VISIEN: VIRTUAL AND IMMERSIVE SOLUTIONS FOR INTEGRATED EDUCATIONAL NEEDS

VISIEN: noun (vizh-uhn / vɪʒən) ~ Foresight or planning for the future

Integrating Immersive Technologies into Education: A REEdI Framework

Foreword

The **Rethinking Engineering Education in Ireland (REEdI)** project at **Munster Technological University (MTU)** advances education in Ireland by integrating Immersive Technologies like Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and Extended Reality (XR). In 2024, educators, leaders, and innovators were united to explore how these tools can transform teaching and learning through the **Virtual Immersive Reality for Transformative University Education (VIRTUE) Network**. Collaborative discussions highlighted the successful use of immersive technologies in a broad range of specialities like engineering, science, technology, architecture, sustainability, multimedia, design, and medical training, to name but a few. This showcases immersive technologies' broad applicability and potential to engage students and meet academic goals.

Recognising the need for a structured integration framework, the VIRTUE Network developed **Virtual and Immersive Solutions for Integrated Educational Needs (VISIEN)**, a strategic framework and guide to adopting and scaling immersive technologies in educational institutions. VISIEN aligns with institutional objectives, enhances student outcomes, and supports educators by addressing challenges like accessibility, scalability, and resource allocation.

Continued collaboration with educators, industry leaders, and policymakers will ensure the framework evolves into actionable strategies, ensuring **Ireland's leadership** in immersive educational innovation. This initiative is a foundation for continued dialogue and development, aiming to unlock the transformative potential of immersive technologies for education nationwide and beyond.

MTU, REEdI and the VIRTUE Network express their gratitude to contributors who made this vision possible.

HMoolman

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1. Introduction

Integrating immersive technologies like AR, VR, MR, and XR into Higher Education Institutions (HEIs) involves a series of steps and considerations. Each technology has different applications, hardware requirements, and cost implications. Integrating immersive technologies into educational institutions offers significant potential and requires careful planning and investment. Educational institutions must assess their educational goals, select appropriate technologies, budget for both upfront and ongoing costs, and ensure they have the necessary infrastructure and support systems in place for a successful implementation.

As technology improves and barriers to adoption, like price, availability, and internet speed disappear, the use cases for these technologies are rapidly evolving. Far from taking people out of their real-life situations, these technologies are used to give us the real world, but with an enhanced toolset. Immersive technologies have emerged as mediums that provide new ways to implement various educational solutions.

With VR's immersive interfaces, educational institutions can enhance learning experiences and improve the delivery of complex content. These technologies allow for advanced visualisation and simulation, helping students better understand abstract concepts through interactive, hands-on experiences. AR and VR offer significant value in areas such as immersive learning, virtual labs, skill-based training, remote collaboration, and knowledge retention. In education, these tools enable innovative approaches to teaching and assessment, improve student engagement and comprehension, and provide cost-effective alternatives to traditional physical resources. By simulating real-world environments and scenarios, immersive technologies prepare students for future careers while fostering creativity, problem-solving, and critical-thinking skills.

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HEIs thinking of investing in immersive technologies need to consider how to measure benefits against outcomes. They need to set concrete goals and be flexible in meeting needs while adopting different measures of success, such as search results and engagement scores. Regularly evaluating methods and carrying out user testing will help deliver a consistently positive user experience.

The objective of the VISIEN **Integration Framework** is to share the learnings from the REEdI program and research into immersive technologies as educational tools to mitigate some of the risk factors often associated with working across new mediums and cutting-edge technologies. This integration framework intends to remove some of the uncertainty around this new and evolving technology. Furthermore, it outlines what educational institutions need to consider before undertaking the integration of immersive technologies.

2. Define Educational Objectives

Aligning learning outcomes with the integration of immersive technologies ensures that these tools are not used for their novelty but to genuinely enhance teaching and learning. This alignment guarantees that the technology directly supports educational objectives, improves engagement, and provides measurable benefits to students' knowledge and skills. Without clear alignment, institutions risk investing in technologies that may not yield significant educational value, leading to wasted resources and reduced adoption by stakeholders. Successful integration of immersive technologies in educational institutions requires aligning the technology's unique capabilities with the educational needs of the subject area. Aligning learning outcomes with the use of immersive technologies maximises their impact while mitigating risks. For management, it ensures strategic and efficient resource use. For educators, it empowers teaching while introducing challenges that require training and adaptation. For students, it creates opportunities for meaningful engagement, provided issues of accessibility and usability are addressed. When alignment is well-executed, immersive technologies can be transformative, elevating education

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across disciplines By clearly linking these technologies to measurable learning objectives, educators can ensure their implementation adds meaningful value to student engagement and outcomes. For example:

Visualising Complex Concepts with AR: AR can help students explore intricate topics like human anatomy, architectural designs, or engineering models by overlaying interactive 3D visualisations onto the physical environment.

Simulating Real-World Scenarios with VR: VR creates fully immersive environments for applications such as medical training, virtual chemistry labs, or exploring controlled social science experiments, enabling safe and cost-effective experiential learning.

Blended Physical-Digital Experiences with MR: MR facilitates interactive, hands-on activities, such as conducting augmented physics experiments or enabling collaborative design workflows where digital objects interact seamlessly with real-world tools.

Extended Interactive Learning Environments with XR: XR combines AR, VR, and MR to support diverse use cases, including virtual campus tours for prospective students, collaborative research environments across disciplines, or fully immersive simulations tailored to various academic fields.

2.1 DICE and DELTA Frameworks for Immersive Technology Integration

The effective integration of immersive technologies into education requires a structured approach to identify their most impactful applications. The **DICE** and **DELTA** frameworks provide a clear methodology for assessing where these technologies can deliver significant value.

DICE focuses on defining scenarios where immersive technologies excel, ensuring their application aligns with challenges that are **Dangerous**, **Impossible**, **Counterproductive**, or **Expensive** to address through traditional methods. This framework helps institutions pinpoint use cases that maximise the safety, creativity, and cost-efficiency benefits of immersive tools.

DELTA explores how immersive technologies meet diverse educational and operational needs. It emphasises the role of immersive technology in **Design**, **Expertise & Education**, **Logistics**, **Try-Before-You-Buy**, and **Analytics**. By framing these capabilities, DELTA highlights opportunities for streamlined processes, enhanced learning experiences, and innovative problem-solving across disciplines and industries.

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Both frameworks are designed to ensure immersive technology adoption is purposeful and aligns with measurable outcomes, transforming how we learn, work, and innovate.

D-I-C-E
Defining situations where AR/VR are perfectly suited for.
DANGEROUS: Training for hazardous situations or in hazardous environments.
IMPOSSIBLE: Look inside impossible objects and explore new worlds through training.
COUNTERPRODUCTIVE: Encourage behavioural change by placing users in different scenarios, e.g. body transfer for racial equality, cutting down a virtual tree encourages people to use less paper.
EXPENSIVE: Cut down travel costs, visit trade shows, etc.

D-E-L-T-A
How can AR/VR be applied to organisations' business needs?
DESIGN: Create specialised designs, reduce design times, design space in a virtual world, and partner with AI.
EXPERTISE & EDUCATION: How to assemble machinery and scale to the team, remote and hands-free.
LOGISTICS: Disaster relief & warehouse management.
TRY-BEFORE-YOU-BUY: Try equipment before you buy and try recruitment before you apply (e.g. British Army Recruitment Process).
ANALYTICS: Represent complex data visually, and cross-team collaboration remotely.

3. The Role of Immersive Technologies in Education

Immersive technologies offer transformative opportunities for higher education institutions. However, their effective implementation requires careful consideration of their unique strengths, limitations, and the needs of different stakeholders. Each technology serves distinct purposes, enabling institutions to innovate in teaching, learning, and management while addressing challenges such as cost, scalability, and accessibility.

For management, these technologies enhance institutional reputation and support strategic initiatives, though they often require substantial investment in infrastructure and training. Educators benefit from the ability to visualise complex concepts, create engaging simulations, and foster collaborative learning, though content creation and technology adoption can present hurdles. Students gain access to interactive and immersive experiences that improve engagement and practical skills, though issues of accessibility and usability must be addressed.

By examining the benefits and challenges of immersive technologies across these groups, educational institutions can make informed decisions that maximise the educational value and transformative potential of immersive technologies.

3.1 Benefits of Integrating Immersive Technologies in Education

Immersive technologies offer transformative benefits in education, enhancing both teaching and learning experiences. These tools promote active learning by engaging students in multisensory ways, improving content retention and overall engagement. Immersive environments also broaden access to otherwise inaccessible places, processes, or phenomena, enabling experiential learning. Additionally, these technologies facilitate collaboration by encouraging teamwork in content creation and simulations, while tools like LiDAR scanners and 360-degree cameras help streamline content creation, making the development of custom educational materials more efficient and accessible. Immersive technologies enhance education by:

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3.2 Challenges of Integrating Immersive Technologies in Education

While immersive technologies hold immense potential for transforming education, several key challenges hinder their widespread adoption. These include high costs associated with devices, software, and maintenance, as well as the limited availability of quality content tailored to educational needs. Additionally, many institutions face infrastructure requirements, such as high-speed internet and advanced computing systems, that are critical for seamless implementation. Lastly, a lack of technical expertise among educators and staff presents barriers to effectively integrating and maintaining these technologies in learning environments. Addressing these challenges is essential to unlocking the full benefits of immersive tools in education.

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3.3 Immersive Technology Hardware Solutions: A Comparative Table

This table highlights the advantages and challenges of each immersive technology for managers, educators, and students in higher education.

Technology	Stakeholder	Pros	Cons
AUGMENTED REALITY	Managers	• Low cost with smartphone/tablet integration • Enhances institutional reputation for innovation	• Limited scalability without AR-enabled devices • Compatibility issues with varying hardware
	Educators	• Simplifies visualisation of	• Learning curve for content creation

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		abstract concepts (e.g., anatomy, engineering models) • Requires minimal hardware investment	• Less immersive than VR or MR
	Students	• Enhances real-world understanding through overlays • Increases engagement and interactivity	• Reliance on devices can limit focus • Less immersive compared to VR
VIRTUAL REALITY	Managers	• High-impact experiences support innovative institutional goals • Ideal for specialised training (e.g., medical simulations)	• High upfront cost for headsets and infrastructure • Requires dedicated space and technical resources
	Educators	• Ideal for simulating real-world scenarios in a safe environment • Engages students in experiential learning	• Expensive and time-consuming content creation • Potential motion sickness issues for some users
	Students	• Fully immersive learning enhances focus and retention • Safe space for practising complex or dangerous tasks	• Accessibility challenges for those without headsets • Can feel isolating compared to MR
MIXED REALITY	Managers	• Combines AR and VR benefits, offering versatile applications • Strengthens innovation portfolio	• High cost of devices (e.g., HoloLens, Magic Leap) • Requires advanced infrastructure and training

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	Educators	• Enables collaborative and interactive learning experiences • Supports real-world and digital blending	• Advanced skills needed for content creation • Limited off-the-shelf content availability
	Students	• Hands-on experiences with real-world relevance • Promotes teamwork in shared environments	• Steeper learning curve compared to AR/VR • Limited device availability can restrict adoption
EXTENDED REALITY	Managers	• Offers a holistic approach across AR, VR, and MR applications • Scalable for diverse educational initiatives	• Expensive to implement and maintain fully • Alignment with curricula can be challenging
	Educators	• Flexible tools tailored to specific objectives • Facilitates cross-disciplinary learning opportunities	• Complex to master multiple immersive technologies • Risk of misalignment with educational outcomes
	Students	• Exposure to the full spectrum of immersive tools prepares for tech-driven careers • Promotes diverse, engaging experiences	• Overwhelming for technology-inexperienced students • Accessibility barriers to comprehensive adoption

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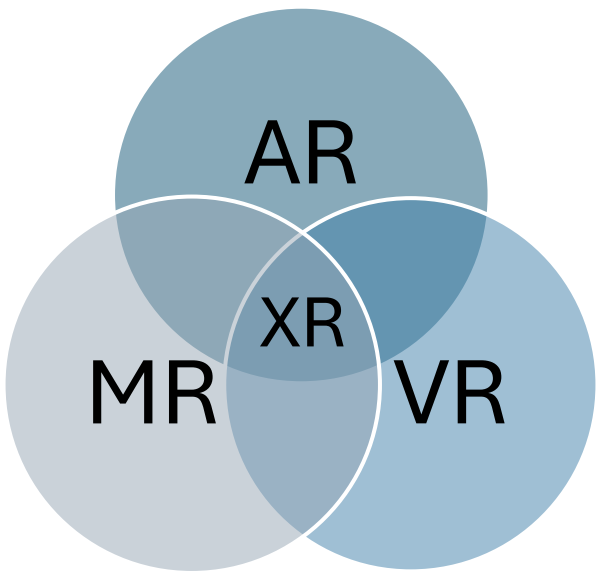
4. Fundamentals: Understanding Immersive Technologies

Immersive technologies are revolutionising the way we interact with digital content by seamlessly blending the physical and virtual worlds. These technologies offer unique capabilities: **AR** overlays digital information onto real-world environments, enhancing our understanding of complex concepts; **VR** creates fully immersive simulations that transport users to entirely virtual spaces; **MR** enables real-time interaction between physical and digital elements, creating dynamic blended experiences; and **XR** serves as an umbrella term, integrating all these technologies to deliver a continuum of immersive solutions. By understanding the distinctions and potential of each, educators, institutions, and learners can harness these tools effectively to transform teaching, learning, and collaboration across disciplines.



4.1 Augmented Reality (AR)

AR is a technology that overlays digital information and virtual objects onto the real-world environment in real time using devices like smartphones, tablets, or AR glasses, enhancing the user's perception of their surroundings. This fusion of physical and digital elements makes AR a powerful tool for immersive learning, professional training, and user engagement. AR is a view of a physical, real-world environment whose elements are augmented by computer-generated items (data, graphics, video, and sound). The real world is not blocked out, users can see the real world as well as virtual objects. AR delivers

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virtual elements as an overlay to the real world, however, interaction with virtual objects is limited.

AUGMENTED REALITY	
Core Technology	AR relies on a combination of hardware (e.g., cameras, sensors, displays) and software (e.g., computer vision, spatial mapping).
Device Types	• AR-enabled smartphones and tablets (e.g., through ARKit for iOS, ARCore for Android). • Wearable AR devices like smart glasses (e.g., Microsoft HoloLens, Magic Leap).
Display Types	AR utilises transparent displays, heads-up displays (HUDs), or screen-based augmentation through handheld devices.
Tracking	• **Marker-based AR**: Uses QR codes or specific images as triggers. • **Markerless AR**: Employs GPS, accelerometers, and gyroscopes to place digital content in real-world coordinates. • **SLAM (Simultaneous Localisation and Mapping)**: Enables AR to understand and interact with complex 3D spaces.
Data Integration	Integrates real-time data feeds for interactive and adaptive experiences.
3D Modelling	Supports digital overlays of 3D objects or animations onto physical environments.
Interactivity	Allows users to manipulate virtual objects through touch, gestures, or voice commands.
Latency	Aim for minimal delay (<20ms) to ensure seamless interaction.

4.2 Virtual Reality (VR)

VR is a fully immersive technology that creates a simulated environment, isolating users from the physical world and allowing them to interact with a computer-generated 3D space. VR's ability to transport users into entirely different environments makes it ideal for education, training, entertainment, and therapeutic applications. VR offer a digital recreation of a real-life setting and can replicate an environment, real or imagined, and simulate a user's physical presence and environment to allow for user interaction and sensory experiences. It is the most immersive experience – the real world is blocked out so users can only see the virtual world and virtual objects, and are unaware of the environment around them. VR requires the user to have specialist equipment to

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experience it. This can range from cheap options like Google Cardboard to the more expensive end of the scale, like headsets from Samsung, Oculus (Meta), HTC, Pico and many more. The focus of VR activity is on experiences and emotional engagement.

VIRTUAL REALITY	
Core Technology	VR relies on real-time 3D rendering, spatial audio, and motion tracking to simulate immersive environments.

Device Types	• **Head-Mounted Displays (HMDs)**:
	  ○ Standalone (e.g., Meta Quest 2 and 3, Pico 3 and 4, PlayStation VR).
	  ○ Tethered (e.g., HTC Vive, Valve Index).
	  ○ Smartphone-based (e.g., Google Cardboard, now less common).
	• **Accessories**: Controllers, haptic gloves, motion trackers, and omnidirectional treadmills enhance interaction.

Display Types	Screen-based augmentation through HMDs.
Display Quality	• High-resolution screens (e.g., 4K or higher) minimise the "*screen door effect*". • Wide field of view (FOV), typically 100°–120°, for immersive perception. • High refresh rates (90Hz–120Hz) reduce motion sickness.
Tracking Systems	• **6DOF (Six Degrees of Freedom)**: Tracks head and body movements in three dimensions (Up/Down, Left/Right, Side to Side). ○ Inside-out tracking (cameras on the device) vs. outside-in tracking (external sensors).
3D Audio	Spatial sound enhances realism by mimicking directional audio sources.
Content Development	Built using engines like Unity, Unreal Engine, or WebXR for immersive and interactive experiences.
Latency and Performance	• Low latency (<20ms) is critical for avoiding motion sickness. • Powerful GPU requirements for smooth and detailed environments.

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Interactivity	Allows interaction with virtual objects through motion controllers, hand tracking, or eye tracking.

4.3 Mixed Reality (MR)

MR is a hybrid technology that blends the physical and digital worlds, allowing real and virtual elements to coexist and interact in real-time. MR's ability to create interactive, context-aware experiences makes it a powerful tool for collaborative work, advanced simulations, and immersive education. MR refers to the combination of virtual environments and real environments that blends both AR and VR, allowing digital and physical objects to interact in real time. MR uses depth and spatial sensors to anchor interactive 3D digital elements into a user's environment. The user can easily navigate around virtual objects that will adjust for size as the user approaches them, for example. MR requires advanced sensors for spatial awareness and gesture recognition that have a nascent but growing solutions ecosystem.

MIXED REALITY	
Core Technology	MR combines the principles of AR and VR, using advanced spatial mapping and interaction models to merge digital content with the physical environment.

Device Types	• **Wearable Headsets**:
	  ○ Dedicated MR devices like Microsoft HoloLens and Magic Leap.
	  ○ MR-capable VR headsets (e.g., Meta Quest Pro or Meta Quest 3 with passthrough capabilities).
	• **Handheld Devices**: Limited MR experiences on high-end smartphones and tablets.

Display Types	• Transparent displays for holographic visuals. • High-quality colour passthrough cameras for virtual overlays on VR-like headsets.
Spatial Mapping	• Uses depth sensors, LiDAR, or cameras to map the physical environment in 3D. • Enables accurate placement of digital objects in the real world.

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Interaction Models	• Gesture-based controls using hand tracking. • Voice commands for seamless interaction with digital elements. • Eye tracking for focus-based navigation and interaction.
Tracking Systems	• Advanced SLAM (Simultaneous Localisation and Mapping) to understand and adapt to complex environments. • Room-scale tracking for freedom of movement and interaction.
Interactivity	• Real-time interaction between physical and virtual elements (e.g., manipulating a digital object resting on a real table). • Persistent digital content that remains anchored to specific locations.
Content Development	• Created using platforms like Unity (MRTK), Unreal Engine, and OpenXR. • Supports both immersive and non-immersive scenarios depending on the hardware.
Latency and Performance	• Requires ultra-low latency (<15ms) to synchronise real and digital elements effectively. • High processing power for simultaneous rendering and spatial analysis.

4.4 Extended Reality (XR)

XR is an umbrella term encompassing AR, VR, and MR, representing all immersive technologies that merge or replace the physical world with digital content, extending the user's experience in both physical and digital worlds.

EXTENDED REALITY	
Core Technology	XR integrates the hardware and software of AR, VR, and MR to provide a spectrum of immersive experiences.
Device Types	• XR-compatible devices include AR glasses, VR headsets, and MR devices.

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	• Standalone (e.g., Meta Quest) and tethered (e.g., HTC Vive Pro) headsets support XR applications.
Display Types	• Transparent displays for AR and MR. • High-resolution VR screens for fully immersive experiences. • Passthrough displays or dual-purpose devices for cross-reality functionality.
Tracking and Interaction	• Utilises 6DOF tracking for accurate head and body movement across AR, VR, and MR. • Hand tracking, voice recognition, and motion controllers for interactive elements. • Eye tracking for gaze-based navigation and enhanced focus.
Content Development	• Developed using versatile engines like Unity, Unreal Engine, and WebXR to target AR, VR, and MR experiences. • Supports cross-platform compatibility to enable seamless transitions between realities.
Latency and Performance	• Low latency (<20ms for AR/VR, <15ms for MR) is critical for realism and reducing motion sickness. • GPU-intensive processing for real-time 3D rendering, spatial mapping, and interaction.
Interactivity	• Adaptive interfaces allow dynamic transitions between immersive (VR) and integrated (AR/MR) modes. • Persistent environments enable users to resume where they left off, regardless of device.
Applications	• Cross-domain applications in education, healthcare, design, entertainment, and training.

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	• Scalable solutions for remote collaboration and hybrid physical-digital workflows.

5. Cutting Edge Hardware: Key Considerations and Trends

Selecting the right hardware is a critical step in implementing immersive technologies in higher education. Hardware choices significantly impact accessibility, cost, and the quality of experiences these technologies can deliver. Each type of immersive technology has unique hardware requirements, ranging from cost-effective solutions like smartphones to advanced devices like mixed-reality headsets.

Institutions must balance affordability with functionality to ensure that the chosen hardware aligns with educational goals and institutional capacity. While some options, such as smartphone-based AR or mobile VR headsets, provide an accessible entry point, more advanced devices like tethered VR systems or mixed-reality glasses enable richer and more immersive experiences at a higher cost. Understanding the range of available hardware and it’s associated costs helps institutions plan effectively for scalable and impactful integration of immersive technologies.

These headsets represent the cutting edge of immersive technology, with options catering to both enterprise and consumer markets across AR, VR, MR, and XR. Each device has its strengths and trade-offs, depending on the specific use case, whether it be for education, industrial applications, professional training, or productivity.

Many of these headsets, particularly AR and MR devices, require developer licenses for creating or testing custom applications. Some devices, particularly enterprise-focused AR/MR headsets like HoloLens 2, Magic Leap 2, and Varjo XR-3, require special business licenses for commercial deployment. For consumer-oriented headsets like Oculus Quest 3 or Meta Quest Pro, licenses are generally not mandatory, but are available for developers.

