of camera for video inspections, a tablet accessing the Network Information System of the utility company.</p> <p>The preparatory session consists of the following activities:</p> <ol style="list-style-type: none"> 1. Request of intervention by the Network Manager,

	<p>having received a note for a HC not possible to locate.</p> <ol style="list-style-type: none"> 2. Preparation of the team for field interventions and of the needed equipment 3. Before going on the field, the WW Network Operator loads on the tablet necessary data from the Network Information System, in case they were not accessible via web services. 4. When arriving at the premise, the WW Network Operator analyses the situation of the network and surrounding area and looks for the problem, as communicated by the BP Management of permissions for sewers connections. 5. Positioning of the equipment in manholes and pipes (e.g., video camera) for inspection and collection of necessary data. Network Information System supports the operator providing data on the network and its main components. 6. Report about network conditions, accompanied with a video, where it is detailed the state of the main sewer in front of the premise. 7. Report whether according to the main pipe inspection the HC was located. <p>The closing of the operation consists of the following:</p> <ol style="list-style-type: none"> 8. HC located. Works for the connection with the main pipe can be executed.
Extensions	<p>The main scenario is based on the usage of a tablet with AR software. AR software is useful to support video inspection and to visualize hidden parts of the network.</p> <p>The usage of a tripod is motivated by the need of using both hands during operation. Another option is to use AR glasses. In such a case, the procedure for registration is different. It is also not investigated to what extent the AR glasses can be used for displaying instructions.</p> <p>In case the registration is not accurate or reliable enough, the Network Operator should be notified about that and new registration procedure should be initiated. In case instructions, forms or other information is missing, there should be an option of downloading such data on site.</p>
Frequency of Use	Once/ Twice a week
Status	Requirement analysis not yet started
Owner	SBN for requirement analysis
Priority	TBD

UC-54	Applied Research using AR
Title	Applied Research (from BP Academic sector – Applied research using AR technology)
Description	The aim is to develop and test a Monitoring System of a Water Supply Network by equipping the water supply infrastructures with appropriate sensors in order to detect leakages in real time.
Primary Actor	Researcher, Lecturer in Civil and Surveying Engineer
Preconditions	When a leakage occurs, it is detected and positioned by sensors in a sensor network. The leakage will then be fixed quickly to avoid extra network damages and water loss.
Postconditions	Network operators fix the leak and the network works properly again
Main Success Scenario	<p>The main success scenario consists of three parts. In the first part (design of sensor network), a specific pilot area is selected, based on certain requirements and then a dedicated algorithm is utilized to specify the optimal positions for installing noise sensors. In the second part (establishment of a GIS database), a GIS system is developed where information about the water network in the pilot area (location, pipes, materials, etc.) is recorded. In the third part (water supply network monitoring), real-time measurements of the sensors are recorded leakages are detected and positioned. The position of a leakage is estimated by correlation of the noise signals from the sensors surrounding the leakage. In case of a leakage, an Augmented Reality (AR) application (to be developed) will support the repair of the leakage by visualising the location of underground networks in the neighbourhood of the leakage (e.g., telephony, electricity, sewage) to avoid causing collateral damages.</p> <p>Specifically:</p> <p>Part1: Design and installation of sensor network</p> <p>The first part of this scenario follows the phases below:</p> <ul style="list-style-type: none"> ● Phase 1: Identification of the pilot area based on certain requirements. ● Phase 2: An optimization-based algorithm is executed for selecting the best positions for installing the noise sensors. <p>Part2: Establishment of a GIS database</p> <ul style="list-style-type: none"> ● Phase 3: Insert the positions of the pipes as well as the positions of the sensors of the pilot area in a Geographic Information System (GIS) system developed to serve

	<p>the aforementioned purposes. In addition, information about other underground utility networks is also inserted.</p> <p>Part 3: Water supply network monitoring</p> <ul style="list-style-type: none"> ● Phase 4: Sensor readings testing: Sensor data are downloaded/streamed and any leakages appear on the GIS. ● Phase 5: Develop and use a dedicated AR application. The AR development goals are as follows: <ol style="list-style-type: none"> 1. Illustrate to the user the pipes that exist at the point of interest. 2. Provide information/characteristics of pipes such as depth, cross section, duct type, duct material, etc. 3. Illustrate the layout of the ducts in a 3D-space so as the user has a better understanding of the current situation 4. Provide interaction to aid the users to resolve any problems. <p>The AR application is designed following the operational requirements identified in collaboration with the Water Supply Networks involved in the project (end users).</p> <p>The main requirements of the AR application are presented below:</p> <ul style="list-style-type: none"> ● Visualise the positions of the pipes in an AR environment. ● Determine the position and orientation of the observer (AR device) through a GNSS/IMU device or by measuring control points. ● Download information/characteristics of the pipes and sensors to the AR database ● Download information of other public utilities which exist in the pilot area to the AR database ● View real-time information of pipelines and sensor recordings and correlation processing ● Interact with the application <p>The application will be easy and simple to use, with high levels of aesthetics (e.g., colours, backgrounds, pipelines, etc.) and realism (shapes and textured substrates and conductors close to their actual shape) elements.</p>
Extensions	<p>The main scenario is based on the usage of a tablet or mobile phone with AR application. AR software is useful to visualize the stream data of the sensors as well as the information of the pipes.</p>
Frequency of	<p>Once a day</p>

Use	
Status	Requirements analysis ongoing
Owner	CUT
Priority	TBD
UC-55	Procurement
Title	Procurement
Description	The goal of this use case is to prepare documents which are required for decisions about investments in AR technologies.
Primary Actor	The primary actor is a procurement manager
Preconditions	Interests in investments in AR technologies has been raised within the organization
Postconditions	A decision has been made if investments in AR technologies should be within a certain time frame made or not.
Main Success Scenario	<ul style="list-style-type: none"> • A request for investments in AR technologies arrives to the procurement division. If there is a general interest in such investments, a pilot study is conducted where experiences are described, and potential costs and benefits are identified. A draft implementation plan may also be outlined. • In case an investment is found to have a good potential for success, the analysis is made more detailed, and outstanding implementation aspects are analyzed.
Extensions	An extension may be to contract subcontractors, either for the preparation of documents, for the implantation of the technologies or for procurement of AR services.
Frequency of Use	Around once every 3 – 5 years in each organization
Status	Requirement analysis not yet started
Owner	Anders Östman for requirement analysis
Priority	TBD
UC-56	WWTP management
Title	WWTP management
Description	The goal of WWTP management is to propose and implement human and technical actions appropriate to improving the current and future situation of water production or wastewater treatment at a plant in such a way that they are in compliance with the regulator's requirements. This process involves supervising the staff and organizing the activities at the plant, analysing plant operations and identifying potential improvements to the plant. The suggested changes and improvements need to be implemented by the plant management and also be assessed and approved by the regulators.