5.1 AR Head-Mounted Displays

AR hardware ranges from accessible smartphone-based solutions to advanced standalone **Head-Mounted Displays** (**HMDs**). Each category serves distinct purposes, from basic interactions to professional-grade simulations. AR technologies are emerging as transformative tools across educational and enterprise landscapes. They enable

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interactive, real-time overlays of information, enhancing learning, training, and productivity. By understanding the capabilities and constraints of AR hardware, educational institutions can select suitable devices for their unique needs. Continued collaboration with industry partners will be essential for expanding content ecosystems and addressing cost barriers to make AR more accessible.

5.1.1 Summary of AR Devices

The table below summarises key AR devices (at the time of publication), highlighting their strengths, limitations, and ideal use cases.

AUGMENTED REALITY HMDs					
Device	**Type**	**Cost (€)**	**Pros**	**Cons**	**Licensing**
Microsoft HoloLens 2	AR/MR	3,500	Exceptional hand-tracking, enterprise integration, ergonomic design	High cost, limited field of view (52°), short battery life	Enterprise licenses (e.g., Microsoft Dynamics 365)
Magic Leap 2	AR/MR	3,299	Wide field of view (70°), superior visuals, lightweight design	Expensive, limited consumer content	Developer licenses
Google Glass Enterprise 2	AR	999	Lightweight, hands-free for industrial tasks	Limited AR functionality, small display	Custom industry-specific licenses
Vuzix Blade Upgraded	AR	800-1,000	Affordable, voice command functionality, portable	Smaller field of view, less powerful than premium devices	General and commercial licenses

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Epson Moverio BT-40	AR	699	Affordable, 1080p display, compatible with multiple devices	Primarily display-focused, limited interaction capabilities	No specific licenses required
Smartphones/Tablets	AR	Free-1,000	Widely accessible, extensive app ecosystem	Limited immersion, dependent on device quality	App-based subscriptions (varies)

5.1.2 Key AR Devices in Detail

Key devices enabling immersive technologies in education, from high-end AR/MR headsets like Microsoft HoloLens 2 to accessible tools like smartphones. Each device's features, applications, and challenges are outlined, helping educators and institutions choose the right tools to enhance learning outcomes effectively.

KEY DEVICES IN DETAIL

DEVICES	OVERVIEW	APPLICATIONS	CHALLENGES
Microsoft HoloLens 2	A premium AR/MR device designed for enterprise environments, featuring precise spatial mapping and integration with the Microsoft ecosystem.	Remote training, design visualisation, and medical simulations.	High cost and technical expertise are required for setup.
Magic Leap 2	Advanced AR headset with improved visuals and ergonomics, targeting developers and businesses.	Industrial prototyping, AR-enhanced product design, and interactive	Expensive with a maturing ecosystem.

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		educational content.	
Google Glass Enterprise 2	Lightweight AR glasses suited for industrial workflows, focusing on hands-free operation.	Manufacturing, logistics, and workflow optimisation.	Limited immersive capabilities.
Vuzix Blade Upgraded	Compact and affordable AR glasses designed for remote assistance and industrial use.	On-the-job training and real-time task support.	Smaller field of view and less computational power.
Epson Moverio BT-40	Cost-effective AR glasses provide basic augmented display features.	Basic AR tasks, such as information overlays in museums or exhibitions.	Limited advanced interaction.
Smartphones and/or Tablets	The most accessible entry point to AR, leveraging existing devices for AR applications.	Education, retail, and entertainment.	Limited immersive potential and dependent on hardware quality.

5.1.3 Emerging Trends and Use Cases

Emerging trends and practical applications of AR across key domains. In education, AR enhances interactive learning and medical simulations. In industry, devices like Magic Leap and Google Glass streamline training, troubleshooting, and workflows. Public engagement benefits from affordable AR tools in tourism and exhibitions, making immersive experiences widely accessible.

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Educational Applications

- AR is extensively used in STEM education for interactive learning, virtual experiments, and 3D visualisation of concepts.
- Devices like HoloLens are integrated into modules for medical training, enabling practice in simulated environments.

Enterprise & Industrial Use

- Magic Leap and Google Glass are revolutionising industries by enabling hands-free training, remote troubleshooting, and workflow enhancements.
- AR supports tasks like assembly-line guidance and complex system navigation.

Public Engagement

- Affordable options like smartphones/tablets and Epson Moverio BT-40 are used in public settings for AR-enhanced experiences in tourism and exhibitions.

5.2 VR Head-Mounted Displays

Immersive technologies, particularly VR and related hardware, are reshaping educational landscapes globally. As these technologies advance, their integration into educational frameworks is becoming a focal point for institutions aiming to enhance engagement, learning outcomes, and skill development. The following section highlights the current state-of-the-art practical implementations, focusing on VR Headsets. Modern VR headsets vary in functionality, cost, and usability, serving diverse educational needs from casual exploratory learning to professional-grade applications. A comparative overview is provided to understand the capabilities, limitations, and suitability of leading hardware options.

5.2.1 Summary of VR Devices

The table below summarises key VR devices (at the time of publication), highlighting their strengths, limitations, and ideal use cases.

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VIRTUAL REALITY HMDs					
Device	**Type**	**Cost (€)**	**Pros**	**Cons**	**Licensing**
Meta Quest 3	Standalone	550	Affordable, no PC/console needed, high resolution (2064x2208 per eye), lightweight	Limited for high-end gaming, requires a Meta account	General licenses for apps/games
Valve Index	Tethered	1080	Superior tracking, high refresh rate (120 - 144Hz), excellent controllers	Requires a powerful PC, and external sensors complicate the setup	SteamVR games only
HTC Vive Pro 2	Tethered	475	Enterprise-grade tracking, high resolution (2448x2448 per eye)	Expensive, complex setup with external base stations	Vive Enterprise licenses for business use
HP Reverb G2	Tethered	1150	Best resolution for price (2160x2160 per eye), comfortable	Mediocre tracking compared to the Valve Index	Windows Mixed Reality or SteamVR
Pico 4	Standalone	409	Lightweight, affordable, high resolution	Limited developer community, immature software ecosystem	Business licenses for enterprise use

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Sony PlayStation VR2	Console-based	637	Great for PlayStation 5, console gaming	Limited to PlayStation games, not suitable for educational diversity	No specific licensing

5.2.2 Key VR Devices in Detail

An in-depth overview of key VR headsets shaping immersive education and training. Each device is evaluated for its capabilities, applications, and limitations, helping educators and institutions select the most suitable technology for their needs. From standalone options like Meta Quest 3 and Pico 4 to advanced systems like Valve Index and HTC Vive Pro 2, these devices cater to a range of use cases, including simulations, soft-skills training, and specialised academic modules.

KEY DEVICES IN DETAIL

DEVICES	OVERVIEW	APPLICATIONS	CHALLENGES
Meta Quest 3	Ideal for immersive learning modules requiring standalone functionality. Lightweight and affordable for institutional use.	Effective for AR functionalities and moderate VR experiences like soft-skills training or interactive classrooms.	Performance lags behind tethered systems for high-fidelity simulations.
Valve Index	Exceptional tracking and visual quality make it ideal for complex simulations in engineering or healthcare education.	Advanced VR labs, engineering prototyping, and research.	High cost and setup complexity.

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HTC Vive Pro 2	Favoured in enterprise environments due to precision and resolution.	Used in professional training scenarios such as medical and industrial skill development.	High cost and challenging setup.
HP Reverb G2	Provides a balance of resolution and affordability for simulation-heavy applications.	Excellent for flight simulations, architecture, or environmental sciences.	Tracking precision is less than headsets with external sensors.
Pico 4	Low-cost alternative for standalone VR.	Suitable for institutions beginning to explore VR.	Lacks the content ecosystem of Meta or SteamVR platforms.
Sony PlayStation VR2	Accessible for educational settings focused on PlayStation ecosystems.	Targeted VR for gaming-related modules or creative media studies.	Limited to console applications, reducing flexibility for diverse educational use.

5.2.3 Emerging Trends and Use Cases

Emerging applications of VR, from enhancing STEM learning to streamlining industrial workflows and creating immersive public experiences, VR is transforming diverse sectors with its innovative capabilities.

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Educational Applications

- VR enables interactive STEM education, virtual experiments, and 3D visualisation of complex concepts.
- Devices like HoloLens are integrated into medical training, providing simulated environments for practical learning.

Enterprise & Industrial Use

- Magic Leap and Google Glass revolutionise workflows by enabling hands-free training, remote troubleshooting, and system navigation.
- VR supports complex tasks such as assembly-line guidance and operational efficiency.

Public Engagement

- Affordable VR tools, like smartphones, tablets, and Epson Moverio BT-40, enhance visitor experiences in tourism and exhibitions.
- These applications make immersive technology widely accessible to audiences.

5.3 MR Head-Mounted Displays

MR technologies are emerging as powerful tools that bridge the gap between physical and virtual worlds. These devices combine elements of AR and VR, offering users interactive and immersive environments for education, training, and professional applications. MR headsets are designed to cater to professional, educational, and enterprise needs. By providing seamless integration of digital content with real-world environments, MR HMDs are driving innovation across education and enterprise. Continued advancements in affordability and content ecosystems will make MR technologies increasingly accessible and impactful in diverse applications.

5.3.1 Summary of MR Devices

The table below summarises key MR devices (at the time of publication), highlighting their strengths, limitations, and ideal use cases.

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MIXED REALITY HMDs

Device	Type	Cost (€)	Pros	Cons	Licensing
Microsoft HoloLens 2	MR, AR	3,500	Advanced hand-tracking, professional-grade MR features	High-cost, limited consumer apps	Enterprise licenses (e.g., Microsoft Dynamics 365)
Magic Leap 2	MR, AR	3,299	Superior field of view (70°), lightweight design	Expensive, smaller app ecosystem	Developer licenses
Meta Quest Pro	MR, VR	999	Versatile for productivity and immersive applications	Mixed reality features are still evolving	Optional developer licenses
Varjo XR-3	MR, XR	5,495/year	Best-in-class visual fidelity, ideal for simulations	Very expensive, requires a high-end PC	Professional licenses
Lynx R-1	MR, AR	849	Affordable, open-source, versatile for developers	Limited software ecosystem, lower resolution	Developer or commercial licenses
HTC Vive XR Elite	MR, VR, XR	1,099	Lightweight, supports both VR and MR	Limited software ecosystem, lower field of view	Viveport platform licenses for enterprise use

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5.3.2 Key MR Devices in Detail

Examining leading MR headsets, highlighting their features, applications, and challenges. These devices bridge the gap between AR and VR, enabling advanced simulations, collaborative training, and interactive learning experiences. From enterprise-grade options like Microsoft HoloLens 2 and Varjo XR-3 to versatile models like Meta Quest Pro and HTC Vive XR Elite, this guide offers insights into their potential for education, research, and industry use.

KEY DEVICES IN DETAIL

DEVICES	OVERVIEW	APPLICATIONS	CHALLENGES
Microsoft HoloLens 2	A flagship MR device blending AR and VR functionalities with excellent hand-tracking and spatial mapping.	Enterprise-focused tasks like remote collaboration, advanced simulations, and interactive training modules.	High initial cost and expertise needed for content creation.
Magic Leap 2	Known for its wide field of view and enhanced visualisation capabilities, Magic Leap 2 targets professionals in design, healthcare, and engineering.	3D prototyping, surgical training, and interactive learning.	A developing ecosystem limits consumer and educational content.
Meta Quest Pro	Combines MR and VR, offering productivity tools and immersive environments at a relatively accessible price point.	Office productivity, creative design, and moderate MR experiences.	Some MR features are still under development.

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Varjo XR-3	Designed for industrial and enterprise applications, the XR-3 delivers unmatched visual fidelity.	High-end simulations, architectural visualisations, and professional-grade training.	Prohibitive cost and the need for a powerful PC setup.
Lynx R-1	Open-source MR headset offering flexibility and affordability, making it ideal for developers and experimental applications.	Educational projects, AR prototyping, and research.	Limited support compared to major brands.
HTC Vive XR Elite	A lightweight, versatile device supporting MR and VR with strong enterprise applications.	Professional training, design reviews, and collaborative environments.	Smaller field of view and a less robust software ecosystem.

5.3.3 Emerging Trends and Applications

MR headsets are transforming how we learn, work, and collaborate by merging physical and digital worlds. From interactive 3D learning experiences in classrooms to high-fidelity simulations in aerospace and healthcare, MR is unlocking new possibilities. This section explores emerging applications of MR, highlighting its growing role in enhancing engagement and innovation across sectors.

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Education

MR headsets like the HoloLens 2 are being used for immersive classroom learning, allowing students to interact with 3D models of molecules, historical sites, or engineering prototypes.

Enterprise

Devices such as Varjo XR-3 are tailored for high-stakes industries like aerospace and healthcare, providing precise simulations for training.

Research and Development

The Lynx R-1's open-source approach supports experimental MR projects in academia and industry.

Collaboration

MR facilitates remote collaboration, enabling geographically dispersed teams to interact in shared virtual spaces.

5.3.4 Feature Comparison of MR Devices

A comparative analysis of leading MR headsets. Key features such as field of view, resolution, weight, and specialised use cases are outlined to help educators, researchers, and enterprises identify the most suitable device for their specific needs, from professional MR applications to lightweight XR/VR experiences.

Feature	**HoloLens 2**	**Magic Leap 2**	**Meta Quest Pro**	**Varjo XR-3**	**Lynx R-1**	**HTC Vive XR Elite**
Field of View (°)	52	70	~70	115	90	110
Resolution (per eye)	2k	1440 x 1600	1800 x 1920	2880 x 2720	1600 x 1600	1920 x 1920
Weight (g)	566	260	722	840	360	625
Best For	Enterprise MR	Design &	Productivity & MR	Professional XR	Developers	Lightweight MR/VR

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	Trainin g				

5.4 XR Head-Mounted Displays

XR mixes requirements, balancing affordability and performance. XR headsets encompass the combined capabilities of AR, VR, and MR. These devices enable seamless transitions across immersive environments, making them versatile tools for education, enterprise, and creative applications. By providing immersive environments that blend real and virtual elements, XR technologies are expanding the boundaries of learning and professional workflows. Continued innovation in cost reduction and content development will be pivotal in making these devices accessible to a broader audience.

5.4.1 Summary of XR Devices

Designed to assist educators, developers, and enterprises, this table highlights the versatility and specialisation of each device (at the time of publication), from professional-grade solutions like Varjo XR-3 to more affordable options like Nreal Light, catering to a range of immersive technology applications.

Extended Reality Headsets

Device	**Type**	**Pros**	**Cons**	**Cost (€)**	**Licensing**
Varjo XR-3	XR, MR, VR	Industry-leading visuals, excellent for professional applications	Extremely expensive, requires high-end PC setup	5,495/year	Professional license
Meta Quest Pro	XR, MR, VR	Combines AR, VR, and MR; high resolution (1800x1920 per eye)	Expensive, limited MR ecosystem	999	Optional developer license
Microsoft HoloLens 2	XR, MR, AR	Best for enterprise XR; precise hand-tracking and spatial mapping	Expensive, enterprise focus limits consumer adoption	3,500	Enterprise and developer licenses

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Pico 4 Enterprise	XR, MR, VR	Affordable, designed for business use	Limited gaming and consumer applications	409	Business license required
HTC Vive Focus 3	XR, MR, VR	Wireless, combines VR and MR for enterprise use	Expensive for a standalone device	1,240	Viveport platform licenses
Nreal Light	XR, AR	Lightweight AR glasses with XR capabilities	Smaller field of view, limited advanced XR functionality	570	Developer and consumer licenses
Apple Vision Pro	XR, MR, VR	Premium build quality, unparalleled visual clarity (23M pixels across two displays), and seamless integration with the Apple ecosystem.	Extremely high cost, limited developer ecosystem for MR-specific content.	~3,500	App Store-based licenses.

5.4.2 Key XR Devices in Detail

From the professional-grade Varjo XR-3 with its unmatched visual fidelity to the affordable Nreal Light offering basic AR functionality, each device serves unique purposes. Versatile options like the Meta Quest Pro and HTC Vive Focus 3 cater to a mix of AR, VR, and MR applications, while enterprise-focused solutions like the Microsoft HoloLens 2 and Pico 4 Enterprise enable advanced training and collaboration. This guide helps identify the right tools for diverse educational, corporate, and industrial needs.

KEY DEVICES IN DETAIL

DEVICES	**OVERVIEW**	**APPLICATIONS**	**CHALLENGES**
Varjo XR-3	Designed for professional and industrial use, the	High-end simulations, architecture, and detailed training.	High annual subscription fee ($5,495) and demanding

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	Varjo XR-3 provides unparalleled visual fidelity (2880x2720 per eye).		hardware requirements.
Meta Quest Pro	A versatile device combining AR, VR, and MR functionalities with robust productivity tools.	Office collaboration, creative design, and training scenarios.	While offering great potential, its MR features are still maturing.
Microsoft HoloLens 2	An enterprise-focused XR device excels in mixed reality applications with advanced spatial mapping.	Remote collaboration, medical training, and industrial workflows.	High price and limited appeal outside professional use.
Pico 4 Enterprise	An affordable, business-oriented XR headset ideal for immersive training and virtual collaboration.	Education, corporate training, and remote teamwork.	Lack of consumer-focused applications and a limited software ecosystem.
HTC Vive Focus 3	Combines VR and MR in a wireless, standalone design tailored for enterprise environments.	Professional training, immersive meetings, and design visualisation.	High cost for a standalone device and reliance on HTC business services.
Nreal Light	Lightweight AR glasses offering basic XR capabilities at an affordable price point.	Information overlays, basic interactive tasks, and AR experiences.	Limited advanced functionality and a smaller field of view.
Apple Vision Pro	A premium XR headset offering exceptional visual clarity (23 million pixels across two	Creative design, productivity, immersive collaboration, and	Extremely high cost (~€3,500) and a developing

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displays) and seamless integration with the Apple ecosystem.	AR-enhanced workflows.	ecosystem for MR-specific content.

5.4.3 Emerging Trends and Applications

The adoption of XR technologies is driving innovation across diverse sectors, transforming workflows, education, and industry practices. This section explores emerging trends and applications in enterprise integration, educational innovation, and cross-industry versatility. From advanced simulations and immersive classrooms to bridging industry-specific needs, XR devices are reshaping how we collaborate, learn, and innovate.

Enterprise Integration

- XR devices like the HoloLens 2 and Varjo XR-3 are revolutionising enterprise workflows through advanced training simulations and collaborative environments.
- Use cases include remote maintenance, design reviews, and project visualisation.

Educational Innovation

- Devices such as Pico 4 Enterprise are being adopted for immersive classroom experiences, virtual field trips, and STEM applications.
- Affordable solutions like Nreal Light are enabling cost-effective experimentation in education.

Cross-Industry Versatility

- The Meta Quest Pro and HTC Vive Focus 3 are bridging gaps across industries, from healthcare to retail, by supporting both immersive and productivity-driven applications.

5.4.4 Feature Comparison of XR Devices

A comparative analysis of leading XR headsets. Key features such as field of view, resolution, weight, and specialised use cases are outlined to help educators, researchers, and enterprises identify the most suitable device for their specific needs, from professional XR applications to lightweight MR/VR experiences.

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Feature	**Varjo XR-3**	**Meta Quest Pro**	**HoloLens 2**	**Pico 4 Enterprise**	**HTC Vive Focus 3**	**Nreal Light**
Field of View (°)	115	~70	52	90	110	60
Resolution (per eye)	2880x2720	1800x1920	2k	3664x1920 (total)	2448x2448	1080x1080
Weight (g)	840	722	566	590	625	88
Connectivity	PC-required	Standalone	Standalone	Standalone	Standalone	Smartphone-tethered

3.5 Other

Immersive technologies extend beyond AR, VR, XR and MR to include tools like immersive rooms, touchscreens, projectors, LiDAR scanners, drones, 3D printers, and 360-degree cameras to expand the scope of immersive technology. These technologies can enhance learning environments and facilitate the creation of educational content across various disciplines.

Immersive rooms enable shared experiences using large-scale projections and interactive systems, ideal for collaborative simulations and group learning. 360 Capture cameras, often costing between €300 and €1,000, allow educators to create bespoke, location-based VR content, providing students with unique, real-world perspectives that enhance engagement and understanding. When used together, these technologies create a seamless ecosystem where physical and digital experiences converge, transforming how students learn and educators teach.

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Touch Screens

Immersive Applications: Touchscreens can serve as interactive portals to immersive experiences, allowing students to manipulate 3D models, navigate virtual environments, or engage with AR content in a collaborative setting.

Use in Education: Interactive learning stations classrooms allow students to engage with educational content in dynamic and tactile ways. These setups facilitate touch-based exploration of scientific models, such as molecular structures or engineering diagrams, enabling deeper understanding through hands-on interaction. Additionally, they support real-time collaboration on design projects or simulations, fostering teamwork and innovative problem-solving in immersive educational settings.

Content Creation: Touchscreens enable intuitive editing of digital assets, such as drawing overlays on virtual maps or annotating 3D models.

Interactive Rooms & Projectors

Immersive Applications: Advanced projectors can create large-scale immersive environments by displaying 360-degree visuals or interactive simulations on walls, floors, or domes. Immersive rooms create dynamic shared environments using large-scale projections and interactive systems, enabling students to experience virtual simulations, engage in interactive storytelling, or collaborate on group projects within a fully immersive setting.

Use in Education: Projection mapping transforms spaces into dynamic environments for historical reconstructions and cultural exhibits, bringing events and artefacts to life. Planetarium-style setups immerse students in astronomy or environmental studies, enhancing their understanding of complex concepts. Additionally, interactive group simulations enable collaborative learning in projected VR-like spaces, fostering teamwork and problem-solving in an engaging, immersive setting.

Content Creation: Projectors can be paired with motion sensors or touch-sensitive surfaces to design interactive educational content, such as virtual labs or visual storytelling.

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LiDAR Scanners

Immersive Applications: LiDAR scanners generate precise 3D models of physical environments, enabling the creation of digital twins for immersive simulations or AR applications.

Use in Education: LiDAR technology captures and digitises archaeological sites for virtual field trips, providing immersive historical exploration. It also supports urban planning and civil engineering by mapping urban areas with precision, enabling the design of infrastructure and spatial layouts. Additionally, LiDAR facilitates real-time environmental analysis for ecology, geography, and engineering applications, such as terrain modelling, structural analysis, and resource management.

Content Creation: LiDAR data can be used to design accurate 3D models for VR environments or AR overlays, enriching educational content with realistic representations of real-world locations.

Drones

Immersive Applications: Drones capture aerial perspectives and generate unique immersive content that can be integrated into educational experiences, such as virtual tours or ecological studies.

Use in Education: Drones play a vital role in education by monitoring environmental changes, such as deforestation and coastal erosion, to support science curricula. They also capture footage for virtual field trips, providing students access to remote or inaccessible locations. Additionally, drones are valuable tools for training students in aerodynamics, robotics, and operational skills, fostering hands-on learning in STEM disciplines.

Content Creation: High-resolution imagery and videos from drones can be converted into AR/VR-compatible formats or used as overlays in interactive maps and simulations.

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3D Printers	**Immersive Applications:** 3D printers bridge the gap between virtual design and physical creation, allowing students to turn digital models into tangible objects.
	Use in Education: 3D printing enhances education by enabling the creation of anatomical models for medical studies and prototypes for engineering projects. It supports hands-on learning in design thinking and STEM disciplines, allowing students to bridge digital and physical worlds. Additionally, 3D printing facilitates the production of physical replicas of virtual objects from VR/AR experiences, enriching immersive learning and fostering creativity.
	Content Creation: Students can design in VR or AR platforms and use 3D printers to bring their digital creations into the physical world, supporting iterative learning.

360-Degree Cameras	**Immersive Applications:** 360-degree cameras create fully immersive videos and environments, allowing students to explore real-world locations or events as if they were there.
	Use in Education: 360-degree cameras enrich education by capturing environments for virtual field trips to historic landmarks or natural habitats, offering students immersive exploration opportunities. They are also used to record performances or experiments, enabling replay in immersive classrooms for enhanced understanding. Additionally, these cameras document student projects, providing valuable resources for review and collaborative learning.
	Content Creation: Educators and students can use 360-degree footage to design VR experiences, AR applications, or interactive learning modules tailored to specific topics.

5.6 Key Highlights

From the enterprise-ready Microsoft HoloLens 2 for AR and MR to the cost-effective Oculus Quest 3 for VR, each device excels in its field. Advanced tools like the Varjo XR-3 for XR, Insta360 Pro 2 for 360° capture, and the Barco CAVE System for immersive group experiences represent the pinnacle of innovation in immersive education and professional applications.

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IMMERSIVE TECHNOLOGIES					
AR	**VR**	**MR**	**XR**	**Other**	
Microsoft HoloLens 2	*Meta Quest 3*	*Microsoft HoloLens 2*	*Varjo XR-3*	*360-degree cameras*	**Immersive Room**
Ideal for hands-free, enterprise-level AR applications.	Combines affordability with performance, making it perfect for education.	Robust MR capabilities for academic and professional environments.	Cutting-edge device with unparalleled XR performance, though cost-intensive.	Delivers high-quality 360° content for immersive education.	*CAVE Systems* offers unmatched group immersion at a premium.

6. Advanced Software Solutions: Key Considerations and Innovation

Immersive technologies are reshaping education by offering tailored solutions for different academic disciplines. Selecting the appropriate technology for a specific subject is key to maximising its potential to enhance learning and engagement.

In **Medical and Health Sciences**, VR simulations provide safe, realistic environments for surgery practice, while MR enables interactive anatomy studies by overlaying digital models onto physical cadavers or mannequins. For Engineering and Architecture, AR facilitates detailed architectural walkthroughs by superimposing designs onto physical spaces, and XR allows for virtual construction experiences that simulate large-scale projects.

The **Social Sciences and Humanities** benefit from VR's ability to transport students to immersive historical tours, recreating significant events or sites, and AR's capacity to enrich museum exhibits with interactive storytelling. In the Natural Sciences, AR aids in visualising molecular structures or biological processes in 3D, while VR creates virtual laboratories where students can safely conduct experiments.

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Arts and Design students can leverage MR to create and interact with virtual objects in real-world contexts, enabling hands-on exploration of digital sculptures or interior designs.

Finally, **Distance Learning** is transformed by XR, which supports remote yet highly interactive and collaborative environments, connecting learners and educators in shared virtual spaces that mimic in-person engagement.

By aligning the strengths of each technology with the needs of specific departments, educational institutions can unlock innovative learning opportunities, fostering deeper understanding and practical skills across disciplines. Different subjects require different immersive technology applications.

Integrating immersive technologies into higher education requires robust software solutions tailored to the specific needs of various academic disciplines

6.1 Examples of Applications by Discipline

Immersive technologies offer students hands-on, interactive experiences that bridge the gap between theoretical knowledge and real-world applications. From Medical and Health Sciences to Distance Learning, immersive platforms enable simulations, design visualisation, and collaborative environments tailored to specific subject needs. Key applications range from surgical simulations and architectural walkthroughs to virtual laboratories and interactive classrooms, all requiring robust technical capabilities to deliver effective learning experiences.

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Medical & Health Sciences

VR Simulation Platforms: Software like *Osso VR* or *Surgical Theater* provides realistic environments for practising surgical procedures.

MR Anatomy Applications: Tools such as *AnatomyX* or *Visible Body* overlay digital models onto physical cadavers or mannequins for interactive anatomy studies.

Core Requirements: High-fidelity 3D modelling, haptic feedback support, and integration with learning management systems (LMS).

Engineering & Architecture

AR Design Tools: Applications like *ARki* or *Fuzor* enable detailed architectural walkthroughs by overlaying 3D designs onto physical spaces.

XR Construction Simulations: Platforms such as *Unity Reflect* or *Enscape* create virtual construction experiences for large-scale project simulations.

Core Requirements: CAD/BIM software integration, real-time rendering engines, and collaborative project-sharing features.

Social Sciences & Humanities

VR Historical Reconstruction: Tools like *TimeLooper* or *ChronoZoom* transport students to significant historical events and locations.

AR Museum Apps: Platforms such as *HP Reveal* or *AugmentifyIt* enhance exhibits with interactive storytelling and augmented content.

Core Requirements: Multimedia content creation, interactive storytelling capabilities, and seamless deployment on mobile or headset devices.

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Natural Sciences

AR Molecular Visualisation: Applications like Molecule Viewer or Chemistry AR allow students to manipulate 3D molecular structures.

VR Virtual Labs: Platforms such as Labster or zSpace create safe, immersive laboratory environments for experiments.

Core Requirements: Accurate scientific simulations, real-time interactivity, and extensive pre-built educational scenarios.

Arts & Design

MR Creative Tools: Software like Tilt Brush or Adobe Aero enables students to create and interact with virtual objects in real-world contexts.

3D Design and Prototyping Platforms: Applications such as Gravity Sketch or Shapr3D facilitate hands-on exploration of virtual sculptures or designs.

Core Requirements: Cross-platform compatibility, advanced design tools, and support for exporting files to 3D printing or animation software.

Distance Learning

XR Collaborative Platforms: Tools like Engage XR or AltspaceVR provide remote learning environments that mimic in-person engagement.

Interactive Classrooms: Applications such as Spatial or VirBELA allow real-time interaction and collaboration in shared virtual spaces.

Core Requirements: Cloud-based deployment, low-latency communication, and compatibility with multiple hardware devices (PC, mobile, VR headsets).

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6.2 Core Software Requirements

By selecting software that aligns with immersive technologies' strengths and specific departments' needs, educational institutions can create transformative learning experiences that foster deeper understanding and practical skills across disciplines. **Appendix E** offers a comprehensive overview of software solutions for immersive technologies. Across disciplines, certain software requirements remain consistent:

- **User-Friendly Interfaces**: Simplified workflows for educators and students.
- **Scalability**: Support for both small-scale and institution-wide implementation.
- **Integration**: Compatibility with existing institutional tools like LMS or analytics platforms.
- **Data Security**: Compliance with data protection regulations, especially in medical or research-related applications.

7. Cost: Evaluating Factors and Budgeting Strategies

Integrating immersive technologies into education requires careful cost planning to ensure successful implementation and sustainability. Costs can vary widely depending on the scale of deployment, from small-scale departmental projects to campus-wide integration. Key expenses include hardware acquisition, software licensing or custom development, and ongoing maintenance and upgrades. This section provides a detailed breakdown of these cost considerations, helping institutions understand the financial investment required to adopt and scale immersive technologies effectively. Costs vary depending on the scale of implementation:

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CATEGORY	DETAILS	COST (€)
HARDWARE	Budgeting for devices such as headsets, computers, and mobile devices.	-
SMALL-SCALE IMPLEMENTATION	A few devices for specific departments.	€5,000–€30,000
CAMPUS-WIDE INTEGRATION	Hardware for multiple departments and immersive classrooms.	€100,000+
SOFTWARE LICENSING AND DEVELOPMENT	Universities can either purchase existing software or develop custom solutions.	-
EXISTING SOLUTIONS	Licensing for immersive education software (e.g., Labster for VR labs).	€500–€10,000 per year
CUSTOM DEVELOPMENT	Developing tailor-made immersive applications with programmers and designers.	€50,000–€250,000+
MAINTENANCE & UPGRADES	Keeping the technology up to date, ensuring devices and infrastructure are maintained.	Ongoing significant costs

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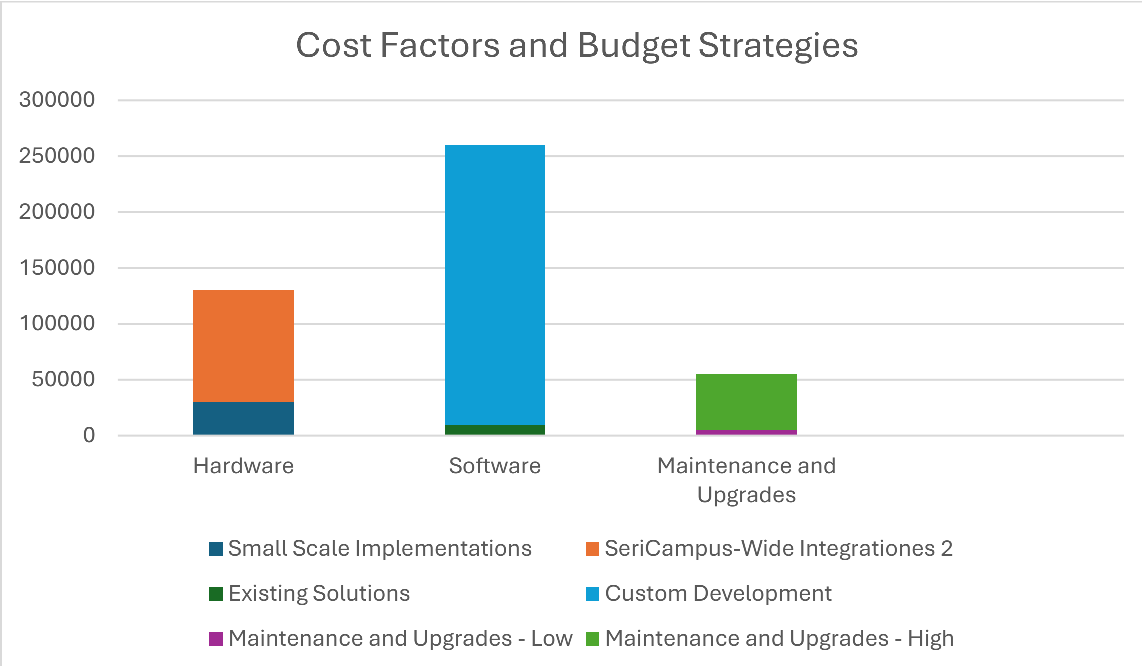

7.1 Subscriptions and Software: Managing Recurring Costs for Immersive Technologies

The total cost of ownership for immersive technologies extends beyond hardware expenses. Subscriptions and software licenses are critical factors that institutions must consider ensuring smooth, scalable integration. These ongoing costs can include software licenses for hardware, access to educational content, and subscriptions to platforms that manage immersive experiences. Thoughtful planning around software and subscription costs ensures that immersive technologies remain both impactful and financially sustainable for higher education institutions.

7.1.1 Software Licenses

Certain immersive technology devices, like Varjo VR headsets, require proprietary software licenses for optimal performance.

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Mandatory Software Licenses: High-end VR devices, such as Varjo headsets, often depend on specialised software to function. These licenses enable advanced features like high-fidelity rendering, eye-tracking, and enterprise-level controls.

Recurring Costs: Licenses may be offered on a subscription basis (e.g., annual or monthly fees), adding to long-term expenses. For example, Varjo's enterprise software licenses can range from €1,000 to €3,000 annually.

Additional Features: Some licenses unlock extra features such as analytics tools or compatibility with other immersive applications, which may be valuable for educational institutions.

7.1.2 Educational Content

The availability and cost of VR content tailored to academic needs are significant considerations:

Pre-Made Educational Content: Many VR platforms offer off-the-shelf educational modules for subjects like anatomy, engineering, or history. Costs for these modules may range from €50 to €500 per license, depending on the content complexity and licensing model.

Custom Content Development: Developing bespoke VR experiences to align with specific curriculum needs is often more expensive. Costs include hiring developers or licensing development tools like Unity or Unreal Engine. Custom content development can range from €5,000 to over €50,000 per module.

Subscription-Based Applications: Some educational applications operate on a subscription model. For instance, VR anatomy platforms or physics simulations may require annual institutional subscriptions costing €2,000–€10,000.

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7.1.3 Platform Subscriptions

Platforms that host or manage VR content and experiences may require separate subscriptions, especially for multi-user environments:

Hosting Platforms: Platforms like Engage, AltspaceVR, etc. allow institutions to host virtual classes, conferences, or collaborative experiences. These platforms often operate on tiered subscription models ranging from free for basic features to €1,000+ annually for advanced options.

Content Distribution: Subscription-based services like SteamVR or Oculus Store provide access to a library of VR content. Institutions may need to purchase individual licenses for students or secure bulk licensing agreements for broader access.

Management Systems: Enterprise VR solutions often include management tools for device monitoring, user access control, and analytics. These systems may involve additional subscription fees, typically €500–€2,000 annually.

7.2 Strategies for Managing Subscription and Software Costs

Managing subscription and software costs effectively is crucial for institutions adopting immersive technologies. Key strategies include aligning software purchases with academic needs to avoid overpaying for unnecessary features and leveraging educational discounts offered by providers. Open-source platforms can significantly reduce recurring expenses while providing essential functionalities. Collaborative efforts with other institutions to share or co-develop VR content can further minimise costs. Centralised management systems streamline the allocation of licenses and monitor usage efficiently. Additionally, budgeting for ongoing updates and maintenance ensures sustainability as technology evolves, securing long-term benefits for educational objectives.

Evaluate Institutional Needs: Identify software features or subscriptions that align closely with academic objectives. Avoid overpaying for advanced features that may not add value to the educational experience.

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Negotiate Educational Discounts: Many software and platform providers offer discounted pricing for educational institutions. Ensure that these opportunities are explored during procurement discussions.

Adopt Open-Source Platforms: Where possible, use free or open-source VR tools, such as Mozilla Hubs, to host and manage content. These platforms reduce recurring costs while offering basic functionalities for education.

Content Sharing and Partnerships: Collaborate with other institutions to co-develop or share VR content, reducing the burden of custom development costs.

Centralised Management: Use platform subscriptions with centralised administration tools that allow efficient distribution of content licenses and user monitoring.

Budget for Updates and Maintenance: Plan for ongoing expenses related to software updates, bug fixes, and additional subscriptions as technology evolves.

7.3 Educational Impact

Effective management of software and subscription costs enables universities to maximise the potential of immersive technologies. By adopting affordable and well-structured plans, institutions can scale their offerings across departments, fostering broader access and integration. Strategic cost management also supports diverse learning needs by providing a variety of VR content tailored to different disciplines. Additionally, maintaining financial sustainability ensures immersive technology programs remain viable over the long term, avoiding budgetary constraints while enhancing educational outcomes. By carefully managing software and subscription costs, universities can:

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Enhance Scalability: Affordable, well-planned subscriptions enable institutions to expand the use of immersive technologies across departments.

Support Diverse Learning Needs: Access to a wide range of VR content ensures a comprehensive educational offering tailored to multiple disciplines.

Ensure Sustainability: Effective cost management avoids budget overruns, ensuring the long-term viability of immersive technology programs

7.4 Off-the-Shelf Apps vs Custom-Created Content: Pros and Cons

When integrating immersive technologies into education, institutions often face a choice between using off-the-shelf apps or investing in custom-created content. Each approach has distinct advantages and challenges depending on the goals, budget, and technical resources available. By balancing these factors, institutions can make informed decisions on whether to adopt off-the-shelf apps or invest in custom-created content for immersive technologies. In many cases, a hybrid approach - using off-the-shelf apps for general needs and custom solutions for specific goals - can offer the best of both worlds.

Factor	**Off-the-Shelf Apps**	**Custom-Created Content**
Cost	**Pros:** Lower initial cost; subscription-based, spreading expenses over time.	**Pros:** Long-term savings if widely used; tailored to specific needs.
	Cons: Ongoing subscription costs can accumulate over time.	**Cons:** High upfront costs for design, development, and testing.

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Time to Implementation	**Pros:** Immediate availability; ideal for rapid integration.	**Pros:** Addresses unique needs not available in off-the-shelf options.
	Cons: Limited customisation for curriculum needs or local standards.	**Cons:** Development requires weeks to months, including testing and adjustments.
Customisation	**Pros:** Standardised, ready-made solutions that often cater to broad educational needs.	**Pros:** Fully tailored to align with institutional goals, cultural contexts, and curriculum standards.
	Cons: Limited ability to tailor to specific curriculum or institutional needs.	**Cons:** Requires significant time and resources for development.
Quality and Depth	**Pros:** High production values, pre-developed by experienced vendors; tested for usability.	**Pros:** Potential for unique, high-quality solutions directly addressing educational objectives.
	Cons: Content quality depends on vendor expertise and may not align perfectly with all educational contexts.	**Cons:** Quality depends on the expertise of hired developers and quality control processes.
Scalability	**Pros:** Designed for scalability; cloud-based solutions simplify updates and multi-device compatibility.	**Pros:** Can be updated or expanded to meet evolving needs across courses or institutions.
	Cons: Scaling beyond the initial design may require significant additional investment.	**Cons:** These may involve redesigns and require institutional infrastructure upgrades for larger-scale use.
Technical Expertise	**Pros:** Minimal expertise needed; plug-and-play functionality simplifies use.	**Pros:** Internal teams gain technical skills through the creation process.

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	Cons: Heavy reliance on vendor support for troubleshooting or adjustments.	**Cons:** Requires significant expertise and resources for development and ongoing maintenance.
Learning Curve	**Pros:** User-friendly designs cater to a broad audience, ensuring ease of adoption.	**Pros:** Educators and students engage deeply through tailored interfaces.
	Cons: Limited features may restrict deep educational engagement.	**Cons:** Training required for effective use; higher initial learning curve.
Support and Updates	**Pros:** Vendor-provided updates, bug fixes, and customer support; access to user communities.	**Pros:** Control over updates and issue resolution; tailored solutions reduce dependency on external vendors.
	Cons: Dependent on vendor stability and responsiveness.	**Cons:** Internal resources or external contracts required for ongoing updates and maintenance.
Long-Term Value	**Pros:** Quick access to diverse, pre-built educational experiences; useful for enhancing specific lessons.	**Pros:** Once developed, reusable content can be updated internally without ongoing external costs.
	Cons: May involve recurring costs; limited flexibility to adjust for long-term objectives.	**Cons:** High initial costs and resource requirements.
Educational Impact	**Pros:** Provides immediate enhancement to lessons with diverse, high-quality experiences.	**Pros:** Custom alignment ensures relevance to objectives and fills gaps left by generic solutions.
	Cons: May not fully align with all educational goals or cover niche topics.	**Cons:** Development timelines may delay the availability of content.

7.4.1 When to Choose Off-the-Shelf Apps

- Institutions need **quick, cost-effective solutions** for immediate integration.

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- Educational goals align closely with available apps (e.g., anatomy or physics simulations).
- Limited **technical resources** or expertise for content creation.
- Institutions are exploring immersive technologies for the first time and want to test their impact before committing to custom development.

7.4.2 When to Choose Custom-Created Content

- The curriculum requires **specialised or niche experiences** not available in off-the-shelf apps.
- Institutions have access to **technical expertise or partnerships** for development.
- Long-term plans involve heavy reliance on immersive technologies, making custom content more cost-effective.
- Institutions aim to create a **unique, branded educational experience** that sets them apart from competitors.

8. Network: Essential Infrastructure Requirements

Implementing immersive technologies in education requires a robust and well-prepared IT infrastructure. Key considerations include network and bandwidth capabilities to support high-speed, low-latency connections, as well as storage and processing power for complex simulations. Integration with Learning Management Systems (LMS) ensures that immersive applications align with existing platforms to track student progress effectively. Additionally, institutions must ensure that Wi-Fi infrastructure can support multiple devices and that hardware compatibility with existing systems is prioritised to enable seamless deployment and usage.

To enable group-shared immersive experiences using immersive HMDs, the network speed and infrastructure play a crucial role in ensuring smooth, synchronised experiences. The exact requirements vary depending on the complexity of the experience, the number of users, and the type of immersive technology being used.

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Network and Bandwidth	• Immersive technologies, especially VR and MR, require robust network capabilities. High-speed internet, low-latency networks, and in some cases, 5G connectivity, are essential. High-quality VR experiences require substantial bandwidth. Ensuring that the institution's network can handle the increased load is crucial.
Storage and Processing Power	• For VR and MR applications, especially when rendering complex simulations, powerful PCs or cloud computing resources may be necessary.
Learning Management Systems (LMS) Integration	• Universities need to ensure that the immersive applications can integrate with their existing LMS (like Moodle, and Blackboard) to track student progress and outcomes.
Wi-Fi Infrastructure	• Adequate Wi-Fi coverage and strength to support multiple VR headsets simultaneously.
Hardware Compatibilit	• Ensure compatibility with existing IT infrastructure, including computers and servers.

8.1 Network Speed Considerations

Key considerations include network speed, bandwidth, and latency, all of which impact the performance and responsiveness of shared immersive environments. For applications like multiplayer VR simulations or AR-enhanced learning, the network must handle high-resolution graphics, real-time interactions, and synchronised communication without lag.

Institutions must evaluate their network types - including wired Ethernet, Wi-Fi 6/6E, and 5G - based on user density, classroom demands, and mobility requirements. Emerging technologies like cloud computing, edge computing, and compression techniques further optimise network performance by reducing latency and bandwidth usage. Special considerations are also needed for scaling immersive experiences for large groups, requiring high-capacity infrastructure to deliver consistent quality. By addressing these factors, institutions can ensure that their network capabilities align with the growing

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demands of immersive education. A breakdown of the network speed considerations for such experiences is summarised below:

	NETWORK SPEED CONSIDERATIONS
Bandwidth Requirements	For group-shared immersive experiences, each user's device needs to send and receive large amounts of data in real time. The network bandwidth must accommodate: • **High-resolution 3D graphics:** Rendering complex 3D models and environments in VR/MR. • **Real-time interactions:** Synchronising movements, interactions, and voice communications across all participants. • **Multiplayer environments:** Allowing multiple users to inhabit the same virtual space without lag.
General Bandwidth Estimates	• VR experiences require a minimum of 50-100 Mbps per user for optimal performance, especially in multi-user environments with high-quality graphics. • AR/MR experiences tend to require less bandwidth than VR, as AR overlays onto the real world rather than rendering entirely virtual environments. A typical AR/MR experience may require 20-50 Mbps per user. • For group experiences (e.g., 10 users in a shared VR space), the collective bandwidth needed would scale up. For instance, 10 users could collectively require 500 Mbps to 1 Gbps or more, depending on the complexity of the shared experience.
Latency Requirements	Latency is a critical factor in immersive experiences, especially in VR and MR, where real-time interaction is key to avoiding disorientation and ensuring smooth communication between users. • **VR and MR headsets:** Require extremely low latency (below 20 milliseconds) to ensure responsiveness in interactions and reduce motion sickness.