Primary Actor	WW Plant manager
Preconditions	An inefficiency or potential for improvement of processes is identified at a wastewater treatment plant. Proposals and plans to solve the inefficiency and to implement the potential improvements need to be developed to such a stage that they can be shown outside of the project team. Or the solutions are already implemented and are ready for evaluation.
Postconditions	A new technical solution or new way of working is implemented allowing to improve the efficiency and effectiveness of the treatment plant and is approved by the regulators.
Main Success Scenario	<p>The main success scenario of this use case consists of the successful demonstration and approval of the proposed/planned or implemented solutions by the project team, the company’s management and the regulator. The way of working with augmented reality will be successful when it is able to reduce the amount of manhours needed to assess the new solutions through reducing the need for the number of people to be directly on site and by allowing quicker understanding and insight into the proposed solutions.</p> <p>A meeting or several meetings and field visits need to be performed to come to the decision for approval of the possible solutions or to get approval for the implemented solution. The use of augmented reality goggles allows for two improvements to the field visits which can also be combined into one format.</p> <ol style="list-style-type: none"> 1. One improvement would be to use augmented reality goggles to compare plans of the solutions to the existing plant both in a planning stage where solutions still need to be implemented and at a final approval stage where solutions are implemented but where for approval the implementation also needs to be compared to how it was approved on plans. <ol style="list-style-type: none"> a. Preparation consists of uploading a BIM or plans attached to a particular “activation zone” (if the user is in this zone the attached plan will be shown on the goggles). If available extra information sheets for more detailed explanations can also be uploaded. b. The session itself consists of members of the project team, management team and/or the regulator team visiting the site and using the AR goggles to during the

visit discuss the solutions while getting a side by side comparison of reality and plans through the goggles. A connection between the goggles could allow the session organizer to share the same view and information with everybody to ensure that the whole group is discussing the same topic. Pointers could also be added to draw attention to specific things being talked about.

c. The session is finalized by summarizing the conclusions and recommendations from the field visit. The field visit could result in either approval of the solutions, further meetings or even more field visits to discuss the solutions and implement further improvements or changes necessary to get approval.

2. A second improvement would be the use of AR goggles to allow remote inspection of a site during a meeting discussing the proposed solution or at an approval meeting.

a. The preparatory steps include sending someone in the field to the inspection location with a camera or AR goggles and a good data connection to the meeting room (existing infrastructure or a portable transmitter). Extra information about a structure such as technical forms can be shown through the AR goggles. The person either preuploads the information or uses services to get extra information (plans, BIM, ...) in his AR goggles. A meeting is setup with stakeholders which combines the preparatory meeting for the field visit, the field visit and the follow-up meeting after the field visit.

b. During the session the stakeholders in the meeting room follow the field inspection by the person on site with the AR goggles. The people in the meeting room see what the person in the field sees, including the extra information displayed through the AR goggles. and can talk with the person in the field. The stakeholders at the meeting can display pointers on the AR goggles to highlight something to the person in the field while also displaying additional information which is shown or discussed by the people in the meeting room. The person onsite can participate in the meeting while the number of necessary movements is kept to a minimum.

	<p>c. The session is followed by the normal follow-up meeting after a field visit allowing to reduce the number of meetings. It will also allow to immediately go from the field visit to the conclusions which result in either approval or recommendations for the changes necessary to get approval. A follow-up field visit using the same system can be used to evaluate the changes and assess whether with the changes the installation can be approved.</p>
Extensions	A possible extension would be to add functionality where the user is able using the information from plans and BIM-models to see what infrastructure (pipes, installations) is behind walls, under water or at other places which are normally not visible during a field inspection.
Frequency of Use	5 times a year, each time a new plant is built or renovated
Status	Requirements analysis not yet started
Owner	VMM
Priority	TBD
UC-57	Public Services – WW Leakage Detection
Title	Public Services – WW Leakage Detection (from BP Public Services – Management of permissions for sewers connections)
Description	This process includes the execution of physical works on a pipe or MH, aiming the restoration of it and prevention of leakage of WW. Pipe or MH leakage request comes from the BP Public Services – Management of permissions for sewers connections.
Primary Actor	WW Network Manager, WW Network Operator
Preconditions	According to the procedures for sewer network management plan, operations must be carried out on site in order for the leakage to end and the network to work properly.
Postconditions	Network operations have been carried out and sewer network work properly again
Main Success Scenario	<p>Each task starts from a WO (work order – issued by the “BP Public Services – Management of permissions for sewers connections”) and finishes either by the completion of the job or a report explaining the reasons why it was not possible to complete the job.</p> <p>Field interventions are carried out by WW Network operators, under the supervision of WW Network Manager, by the support of camera for video inspections, a tablet accessing the</p>

	<p>Network Information System of the utility company.</p> <p>The preparatory session consists of the following activities</p> <ol style="list-style-type: none"> 1. Request of intervention by the Network Manager, having received a note for WW leakage. 2. Leakage might be the result of a broken pipe or blockage of pipe/HC 3. Preparation of the team for field interventions and of the needed equipment 4. Before going on the field, the WW Network Operator loads on the tablet necessary data from the Network Information System, in case they were not accessible via web services. 5. When arriving on site, the WW Network Operator analyses the situation of the network and surrounding area and looks for the problem, as communicated by the BP Management of permissions for sewers connections. 6. Positioning of the equipment in manholes and pipes (e.g., video camera) for inspection and collection of necessary data. Network Information System supports the operator providing data on the network and its main components. 7. Report about network conditions, accompanied with a video, where it is detailed the state of the pipe or MH or HC. 8. Report on the cause of leakage – Broken main sewer/HC or blocking of pipe or HC, including description and position of breakage or blocking and/or other malfunctions detected 9. Planning of maintenance interventions, according to the failure detected with the inspection and supported by the NIS 10. Field intervention for pipe repairing, which might involve works of excavation and replacement/repairing the broken part, or intervention for pipe unblocking as per UC4. If needed cleaning of manholes from insects and spraying to prevent. <p>The closing of the operation consists of the following:</p> <ol style="list-style-type: none"> 11. Leakage restored. Network works properly. This process can also report abnormalities found in installations, for which structural field interventions are needed.
<p>Extensions</p>	<p>The main scenario is based on the usage of a tablet with AR software. AR software is useful to support video inspection and</p>

	<p>to visualize hidden parts of the network.</p> <p>The usage of a tripod is motivated by the need of using both hands during operation. Another option is to use AR glasses. In such a case, the procedure for registration is different. It is also not investigated to what extent the AR glasses can be used for displaying instructions.</p> <p>In case the registration is not accurate or reliable enough, the Network Operator should be notified about that and new registration procedure should be initiated. In case instructions, forms or other information is missing, there should be an option of downloading such data on site.</p>
Frequency of Use	Once/ Twice a month (TBC)
Status	Requirement analysis not yet started
Owner	SBN for requirement analysis
Priority	TBD

7.4 APPENDIX 4 Detailed description of learning material

Table 10 ALLIANCE4XR Learning Material for Higher Education Institutions

LM-01	FLAME – Facilitated Learning with Animated Multi-media Engagement
Learning Objective	FLAME aims to empower educators to create online 3D interactive material to support learning rather than accept limited materials burdened by fees and vendor lock-in (e.g., 3DEXPERIENCE, Jigsaw, H5P). A clear gap exists in availability, accessibility, and cost of interactive learning materials.
Target Audience	Lectures and students in engineering in higher level education.
Content Type	WebXR – browser-based 3D models and interactivity (FLAME Summer workshop Showcase ⁴¹)
Learning Outcomes	<ul style="list-style-type: none"> • Competencies with engineering principles, design, testing, validation, reporting, immersive technologies. • Concepts related to 3D modelling, texturing, animation, rendering, HTML and JavaScript. • A new Brightspace module to teach deployment of interactive 3D media. • Establish the Digital Library. • Physical artefacts to link online learning to

⁴¹ <https://nolankucd.github.io/FLAME/showcase.html>

	<p>physical touch.</p> <ul style="list-style-type: none"> Establish and disseminate effectiveness of produced material to a wider educator audience.
Key Concepts	Using immersive technologies to enhance engineering in higher level education.
Interactive Elements	The creation of several 3D models with animations
Media Assets	3D models and 360 images
Accessibility Features	N/A
Technical Requirements	3D models created using Blender. Final assets available using desktop and laptop devices.
Integration with LMS	Brightspace module with a library of 3D assets. Built-in analytics.
LM-02	Training Wind Turbine Engineers using Virtual Reality Training Experiences (WMC Galway)
Learning Objective	The aim of this course is to create fresh opportunities for training and upskilling students using high-quality enhanced-learning skills embedded into state-of-the-art Virtual Reality imaging tools.
Target Audience	Undergraduate student learners
Content Type	VR (6DOF)
Learning Outcomes	The focus will be on the training requirements for Wind Turbine Engineers as it is relevant to both the onshore and offshore renewable wind energy generation. The Training developed will have applicability across other renewable energy disciplines and technologies and the potential for deployment across other industries and sectors in the future.
Key Concepts	The training is centred on reacting to disaster relief in a confined space. The user is given a choice to react on the spot to a potential life-threatening fire. The unique pathways implemented into the scenario allow the user to make their own decisions in a safe environment. The experience is guided by a voiceover to ensure they can be fully immersed in and focused on the experience, looking around and learning in a natural way – just like it would happen in the real world.
Interactive Elements	VR Scenarios
Media Assets	3D and 360 assets for demonstration purposes.
Accessibility Features	N/A
Technical Requirements	Some materials for VR headsets but training material

	found online.
Integration with LMS	Planned Moodle Module
LM-03	Virtual Reality Welding Training Simulator (Dundalk Institute of Technology)
Learning Objective	Virtual reality welding trainers for dual users simulates welding for hands on welding training for two students at a time on one machine.
Target Audience	Undergraduate student learners
Content Type	VR
Learning Outcomes	The focus will be on the training requirements for Wind Turbine Engineers as it is relevant to both the onshore and offshore renewable wind energy generation. The Training developed will have applicability across other renewable energy disciplines and technologies and the potential for deployment across other industries and sectors in the future.
Key Concepts	Replicates proper machine set-up using a Welding Procedure Specification. Students must select gas type, process, gas flow, amperage/voltage and wire-feed speed in the system. Tracks and scores key weld parameters including work angle, travel angle, travel speed, distance and position.
Interactive Elements	VR Scenarios with welding tools
Media Assets	3D Environments
Accessibility Features	N/A
Technical Requirements	Some materials for VR headsets but training material found online.
Integration with LMS	Moodle Module
LM-04	Innovation Academy UCD: Virtual Reality for Future Skills
Learning Objective	This module utilises VR to develop and practise transversal skills. Participants progress through a multi-stage immersive VR experience completing tasks, making decisions, and exercising their critical faculties in a virtual workplace. The VR experience replicates a real-world enterprise, allowing participants to identify their areas of strength and tackle realistic workplace challenges in a safe environment.
Target Audience	The programme was developed in 2021, piloted in the academic year 2022-23 and is now a fully accredited 5 ECT elective module for Undergraduate students in UCD.

Content Type	A mix of teaching and learning activities including VR.
Learning Outcomes	Students use VR to become more aware of and using individual strengths, developing capacity for creative thinking, fostering innovation and curiosity, adopting an entrepreneurial and growth mindset, applying critical and analytical thinking to support decision making, effective communication and strategic thinking.
Key Concepts	Using immersive technologies to enhance future skills.
Interactive Elements	VR rooms with specific themes related to customer relations, recruitment, and marketing.
Media Assets	3D rooms with premade scenarios
Accessibility Features	N/A
Technical Requirements	Quest 2 or Quest 3 devices.
Integration with LMS	Brightspace module. Built-in analytics.
LM-05	UCD School of Computer Science: Augmented and Virtual Reality (COMP3025J)
Learning Objective	<p>The course will cover recent developments in the field and teach the fundamental foundations of Mixed Reality, which combines both fields. The course material includes:</p> <ul style="list-style-type: none"> • History of Augmented and Virtual Reality (AR/VR) • Display technologies to produce AR/VR environment (Reality-Virtuality continuum) • Tracking technologies • 3D Reconstruction • 3D Printing • VR/AR Game Engines • Mobile AR/VR • CAVE VR Environments • VR HMD • 3D photogrammetry • Computer vision fundamentals • Case study on Medical VR/AR applications • Case study on Educational VR/AR applications
Target Audience	Undergraduate Computer Science students in UCD.
Content Type	A mix of teaching and learning activities including AR and VR.
Learning Outcomes	Acquire knowledge of fundamental techniques to produce VR and AR applications. The student will have knowledge of the latest developments in VR/AR and the competence to improve on this

	understanding in the future. They will also be exposed to the fundamental concepts of image processing used in VR/AR applications.
Key Concepts	Exploring the fundamental foundations of MR
Interactive Elements	Teaching and learning material found here ⁴² .
Media Assets	3D and 360 assets for demonstration purposes.
Accessibility Features	N/A
Technical Requirements	Some materials for VR headsets but training material found online.
Integration with LMS	Brightspace module. Built-in analytics.

Table 11 ALLIANCE4XR Learning Material for Vocational Education and Training

LM-06	Pulse XR (Education Training Board – Ireland)
Learning Objective	Pulse XR offers an immersive experience that transports healthcare assistance students into a virtual hospital setting. Here, they encounter a variety of patient care scenarios, each designed to hone their clinical skills, critical thinking, and decision-making abilities. The VR environment replicates the sights, sounds, and the stress of a real-world clinical setting, but without the risk of harm to actual patients.
Target Audience	Students training to be healthcare professionals.
Content Type	VR
Learning Outcomes	Improve clinical skills, critical thinking, and decision-making abilities using a VR environment
Key Concepts	Using immersive technologies to enhance healthcare training in VETs.
Interactive Elements	3D environment with added scenarios
Media Assets	3D models and 360 images
Accessibility Features	N/A
Technical Requirements	A Quest 2 or 3 headset
Integration with LMS	Online module accessible through Moodle. Built-in analytics.
LM-07	BodySwaps⁴³
Learning Objective	Students are required to complete various scenarios to earn digital badges. Students are faced with several challenges including interview training, and conflict resolution.