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	• **AR applications:** Have a slightly higher tolerance for latency but should still aim for less than 50 milliseconds to maintain a seamless experience.
	• **Multi-user immersive environment:** In a multi-user immersive environment, low latency is especially important to:
	  o Ensure smooth communication and interaction.
	  o Avoid lag between user actions and the environment's response.
	  o Maintain synchronisation between different users' viewpoints and positions.

Network Type	• **Wired Connections (Ethernet):** For high-quality, shared immersive experiences with multiple users, a wired connection is generally preferable, especially when high data transfer rates and low latency are critical. A typical gigabit Ethernet connection (1 Gbps) can comfortably support multiple users sharing a group experience.
	• **Wi-Fi (Wireless):**
	  o **Wi-Fi 5 (802.11ac):** Can deliver speeds up to 1 Gbps in ideal conditions but may struggle with multiple simultaneous users and heavy data loads.
	  o **Wi-Fi 6 (802.11ax):** Better suited for multi-user environments, as it offers improved data rates, efficiency, and reduced latency compared to Wi-Fi 5. Speeds of up to 10 Gbps are possible, but more importantly, it is optimised for high-density environments like classrooms.
	  o **Wi-Fi 6E:** Expands Wi-Fi 6 capabilities into the 6 GHz band, reducing congestion and further improving performance in dense environments.
	• **5G Networks:** 5G offers ultra-low latency (under 10 milliseconds in ideal conditions) and high speeds (up to 10 Gbps), making it an excellent option for untethered, shared immersive experiences, especially in outdoor or larger

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	campus settings. However, the quality of 5G performance depends on the local infrastructure.
Cloud-Based Immersive Experiences	Many immersive experiences leverage cloud computing to offload some of the processing work from the headset to remote servers. In these cases, fast network speeds are crucial to ensure seamless communication between the local device and the cloud.
Edge Computing	Using edge computing, where data is processed closer to the user (e.g., through local data centres), can further reduce latency and bandwidth requirements. This is especially useful for group experiences where the environment is rendered in real time and sent back to the users with minimal delay.
Peer-to-Peer vs. Server-Based Networks	• **Peer-to-Peer Networks:** These allow each user's device to communicate directly with the others in the group, reducing the need for a central server. This can reduce overall network load, but still requires sufficient bandwidth for each user to interact with every other participant. • **Server-Based Networks:** A central server processes and synchronises all user interactions. This can simplify synchronisation but may require higher bandwidth and lower latency to avoid bottlenecks.
Compression and Streaming Technologies	Some immersive experiences use advanced compression and streaming techniques to reduce the bandwidth required for high-quality graphics and real-time interactions. Technologies like NVIDIA CloudXR or foveated rendering can dynamically reduce the resolution of peripheral vision in VR/AR headsets, focusing high-quality graphics only where the user is looking. This can lower bandwidth demands, especially in multi-user scenarios.
Scaling for Large Groups	For large-scale group immersive experiences (e.g., a virtual classroom of 50 students): • **Bandwidth per user:** 20-100 Mbps depending on the level of immersion and complexity of the graphics. • **Network infrastructure:** High-capacity routers, switches, and sufficient backhaul bandwidth (1 Gbps to 10 Gbps) to ensure consistent performance across all users.

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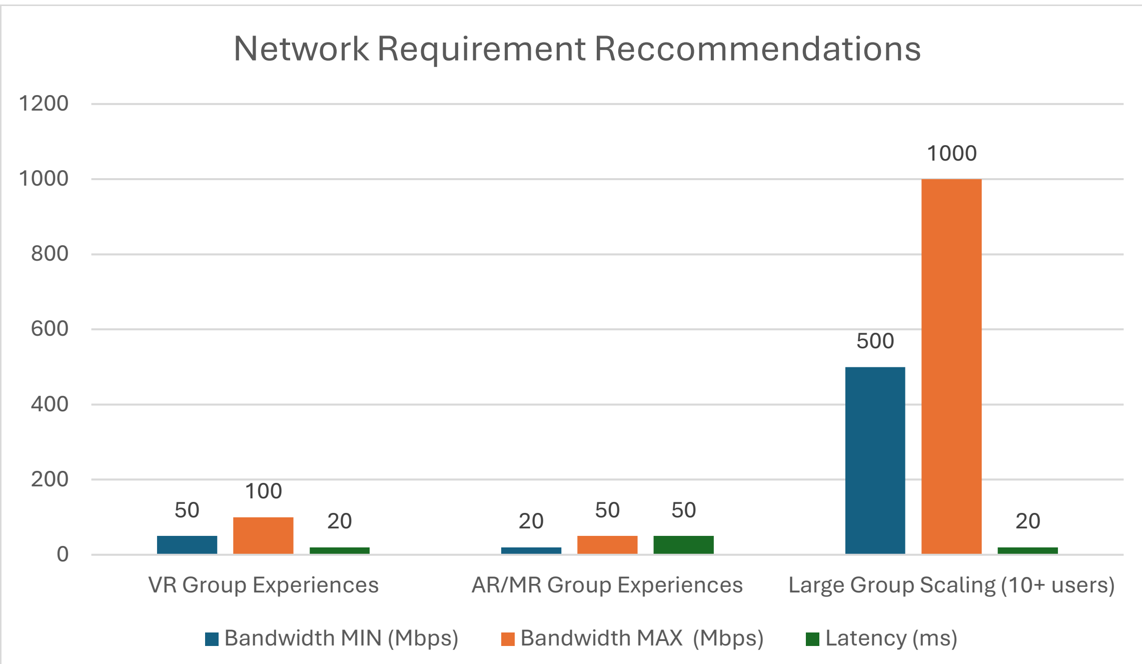
8.2 Network Requirements Recommendations

When implementing immersive technologies such as VR and AR for educational purposes, it is crucial to establish robust network requirements to ensure a seamless and effective experience. For group VR experiences, each user requires a bandwidth of 50–100 Mbps with latency under 20 ms, ideally facilitated through wired connections or high-quality Wi-Fi 6/5G networks. In AR/MR scenarios, bandwidth needs range from 20–50 Mbps per user, with latency requirements being less than 50 ms for AR and under 20 ms for MR, supported by similarly strong wireless or wired infrastructure. Scaling to larger groups necessitates cumulative bandwidths exceeding 500 Mbps to 1 Gbps or more, tailored to the complexity of the experience. These benchmarks highlight the importance of investing in high-performance networks to unlock the full potential of immersive education.



8.3 Network Infrastructure Recommendations

For all configurations, it's critical to incorporate redundancy to avoid downtime and plan for scalability to accommodate growing user numbers and more demanding applications in the future. By investing in these infrastructural elements, educational institutions can effectively support both small-scale group sessions and large-scale immersive experiences.

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VR Group Experience Infrastructure Requirements	AR/MR Group Experience Infrastructure Requirements	Large Group Scaling Infrastructure Requirements
• **Wired Connections**: A wired Ethernet connection is preferred for VR experiences, as it provides the highest bandwidth and lowest latency, ensuring smooth interactions and minimizing interruptions during group sessions. • **High-Quality Wireless Networks**: ○ **Wi-Fi 6**: Offers enhanced bandwidth, reduced latency, and the ability to handle multiple devices simultaneously without degradation in performance, crucial for high-density user environments. ○ **5G Networks**: Essential for untethered VR experiences, particularly in environments where mobility is critical. 5G's ultra-low latency and high data rates make it suitable for real-time interactions. • **Access Points and Distribution**: Multiple access points should be strategically distributed to avoid network congestion and ensure consistent signal strength across the space. • **Traffic Management**: Networks should employ Quality of Service (QoS) protocols to prioritize VR traffic, ensuring consistent performance.	• **Wireless Connectivity**: ○ **Wi-Fi 6 or 5G**: These are crucial for untethered AR/MR devices to deliver high-resolution visuals and seamless real-world overlays. They support high data throughput and reduce latency to levels necessary for interactive experiences. • **Wired Connections for Optimal Performance**: For fixed or semi-fixed setups, wired connections offer stability and reliability, crucial for mixed-reality applications where interruptions can disrupt the user experience. • **Edge Computing**: Deploying edge servers close to the users can help process AR/MR data locally, reducing latency and improving performance for real-time applications.	• **Cumulative Bandwidth Planning**: ○ For 10 or more users, the cumulative bandwidth needs often exceed 500 Mbps to 1 Gbps or more. This depends on the nature of the VR/AR/MR experiences, with high-fidelity or interactive sessions requiring greater capacity. • **Multiple Access Points (APs)**: ○ Deploy multiple APs with Wi-Fi 6 capabilities and mesh networking to ensure load balancing and minimise dead zones. ○ Configure each AP to handle a limited number of devices effectively to avoid bandwidth competition. • **Backhaul Connectivity**: ○ Ensure robust backhaul connections, such as fibre-optic links, to support the aggregated data requirements of the group. • **Network Load Balancers**: ○ Use load balancers to evenly distribute traffic across the network, preventing any single point from becoming a bottleneck. • **Infrastructure Design**: ○ Use dedicated VLANs for immersive technologies to isolate traffic and improve security and performance. • **Power Over Ethernet (PoE)**: Supports high-density setups by simplifying power distribution to multiple APs in large environments.

9. Training and Support

Effective training and support are critical for maximising the benefits of immersive technologies in education. Both educators and students need tailored resources to ensure smooth adoption and usage. Faculty training should focus on integrating VR/AR tools into curricula and pedagogical strategies, while students benefit from onboarding sessions

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and technical literacy support. Dedicated IT personnel, centralised device management, and real-time assistance ensure seamless operation. Collaboration in training and alignment with learning management systems (LMS) enhances effectiveness. With annual costs ranging from €10,000 to €50,000, sustainable investment in training ensures long-term success and inclusivity in immersive learning environments.

Category	**Training and Support Details**
EDUCATORS	
Faculty Training	- Workshops, webinars, certification programs, and peer mentorship. - Ongoing support to stay updated on tools, features, and best practices.
Curriculum Development	- Assistance in redesigning curricula to incorporate immersive technologies. - Align VR/AR tools with learning outcomes and assessments.
Pedagogical Training	- Strategies for immersive learning, e.g., facilitating virtual discussions and ensuring accessibility.
STUDENTS	
Onboarding Sessions	- Guided tutorials, safety guidelines, and usage tips for VR/AR devices.
Technical Literacy	- Basic troubleshooting skills for minor issues. - Guidance on using immersive tools in projects and collaboration.
Accessibility Support	- Specialised training or adjustments for students with disabilities. - Alternative engagement methods, like non-VR versions of experiences.

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IT SUPPORT & DEVICE MANAGEMENT	
Dedicated IT Personnel	- Staff trained to manage devices, troubleshoot hardware/software, and integrate with institutional systems.
Device Management Systems	- Platforms for centralised software updates, device configurations, and license tracking.
Support Desk	- Real-time assistance for technical issues, available to both students and faculty.
INTEGRATION AND COLLABORATION	
LMS and Tools Integration	- Training to integrate VR/AR tools with existing learning management systems (LMS) and software.
Collaborative Training	- Sessions involving both educators and students to explore immersive technologies. - Peer-led workshops or student ambassadors to enhance learning support.
COSTS AND SUSTAINABILITY	
Cost Considerations	- Annual costs of €10,000–€50,000 for training and support, depending on scale. - Budget for long-term training programs to ensure sustainability.
Ongoing Development	- Participation in conferences, certifications, and communities of practice focused on immersive technology.

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10. Long-Term Objectives: Sustainability and Scalability

To ensure immersive technologies provide lasting value in higher education, universities must develop strategies that address their long-term sustainability and scalability. While pilot programs and initial implementations help to introduce these tools, institutions must plan for their ongoing growth, relevance, and impact. By addressing these areas strategically, universities can ensure that immersive technologies are not just a short-term novelty but a transformative and enduring part of their educational framework. Universities should consider the long-term sustainability of immersive technology integration:

- **Expanding Use:** As technology becomes more embedded, universities might want to scale up, requiring additional hardware and software.
  - **Increased Hardware Investments:** Procuring additional devices, such as VR headsets or AR glasses, to meet the growing demand from students and faculty.
  - **Broadening Access:** Ensuring equitable access to immersive technology, particularly for remote learners or students with disabilities.
  - **Enhanced Infrastructure:** Upgrading networks, storage, and computing power to support more devices and users, especially as experiences become more resource-intensive.
- **Content Updates:** Immersive content (especially in VR/AR simulations) needs regular updates to stay relevant and accurate.
  - **Regular Revisions:** Updating VR simulations or AR overlays with the latest research findings, industry practices, or educational standards.
  - **Dynamic Content Management:** Partnering with developers or adopting software platforms that simplify content updates and distribution across devices.
  - **Faculty Engagement:** Training educators to co-develop or adapt content, ensuring relevance while reducing dependence on external vendors.
- **Funding** Universities may need to explore grants, partnerships with technology companies, or student fees to support long-term use.
  - **Grants and Partnerships:** Seeking government grants, research funding, or partnerships with technology companies to reduce costs. Initiatives like Horizon Europe can support projects involving cutting-edge educational technologies.
  - **Cost-Sharing Models:** Introducing optional student fees for access to specialised tools, labs, or content subscriptions.

    - **Revenue Streams:** Exploring opportunities to monetise immersive content by licensing or collaborating with industry partners.
- **Future Proofing:** Considering future needs and technological advancements to ensure that the investment remains relevant over time.
    - **Hardware Longevity:** Select modular or upgradable devices, such as standalone VR headsets with firmware support or AR glasses with removable components.
    - **Interoperability:** Choosing software and platforms that are compatible with multiple hardware types to avoid being locked into a single vendor ecosystem.
    - **Tracking Trends:** Staying informed about advancements in immersive technologies, such as the integration of AI in simulations or 6G network capabilities for enhanced experiences.
- **Long-Term Benefits of Sustainability and Scalability:**
    - **Increased Adoption:** Providing reliable, updated, and accessible tools builds confidence among faculty and students, encouraging widespread use.
    - **Reputation for Innovation:** Universities leading in immersive technology adoption are more attractive to prospective students and faculty, boosting enrolment and funding opportunities.
    - **Educational Impact:** Scalable, well-maintained immersive solutions enable a broader range of disciplines to benefit, enriching the overall learning experience and ensuring alignment with workforce demands.

A structured overview of how educational institutions are achieving long-term sustainability and scalability in immersive technologies with real-world examples.

Category	Real-World Examples
EXPANDING USE	
Increased Hardware Investments	Arizona State University provides standalone VR headsets like Meta Quest to students, enabling broader access and reducing reliance on shared resources.
Broadening Access	Dublin City University offers virtual campus tours and immersive environments, ensuring remote and disabled learners can participate equally in educational activities.

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Enhanced Infrastructure	The University of Cambridge upgraded its networks to support AI-enhanced simulations in virtual labs, facilitating the seamless use of immersive technologies.
CONTENT UPDATES	
Regular Revisions	Harvard Medical School updates VR surgical training modules annually to include the latest medical research and practices.
Dynamic Content Management	Munster Technological University collaborates with developers for centralised VR content updates, allowing easy distribution across devices.
Faculty Engagement	University of Glasgow trains educators in platforms like Unity and Unreal Engine, empowering them to co-create and tailor immersive content for curricula.
GRANTS AND PARTNERSHIPS	
Grants and Partnerships	HEA HCI funds projects like REEdI, enabling Irish universities to scale immersive tools for engineering education.
Cost-Sharing Models	The University of Southern California introduces optional tech fees for students accessing immersive labs, balancing affordability with sustainability.
Revenue Streams	The University of Oxford licenses proprietary VR simulations to healthcare providers, generating revenue while sharing resources with industry.
FUTURE-PROOFING	
Hardware Longevity	Stanford University uses modular VR headsets, extending device lifespans through upgradable components and firmware updates.
Interoperability	MIT utilises open-source platforms like Mozilla Hubs to ensure compatibility across multiple hardware ecosystems, avoiding vendor lock-in.
Tracking Trends	Imperial College London integrates AI into VR simulations, preparing for advancements like personalised, adaptive learning experiences.
BENEFITS IN ACTION	

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Increased Adoption	University of Maryland's VR-integrated engineering curriculum has seen greater faculty and student participation, encouraging adoption across other disciplines.
Reputation for Innovation	The University of Melbourne uses immersive technology to attract international students and form global partnerships, boosting its reputation.
Educational Impact	Purdue University applies immersive labs across fields like veterinary science and aviation, aligning student skills with workforce demands and enhancing learning outcomes.

11. Accessibility: Ensuring Inclusive and Comfortable Use

Accessibility is a critical consideration for integrating immersive technologies like VR, AR, and MR into higher education. To deliver equitable and effective learning experiences, universities must address both physical accessibility for students with disabilities and user comfort to ensure that immersive environments are safe and inclusive for all. Making immersive technologies accessible is not just a legal and ethical obligation; it is a strategic imperative to maximise their impact and ensure all students benefit equally from the transformative potential of these tools.

11.1 Physical Accessibility

Immersive technologies must be designed and implemented to accommodate students with varying physical, sensory, and cognitive abilities:

Accessible Hardware: Select hardware that accommodates diverse needs, such as headsets with adjustable straps for users with limited dexterity or devices compatible with assistive technologies like screen readers or voice controls.

Alternative Input Methods: Provide options for alternative input devices, such as eye-tracking systems or adaptive controllers, to ensure students with mobility impairments can interact seamlessly with VR and AR environments.

Space Considerations: Ensure VR setups are housed in spaces that are wheelchair-accessible, including clear pathways, appropriate furniture height, and sufficient room for movement.

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Inclusive Content Design: Develop or select VR and AR content that avoids relying on specific physical movements or sensory modalities. For example, replacing auditory cues with visual indicators ensures inclusivity for hearing-impaired students.

Compliance Standards: Adhere to established accessibility guidelines, such as the Web Content Accessibility Guidelines (WCAG) for digital content or regional regulations for physical accommodations.

11.2 User Comfort

Immersive experiences must be designed to minimise discomfort and ensure a positive experience for all users:

Motion Sickness Mitigation
- Use headsets with high refresh rates (90Hz or more) to reduce lag and minimise motion sickness.
- Design content with smooth transitions, stable camera perspectives, and limited rapid movements.
- Offer shorter VR sessions or breaks during extended use to accommodate users prone to discomfort.

Physical Ergonomics
- Provide adjustable and lightweight headsets to ensure they fit comfortably on users of different ages and head sizes.
- Consider hygiene by offering disposable face covers for shared devices.

Customisable Experience
- Allow users to adjust visual settings, such as brightness, field of view, or text size, to cater to individual preferences or needs.

Training and Guidance
- Educate users on how to adjust equipment for optimal comfort and how to handle any discomfort, such as dizziness or eye strain.

11.3 Additional Strategies to Enhance Accessibility

Ensuring accessibility in immersive technologies is essential to creating inclusive educational environments that cater to all students. Key strategies include offering remote access options for those unable to use physical setups, providing assistive training to staff to address diverse student needs, and fostering ongoing student feedback to identify and overcome barriers. Additionally, establishing support ecosystems with dedicated teams ensures technical issues are resolved effectively, enabling students to maximise their learning experience with immersive tools.

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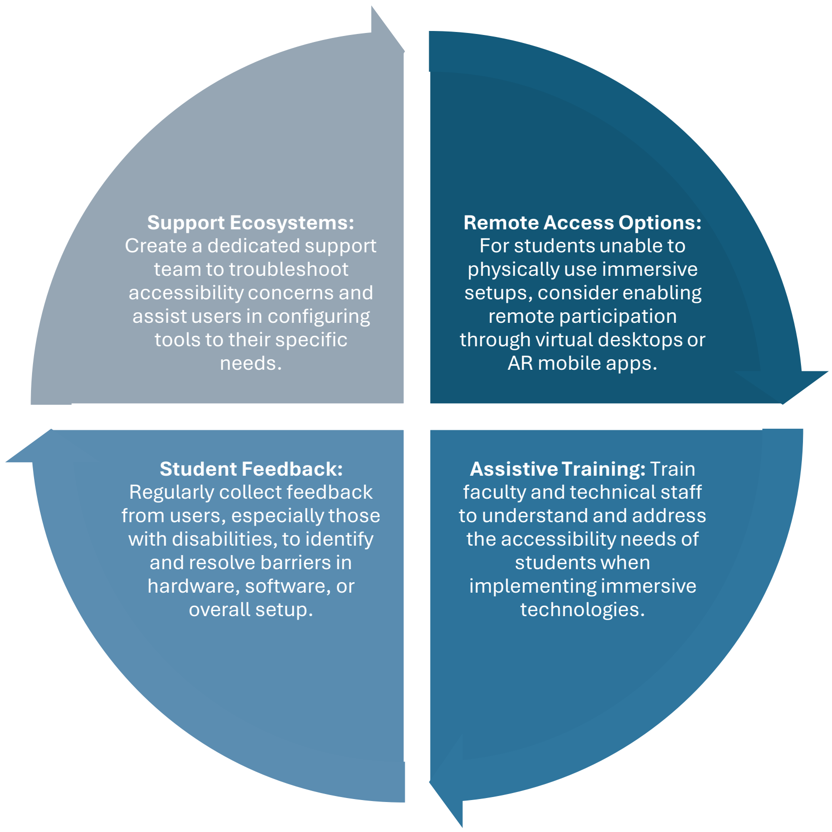

11.4 The Educational Impact of Accessible Immersive Technologies

Accessibility in immersive technologies plays a critical role in creating equitable and inclusive learning environments. By ensuring that all students can engage with these tools, institutions can promote equity, giving every learner an equal opportunity to succeed. Accessible content and tools also enhance learning outcomes by improving knowledge retention and skills acquisition. Furthermore, prioritising accessibility helps foster institutional reputation, demonstrating a strong commitment to inclusivity and setting a standard for best practices in education. When accessibility is prioritised, immersive

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technologies can:

11.5 Ensuring Accessibility in Immersive Technologies: Strategies and Examples

Accessibility to immersive technologies is essential to fostering an inclusive and equitable educational environment. By prioritising physical accessibility, user comfort, and adaptive strategies, educational institutions can ensure that immersive technologies are effective for all students, including those with disabilities. Practical measures, such as accessible hardware, alternative input methods, and inclusive content design, address diverse needs. Meanwhile, investments in remote access options, assistive training, and ongoing user feedback further enhance inclusivity. These efforts not only promote equity and improved learning outcomes but also elevate institutional reputation by demonstrating a commitment to accessibility and innovation.