⁴² https://drive.google.com/drive/folders/15u_YRRuuHCn0twydgBwMMYdGcSusM4GA

⁴³ <https://bodyswaps.co/>

Target Audience	Mechanical and Manufacturing Student Engineers
Content Type	VR simulations
Learning Outcomes	Students are competent in soft skills like interviews and conflict resolution.
Key Concepts	<ul style="list-style-type: none"> • Interpersonal, communication. • Interaction with immersive environments. • Using immersive technologies to enhance education.
Interactive Elements	Quizzes, simulations, practice
Media Assets	PPT, notes, images
Accessibility Features	N/A
Technical Requirements	Meta Quest 2 or 3 VR headset. Individual licenses.
Integration with LMS	Not supported. Built-in analytics.
LM-08	Gadgeteer⁴⁴
Learning Objective	Students are taught engineering principles through the VR Gadgeteer app. The app is based on the Rube-Goldberg machine (a machine that achieves a simple task through an overly complicated process). Students must traverse a pre-defined space using a combination of tools/objects to the end location. Engineering principles are taught along the way such as pendulums, catapults, push mechanism and more. Students must use a minimum of 10 pre-defined tools to reach the goal, and the final Machine has to run at an 80% success rate at the end of the semester's evaluation by the lecturers. The module also provides students with a gradual introduction to VR.
Target Audience	Mechanical and Manufacturing Student Engineers
Content Type	VR
Learning Outcomes	Competencies with engineering principles, design, testing, validation, reporting, immersive technologies
Key Concepts	<ul style="list-style-type: none"> • Interaction with immersive environments and their limitations. • Using immersive technologies to enhance education
Interactive Elements	Creating a fully interactive and immersive environment that allows the user to start a complex process and perform an E-Stop when require.
Media Assets	Off-the-shelf application
Accessibility Features	N/A
Technical Requirements	Meta Quest 2 or 3 VR headset. Individual licenses.

⁴⁴ <https://gadgeteergame.com/>

Integration with LMS	Not supported. Built-in analytics.
LM-09	Virtual Shoe Fablab
Learning Objective	<ul style="list-style-type: none"> • Promotion of Augmented Reality for trainers to teach practical footwear manufacturing skills; • Use of Augmented Reality for trainees to practice footwear manufacturing skills.
Target Audience	<ul style="list-style-type: none"> • Trainers/teachers/coaches in the footwear sector • VET providers, institutes and Higher Education institutions • Students and trainees wanting to learn practical skills in footwear manufacturing in a precise, efficient and stimulating way.
Content Type	AR applications
Learning Outcomes	<ol style="list-style-type: none"> 1. Learning-by-doing experience through a fully digital, immersive, accessible form; 2. Solving problems in context; 3. Testing their knowledge, and applying it to practical problems; 4. Enhancing students' technological understanding; 5. Improving their digital literacy.
Key Concepts	<ol style="list-style-type: none"> 1. Testing Materials and Components 2. Footwear pattern-making 3. Footwear Collection Development 4. Rapid Prototyping 5. Manufacturing Technologies 6. Footwear Production Processes
Interactive Elements	<ul style="list-style-type: none"> • Interactive lessons • Hands-on activities • Self-assessment
Media Assets	Android
Accessibility Features	Text is included to make necessary descriptions of materials and steps.
Technical Requirements	Phone (android system) – Screening QR codes to access the contents; Computer.
Integration with LMS	<ul style="list-style-type: none"> • All the training materials could be exported to an LMS platform, like Moodle, and be integrated into school practices. • On job training could benefit from the availability of such content in platforms like ISO traing to cover all the important points efficiently and reduce internal costs.

LM-10	VM STEM
Learning Objective	<ul style="list-style-type: none"> ● Promotion of Virtual Reality ● Learning through an experience that is immersive, interactive and engaging
Target Audience	<ol style="list-style-type: none"> 1. Trainers/teachers STEM 2. Students STEM
Content Type	<ul style="list-style-type: none"> ● Pedagogical guide ● A creation and user guide ● A virtual museum (with 60 collections)
Learning Outcomes	<ol style="list-style-type: none"> 1. Enhancing student engagement; 2. Improving their digital literacy.
Key Concepts	<ol style="list-style-type: none"> 1. Virtual Museum Navigation 2. Science Exhibitions 3. Technological advancements 4. Contemporary Engineering 5. Hidden Mathematics 6. Pedagogical guide 7. Interactive lessons
Interactive Elements	Interactive lessons
Media Assets	<ul style="list-style-type: none"> ● Android ● PC ● VR glasses
Accessibility Features	<p>Text is included to give the necessary steps and directions.</p> <p>Text is included to describe some objects/features of the exhibitions.</p>
Technical Requirements	Phone (android system); PC; VR glasses
Integration with LMS	All the training materials could be exported to an LMS platform, like Moodle, and be integrated into school practices.
LM-11	Principles of Augmented Reality Technologies
Learning Objective	<p>In this module, the main technical aspects related to Augmented Reality techniques and applications are studied, with a focus on the specific case of ARinfuse. The module is structured in three parts:</p> <p>Computer Vision and Augmented Reality: This lecture introduces the core components of an augmented reality (AR) application. The following topics are introduced in this presentation: computer vision and computer graphics, tracking in computer vision, and visualization principles and AR.</p> <p>Device calibration and registration: This lecture explains the basics of camera calibration and the pose</p>

	<p>estimation problem in computer vision.</p> <p>Augmented reality applications: AR solutions has been developed for many domains in the past years. In this lecture some of the applications and the challenges have been discussed. A background of technical aspects in AR is presented in the second part of the lecture, which includes general explanation about camera calibration and pose estimation.</p> <p>Finally we suggest the video of an ARinfuse workshop held in the context of the ASITA conference 2019 in Trieste, Italy.</p>
Target Audience	Students, Managers, Planners and Newcomers to AR.
Content Type	AR Principles
Learning Outcomes	<p>When completing this module, the learner should be able to describe the difference between computer graphics and computer vision, moreover they should be able to describe the very basics of augmented reality components. In more details, the learner should be able to illustrate tracking in computer vision and how it results to AR as an application.</p> <p>The module provides a general understanding of how AR can be beneficial and what technical aspects are tackled in research for AR and in the case of ARinfuse</p> <p>The learner should be able to explain what a pinhole camera is and how it forms images. They should be able to define the process known as camera calibration and pose estimation, and distinguish between them. A basic understanding of calibration methods is essential at the end.</p>
Key Concepts	<p>The module is made of 3 slide-based lectures and one video:</p> <ol style="list-style-type: none"> 1. Computer Vision and Augmented Reality 2. Device calibration and registration 3. Augmented reality applications 4. Video: ARinfuse workshop in ASITA 2019
Interactive Elements	N/A
Media Assets	Video presentation
Accessibility Features	N/A
Technical Requirements	N/A
Integration with LMS	Moodle
LM-12	From spatial data to Augmented Reality
Learning Objective	In this module, a presentation of spatial database management systems and the related technologies is

	<p>given.</p> <p>The material mainly focuses on how the spatial database could be designed and how to query data efficiently as well as a rough description of spatial indexing techniques are presented. In addition, this training module establishes the connection between the spatial data and the AR tools and technologies.</p> <p>Material focuses on which attributes of GIS data are mandatory and why in order to be used by an AR software to produce a 3D scene of utilities networks.</p> <p>The first lecture of the module is intended to provide an introduction to the fundamentals of spatial database management systems. Participants will be able to understand the basic concepts related to the spatial database architecture. At the beginning basic definitions and concepts are introduced. During the presentation, the participant will be able to learn how to design a spatial database system as well query information in an efficient way by using spatial indexing techniques. Participants will have access to additional material related to spatial networks and spatial data mining techniques.</p> <p>In the last part of this module, the participant will be able to understand the connection between the spatial data and the AR technologies; more practical information will be provided in the second lecture.</p> <p>The second lecture is intended to provide a short guide of how the user should prepare the GIS data related to the utilities networks into data which can be consumed by an AR software. The main characteristics of the GIS data for an AR software are given along with some examples by using the ARinfuse tool which is implemented during the project period.</p>
Target Audience	Managers, Planners and Newcomers to GIS, Geospatial Technologies and Geospatial Data. Specially those related to the utilities sector.
Content Type	AR applications
Learning Outcomes	When completing this module, the learner should be able to design and create a spatial database. In addition, it should be able to query information from a spatial database system. In addition, the learner will be able to understand concepts related to spatial indexing. Finally, the learner should be able to prepare

	GIS data in the form which can be consumed by an AR software.
Key Concepts	<ol style="list-style-type: none"> 1. Definition & Applications of Spatial Database Management Systems 2. Architecture of Spatial Database System 3. Spatial Database Design 4. Spatial Query Languages – SQL 5. Spatial Indexing 6. Spatial data to AR 7. Spatial data & Utilities Networks 8. Spatial data & AR attributes 9. ARinfuse tool – Examples
Interactive Elements	Self-test
Media Assets	PP slides
Accessibility Features	N/A
Technical Requirements	N/A
Integration with LMS	Moodle
LM-13	Visualisation of underground utility networks in Augmented Reality
Learning Objective	<p>Basic principles of cartographic representation (Lecture) Cartographic design projects emphasizing effective visual thinking and visual communication with geographic information systems. This course covers design principles and techniques for creating maps with contemporary mapping tools. Furthermore, this module explores the strategies used to design nice map layouts and different types of cartographic outputs.</p> <p>3D Cartographic Visualisation strategies (Lecture) The world around us is three-dimensional. However, in many geo-applications, this world is reduced -often for pragmatic reasons -to two dimensions only. Is this necessary? This module will demonstrate how the three dimensions world can be visualized without reducing the number of dimensions</p> <p>Exercise (Review Questions) In the course “3D Cartographic Visualization strategies”, you learned techniques for visualizing data in 3D to identify patterns not apparent in 2D. In this questionnaire, you will check the knowledge you gain from this course.</p> <p>Fundamentals of BIM for AR (Lecture) This lecture provides an introductory overview of</p>

	<p>Fundamentals of BIM for Augmented Reality (AR), which enables the co-location of digital and physical data in a single medium. AR enables the overlay of detailed, 3D BIM information onto the physical project site in real time and at full scale. AR can successfully support common field tasks such as intuitive visualizations of design models in context, identifying the location of concealed work, layout and installation, etc.</p>
Target Audience	<p>The expected audience of this module are university students in surveying engineering or professionals in the utility network sector.</p>
Content Type	<p>AR application</p>
Learning Outcomes	<p>Basic principles of cartographic representation (Lecture)</p> <p>This course covers design principles and techniques for creating maps. Students will learn the basic cartographic theory to practical problems, with a focus on making optimal design decisions during tasks such as selecting visual variables, classifying and standardizing data, applying principles of color and contrast, and choosing the most effective type in map design for your data.</p> <p>At the successful completion of this course, you will be able to:</p> <ol style="list-style-type: none"> 1. Select and combine appropriate visual variables to clearly represent geospatial data and communicate map content; 2. Apply principles of color and contrast, 3. Discuss current trends in cartographic science & technology 4. Demonstrate mastery in map production for communication and research; analyze, critique, and share high-quality maps. <p>3D Cartographic Visualization strategies (Lecture)</p> <p>In this course, you will learn techniques for visualizing data in 3D to identify patterns not apparent in 2D. The course will introduce the types of data that can be used in 3D. When completing this module, the learner is expected to know and understand the fundamental basics of a 3D Geovisualization and how these can be depicted using VR and AR environments. The learner will also be able to identify real and potential</p>

	<p>applications of 3D geovisualizations. At the successful completion of this course, the learner will also be able to :</p> <ol style="list-style-type: none"> 1. Argue for the need for 3D graphic representation 2. Describe the difference between a 2d and 3d map 3. Differentiate between the kinds of (thematic) three-dimensional maps 4. Explain the application of depth cues and their different perceptions properties 5. Understand the requirements of the 3d viewing environment 6. List and describe data necessary for 3D Geovisualizations. 7. Perform techniques to visualize raster data in 3D. 8. Choose appropriate cartographic techniques to create 3D data. 9. How to author better 3D scenes for AR-VR <p>Exercise-Questionnaire (Review Questions) In this questionnaire, you will check the knowledge you gain from this course module 3D Cartographic Visualization strategies (Lecture)</p> <p>Fundamentals of BIM for AR (Lecture) Upon completion of this lecture, the learner will have a basic understanding of the fundamentals of BIM process and concepts for Augmented Reality. The learner will be able to describe the methods/approaches for transformation of GIS/BIM data for 3D visualization in an AR application. As well, the learner will be able to describe the process of storing and managing data from a GIS and a BIM to be used in an Augmented reality application.</p>
<p>Key Concepts</p>	<p>The structure of the modules is the following.</p> <p>Basic principles of cartographic representation (Lecture)</p> <ul style="list-style-type: none"> ● Part 1: Symbolization and thematic representation of cartographic data. ● Part 2: Lettering & Layout ● Part 3: Thematic Visualization ● Part 4: Data Standardization and symbolisation

	<p>3D Cartographic Visualisation strategies (Lecture)</p> <ul style="list-style-type: none"> • Part 1: Introduction to 3D Visualization Theory • Part 2: Creating 3D Data • Part 3: 3D Cartographic Techniques • Part 4: 3D Viewing environments <p>Exercise (Review Questions)</p> <p>The questionnaire is divided into four parts. In the first part, you should define basic principles of cartographic process and three of the basic steps or processes that are useful to 3D visualization of geodata.</p> <ul style="list-style-type: none"> • In the second part, you will be examined in the Cartographic Data symbolization and Classification as well as in the way that 3D visualization is used to depict different kinds of features. • The third part is dealing with the selection of the correct data type for specific 3D visualizations. • Finally, in the fourth part, you will define a) which are the two basic types of 3D GIS data and b) what are the surface models that are used in GIS software. <p>Fundamentals of BIM for AR (Lecture)</p> <ul style="list-style-type: none"> • Description of BIM and AR • Approaches for transformation of GIS/BIM data for 3D visualization in an AR application • Examples of 3D visualization
Interactive Elements	PP lectures and self-test
Media Assets	N/A
Accessibility Features	N/A
Technical Requirements	N/A
Integration with LMS	Moodle
LM-14	Putting AR in operation
Learning Objective	<p>This module mainly deals with the motivation for implementing AR technologies in an organisation. Support may be required at different levels, such as upper management, operational management as well as among operators and other employees. Important topics being covered are for instance</p> <ol style="list-style-type: none"> 1. Basic theories (business model canvas, business process modelling and notation