Category	Practical Real-World Examples
PHYSICAL ACCESSIBILITY	
Accessible Hardware	Meta's Quest 3 VR headsets include adjustable straps and lightweight designs, improving usability for individuals with limited dexterity.

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Alternative Input Methods	Tobii's eye-tracking technology enables users with mobility impairments to navigate VR environments using gaze control.
Space Considerations	The University of California, Berkeley ensures VR labs are wheelchair accessible, with adjustable furniture and clear pathways for ease of movement.
Inclusive Content Design	Microsoft's "Seeing AI" app integrates with AR environments, providing audio descriptions for visually impaired users and ensuring sensory inclusivity.
Compliance Standards	Universities like Stanford adhere to WCAG 2.1 standards for VR content to ensure digital accessibility and meet regulatory requirements.
USER COMFORT	
Motion Sickness Mitigation	Oculus' VR headsets use 90Hz refresh rates and low-latency design to reduce motion sickness, while VR apps like Wander focus on smooth transitions for comfort.
Physical Ergonomics	HP's Reverb G2 VR headsets include ergonomic designs, and disposable face covers to enhance comfort and hygiene for shared use.
Customisable Experiences	Google Expeditions allows users to adjust text size, brightness, and display settings, ensuring accessibility for various vision needs.
Training and Guidance	MIT provides users with detailed guides and workshops on optimising headset settings and managing potential discomfort during extended VR sessions.
ADDITIONAL STRATEGIES	
Remote Access Options	Zoom's AR integration and platforms like Mozilla Hubs enable remote access to immersive environments for students unable to use physical setups.
Assistive Training	Dublin City University trains staff on accessibility tools like voice controls and adaptive controllers to ensure inclusivity in immersive technology adoption.

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Student Feedback	The University of Melbourne collects regular feedback through surveys to identify and resolve barriers faced by users with disabilities in immersive setups.
Support Ecosystems	Purdue University has established dedicated VR support teams to assist with configuring accessibility tools and troubleshooting issues for students with special needs.
EDUCATIONAL IMPACT	
Promote Equity	The University of Glasgow's VR labs provide equal access for all students, ensuring immersive learning opportunities are inclusive of those with disabilities.
Enhance Learning Outcomes	Harvard Medical School uses accessible VR surgical simulations, improving learning outcomes for students with diverse physical abilities.
Foster Institutional Reputation	Imperial College London's focus on accessibility in its VR programs has earned it recognition as a leader in inclusive education practices.

12. Legal And Ethical Considerations: Establishing Responsible Use of Immersive Technologies

The integration of immersive technologies like VR, AR, and MR into higher education introduces new legal and ethical challenges. Institutions must proactively address these considerations to ensure compliance with laws, safeguard users, and maintain the integrity of educational practices. Developing robust usage policies and promoting ethical practices are central to achieving this goal. By addressing these legal and ethical considerations, universities can create a foundation for the responsible and impactful use of immersive technologies in education.

12.1 Usage Policies

Clear and comprehensive usage policies provide a framework for the responsible deployment of immersive technologies in educational settings:

Acceptable Use: Define what constitutes acceptable use of VR technologies, outlining appropriate behaviours for students and staff. Policies should address issues such as misuse, tampering with hardware, or unauthorised access to content.

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Supervision Guidelines: Establish protocols for monitoring the use of immersive technologies, particularly for younger students or first-time users, to ensure their safety and well-being during VR sessions.

Time Limits: Prolonged use of immersive technologies can lead to physical discomfort, eye strain, or overexposure. Policies should set reasonable time limits for sessions to safeguard health while ensuring optimal learning experiences.

Data Privacy and Security: Address how user data, such as biometrics or behavioural analytics collected during VR interactions, will be stored, used, and protected. Compliance with laws like GDPR is essential to maintain trust and avoid legal repercussions.

Content Ownership and Licensing: Clarify ownership rights for any VR content developed or used within the institution, ensuring compliance with copyright laws and preventing unauthorised distribution.

12.2 Ethical Use

The ethical implementation of immersive technologies ensures they are used in ways that align with the institution's values and promote positive learning experiences:

Appropriate Content: Institutions must vet VR content to ensure it is age-appropriate, culturally sensitive, and aligned with educational objectives. For instance, simulations involving sensitive topics like conflict or trauma should be carefully designed to avoid harm or distress.

Informed Consent: Students and staff should be informed about the purpose of VR use, any potential risks (such as motion sickness), and how their data will be handled. Obtain explicit consent before participation, particularly in experimental or research-based applications.

Accessibility and Inclusivity: Ethical use ensures all students, regardless of ability or background, have equitable access to VR tools and experiences. Excluding certain groups due to physical, financial, or technical barriers undermines the principles of fairness and inclusion.

Avoiding Manipulation: Immersive technologies can deeply influence perceptions and behaviours. Institutions must avoid using VR in ways that could manipulate users unethically, such as presenting biased content or imposing specific ideologies.

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Transparency in Learning Outcomes: Ensure students understand the purpose of VR in their learning journey and how it complements traditional educational methods, avoiding any overreliance on technology as a substitute for effective pedagogy.

12.3 Additional Legal and Ethical Challenges

Simulated Environments: Some VR applications simulate real-world scenarios involving ethical dilemmas or controversial topics. Guidelines should address how these scenarios are designed and debriefed to prevent harm.

AI and VR Intersections: As AI becomes integrated into immersive experiences, ensure that its applications, such as automated feedback or adaptive learning, adhere to ethical standards, avoiding biases or unintended consequences.

Third-Party Partnerships: Collaborations with external VR developers or vendors should include agreements on ethical standards, data protection, and intellectual property rights.

12.4 Educational and Institutional Benefits

Addressing legal and ethical considerations proactively can:

Build Trust: Clear policies and ethical use demonstrate the institution’s commitment to student and staff well-being, fostering trust among stakeholders.

Enhance Reputation: By upholding high standards for the use of innovative technologies, institutions position themselves as leaders in responsible tech integration.

Prevent Legal Risks: Robust compliance with privacy laws, copyright regulations, and accessibility standards reduces the likelihood of legal challenges or penalties.

Support Positive Learning Outcomes: Ethical practices ensure immersive technologies contribute meaningfully to education without compromising safety, inclusivity, or fairness.

13. Security: Protecting Users and Systems

The use of immersive technologies like VR, AR, and MR in higher education introduces unique security challenges that institutions must address to safeguard user data, prevent unauthorised access, and maintain the integrity of their systems. Effective security measures are essential for building trust among students, faculty, and stakeholders,

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particularly as these technologies collect and process sensitive data. Institutions can protect users and maintain trust by addressing data privacy, network security, and user authentication while evaluating vendor agreements like Meta's terms. These proactive measures ensure compliance with legal requirements and foster a secure and ethical environment for immersive learning.

13.1 Data Privacy

Using immersive technologies in education involves collecting and managing various types of user data, including sensitive information such as biometrics, usage patterns, and geolocation details. To protect user privacy and ensure compliance with regulations, institutions must prioritise secure data storage through encryption and protocols like GDPR. Adopting a limited data collection approach, where only necessary information is gathered, helps mitigate risks while ensuring transparency. Additionally, clear and user-friendly consent forms are essential to inform users about what data is collected, how it will be used, and who may access it. Protecting the privacy of users is critical, as immersive technologies often collect a wide range of personal and behavioural data.

Types of Data Collected

- VR systems may capture sensitive information such as biometrics (e.g., eye-tracking data, physical movements), usage patterns, and performance metrics. AR and MR tools might also use geolocation and environmental data from users' devices.

Secure Data Storage

- Institutions must ensure that all collected data is securely stored using encryption and other advanced security protocols. Storage solutions should comply with data protection regulations such as GDPR.

Limited Data Collection

- Adopting a minimal data collection approach can reduce risks. Only necessary data for educational objectives should be collected, and users should have transparency on what is being stored.

User Consent

- Provide clear, user-friendly consent forms detailing what data is collected, how it will be used, and with whom it may be shared.

13.2 Network Security

The integration of immersive technologies in education requires robust security measures to protect data and ensure safe usage. Institutions must prioritise firewalls and encryption to safeguard sensitive information from hacking or interception. Additionally,

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implementing secure Wi-Fi networks dedicated to VR systems helps reduce vulnerabilities by isolating them from general-use networks. Regular security audits are essential to identify and address potential weaknesses across network, hardware, and software systems, ensuring a secure and resilient immersive learning environment. Secure networks are essential for preventing unauthorised access to immersive technologies and the data they process.

13.3 User Authentication

Ensuring secure access to immersive technologies is essential to protect sensitive content and maintain institutional integrity. Key measures include implementing Two-Factor Authentication (2FA), which adds an extra layer of security by requiring additional verification steps. Biometric authentication, such as fingerprint or iris scans, further enhances security and is supported by many immersive devices. Additionally, Role-Based Access Control ensures that only authorised users, like educators or administrators, can access specific content or settings, safeguarding both data and functionality in immersive learning environments. Strong user authentication methods prevent unauthorised access to VR systems, devices, and content.

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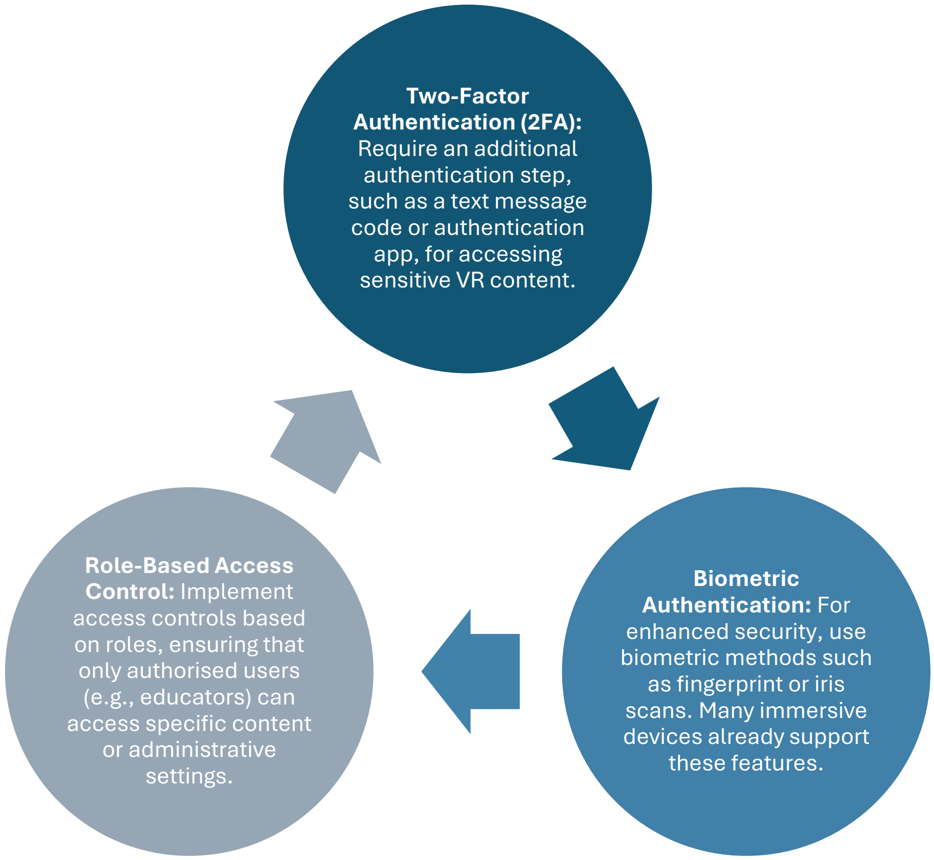

13.4 Meta User Agreement and Data Permissions

Because the Meta Quest headset is the preferred choice for many educational institutions (low cost, widely supported, etc), it is worth highlighting Meta's policies around user permissions and the importance of understanding the terms of service when using devices like Meta's VR headsets (e.g., Meta Quest).

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*"**3. The permissions you give us.** We need certain permissions from you to provide our services: <u>Permission to use content that you create and share:</u> Some content that you share or upload, such as photos or videos, may be protected by intellectual property laws. You retain ownership of the content that you create and share on Facebook and other Meta Company Products that you use, and nothing in these Terms takes away the rights that you have to your own content. You are free to share your content with anyone else, wherever you want. To provide our services, however, we need you to give us some legal permissions to use this content. **However, to provide our services, we need you to give us some legal permissions (known as a "Licence") to use this content. This is solely for the purposes of providing and improving our Products and services as described in Section 1 above. Specifically, when you share, post or upload content that is covered by intellectual property rights on or in connection with our Products, you grant us a non-exclusive, transferable, sub-licensable, royalty-free and worldwide licence to host, use, distribute, modify, run, copy, publicly perform or display, translate and create derivative works of your content (consistent with your privacy and application settings). This means, for example, that if you share a photo on Facebook, you give us permission to store, copy and share it with others (again, consistent with your settings) such as Meta Products or service providers that support those products and services.** This licence will end when your content is deleted from our systems."* In summary, users retain ownership of their content on Meta platforms but grant Meta a non-exclusive, transferable, sub-licensable, royalty-free, and worldwide licence to use, store, distribute, and modify it for service improvement. This licence extends to hosting, translation, and creating derivative works. Meta may share user content with service providers, which could raise privacy concerns. The licence is revoked when users delete their content, though it may temporarily persist in backups.

- **Ownership of Content:** While users retain ownership of their content, Meta requires a licence to use, store, distribute, and modify the content shared on their platforms.
- **Scope of Licence:** Meta's licence is non-exclusive, transferable, sub-licensable, royalty-free, and worldwide. It covers hosting, distribution, translation, and derivative work creation but is limited to improving their services.
- **Data Sharing with Partners:** Meta reserves the right to share user content with service providers that support their products, raising potential privacy concerns.
- **Revocation of Licence:** The licence ends when users delete their content from Meta's systems. However, deleted content may persist in backups for a limited time.

13.4.1 Ethical Concerns Around Meta's Practices

As immersive technologies like Meta devices become increasingly integrated into educational settings, ethical considerations surrounding their use must be critically examined. Key concerns include transparency regarding data permissions, potential privacy risks, and the unique challenges posed within educational contexts. Institutions need to understand and evaluate the implications of these practices to safeguard student data and ensure the ethical implementation of such technologies.

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Transparency Issues: While Meta's terms describe their practices, many users may not fully understand the implications of granting such broad permissions.

Privacy Risks: Behavioural and content data collected by Meta could potentially be analysed or shared in ways that users did not anticipate.

Educational Context: When using Meta devices in education, institutions must carefully evaluate the implications of these policies, especially when student-generated content or sensitive data is involved.

13.5 Best Practices for Educational Institutions

To address growing concerns around data privacy and transparency in the use of immersive technologies, institutions must adopt a proactive and strategic approach. This includes creating clear policies for data collection, negotiating vendor agreements that prioritise privacy, educating stakeholders on data implications, and exploring alternative platforms with enhanced controls. These steps collectively empower institutions to protect user privacy, maintain compliance with standards, and ensure informed use of third-party technologies.

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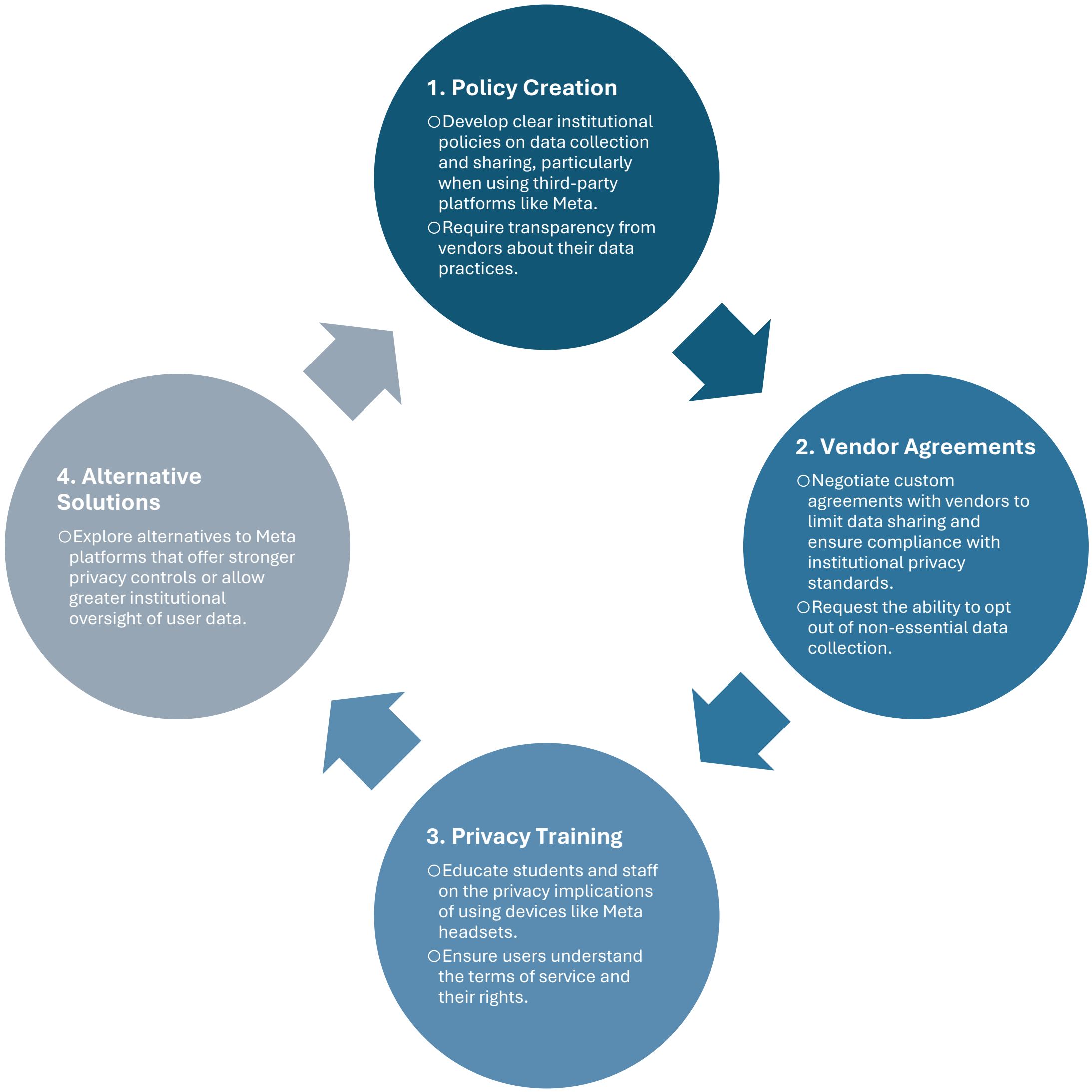

14. User Experience: Enhancing Engagement and Continuous Improvement

The success of immersive technologies in higher education hinges on delivering a high-quality user experience. Ensuring that VR, AR, and MR tools effectively engage students while being easy to use for both learners and educators is crucial for achieving positive learning outcomes. Two key components of optimising user experience are measuring student engagement and implementing robust feedback mechanisms to refine and improve the overall experience. By consistently measuring student engagement and implementing effective feedback mechanisms, institutions can ensure immersive

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technologies remain impactful, user-friendly, and aligned with the needs of students and educators alike.

14.1 Student Engagement

Immersive technologies offer unparalleled opportunities to enhance engagement by placing learners in interactive, dynamic environments. However, their impact on engagement must be measured and understood to ensure they deliver meaningful educational value:

Assessing Learning Outcomes: Use metrics such as test scores, retention rates, and skill acquisition to evaluate how immersive experiences influence learning outcomes compared to traditional methods. For example, VR simulations for medical students practising surgical techniques can be assessed for accuracy, confidence, and real-world application.

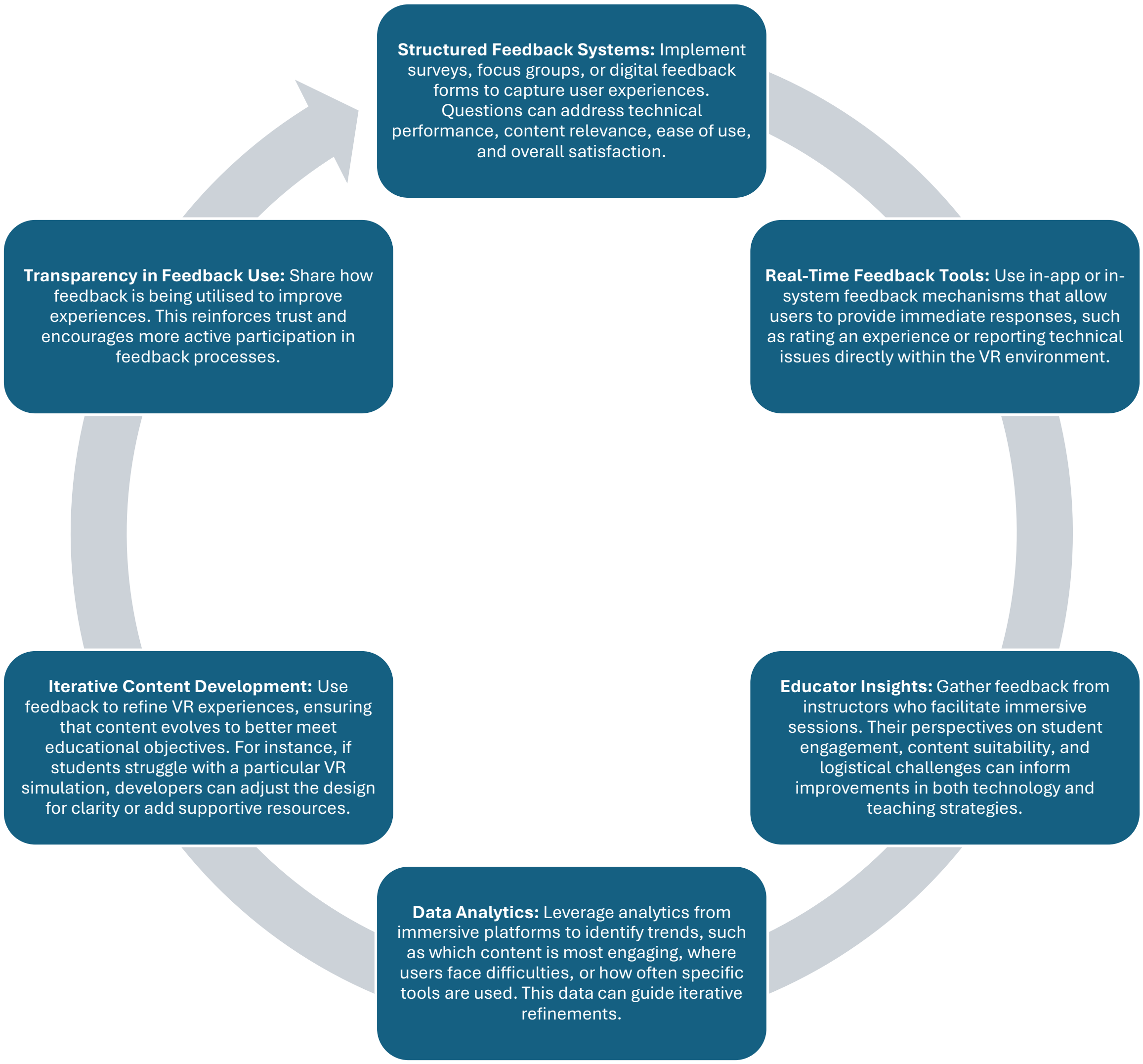
Behavioural Engagement: Track how students interact with the immersive environment, including the duration of engagement, the number of completed tasks, and their level of curiosity or enthusiasm. Metrics such as headset usage time or task completion rates can provide insights into user involvement.