	<p>(BPMN), usability testing, design patterns)</p> <ol style="list-style-type: none"> How to describe AR implementations (value proposition, technical solutions, organisational impact) How to prepare a cost-benefit analysis (basic concepts of CBA, estimating costs and benefits, uncertainty analysis). How to design pilot tests (metrics to be measured, System Usability Scale(SUS) questionnaire) The module is a self-learning module
Target Audience	The expected audience of this module are university students in civil engineering or surveying engineering or professionals in the utility network sector.
Content Type	AR applications
Learning Outcomes	<p>At the end of this module, the learner is expected to be able to:</p> <ol style="list-style-type: none"> Describe different AR implementations according to business model, technical solution and organizational impact. Identify existing processes which may need improvement by AR technology Identify new operational processes where AR may be used Describe usages of AR technology, as reported by other organizations Analyze why some AR implementations are successful Compare different AR implementations and their outcome(s) Outline new potential usages of AR technologies
Key Concepts	<p>List of learning units (LU):</p> <ul style="list-style-type: none"> LU 1: Putting AR in operation – Introduction (short lecture) LU 2: Describing AR implementations (lecture) LU 3: Describing business processes and values (exercise) LU 4: Cost-Benefit Analysis (lecture) LU 5: Designing AR processes (lecture) LU 6: Designing pilot tests (lecture) LU 7: Putting AR in operation – Summary (short lecture) LU 8: Self-test

Interactive Elements	Exercise and self-test
Media Assets	Lectures with voice
Accessibility Features	N/A
Technical Requirements	N/A
Integration with LMS	Moodle

Table 12 ALLIANCE4XR Learning Material for Structural Engineering and Construction

LM-15	Outdoor AR application for site instruction and real-scale anchoring
Learning Objective	<ol style="list-style-type: none"> 1. Understanding the use of mixed reality in bridge engineering field. 2. Creation of augmented reality content and interact with it. 3. Collaborative discussion using AR simulation or emulator.
Target Audience	Students (BSc Msc PhD)
Content Type	<ol style="list-style-type: none"> 1. AR simulation and emulator 2. AR application 3. MR interaction modules
Learning Outcomes	<ul style="list-style-type: none"> • The use of a game engine (Unity) to create the XR contents (3D model and automations) • Interact with the AR content directly or through the change of input data • Making real-scale simulation and mapping to the real bridge assets
Key Concepts	<ol style="list-style-type: none"> 1. Data-driven design 2. Spatial anchoring
Interactive Elements	<ul style="list-style-type: none"> • Basic interact with XR contents (pop-up 3D model and move, rotate, scale, check dimensions, assembly parts, tap for automations etc.) • Simulation of design changes according to different input data (.csv; .xls; etc.) • Interact with AR application through dashboard • Instruction for site work such as assembly of reinforcement or bridge structures • Real-scale dimensions checking for large-scale project (e.g., 300m pylon)
Media Assets	<ol style="list-style-type: none"> 1. 3D model of the bridges and machines 2. Video for outdoor application for site work instruction and real-scale anchoring

Accessibility Features	N/A
Technical Requirements	<ol style="list-style-type: none"> 1. Microsoft HoloLens device (gen1 or gen2) 2. Unity game engine and MRTK 3. Azure Spatial anchoring library
Integration with LMS	N/A
LM-16	In door AR application for bridge design
Learning Objective	<ul style="list-style-type: none"> • Understanding the use of mixed reality in bridge engineering field. • Creation of augmented reality content and interact with it. • Collaborative discussion using AR simulation or emulator.
Target Audience	Students (BSc Msc PhD)
Content Type	<ol style="list-style-type: none"> 1. AR simulation and emulator 2. AR application 3. MR interaction modules
Learning Outcomes	<ul style="list-style-type: none"> • The use of a game engine (Unity) to create the XR contents (3D model and automations) • Interact with the AR content directly or through the change of input data
Key Concepts	<ol style="list-style-type: none"> 1. Data-driven design 2. Spatial anchoring
Interactive Elements	<ul style="list-style-type: none"> • Basic interact with XR contents (pop-up 3D model and move, rotate, scale, check dimensions, assembly parts, tap for automations etc.) • Simulation of design changes according to different input data (.csv; .xls; etc.)
Media Assets	<ol style="list-style-type: none"> 1. 3D model of the bridges and machines 2. Video for indoor application
Accessibility Features	N/A
Technical Requirements	<ol style="list-style-type: none"> 1. Microsoft HoloLens device (gen1 or gen2) 2. Unity game engine and MRTK
Integration with LMS	N/A

Table 13 ALLIANCE4XR Learning Material for Maritime Professions

LM-17	Design and construction of zero-emission vessels.
Learning Objective	Understand the principles and techniques involved in the design and construction of zero-emission vessels.
Target Audience	<ol style="list-style-type: none"> 1. Engineering students specialising in naval architecture, marine engineering, or

	<p>sustainable transportation.</p> <ol style="list-style-type: none"> 2. Professionals in the maritime industry who are interested in zero-emission solutions.
Content Type	<ul style="list-style-type: none"> • Interactive XR simulation. • 3D models of green vessel designs. • Infographics on emission reductions.
Learning Outcomes	<ol style="list-style-type: none"> 1. Identify key components (propulsion arrangement, design characteristics) of vessel design. 2. Explain the environmental benefits of zero-emission vessels. 3. Evaluate the feasibility of implementing zero-emission technologies in maritime projects.
Key Concepts	<ul style="list-style-type: none"> • Hydrodynamic design principles. • Propulsion arrangement for different types of vessels. • Propeller/rudder/fins design process and optimisation based on their effect on vessel performance. • Energy storage systems (connection arrangement of batteries, operation of fuel cells). • Visualisation of green shipping technologies (wind-assisted propulsion, solar panels). • Illustration of emissions reduction for different arrangements and compliance with regulatory standards.
Interactive Elements	<ol style="list-style-type: none"> 1. Virtual walkthroughs of zero-emission vessels. 2. Simulation of green propulsion systems. 3. Illustration of energy flows of green shipping technologies. 4. Interactive quizzes on the principles of ship propulsion. 5. Assembling different technologies based on the vessel characteristics.
Media Assets	<ul style="list-style-type: none"> • 3D models of zero-emission vessels with improved quality. • Video interviews with industry experts on sustainable maritime technologies. • Infographics illustrating emission reduction strategies.
Accessibility Features	<ol style="list-style-type: none"> 1. Text-to-speech functionality for audio descriptions. 2. Adjustable font sizes and contrast options.