Affective Engagement: Evaluate emotional responses to immersive experiences through surveys or observation. Immersive environments that evoke curiosity, excitement, or empathy are more likely to resonate with students and lead to long-term retention. For instance, VR simulations depicting environmental challenges can spark emotional engagement with sustainability issues.

Personalisation and Adaptability: Tailor immersive experiences to match individual learning styles or pace. Personalisation can help students feel more connected to the material, boosting engagement and reducing frustration.

14.2 Feedback Mechanisms

To ensure the ongoing success and usability of immersive technologies, continuous feedback from both students and educators is essential. This feedback drives improvements and helps institutions adapt the technology to meet evolving needs.



14.3 Enhancing the User Experience

The successful integration of immersive technologies in education relies on delivering a positive and engaging user experience. By focusing on adoption rates, learning outcomes, institutional innovation, and long-term sustainability, institutions can maximise the value of these tools. A well-structured approach ensures greater acceptance among students and educators, improved learning retention, and a sustainable investment that positions

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universities as leaders in educational technology. A focus on user experience leads to significant benefits for immersive technology adoption in higher education.

Increased Adoption Rates

A positive user experience encourages greater acceptance and use among students and educators, ensuring immersive technologies are embraced as a valuable part of the learning process.

Improved Learning Outcomes

Engaged students are more likely to retain information and develop practical skills, especially when their feedback helps shape the educational tools they use.

Institutional Innovation

By refining user experiences based on feedback, universities position themselves as leaders in the innovative use of technology for education.

Long-Term Sustainability

A strong focus on user satisfaction ensures the continued relevance and effectiveness of immersive tools, making them a sustainable investment for institutions.

15. User Interface and User Experience (UI/UX) Considerations for Immersive Applications

Immersive technologies redefine how users interact with content, making User Interface (UI) and User Experience (UX) critical components of successful educational deployment. Unlike traditional 2D interfaces, immersive environments introduce three-dimensional interaction, spatial navigation, embodied cognition, and sensory feedback, all of which significantly alter the design paradigms for educational tools and experiences.

15.1 Principles of UI/UX Design in Immersive Learning Environments

Effective UI/UX design in immersive education must balance engagement with cognitive load management and accessibility. Core principles include:

Simplicity and Clarity: Interfaces should minimise clutter and avoid overwhelming the user. Icons, controls, and instructions must be easy to locate and interpret in a 3D space.

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Context-Aware Interaction: UI elements should appear or adapt based on the learner's activity and spatial context to reduce distraction and cognitive overload.

Intuitive Navigation: Users must be able to move through immersive spaces without confusion or disorientation. Visual cues, teleportation, or smooth locomotion must be adapted to the target user group (e.g. novice vs. experienced users).

Consistent Feedback Loops: Immediate and clear feedback (visual, auditory, or haptic) is vital to affirm user actions and support learning-by-doing.

Embodied Cognition Alignment: UI/UX design should leverage body movements, gestures, and spatial memory to enhance learning outcomes through kinaesthetic engagement.

15.2 Design Considerations Specific to HEIs

For higher education contexts, immersive UI/UX design must consider:

Pedagogical Intent: The interface must support the learning outcomes rather than distract from them. For example, in a VR chemistry lab, UI elements should assist hypothesis testing and procedural understanding, not mimic game HUDs.

Accessibility and Inclusivity: HEIs must ensure that immersive applications accommodate diverse learner needs:

- Text-to-speech for visually impaired users.
- Voice control or simplified controllers for users with motor disabilities.
- Language localisation and adjustable reading levels.

Device and Platform Constraints: UI/UX designs must account for different levels of device capability (e.g., high-end VR headsets like the Meta Quest 3 vs. mobile AR on iPads). Interfaces must be adaptable and not overly dependent on specific hardware.

Cognitive Load and Flow: Avoid multitasking demands in high-immersion environments. Educational UX should promote flow, keeping learners engaged and progressing smoothly without confusion or fatigue.

Collaborative Design Thinking: Educators, learning designers, developers, and students should collaborate in the UI/UX development process, ensuring alignment with real classroom scenarios and curricular standards.

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15.3 Common UI Components in Immersive Education

Component	Description	Best Practice for HEIs
HUD (Heads-Up Display)	Floating interface elements within the user's field of vision.	Use sparingly; should not obstruct learning visuals.
Tooltips & Annotations	Contextual information or guidance.	Ideal for laboratory simulations or anatomy models.
Voice Commands	Spoken input to control actions or retrieve info.	Ensure multilingual and dialectic recognition.
Virtual Hands/Controllers	Representations of user interaction tools.	Keep gestures consistent and ergonomically designed.
Teleportation Markers	Used for spatial navigation	Place at logical transition points to guide users.

15.4 Evaluation Metrics for UI/UX in Immersive Education

Institutions should implement structured evaluation to iteratively refine immersive experiences. Consider the following metrics:

Task Completion Time: Measures how quickly students can perform educational objectives using the interface.

Error Rate: Identifies usability problems by tracking incorrect inputs or failed actions.

User Satisfaction: Collected through post-session surveys, often using standardised tools like the *System Usability Scale* (SUS).

Cognitive Load Assessment: Evaluate using, for instance, the *NASA Task Load Index* (NASA-TLX) or similar scales to ensure the UI/UX does not overload students mentally.

Learning Efficacy: Link user experience quality to measurable academic performance or skill acquisition.

15.5 Recommendations for Institutional Integration

To support high-quality UI/UX in immersive applications, institutions should:

Develop Institutional UI/UX Guidelines for XR: Establish a set of reusable standards and design kits for developers and educators.

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Train Design Teams in Immersive UX Principles: Offer Continuing Professional Development (CPD) workshops or microcredentials focused on immersive instructional design.

Include End-Users Early: Engage both students and educators in co-design phases to validate interface choices early in development.

Pilot and Iterate: Test immersive applications in real learning environments and adjust UI/UX based on feedback and learning outcomes.

The report titled "***AR/VR Research Report 2020 | Interpret Studio and Institute of Art Design and Technology (IADT)***" by authors *Robert Griffin*, *Iva Bedzula Prebeg*, and - featured as **Appendix F** - offers an in-depth exploration of these and related topics. It stands out as an exceptional resource in its own right and significantly enriches the VISIEN Framework as both a complementary and a standalone reference.

16. Health and Safety: Considerations for Integrating Immersive Technologies in Education

Immersive technologies offer transformative educational opportunities, but they also introduce specific health and safety risks that institutions must address to ensure student and staff well-being. Key considerations include conducting risk assessments, obtaining legal permissions, and implementing guidelines around age limits and usage durations. By addressing these health and safety considerations, institutions can create a safe and inclusive environment for using immersive technologies, maximising their benefits while protecting users.

16.1 On-Site and Off-Site Risk Assessments

The safe use of immersive technologies, whether on-site or off-site, requires careful risk assessment and proactive measures to protect users. On-site considerations include addressing physical hazards like tripping, collisions, and ventilation, particularly for VR environments where spatial awareness is reduced. For off-site AR or outdoor experiences, environmental factors such as terrain, weather, and proximity to hazards must be evaluated. By implementing safety guidelines, ensuring proper equipment management, and maintaining hygiene protocols, institutions can create secure and effective immersive learning environments. **Appendices A and B** are sample templates of the Risk Assessment carried out before delivering immersive experiences, both on-site and off-site.

On-Site Risks	Off-Site Risks
Assess physical spaces where immersive technologies will be used to identify and mitigate risks such as tripping hazards, collisions, or overcrowding.	For field-based immersive experiences, such as AR-enhanced outdoor learning, assess environmental hazards like uneven terrain, weather conditions, or proximity to roads.
Ensure the area is clear of obstacles and has adequate ventilation, lighting, and space for safe movement, particularly for VR, where users may be unaware of their physical surroundings.	Provide clear guidelines for safely using devices outside, including how to maintain awareness of real-world surroundings.
Evaluate electrical safety for devices requiring power, ensuring cables are secured and not a trip hazard.	
Implement safeguards for shared devices, including regular cleaning and disinfecting to prevent hygiene issues.	

16.2 Legal Permissions and Waiver Forms

Appendix C is a sample template of the Permissions and Waivers that all users need to read, understand and agree to before taking part in immersive experiences. These samples have been cleared by the Legal Team and applied to REEdI at MTU. Each institution that wishes to adopt or modify these documents for its purpose will need to clear them past their Legal teams and processes.

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User Consent	Require users (or their guardians, if underage) to sign waivers acknowledging the potential risks associated with immersive technologies, such as motion sickness, eye strain, or disorientation.
	Include detailed information about data privacy, explaining how user data may be collected, stored, and used, in compliance with regulations such as GDPR.
Liability Waivers	Include clauses in waiver forms to protect the institution from liability in cases of minor injuries or discomfort resulting from immersive technology use.
	Ensure waivers specify that users must follow safety guidelines and instructions provided by staff or embedded in the technology.
Medical Disclosures	Ask users to disclose any pre-existing conditions that could be exacerbated by immersive experiences, such as epilepsy, vertigo, or motion sensitivity.
Accessibility Accommodations	Address accessibility needs in the forms, ensuring users can request modifications or alternative formats to participate safely in immersive experiences.

16.3 Recommendations for Age Limits

Establishing age limits and guidelines for using immersive technologies in education ensures both the safety and suitability of these tools for learners. VR and AR offer transformative potential, but their use must be aligned with the developmental stages and well-being of students. Adhering to manufacturer recommendations, securing parental consent, and ensuring age-appropriate content are key strategies to maximise the benefits while minimising risks associated with these technologies.

Age-Appropriate Use

- Follow manufacturer guidelines for minimum age requirements, which typically recommend VR use for users aged 13 and above due to potential impacts on vision development and susceptibility to discomfort.
- For younger students, consider AR tools that use tablets or smartphones, which are less immersive and pose fewer health risks.

Parental or Guardian Consent

- For users under 18, obtain explicit consent from a parent or guardian, and ensure they understand the potential risks.

Content Suitability

- Verify that the immersive content is age-appropriate, avoiding simulations or experiences that could cause distress, confusion, or harm.

15.4 Recommendations for Time Using Immersive Technologies

The effective use of immersive technologies, such as Virtual Reality (VR) and Augmented Reality (AR), requires careful consideration of user comfort and well-being. Recommendations for session duration, break intervals, and user acclimatisation are vital to prevent discomfort and enhance the overall experience. These guidelines are especially important for younger users and first-time participants to ensure a safe and positive introduction to immersive learning.

Timed Sessions and Regular Breaks: Limit VR sessions to 20–30 minutes for younger users and 30–60 minutes for adults, depending on the intensity of the experience. Prolonged use can lead to eye strain, fatigue, or discomfort. Encourage breaks of at least 10–15 minutes between sessions to allow users to rest their eyes, reorient themselves, and reduce the risk of overexposure.

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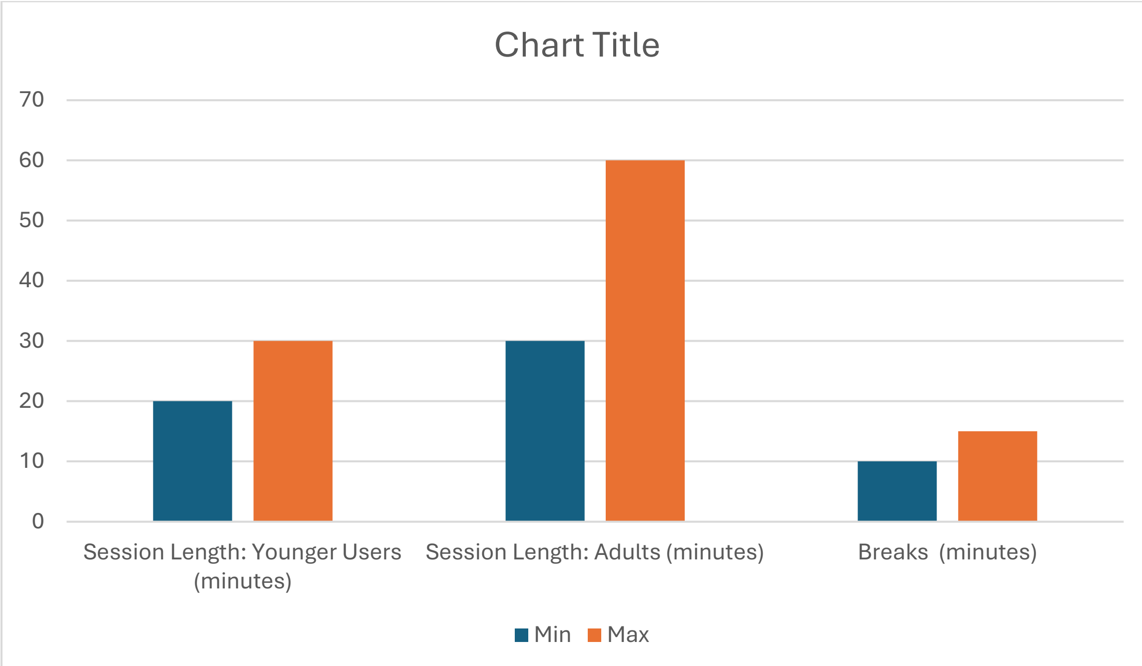

Gradual Acclimatisation: For first-time users, start with shorter sessions to help them adjust to immersive experiences and minimise the risk of motion sickness or dizziness.

Monitoring Discomfort: Instructors or facilitators should monitor users for signs of discomfort, such as nausea, headaches, or disorientation, and intervene promptly if necessary.

16.6 Best Practices for Implementation

Safety Training: Train staff to manage immersive technology use, including how to set up equipment safely, supervise users, and respond to any health or safety concerns.

Signage and Instructions: Display clear instructions in immersive technology areas, outlining safe usage practices, time limits, and emergency procedures.

Hygiene Protocols: Establish hygiene standards for shared devices, such as providing disposable headset covers and sanitising equipment between uses.

Feedback Mechanisms: Allow users to report health and safety issues, ensuring continuous improvement of protocols and risk management.

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Appendix A – C are templates utilised at REEdi and MTU for Health and Safety assessments for all users of immersive technologies. It is recommended that these are assessed by individual institutions' Health and Safety, as well as Legal teams.

17. The Human Factor: Resources and Skillsets Required

Successfully integrating immersive technologies into education requires a diverse range of expertise spanning technical, pedagogical, and administrative domains. By assembling a multidisciplinary team with these skillsets, educational institutions can effectively plan, deploy, and sustain immersive technologies to enhance teaching and learning experiences.

17.1 Overview of Key Roles and Skills

Below is an overview of the key roles and the skills they bring to the implementation, management, and scaling of these technologies:

17.1.1 Developers

- **Responsibilities:**
  - Design and develop custom VR, AR, or MR applications tailored to educational goals.
  - Use tools such as Unity, Unreal Engine, or WebXR for content creation.
  - Implement interactive features and optimise performance for various devices.
- **Required Skills:**
  - Proficiency in programming languages like C#, Python, or JavaScript.

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   - Experience with 3D modelling and animation integration.
   - Knowledge of device-specific software development kits (SDKs) for platforms like Oculus, Magic Leap, or HoloLens.

17.1.2 Learning Technologists

- **Responsibilities:**
   - Bridge the gap between technology and pedagogy by aligning immersive tools with curriculum objectives.
   - Train educators on how to integrate immersive technologies into their teaching practices.
   - Evaluate the educational impact of immersive tools and recommend improvements.
- **Required Skills:**
   - Expertise in instructional design and digital pedagogy.
   - Familiarity with immersive platforms and educational technologies.
   - Strong communication and training skills.

17.1.3 Technicians

- **Responsibilities:**
   - Manage the installation, maintenance, and troubleshooting of immersive technology hardware.
   - Ensure devices such as VR headsets, AR glasses, projectors, and sensors are functioning optimally.
   - Set up and support immersive classrooms, labs, or studios.
- **Required Skills:**
   - Proficiency in hardware and software troubleshooting.
   - Understanding of networking, device compatibility, and integration.
   - Ability to provide on-the-spot technical support during immersive sessions.

17.1.4 Content Creators

- **Responsibilities:**
   - Develop immersive educational content, such as 3D models, animations, simulations, and virtual tours.
   - Use tools like Blender, Maya, or Adobe Creative Suite for designing visual assets.
   - Collaborate with subject matter experts (SMEs) to ensure content accuracy and relevance.

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- **Required Skills:**
  - Strong 3D design, animation, and video editing expertise.
  - Knowledge of user experience (UX) design principles for immersive environments.
  - Creative skills to design engaging and interactive content.

17.1.5 Procurement Specialists

- **Responsibilities:**
  - Identify and evaluate hardware and software solutions that align with institutional needs and budgets.
  - Negotiate with vendors and manage licensing agreements.
  - Ensure compliance with institutional procurement policies and legal standards.
- **Required Skills:**
  - Expertise in vendor management and contract negotiation.
  - Knowledge of immersive technology hardware and software markets.
  - Budget planning and financial analysis capabilities.

17.1.6 Finance Professionals

- **Responsibilities:**
  - Develop budgets for immersive technology implementation, maintenance, and scaling.
  - Identify funding sources, including grants, partnerships, or institutional allocations.
  - Monitor and report on financial performance and ROI for immersive projects.
- **Required Skills:**
  - Strong financial planning and analysis capabilities.
  - Understanding of funding mechanisms and cost management.
  - Ability to forecast long-term financial sustainability of technology initiatives.

17.1.7 Educators and Subject Matter Experts (SMEs)

- **Responsibilities:**
  - Provide content expertise to guide the development of immersive educational materials.
  - Test immersive tools and offer feedback to improve usability and relevance.
  - Integrate immersive experiences into lesson plans and deliver them effectively.

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- **Required Skills:**
  - Deep subject knowledge and curriculum design experience.
  - Willingness to adapt to new technologies and teaching methodologies.
  - Strong communication and feedback skills for collaboration with developers and technologists.

17.1.8 IT Support Staff

- **Responsibilities:**
  - Manage the technical infrastructure for immersive technologies, including networks, servers, and cloud services.
  - Ensure data security and compliance with privacy regulations.
  - Provide ongoing technical support for users and administrators.
- **Required Skills:**
  - Expertise in IT infrastructure, cybersecurity, and cloud management.
  - Knowledge of immersive technology systems integration.
  - Troubleshooting and user support skills.

17.1.9 Project Managers

- **Responsibilities:**
  - Oversee the end-to-end implementation of immersive technology projects.
  - Coordinate between departments, vendors, and stakeholders to ensure timely delivery.
  - Monitor project milestones, budgets, and outcomes.
- **Required Skills:**
  - Strong organisational and leadership skills.
  - Knowledge of project management methodologies like Agile or PRINCE2.
  - Ability to manage cross-functional teams effectively.

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17.2 Summary of Roles and Their Contributions

Role	Key Contribution
Developers	Create custom software and applications for immersive learning experiences.
Learning Technologists	Ensure alignment of immersive technologies with educational goals and provide training for educators.
Technicians	Maintain and troubleshoot hardware and software systems for smooth operation.
Content Creators	Design interactive and engaging educational materials for immersive platforms.
Procurement Specialists	Manage the acquisition of hardware and software, ensuring cost-effectiveness and compliance.
Finance Professionals	Budget planning, funding allocation, and financial oversight for immersive projects.
Educators and SMEs	Provide subject expertise and integrate immersive tools into teaching practices.
IT Support Staff	Manage technical infrastructure and ensure data security for immersive systems.
Project Managers	Coordinate and deliver immersive technology projects within scope, budget, and timeline.

18. Maximising Educational Value

The true potential of immersive technologies in higher education lies in their ability to enrich learning experiences and improve outcomes. To realise this value, universities must strategically align these tools with curriculum goals, invest in content development, and provide robust training for educators. By focusing on curriculum integration, high-quality content development, and comprehensive teacher training, universities can maximise the educational value of immersive technologies and create transformative learning experiences.

Curriculum Integration: Immersive technologies must be intentionally woven into the curriculum to ensure they contribute meaningfully to educational objectives. First, aligning these tools with specific learning outcomes is essential; for instance, VR simulations can help bring abstract scientific concepts to life or provide practical training in clinical skills. Additionally, universities can customise the use of immersive tools to address discipline-specific needs, such as using AR in architecture to visualise designs in real-world settings or employing MR in engineering for collaborative problem-solving. Beyond functionality, immersive technologies enhance engagement by immersing students in active learning environments. For example, students can explore historical landmarks in VR or simulate real-world business scenarios, fostering deeper engagement and better retention of material. Ultimately, integrating these tools strategically can significantly improve educational outcomes.

Content Development: Creating or sourcing high-quality, curriculum-aligned content is critical to the success of immersive technologies. Institutions can collaborate with developers or utilise in-house resources to create bespoke VR and AR modules that reflect local educational standards and cultural contexts. Alternatively, universities can partner with established providers to access pre-designed simulations and content libraries tailored to academic disciplines. It is vital to ensure that the content is interactive and adaptable, accommodating various learning styles to make it more inclusive and effective. For instance, gamified VR simulations can cater to both visual and experiential learners. Furthermore, regular updates to immersive content ensure alignment with evolving academic fields, keeping materials relevant and accurate to meet changing educational standards.

Teacher Training: Educators are pivotal in leveraging immersive technologies effectively, and comprehensive training ensures they are confident and prepared to integrate these tools into their teaching practices. Training should cover technical skills, such as setting up, operating, and troubleshooting hardware and software like VR headsets or AR-enabled apps. Pedagogical approaches also need to be developed, helping educators design instructional strategies that integrate immersive technologies to complement traditional teaching methods. For example, educators could use VR to simulate fieldwork or AR for interactive lab sessions. Moreover, content creation training can empower educators to customise or develop immersive content that aligns with their teaching goals. Finally, establishing ongoing support systems, such as helpdesks or peer collaboration networks, can help educators resolve technical or instructional challenges, ensuring their sustained confidence and effectiveness in using these tools.