	<ol style="list-style-type: none"> Alternative text for images and diagrams.
Technical Requirements	<ul style="list-style-type: none"> Compatible with VR headsets (e.g., Oculus Rift, HTC Vive). Accessible via web browsers for non-VR users. Requires a stable internet connection for streaming media assets.
Integration with LMS	<ol style="list-style-type: none"> Track user progress and completion rates within the XR modules. Embed XR content directly into course modules within the LMS. Enable discussion forums for students to engage with the XR materials.
LM-18	Engine Room Operations
Learning Objective	Explore the different machinery components of the engine room onboard a vessel to assess their proper operation.
Target Audience	<ul style="list-style-type: none"> Marine and Mechanical engineering students. Professionals in the shipping industry (e.g., engine manufacturers, engine & electro-technical officers, technicians) interested in engine room operations.
Content Type	<ol style="list-style-type: none"> Interactive/Immersive XR simulation. Virtual tours of onboard engine rooms during operation. 3D models showcasing the assembly of different engine components and the early fault detection in the engine room. 3D models illustrating the integration of new (emission control) technologies in the engine room, to identify/aid design and avoid conflicts with existing machinery for achieving optimisation of space, weight, etc.
Learning Outcomes	<ul style="list-style-type: none"> Understand the operation of the engine components on board a vessel. Examine the parameters that affect the efficiency, and therefore the fuel consumption and emissions of the engine. Predictive maintenance training to identify faults within the engine room or misalignment of the propulsion system. Familiarisation of the crew with existing and new (emission control) technologies on board.
Key Concepts	<ol style="list-style-type: none"> Visualise the thermodynamic laws and cycles of marine engines (Carnot, Rankine, Otto,

	<p>Diesel, etc.).</p> <ol style="list-style-type: none"> 2. Understand the fluid properties, statics and dynamics of the flow (Bernoulli) in pipes and channels (e.g., lubrication system, turbocharging system, exhaust system). 3. Identify the wear and faults in turbomachinery systems (bearings, pumps, compressors, and turbines). 4. Understand the principles of heat transfer (Conduction, convection, and radiation) of heat exchangers, boilers, coolers etc. 5. Perform on-board engine diagnostics (e.g. vibration analysis, thermography, stress analysis and noise to machinery parts). 6. Understand emission control technologies (catalytic converters, particulate filters, HVAC systems), their onboard arrangement and how their integration on existing systems can affect the proper operation of the engine room. 7. Visualise manufacturing processes for engine components (casting, forging, machining) and examine the properties of metals, ceramics, and composite materials used in engine components. 8. Understand the different injection/ ignition and combustion mechanisms of marine fuels (flame propagation and pollutants). 9. Perform the assembly of different engine components, identify faults and optimize weight to examine their operation.
<p>Interactive Elements</p>	<ul style="list-style-type: none"> ● Virtual engine room tours. ● Simulation of engine operation, flow in pipes and exhaust system, wear and faults in turbomachinery systems, heat transfer between surfaces, injection and combustion of marine fuels, and stress analysis on components. ● Illustration of emission control technologies.
<p>Media Assets</p>	<ol style="list-style-type: none"> 1. 360-degree videos of the engine room in operation. 2. Infographics on the manufacturing and material of the different engine parts. 3. Interviews with engine and auxiliary equipment manufacturers discussing the

	long-term or short-term feasibility of new (emission control) technologies in maritime transportation.
Accessibility Features	<ul style="list-style-type: none"> • Audio descriptions for visual elements. • Closed captions and transcripts for videos. • Compatibility with screen readers for text-based content.
Technical Requirements	<ol style="list-style-type: none"> 1. XR experience optimised for both VR headsets and standard desktop/mobile browsers. 2. High-speed internet connection for streaming multimedia content. 3. Compatibility with WebGL for 3D graphics rendering.
Integration with LMS	<ul style="list-style-type: none"> • Seamless integration with course modules within the LMS for easy access by students. • Track learner progress and engagement with XR activities. • Provide assessments and quizzes related to the XR content within the LMS platform.
LM-19	Shore Side Electricity (Cold-Ironing)
Learning Objective	Understand the concept of Shore Side Electricity (Cold-Ironing) and its significance in reducing emissions from ships while berthed.
Target Audience	<ol style="list-style-type: none"> 1. Maritime engineering students. 2. Port operators and managers. 3. Environmentalists and policymakers focusing on reducing port emissions.
Content Type	<ul style="list-style-type: none"> • Immersive XR simulations of port facilities equipped with Shore Side Electricity systems. • Virtual tours demonstrating the connection process between ships and shore power. • 3D models illustrating the infrastructure required for implementing Cold-Ironing.
Learning Outcomes	<ol style="list-style-type: none"> 1. Explain the environmental benefits of Shore Side Electricity for reducing air pollution in ports. 2. Identify the technical requirements and challenges associated with implementing Cold-Ironing. 3. Analyse the economic implications and regulatory incentives driving the adoption of shore power solutions.
Key Concepts	<ul style="list-style-type: none"> • Shore Side Electricity infrastructure. • Power distribution systems at ports.

	<ul style="list-style-type: none"> • Compatibility with different types of vessels and power requirements. • Techno-economic and Socio-economic assessment of Cold-Ironing implementation.
Interactive Elements	<ol style="list-style-type: none"> 1. Interactive demonstrations of the shore power connection process for different types of ships. 2. Simulation of energy consumption and emission reductions achieved through Cold-Ironing. 3. Scenario-based decision-making exercises on port infrastructure planning for Shore Side Electricity deployment.
Media Assets	<ul style="list-style-type: none"> • 360-degree videos of ports with Shore Side Electricity facilities in operation. • Infographics illustrating the environmental impact of Cold-Ironing. • Case studies showcasing successful implementation of shore power solutions in different ports worldwide.
Accessibility Features	<ol style="list-style-type: none"> 1. Audio descriptions for visual elements. 2. Closed captions and transcripts for videos. 3. Compatibility with screen readers for text-based content.
Technical Requirements	<ul style="list-style-type: none"> • XR experience optimised for both VR headsets and standard desktop/mobile browsers. • High-speed internet connection for streaming multimedia content. • Compatibility with WebGL for 3D graphics rendering.
Integration with LMS	<ol style="list-style-type: none"> 1. Seamless integration with course modules within the LMS for easy access by students. 2. Track learner progress and engagement with XR activities. 3. Provide assessments and quizzes related to the XR content within the LMS platform.

Table 14 ALLIANCE4XR Learning Material for Grids and Energy

LM-20	Energy3D
Learning Objective	<ol style="list-style-type: none"> 1. Energy3D is a simulation-based engineering tool for designing green buildings and power stations that harness renewable energy to achieve sustainable development.

	2. Energy3D allows users to design and analyze renewable energy systems, including solar panels and wind turbines
Target Audience	Students, professionals
Content Type	VR simulations - Users can quickly sketch up a realistic-looking structure and then evaluate its energy performance for any given day and location
Learning Outcomes	Energy3D can rapidly generate time graphs (resembling data loggers) and heat maps (resembling infrared cameras) for in-depth analyses.
Key Concepts	Energy3D has been primarily developed to provide a simulated environment for engineering design to support science and engineering education and training.
Interactive Elements	Energy3D allows users to print it out, cut out the pieces, and use them to assemble a physical scale model.
Media Assets	3D models, videos
Accessibility Features	N/A
Technical Requirements	Compatible devices, software platforms
Integration with LMS	N/A
LM-21	VR Vision
Learning Objective	VR Vision provides innovative virtual reality training solutions. It specializes in two dynamic VR training modes: Interactive 360 Video and CGI Simulations.
Target Audience	Energy Companies
Content Type	Virtual reality training courses tailored for energy and utility companies
Learning Outcomes	Courses encompass a variety of levels, from basic walkthroughs and orientations to intricate multiplayer simulations. In these simulations, technicians can seamlessly engage in tasks such as operating vehicles, managing switchgear, and much more.
Key Concepts	Virtual reality training facilitates maintaining the functionality of grids and ensuring the continuous flow of electricity. Top Applications of XR Technology in Energy Sector Training: <ol style="list-style-type: none"> 1. Electrical work 2. Transmission and distribution 3. Troubleshooting and maintenance

	<ol style="list-style-type: none"> 4. Walkthroughs and orientation 5. Wind Turbine Technician 6. Power Line Installers/Repairers
Interactive Elements	Interactive 360 video
Media Assets	3D environment, 3d video, Digital Twins
Accessibility Features	Trainees interact with virtual objects and environments, including how they navigate, manipulate objects, and interact with others.
Technical Requirements	Compatible devices, software platforms
Integration with LMS	N/A
LM-22	ThingLink - Fingrid example
Learning Objective	Virtual electricity power station environments for immersive, effective site safety training
Target Audience	Electricity power station staff, service providers and maintenance personnel
Content Type	Virtual learning environment to support site orientations.
Learning Outcomes	<ol style="list-style-type: none"> 1. About 300 employees use these online learning training materials. 2. The virtual learning environment has solved what was previously a serious challenge, namely that orientation staff and new employees had to travel tens or hundreds of kilometers to the substation.
Key Concepts	<ul style="list-style-type: none"> • Cut down on the time and environmental impact of the onboarding training process • The main benefit of the Fingrid-ThingLink solution is that all materials are created and edited in-house, allowing organizations to have complete control over their content and updates, whilst still maintaining a high-quality materials with a professional look and feel.
Interactive Elements	Videos, 360 photos, 3D models, virtual tours
Media Assets	Videos, 360 photos, 3D models, virtual tours, links and pictures of the instructions are combined into a clear whole.
Accessibility Features	<ol style="list-style-type: none"> 1. New employees can practice navigating their way around virtual versions of the substation locations in the safest possible way. 2. Within the 360 images, essential information is presented in context using informational text and media tags, which can contain images, videos and even 3D models. Users are also

	directed to additional information via embedded links in other tags.
Technical Requirements	Compatible devices, software platforms
Integration with LMS	N/A

Table 15 ALLIANCE4XR Learning Material for Remote Collaboration and AR/VR/MR

LM-23	ITI VR CRANE SIMULATOR
Learning Objective	Machinery operation training
Target Audience	Machinery operators for structural engineering
Content Type	Machinery operators for structural engineering
Learning Outcomes	Operators learn how to handle machinery through a variety of scenarios with customizable variables (like weather).
Key Concepts	Crane operating training
Interactive Elements	Hands-on activities in a variety of simulated scenarios
Media Assets	3D models
Accessibility Features	N/A
Technical Requirements	<ol style="list-style-type: none"> 1. Portable desktop platform, or the immersive motion base platform 2. VR Headset
Integration with LMS	N/A
LM-24	SimX
Learning Objective	Virtual Reality Simulation for Nursing Education
Target Audience	Healthcare and nursing students
Content Type	VR Simulations
Learning Outcomes	<ol style="list-style-type: none"> 1. Experiential learning, through virtual simulation of patient treatment 2. Applying theory in practice 3. Practicing empathy, compassion, communication, and other essential aspects of person-centered care
Key Concepts	<ul style="list-style-type: none"> • Conduct appropriate assessment • Gather patient history • Document all findings, interventions, and patient responses • Recognize abnormal findings and respond with needed interventions • Ensure patient safety • Communicate effectively with provider and patient
Interactive Elements	<ol style="list-style-type: none"> 1. Interactive sessions with patients

	<ol style="list-style-type: none"> Interaction with medical equipment and drugs Virtual medical documents (patient history, important notes, etc)
Media Assets	3D models of virtual hospital rooms, patients and medical equipment
Accessibility Features	N/A
Technical Requirements	<ul style="list-style-type: none"> Compatible VR headsets Recommended system: <ul style="list-style-type: none"> OS: Windows 10 Processor: Intel Core i7-2300 AMD FX-4350 Memory: 8 GB RAM Graphics: Nvidia GeForce GTX 3060 DirectX: Version 11 Storage: 12 GB available space
Integration with LMS	SimX platform provides Assessment & Reporting Tools
LM-25	Industry 4.0 VR Hub
Learning Objective	To educate users about Industry 4.0 and the principles of the circular economy through immersive, hands-on VR experiences.
Target Audience	<ol style="list-style-type: none"> Industry professionals Students and educators in technical and vocational fields Organizations looking to train their workforce on Industry 4.0 technologies and practices <p>The project is permanently exhibited in 2 cities in Lithuania</p>
Content Type	<ol style="list-style-type: none"> VR simulations Interactive VR training modules 360-degree video experiences⁴⁵
Learning Outcomes	<ul style="list-style-type: none"> Understanding of Industry 4.0 concepts and applications Knowledge of circular economy principles Practical skills in modern factory configuration, automatised production, and production line process optimization Enhanced teamwork and communication skills through multiplayer interactions Competence in technical tasks such as electrical vehicle repair and universal collaborative robot assembly and setup through realistic, hands-on training

⁴⁵ <https://youtu.be/7ebOspiqz4>

	<p>simulations</p> <ul style="list-style-type: none"> • Ability to apply learned skills in real-world scenarios
Key Concepts	<ol style="list-style-type: none"> 1. Industry 4.0 technologies and advancements 2. Circular economy principles and benefits 3. Factory layout and configuration 4. Collaborative work in virtual environments 5. Robotics 6. Electrification of the automotive industry 7. Soft skills such as teamwork and communication 8. Technical skills related to machinery and equipment operation
Interactive Elements	<ul style="list-style-type: none"> • Realistic simulations for soft and hard skills training • Hands-on activities in a virtual factory configurator • Training on UR16 cobot setup • Training on EV repair • Virtual factory tour with interactive info points • Multiplayer interactions for collaborative learning (audio connection, avatars)
Media Assets	<ol style="list-style-type: none"> 1. 3D models of machinery and factory equipment 2. 360-degree production videos 3. Audio narration and ambient sounds 4. Customizable media files for personalized content 5. Visual and textual information displays
Accessibility Features	Audio guide with visual hints
Technical Requirements	<ul style="list-style-type: none"> • Compatible devices: HP Reverb G2, Varjo, Meta Quest 2/3 (desktop VR) • Operation system: Windows 10 • Hardware requirements: PC with NVIDIA GeForce RTX 3080 10 GB GDDR6X FH PCIe x16 Graphics, Intel Core i7-12700 2.10G 25MB 12 cores 65W
Integration with LMS	Option for exporting session data to LMS for performance analysis

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