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19. Maximising Educational Impact

The true potential of immersive technologies in higher education lies in their ability to enrich learning experiences and improve outcomes. To fully harness this potential, universities must strategically align these tools with curriculum goals, invest in high-quality content development, and provide robust training for educators. When implemented effectively, immersive technologies can yield numerous benefits, including enhanced learning outcomes, increased inclusivity, improved educator confidence, and a strengthened institutional reputation.

Enhanced Learning Outcomes: Immersive experiences make abstract concepts more tangible, enabling students to better grasp difficult material. By engaging students in interactive and hands-on activities, these technologies improve skill acquisition and retention rates. For example, virtual reality (VR) simulations can allow students to explore complex scientific phenomena or practice medical procedures in a safe and controlled environment, leading to deeper learning and application of knowledge.

Greater Inclusivity: The customisable and interactive nature of immersive content ensures that it can accommodate diverse learning styles and abilities. By catering to visual, auditory, and experiential learners, these technologies create a more inclusive educational environment. For instance, students with disabilities can benefit from tailored simulations that adapt to their needs, removing barriers to participation and fostering equitable access to education.

Improved Educator Confidence: With the right training and ongoing support, educators are more likely to embrace immersive technologies and integrate them consistently into their teaching practices. When educators feel confident using tools like VR or augmented reality (AR), they can deliver more impactful lessons and experiment with innovative approaches, ensuring students benefit fully from these technologies.

Institutional Reputation: Successfully integrating immersive technologies can position universities as leaders in educational innovation, attracting prospective students, faculty, and research opportunities. Institutions that demonstrate a commitment to cutting-edge teaching methods are more likely to gain recognition and secure partnerships with industry leaders, further enhancing their prestige.

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20. Pilot Programs: A Strategic Approach to Immersive Technology Integration

Pilot programs are an essential step in the thoughtful adoption of immersive technologies within higher education. By implementing small-scale trials before committing to institution-wide integration, higher education institutions can evaluate the practical implications of using immersive tools, ensuring they meet educational objectives and align with budgetary and operational constraints. Pilot programs serve as a low-risk, high-value approach to ensure immersive technologies deliver on their potential while aligning with the strategic goals of the institution.

20.1 The Role of Pilot Programs in Evaluating and Scaling Immersive Technology Integration

Before full-scale integration, launching a pilot program to test the effectiveness and feasibility of immersive technology integration can help. They provide institutions with the opportunity to evaluate the effectiveness of tools like VR and AR in enhancing learning outcomes while gathering valuable feedback from students and faculty on usability and impact. These programs also help to identify technical or pedagogical challenges, such as device compatibility or integration into curricula, and allow institutions to adjust cost estimates based on real-world use. Furthermore, pilots are instrumental in building stakeholder confidence by demonstrating measurable benefits, such as increased engagement and skill acquisition, encouraging further investment and adoption.

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Test the technology's effectiveness: Pilot programs allow institutions to assess how well immersive technologies enhance learning outcomes. For example, testing AR for visualising anatomy or VR for simulating hazardous lab environments can demonstrate practical benefits in real-world teaching contexts.

Gather feedback from students and faculty: Feedback from both students and faculty provides invaluable insights into the usability, engagement, and educational value of the technology. Faculty can highlight content creation challenges, while students can share perspectives on usability, accessibility, and impact on learning.

Identify any technical or pedagogical challenges: Pilots can uncover technical issues such as device compatibility, connectivity problems, or hardware limitations. Pedagogical challenges, such as the need for tailored training or integrating technology into existing curricula, can also be identified and addressed.

Adjust cost estimates based on real-world use: Testing in a controlled environment helps institutions refine initial cost estimates. This includes accounting for hardware, software, training, and ongoing maintenance costs, ensuring better financial planning for scaled deployment.

Building Stakeholder Confidence: Pilot programs can demonstrate the value of immersive technologies to stakeholders, including administrators, educators, and students. By showcasing measurable benefits, such as increased engagement or improved skill acquisition, institutions can gain support for further investment.

20.2 Example Pilot Strategies: Exploring Targeted and Collaborative Applications

Each of these pilot strategies serves as a stepping stone toward understanding the practicalities, benefits, and challenges of integrating immersive technologies into education. By tailoring these pilots to specific use cases, institutions can gather the insights needed to scale implementation effectively and maximise the impact of these tools in a variety of learning contexts.

Department-Level Trials: Starting with department-specific pilots allows institutions to test immersive technologies in areas where they have immediate and practical applications. For instance, in the engineering department, VR can simulate complex machinery, enabling students to explore components and functionality without requiring physical equipment. Similarly, in healthcare education, MR can be used for clinical simulations, such as virtual anatomy dissections or practising surgical techniques in a risk-free environment. These trials provide an opportunity to evaluate the effectiveness of

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the technology in discipline-specific scenarios, identify potential challenges such as hardware limitations or usability issues, and gather targeted feedback from faculty and students who are directly engaged with the tools.

Student Cohort Pilots: Focusing on a specific cohort of students allows for a controlled environment to test how AR or other immersive technologies enhance learning outcomes. For example, AR-enabled course materials can be used to help students visualise abstract or complex concepts in subjects like mathematics, physics, or chemistry. A cohort pilot could involve integrating AR to demonstrate molecular structures in real-time or overlaying 3D visualisations on engineering blueprints. By gathering detailed feedback from the cohort, institutions can assess how well the technology improves comprehension, engagement, and retention of the material, as well as any adjustments needed for effective implementation across larger groups.

Cross-Disciplinary Pilots: Cross-disciplinary pilots allow institutions to explore how immersive technologies can foster collaboration between different fields of study. For example, a pilot combining VR in engineering and MR in architectural design could simulate real-world projects where students work together to design and analyse structural models in virtual environments. These pilots can also involve interdisciplinary applications, such as using VR for environmental studies (e.g., simulating ecosystems) while combining it with AR for data overlays during field research. Such collaborative pilots provide insights into how immersive technologies can break down silos between disciplines, promote teamwork, and offer a broader range of educational benefits.

20.3 Scaling After the Pilot: Building a Robust Implementation Plan

Once the pilot program concludes, institutions can thoroughly analyse the results to create a comprehensive and effective implementation plan for scaling immersive technologies. This phase is crucial to ensure that the broader deployment addresses the challenges encountered during the pilot and leverages its successes to maximise impact. Institutions can develop a robust scaling strategy that not only enhances the adoption of immersive technologies but also ensures sustainable and impactful usage across all levels of their educational framework. Key considerations for scaling include expanding infrastructure, training staff, and optimising processes for smoother adoption:

Expanding Infrastructure Based on Feedback and Identified Needs: The pilot phase often highlights gaps in existing infrastructure, such as insufficient hardware, network capacity, or space for immersive technology setups. Based on the feedback from pilot users, institutions can identify specific needs, such as acquiring additional VR headsets,

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upgrading server capabilities, or creating dedicated spaces for immersive experiences. Addressing these needs ensures that the technology can scale effectively without compromising performance or user experience. For instance, enhancing Wi-Fi connectivity in classrooms or investing in standalone VR hardware might be necessary to accommodate larger user bases.

Training Additional Faculty and Support Staff: Scaling immersive technologies requires a well-trained team to support both technical and pedagogical needs. During the pilot, initial training may have been limited to a small group of educators and IT staff. For broader adoption, additional faculty and support staff must be trained to confidently integrate the technology into their teaching workflows. This training should go beyond basic operations to include advanced troubleshooting, innovative instructional strategies, and ongoing professional development to keep up with technological advancements.

Incorporating Lessons Learned to Optimise Technology Usage: The pilot provides valuable insights into what works and what doesn't. Institutions should incorporate these lessons into their scaling strategy to streamline technology usage and minimise potential challenges. For example, if certain content delivery methods or interaction designs were found to be particularly effective, these can be standardised across programs. Conversely, any issues, such as VR motion sickness or compatibility problems, should be addressed proactively by refining user guidelines, improving content quality, or updating hardware specifications. By integrating this feedback into the deployment plan, institutions can ensure a smoother transition to full-scale implementation.

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APPENDIX A

DOCUMENT: IMMERSIVE TECHNOLOGY RISK ASSESSMENT

COURSE: MECHANICAL AND MANUFACTURING ENGINEERING, RETHINKING ENGINEERING EDUCATION IN IRELAND (REEDI)

HARDWARE: IMMERSIVE TECHNOLOGY HMDS INCLUDING META QUEST 2/3, MICROSOFT HOLOLENS ETC

	RISK ASSESSMENT NUMBER: MTU-KY_		**Assessor(s):**	**Risk Assessment Date :**	
			(H&S Officer)	**Safety Group Responsible:**	
MTU - Kerry Campus	**Risk Assessment Area being assessed:**	Using VR headsets		**Person Responsible for this RA:**	

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	Previous revision reference:		N/A										
Hazards													
Area	**Hazard**	**Risk Associated**	**Existing Procedures and Controls**	**L**	**S**	**LxS**	**Risk Rating**	**Actions, Improvements and Additional Controls**	**L**	**S**	**LxS**	**Risk Rating**	**Person responsible**
				1	5	5	L		1	5	5	L	
All Scenarios: Wearing of VR headsets	Users may experience motion sickness and/or eye strain. Slips, trips, falls and collisions. Wearing a headset may cause seizures in extremely rare cases.	Falling, eye strain, fatigue, headaches, nausea, choking, seizures (extremely rare)	All team members have received First Aid training. Users are encouraged to remove the headset as soon as negative symptoms present. Users are limited to max 15 minutes per			0		Users to read and sign/agree waivers of risks associated with VR headsets - Waivers approved by MTU Legal. Controlled use and time spent using VR headsets. Recommended age limits in place to ensure users <			0		REEdI Team

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			session with 10-minute breaks. Users are seated in designated areas.					12 years old do not have access to VR headsets.					
MTU Kerry North Campus and any lecture hall/classroom throughout MTU Kerry including KSA	Slips trips and falls as the users' field of view is completely blocked. Collisions with objects including other users.	Slips trips and falls. Struck by other users using VR controllers. Bumping into objects if not seated.	Users are seated in designated areas with enough clearance (2m x 2m) for each user when using headsets. The number of users is limited to the space available. Time limits on continuous use of headsets per session - max 15 mins per session with 10 mins breaks.			0		Users to read and sign/agree with waivers of risks associated with VR headsets - Waivers approved by MTU Legal. Controlled use and time spent using VR headsets. Adequate and appropriate space is allocated for using VR headsets. Adequate staff/user ratios for effective management of group sizes.			0		REEdI Team

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Off site visits such as schools or public spaces	Slips trips and falls as the users' field of view is completely blocked. Collisions with objects including other users.	Slips trips and falls. Struck by other users using VR controllers. Bumping into objects if not seated.	Users are required to be seated in designated areas with enough clearance when using headsets. Number of users limited to the space available. Protocols left to individual off-site managers to provide adequate space for using headsets. Time limits on continuous use of headsets per session - max 15 mins per session with 10 mins breaks. Pre-assessment of areas to ensure			0		Users to read and sign/agree waivers of risks associated with VR headsets - Waivers approved by MTU Legal. Managers to comply with requirements and sign waivers on behalf of users where needed. Adequate and appropriate space allocated for using VR headsets. Adequate staff/user ratios for effective management of group sizes. Recommended age limits in place to ensure users < 12 years old do not have access to VR			0		REEdI Team present on day. Representative(s) at visiting location.

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			location is adequate - Off-site venues to confirm suitability of locations via MTU checklist based on MTU requirements as stipulated in Waivers.					headsets.					

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APPENDIX B

DOCUMENT: IMMERSIVE REALITY TRAINING | RISK ASSESSMENT, MITIGATION AND RESPONSES | RISK ASSESSMENT PROTOCOL FOR TRAINING USERS USING IMMERSIVE TECHNOLOGIES

COURSE: MECHANICAL AND MANUFACTURING ENGINEERING, RETHINKING ENGINEERING EDUCATION IN IRELAND (REEDI)

HARDWARE: IMMERSIVE TECHNOLOGY HMDS INCLUDING META QUEST 2/3, MICROSOFT HOLOLENS ETC

Purpose:

This risk assessment protocol aims to identify the risks associated with using VR headsets for training purposes and establish appropriate risk mitigation protocols and risk responses to ensure the safety of personnel and property.

Risk Assessment:

Property Damage:

Risk: VR headsets can be damaged if they are not handled properly or if they are dropped, resulting in potential property damage.

Risk Mitigation: Train users on the proper handling and care of VR headsets, provide a secure storage location for headsets when not in use, and establish a policy for reporting damage immediately.

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Risk Response: Repair or replace damaged headsets as necessary.

Hardware Malfunction:

Risk: Hardware malfunction can occur during use, resulting in the potential loss of data or personal injury.

Risk Mitigation: Conduct regular maintenance checks on VR headsets, establish a protocol for users to report any hardware issues immediately, and keep spare hardware on hand for replacement if necessary.

Risk Response: Repair or replace malfunctioning hardware as necessary, and back up data to prevent data loss.

Health and Safety:

Risk: Prolonged use of VR headsets can cause motion sickness, eye strain, and other health issues. Additionally, users may trip, fall or collide with other objects or individuals in the real-world environment while using the VR headset.

Risk Mitigation: Limit VR headset use to shorter durations, provide breaks between sessions, train users on proper posture and movement while using the headset, and establish a safe and secure training environment.

Risk Response: Provide medical attention or first aid as necessary in the event of an injury or illness and address any safety concerns or hazards promptly.

Personal Injury:

Risk: Users may trip, fall, or collide with other objects or individuals in the real-world environment while using the VR headset, resulting in personal injury.

Risk Mitigation: Establish a safe and secure training environment, limit VR headset use to shorter durations, provide breaks between sessions, and train users on proper posture and movement while using the headset.

Risk Response: Provide medical attention or first aid as necessary in the event of an injury and address any safety concerns or hazards promptly.

Conclusion:

The risks associated with using VR headsets for training purposes can be mitigated through proper training, maintenance, and risk response protocols. Regularly assessing and

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addressing risks will ensure a safe and secure training environment for all personnel involved.

APPENDIX C

DOCUMENT: IMMERSIVE TECHNOLOGIES PERMISSIONS AND WAIVERS FORM (SEPT 2022 – JULY 2025)

COURSE: MECHANICAL AND MANUFACTURING ENGINEERING, RETHINKING ENGINEERING EDUCATION IN IRELAND (REEDI)

HARDWARE: META QUEST 3 INCL. BATTERY + STRAP AND CARRY CASE

Requests for Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and Extended Reality (XR) Permissions and Waivers Form for all users.

Users' utilisation of Immersive Technologies - henceforth referred to as Immersive Technologies – including software and hardware such as head-mounted displays differ based on factors such as their usage preferences, device choice, physical environment (e.g., a VR lab versus a chair in a library), personal restrictions, facility constraints, desired outcomes for events or classes, number of participants involved, etc. This Permission and Waiver Form encompasses the unique circumstances and requirements of Munster Technological University, Kerry, and its facilities. ***Information shared during online registrations or interactions, whether through software, apps, or online access, is protected by strict international privacy laws, such as the EU GDPR and other privacy regulations. These laws specifically apply to children under the age of 13.***

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Acknowledgment

I, the below-signed participant, or designated representative, acknowledge that I have voluntarily chosen to use Immersive Technologies provided by Munster Technological University, Kerry. I understand that using Immersive Technologies involves certain risks, and I agree to release and hold harmless Munster Technological University, Kerry from any liability arising from my use of Immersive Technologies.

Assumption of Risk

I am aware that participating in Immersive Technologies involve potential risks, including but not limited to:

- Physical injury or discomfort, such as motion sickness (cybersickness)*, dizziness, eyestrain, nausea, increased heart rate, increased body temperature, disorientation, vertigo, seizures, injury from other players, self-injury due to user confusion, for example, bumping into walls or objects, tripping, jumping or throwing, etc., tripping, falling, or colliding with objects or persons due to impaired vision or altered perception**, injury due to improper or excessive use of Immersive Technologies equipment.
- Emotional or psychological distress caused by exposure to virtual environments or stimuli.

While using Immersive Technologies:

- Flickering screens and flashing images could trigger underlying health conditions.
- Equipment may affect medical devices such as cardiac pacemakers etc.
- The media content of some experiences may affect those with pre-existing medical or mental health conditions.
- It is possible to feel claustrophobia, panic, or feel other phobias.
- Objects in the real world may not be visible in the virtual world.
- Objects in the virtual world may not exist in the real world.
- You must self-monitor your health and pause or stop if you become unwell.
- Negative health effects may not present immediately.

Fitness to Practise and Study and Student Health

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Fitness to study is described as the possession of the requisite skills, knowledge, health (mental or physical), character, and ability to participate in studies at Munster Technological University safely and effectively. Students are required to have adequate health to undergo their chosen course of study and profession. It is important to note that this does not mean that students must be free of any disability. Munster Technological University, Kerry will comply with Equal Status legislation and make appropriate reasonable accommodations. A student on a Relevant Programme is required to complete a health declaration on first registration and thereafter annually. Where there is a fitness to practice and/or study concern requirement regarding a student's health, the student may be referred to a relevant healthcare professional. The student is obliged under this Policy to attend such medical consultation as required. A process under this Policy can proceed notwithstanding the failure of the student to attend the nominated healthcare professional.

Guidelines

Before using Immersive Technologies, make sure the "*playing area*" is free of any obstructions such as chairs, backpacks, or other objects that might pose a tripping hazard, and allow for 2x2 meter sq. space between users.

Be respectful of people using the Immersive Technologies. No horseplay in the Immersive Technologies Area.

Take at least a 10-to-15-minute break for every 30 minutes of use.

Release of Liability

In consideration for being permitted to use the Immersive Technologies, I hereby release, waive, discharge, and covenant not to sue Munster Technological University, Kerry, its officers, employees, agents, representatives, and affiliates from any and all liability, claims, demands, actions, or causes of action arising out of or related to any loss, damage, or injury, including death, that may be sustained by me or to any property belonging to me, whether caused by negligence or otherwise, while using the Immersive Technologies.

Medical Fitness

I acknowledge that I am in good health and free from any conditions that may be aggravated by using Immersive Technologies. If I have any pre-existing medical conditions, I have notified Munster Technological University, Kerry of these conditions before engaging

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in Immersive Technologies, or I have consulted with a qualified healthcare professional and obtained their approval to use Immersive Technologies.

Indemnification

I agree to indemnify and hold harmless Munster Technological University, Kerry from any and all claims, actions, suits, costs, expenses, damages, or liabilities, including attorney fees, arising from my use of Immersive Technologies.

Privacy and Age Restrictions

Information shared during online registrations or interactions, whether through software, apps, or online access, is protected by strict international privacy laws, such as the EU GDPR and other privacy regulations. These laws specifically apply to children under the age of 13. Generally, individuals under 13 years old should refrain from accessing various VR platforms and stores like META Quest VR, as well as social VR apps such as AltspaceVR and VR Chat. This Permissions and Waiver Form ensures compliance with both local laws and Munster Technological University, Kerry requirements, which users must agree to in accordance with the privacy policy. It is important to note that individual virtual apps may have their own age restrictions and recommendations for usage.

Binding Agreement

I (or my child/dependent/minor) understand that this waiver is a binding agreement and that by signing it, I acknowledge that I have read and understood all the terms of this release form and that I am giving up substantial legal rights.

I understand that Munster Technological University, Kerry has taken reasonable measures to ensure my safety, including providing instructions and guidelines for the use of Immersive Technologies. I agree to follow all provided instructions and use the Immersive Technologies responsibly.

I (or my child/dependent/minor) am using the Immersive Technologies voluntarily.

I (nor my child/dependent/minor) have any known physical, mental, or health-related reasons or problems that should preclude or restrict my or my child's/dependents/minor's participation in the included activities.

I am the parent or legal guardian of the child/dependent/minor named below. I have the legal right to consent to and, by signing below, I hereby do consent to the terms and conditions of this Release of Liability.

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I assume all the physical, psychological, and financial risks associated with the use of Immersive Technologies.

PLEASE NOTE: You will not be able to take part in the Immersive Technologies without agreeing with and signing this waiver.

Immersive Technologies Health and Safety Permissions and Waivers Form	
Full Name	
T (MS) Number	
Student MTU Email	
Date	

** Cybersickness: Research into cybersickness, VR sickness, and motion sickness experienced in VR headsets has been found to impact a percentage of users, and adaptation to overcome the nauseous feeling can be minimised or controlled with at least three sessions. Other studies have shown that chewing mint or ginger-flavoured gum relieves the nauseous feeling for some VR users.*

*** Users with visual impairments like photo-sensitivities and physical and health impairments or conditions may struggle to use VR.*

*** Users with visual impairments like photo-sensitivities and physical and health impairments or conditions may struggle to use VR.*

APPENDIX D

MTU
Ollscoil Teicneolaíochta na Mumhan
Munster Technological University

DOCUMENT: STUDENT LOAN AGREEMENT (SEPT 2022 – JULY 2025)

COURSE: MECHANICAL AND MANUFACTURING ENGINEERING, RETHINKING ENGINEERING EDUCATION IN IRELAND (REEDI)

HARDWARE: META QUEST 3 INCL. BATTERY + STRAP AND CARRY CASE

1. General

1.1 This Agreement is made between Munster Technological University, Kerry (MTU Kerry) ("the University"), and the student ("You"/ "Your") for the loan of an META Quest 3 VR Headset and any associated accessories and equipment ("the IT equipment") as outlined below. This Agreement will prevail over any previous agreement relating to the IT equipment. No variation to this Agreement will be binding unless made in writing and agreed by both parties.

1.2 To be eligible for the loan of IT equipment from the University, You must be a current student at the University and have a valid MTU Student ID Card, IT Username (T/MS Number), and password.

1.3 You agree to use the IT equipment following the University's IT policies of use and sign the IT equipment Loan Record (Appendix 1).

1.4 You must agree to and sign the University *Permissions and Waivers Form* before being able to use the IT equipment.

2. Loan and Return of IT equipment

2.1 The University agrees to loan You the IT equipment as itemised in the '*IT Equipment Loan Record and Movement Order Form"* (Appendix 1), in accordance with these terms and conditions.

2.2 The IT equipment may be collected by You at a specified time and location from a pre-determined University IT Service Desk.

2.3 The IT equipment must be returned at the end of each academic year at a specified date to a pre-determined University IT Service Desk. If you are unable to return the IT equipment at this date for any reason, this should be clearly communicated to Mechanical and Manufacturing Engineering Faculty Staff (MMEFS) and you must make alternative arrangements to return the IT equipment at the earliest opportunity at a date and location that is suitable for the Mechanical and Manufacturing Engineering Faculty Staff (MMEFS).

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2.4 The IT equipment must be returned to the IT Service Desk immediately if You are suspended, excluded, withdraw from, or complete Your studies at the University.

2.5 If You fail to return the IT equipment by the specified date, this will result in a fine being charged at a rate of €5 per day. Failure to return any overdue IT equipment within one week of the return date will result in your IT account being disabled and/or examination results being withheld and/or a ban from using the loan service in the future. The University reserves the right to take appropriate action to recover the IT equipment or to charge You for the full cost of replacing an updated version of the IT equipment.

3. Your Responsibilities

3.1 Upon receipt of the IT equipment, You undertake to maintain it appropriately.

3.2 Any software installed, or files downloaded to the IT equipment must be in accordance with the appropriate software licensing, MTU IT Policies, and adhere to Irish copyright law.

3.3 Any work saved to the hard drive of any of the IT equipment by You must be deleted upon its return.

3.4 You are required to inform the University as soon as possible of any faults with the IT equipment. Where the fault occurs on a weekend or in the evening You must inform MMEFS on the next available working day, making it clear that the IT equipment is a loan item. You must not attempt to fix any hardware problems yourself as this could invalidate the warranty and leave you liable for damage/ replacement costs.

3.5 You must return the IT equipment to the University in the same condition as You received it in, except for reasonable wear and tear. You must return the IT equipment in person so that it can be inspected for any visible damage.

3.6 In the event that You do not return the IT equipment to the University, and the University as a result in accordance with Clause 2.6 charges You for the cost of the IT equipment, You agree to comply with any laws governing the disposal of electronic equipment at the expiry of the life of the IT equipment and indemnify the University for any liability it may incur as a result of your breach of this clause.

4. Damage to or Loss of the IT equipment

4.1 You accept full responsibility for any loss or damage to the IT equipment caused by Your negligence or improper use. “Improper Use” includes (but is not limited to), using the IT equipment otherwise than in accordance with the manufacturer’s and/ or the University’s instructions, using the IT equipment for a purpose other than intended or

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allowing the equipment out of your control and custody and failing to protect it from loss or damage.

4.2 You undertake that You have sufficient household insurance to afford protection to the IT equipment both inside and outside of Your place of residence. If the IT equipment is lost or damaged as a consequence of Your failure to comply with the above clause 4.1, You will be required to reimburse the University for the cost of repairing or replacing the hardware.

5. Third Party Rights

5.1 It is a condition of this Agreement that You will not use or allow the IT equipment to be used in any way that will breach any third-party rights, including but not limited to any rights in respect of confidential information or trade secrets, patent, copyright, design right, design registration, trademark or any other intellectual property rights or title.

5.2 You will indemnify the University and ensure that the University is fully and effectively indemnified against any claims by third parties for infringement of their rights caused by Your use of the IT equipment. Furthermore, You will ensure that the University is indemnified in respect of any loss or expense including legal fees which the University may incur in connection with any such claim or threatened claim by a third party.

5.3 If You breach any of the provisions in sub-clause 5.1 above, the University may at its discretion terminate this Contract forthwith in which event the provisions in Clause 2 will apply.

6. Contact (Rights of Third Parties) Act 1999

6.1 This Agreement does not create, confer or purport to confer any benefit or right enforceable by any person not a party to it.

7. Liability

7.1 The University will indemnify You and keep you fully and effectively indemnified against loss or damage to any property or injury to or death of any person caused by any negligent act or omission or wilful misconduct by the University, its employees, agents, or sub-agents.

7.2 The University shall not in any event be liable for any consequential loss or loss of profits or of contract whatsoever.

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7.3 Except in respect of injury to or death of any person, for which no limit applies, the University's liability under this Contract or in tort in respect of each event or series of connected events shall not exceed the total value of the IT equipment.

8. Termination

8.1 The University may suspend or terminate this Agreement for the loan of IT equipment if You fail to make any payment when due or otherwise default in any of Your obligations under this Agreement or become bankrupt or insolvent or have a trustee in bankruptcy or liquidator or receiver or administrative receiver or administrator appointed over Your assets or if the University in good faith believes that any of these instances may occur. Where the Agreement is terminated You will be required to return the IT equipment to the University forthwith and the provisions of Clause 2 will apply.

9. Data Protection

9.1 All information and supporting documentation supplied by you with this Agreement will be used for the sole purpose of providing the IT equipment and related software to enable the IT equipment functionalities. Your IT Loan Record and related information will be held and maintained in accordance with the provisions of Data Protection Legislation. The data will not be passed to any other third party without your consent, except when the University is required to do so by law.

9.2 The General Data Protection Regulation (GDPR) applies from 25 May 2018. It has general application to the processing of personal data in the EU, setting out more extensive obligations on data controllers and processors, and providing strengthened protections for data subjects. In Ireland, the national law, which, amongst other things, gives further effect to the GDPR, is the Data Protection Act 2018. The GDPR places direct data processing obligations on businesses and organisations at an EU-wide level. According to the GDPR, an organisation can only process personal data under certain conditions. For instance, the processing should be fair and transparent, for a specified and legitimate purpose and limited to the data necessary to fulfil this purpose. Full details can be found online at https://www.ittralee.ie/en/InformationAbout/GDPR/. For any queries please contact: Data Protection Office, Munster Technological University - Kerry Campus, Co. Kerry V92 CX88, Telephone: 066 -7191813, Email: dataprotection@ittralee.ie

10. Waiver of Remedies

10.1 No forbearance, delay, or indulgence by the University in enforcing the provisions of this Agreement shall prejudice or restrict its rights in any way, nor shall any waiver of the

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University's rights operate as a waiver of any subsequent breach nor in any way affect the validity of the whole or any part of this Contract nor prejudice the University's rights to take subsequent action.

11. Severability

11.1 If any of these conditions is considered void, voidable or otherwise unenforceable by a tribunal or proceedings of competent jurisdiction then it must be severed from the Agreement in question which will otherwise remain in full force and effect.

12. Notices

12.1 Any notice to be given under this Agreement will be in writing and transmitted by email, facsimile, or delivered, or forwarded by first class prepaid letter to the receiving party.

13. Law

13.1 The construction and performance of these conditions will be governed by Irish law. All disputes which may arise under, out of or in connection with or in relation to these conditions will be submitted to the Irish Courts.

Appendix 1

IT Equipment Loan Record & Movement Order

IT Equipment and Student Details

FOR STUDENT USE

I hereby acknowledge receipt of the equipment listed above. I have read and understood this agreement and will comply with the terms and conditions the

DOCUMENT: STUDENT LOAN AGREEMENT (SEPT 2022 – JULY 2025) **COURSE:** MECHANICAL AND MANUFACTURING ENGINEERING, RETHINKING ENGINEERING EDUCATION IN IRELAND (REEDI) **HARDWARE:** META QUEST 3 INCL. BATTERY + STRAP AND CARRY CASE
META Quest 3 Headset

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				Please tick as received			
Student ID	***Headset ID***	***Student Signature***	***O-CPT Signature***	***Bundle Pack****	***Battery + Strap***	***Carry Case***	***Loan Date***
	Course_Y24_S1						
	Course _Y24_S2						
	Course _Y24_S...						

APPENDIX E

AR USE CASES

	MAINTENANCE - WORKER
DESCRIPTION	**Maintenance Training On Equipment And Machinery.**
USE CASES	• Machine maintenance on workstation machinery. Some shop floor machinery may require periodic maintenance. Workers can carry out these maintenance tasks using an AR Headset that overlays information on the physical object. This can include regular cleaning of certain parts, how to get access to components, how to remove or replace parts etc. • Customers depend on contractors to perform equipment maintenance and repairs. Using Remote AR applications, customers can have contractors service the equipment in a much more efficient way. • AR-enabled wearables in manufacturing can help measure changes, identify unsafe working conditions, and visualize design components and structures. With field-service knowledge engineers and technicians can monitor the field and provide remote expert support in real-time. Organizations are also using AR to improve productivity in out-of-office or away-from-desk jobs.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar) or AR-enabled mobile devices (phones or tablets).
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).

PROS	• Reduced equipment downtown and support costs • Reduction in service trips and a reduction in labour costs. • Reduced human errors. • Reduced execution time. • Reduced breakdowns. • Increased productivity. • Increased operation speed. • Increased fix rates. • Increased compliance. • Increased profit margins. • Increased diagnosis success rate.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing training scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://upskill.io/landing/ge-aviation-case-study/ • https://upskill.io/landing/ge-renewables-case-study/ • https://www.ptc.com/en/service-software-blog/augmented-reality-maintenance-and-repair • https://www.re-flekt.com/reflekt-one
TECHNOLOGY PROVIDERS	• https://daqri.com/ • https://upskill.io/ • https://www.scopear.com/solutions/work-instructions/ • https://www.ptc.com/en/service-software-blog/augmented-reality-maintenance-and-repair • https://www.re-flekt.com/reflekt-one • https://www.fieldbit.net/ • https://pale.blue/ • https://www.linup.it/

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CASE STUDY

Reinventing aerospace manufacturing and supply chain operations - Boeing Tests Augmented Reality in the Factory

Installing electrical wiring on an aircraft is a complex task that leaves zero room for error. That is why Boeing is testing augmented reality as a possible solution to give technicians real-time, hands-free, interactive 3D wiring diagrams - right before their eyes.

“A person working in an industrial setting has a lot of distractions in that environment and a lot of data to think about and process. Traditionally technicians had to look at and interpret a two-dimensional twenty-foot-long drawing and construct that image in their mind and attempt to wire based on this mental model,” said Brian Laughlin, IT Tech Fellow. “By using augmented reality technology, technicians can easily see where the electrical wiring goes in the aircraft fuselage. They can roam around the airplane and see the wiring renderings in full depth within their surroundings and access instructions hands-free.”

Paul Davies, Boeing Research & Technology Associate Technical Fellow, is working closely with the program and Boeing IT to develop and test augmented reality technology on the Tanker. “Our theory studies have shown a 90 percent improvement in first-time quality when compared to using two-dimensional information on the airplane, along with a 30 percent reduction in time spent doing a job.”

Bruce Dickinson, Vice President and General Manager of the 767/747 Program, said, “The cross-functional team working on this technology has made a step-change break-through in our quality and productivity by following their passion to pursue a great idea. We don’t often see 40% improvements in productivity, and I’m convinced that it was a culture of innovation and leaders who are willing to say ‘yes’ that enabled this idea to come to life.”

https://www.boeing.com/features/2018/01/augmented-reality-01-18.page

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MAINTENANCE - CUSTOMER

DESCRIPTION	**Maintenance Tutorials On Equipment And Machinery.**
USE CASES	• Manufacturers of complex industrial machinery often face two main challenges with their customers. First, how can they effectively educate their potential customers on key technical differentiators that separate their products from their competitors? Machinery is often too large to bring to a customer, too expensive to dismantle, or too complex for a simple explanation. How can the manufacturers support customers in a cost-effective way that maintains machinery and increases uptime without involving expensive specialists? • Using Object Markers, customer can visually explore the components and features of their physical equipment by scanning the equipment with an AR-enabled device (mobile or tablet) and get a 3D overlay onto the physical equipment. The overlay can feature callouts and points of interest to the customer. The customer can click on any of these points to get basic maintenance tutorials e.g. how to replace a routinely serviced part e.g. removing and replacing air filters, cleaning, setting parts to required spec etc. • In addition, customers can learn how to do a parts exchange through an easy-to-follow step-by-step guide in AR—allowing inexperienced users and technicians to maintain equipment on their own.
TECHNOLOGY USED	AR-enabled mobile devices (phones or tablets).
COST	High. Development of software. Requires AR-enabled handheld devices (phones or tablets)
PROS	• Reduced equipment downtown and support costs. • Increased diagnosis success rate. • Reduction in service trips. • Reduction in labour costs.
CONS	• Cost of developing scenarios. • Requires high-end AR-enabled handheld device. • Users' resistance to change.
REAL WORLD EXAMPLES	• https://newatlas.com/hyundai-introduces-3d-augmented-reality-owners-manuals/40339/

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	• https://www.caranddriver.com/features/a23786553/mercedes-genesis-augmented-reality-owners-manual/
TECHNOLOGY PROVIDERS	• https://daqri.com/ • https://upskill.io/ • https://www.scopear.com/solutions/work-instructions/ • https://www.ptc.com/en/service-software-blog/augmented-reality-maintenance-and-repair • https://www.re-flekt.com/reflekt-one • https://www.fieldbit.net/ • https://pale.blue/ • https://www.helmes.com/ • https://eonreality.com/

ASSEMBLY AND INSTALLATIONS

DESCRIPTION	**Assembly And Installation Of After-Market Parts.**
USE CASES	An AR app that overlays digital instructions onto existing products to provide details on the assembly and installation of service or aftermarket parts. Or how to connect different components. Using the advances in camera technology, users can also turn their smart device into a tape measure to measure spaces to ensure the correct fit of machinery.
TECHNOLOGY USED	AR-enabled mobile devices (phones or tablets)
COST	Low. Only requires AR-enabled handheld device (phones or tablets)
PROS	• 90% Improvement in first-time quality when compared to using two-dimensional information. • Decreased time required to do work by up to 30%.
CONS	• Cost of developing scenarios. • Requires high-end AR-enabled handheld device. • Users' resistance to change.
REAL WORLD EXAMPLES	• https://www.dezeen.com/2018/03/23/ikea-assembly-made-easier-through-augmented-reality-app/
TECHNOLOGY PROVIDERS	•

STANDARD OPERATING PROCEDURES (SOP)

DESCRIPTION	**DIGITISING STANDARD OPERATING PROCEDURES**

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USE CASES	Using AR Headsets, SOPs can be digitised and always accessible by workers. This can apply to all situations where complex tasks need to be performed, and the working environment allows for it. These can include machine start-up/shutdown procedures, safety precautions, emergency stop procedures, fire training etc.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar)
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• Increased efficiency and reduced downtime. • Increased worker confidence. • Increased level of support.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://www.vksapp.com/case-studies/clearpath-robotics-has-reduced-training-using-vks • https://www.vksapp.com/case-studies/10-reasons-carpentry-school-went-building-11-88-stairs
TECHNOLOGY PROVIDERS	• https://upskill.io/ • https://www.vksapp.com/ • https://www.ptc.com/en/product-lifecycle-report/augmented-reality-strategy

TRAINING – WORKER

DESCRIPTION	**AR-Based Hands-Free On-The-Job Training For New And Current Employees.**
USE CASES	• A key contribution of augmented reality is in training. The technology enables trainees to familiarize themselves with farm machinery without having to operate it in the actual sense. • AR-based hands-free devices are proving to be an engaging and efficient training tool, as they can overlay virtual tutorials onto wearable equipment to provide new personnel with quick, visual demonstrations. It is

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	much easier to learn when viewing a digitally rendered 3D model than a 2D diagram. • New staff can also learn on the job, rather than repeatedly checking the training manual. As such, the use of Augmented Reality in manufacturing training and other related fields is becoming increasingly popular. • Augmented Reality enterprise use cases like this are especially effective when it comes to highly complex tasks, such as large machinery/equipment assembly and maintenance.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar)
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• Reduce production time by 25% and lower error rates to nearly zero. • Improving safety and enhancing the consistency of SOPs. • AR can provide supplemental training for workers. These easily consumable training experiences can improve comprehension and reduce training time by 60%. • There can be up to 35-50% reduction in overall technician time. • 90-99% reduction in time to information.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://upskill.io/skylight/use-cases/ • https://www.vaderstad.com/en/
TECHNOLOGY PROVIDERS	• https://upskill.io/ • https://www.vsight.io/

SALES - WORKER

DESCRIPTION	**Sales Conversion Tool And Techniques.**
USE CASES	Using an AR-enabled device, the Salesperson can launch their catalogue of products in front of potential customers without having the physical products present. This is especially useful

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	in instances where equipment is too big to transport to customers, or where customers live far away from showrooms. Salesperson launches AR models in front of customers on an enterprise-only app.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar) or AR-enabled mobile devices (phones or tablets).
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• Increased confidence and efficiency. • Can be placed in any number of scenarios and environments.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	• https://daqri.com/ • https://upskill.io/ • https://www.scopear.com/solutions/work-instructions/ • https://www.ptc.com/en/service-software-blog/augmented-reality-maintenance-and-repair • https://www.re-flekt.com/reflekt-one • https://www.fieldbit.net/ • https://pale.blue/

SALES - CUSTOMER

DESCRIPTION	**3D AR View Of Products In Your Personal Space. Virtual Showroom. Low-Cost Visualisation Of High-Cost Assets.**
USE CASES	• High-cost assets often carry a high-cost sales cycle because customers hesitate to purchase something they cannot properly visualise. Using AR, models of high-cost assets can be developed at a much lower cost, increasing accessibility. • Sales conversion - End users launch AR models in their locations via the app store available app. In today's physical retail environment, shoppers are using their smartphones more than ever to compare prices or look

	up additional information on products they are browsing. Companies can develop an AR app that customers can use at home to launch and view products. Users can also customize it using the app to see which colours and features they might like. • Sales Conversion - Machine Servicing - customers can perform basic machine servicing (oil, water top-up etc.) by following along with instructional content. • A 3D app can include high-quality digital 3D versions of products so customers can view them in their space before purchasing. • 5G can optimize warehouse resources, enhance store traffic analytics, and enable beacons that communicate with shoppers' smartphones.
TECHNOLOGY USED	AR-enabled mobile devices (phones or tablets).
COST	Low. Only requires AR-enabled handheld devices (phones or tablets).
PROS	• Real-word visualisation of products. • Better engagement.
CONS	• Cost of developing scenarios. • Requires high-end AR-enabled handheld device. • Users' resistance to change.
REAL WORLD EXAMPLES	• https://www.dezeen.com/2019/05/09/nike-fit-app-ar-ai-trainers/ • https://www.dezeen.com/2020/04/17/all-show-augmented-reality-exhibition-sebastian-errazuriz/ • https://futurestores.wbresearch.com/blog/loreal-augmented-reality-virtual-reality-in-store-experience-strategy • https://techcrunch.com/2019/02/04/warby-parker-dips-into-ar-with-the-launch-of-virtual-try-on/ • https://newsroom.inter.ikea.com/news/ikea-place-app-launches-on-android--allowing-millions-of-people-to-reimagine-home-furnishings-using-/s/28215cac-8f4e-4ee5-87a4-56a998290856
TECHNOLOGY PROVIDERS	• https://www.alibaba.com/ • https://daqri.com/ • https://upskill.io/ • https://www.scopear.com/solutions/work-instructions/

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	• https://www.ptc.com/en/service-software-blog/augmented-reality-maintenance-and-repair • https://www.re-flekt.com/reflekt-one • https://www.fieldbit.net/ • https://pale.blue/

HEALTH & SAFETY

DESCRIPTION	**Emergency Procedures Training Tool.**
USE CASES	• Where to locate emergency stops on machinery using Model Marker solutions. • First responders wearing AR glasses can be alerted to danger areas and show in real-time individuals that need assistance while enabling them to still be aware of their surroundings. • For those in need, geolocation-enabled AR can show them directions, and the best route to, safe zones and areas with firefighters or medics.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar).
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• Increased confidence and efficiency. • Can be placed in any number of scenarios and environments. • Real word visualisation and better engagement.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

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REMOTE TROUBLESHOOTING, ASSISTANCE AND KNOWLEDGE SHARING

DESCRIPTION	**Remote Troubleshooting Tool Using AR/XR Systems Including XR Headsets Or Mobile Devices (Phones Or Tablets).**
USE CASES	The loss of expertise in its companies due to retirement, and lack of know-how among newer hires, can lead to costly downtime in facilities. The solution to this is a live AR support application that allows technicians to collaborate with experts remotely. Users can share their view of a situation with a remote expert, and the AR maps work instructions and expert collaboration directly onto an object or area.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar) or AR-enabled mobile devices (phones or tablets).
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• 50% Reduction in downtime in facilities where the AR tools are in use, creating a direct ROI of 1,717% of the initial investment. • Costly and time-consuming downtimes can be avoided. • With a connection to a server, companies can document errors and consider them to be included in future maintenance plans. • Employees feel empowered to problem-solve and improve their daily work processes. • Decreasing costly repeat technician visits by increasing First Time Resolution rates. • Extending expert reach. • Streamlining the training of novice technicians.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. Users' resistance to change. Wearing cumbersome headwear for long periods. Battery life of the hardware. Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://techsee.me/blog/vodafone-innovation-augmented-reality/ • https://www.samsung.com/it/business/insights/case-study/joinpad-e-tablet-samsung/ • https://upskill.io/skylight/use-cases/ • https://www.youtube.com/watch?v=z5HOHNECW20&feature=youtu.be

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TECHNOLOGY PROVIDERS	• https://upskill.io/

USER MANUALS - CUSTOMERS

DESCRIPTION	**Digitising User Manuals For Online And Offline Viewing.**
USE CASES	• Replacing paper user manuals with immersive, visual AR instruction manual experiences helps customers navigate various steps including initial product setup, configuration, troubleshooting, and routine maintenance. The most advanced AR user manuals are built around Computer Vision technology, which auto-identifies an issue and guides the customer toward self-resolution. For example, utilising the original diagrams in paper instructions can be overlaid with animation and life-size references to simplify any assembly process. • AR-enabled app that allows the user to point their smartphone at different parts of equipment, at which point AR instructions appear, overlaying information such as how to change the air filter, engine oil, or brake fluid.
TECHNOLOGY USED	AR-enabled mobile devices (phones or tablets).
COST	Low. Only requires AR-enabled handheld devices (phones or tablets).
PROS	• AR instructions achieve better results, significantly alleviating the pressure on customer service departments. • Decreased calls to contact centres • Less need to dispatch technicians to customers' homes. • Decreased return rates due to lack of customer product knowledge.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.

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REAL WORLD EXAMPLES	• https://techsee.me/blog/diy-product-unboxing-taking-the-visual-experience-to-the-next-level/ • https://techsee.me/consumer-electronics/
TECHNOLOGY PROVIDERS	• https://techsee.me

OPERATIONS AND LOGISTICS

DESCRIPTION	**Better Warehouse Operations And Logistics.**
USE CASES	• AR can be used to improve navigation around large spaces (e.g. warehouses, large installations). AR can also assist with behavioural analytics, people movement (where people go), simulations (how claustrophobic would people be in certain places), and scenario planning (emergency/disaster-mandated planning). • AR technology empowers logistics staff by providing the right information at the right time and in the right place, an efficiency that is especially important to complex distribution networks. For example, a worker can see task instructions overlaid on their HMD, which can be configured to assist with GPS navigation within the facility or with auto-reading of barcodes. • Smart glasses help personnel locate, scan, sort, and move inventory without handheld scanners. The company gives warehouse workers smart glasses (e.g. Google Glass Enterprise Edition) which help them locate, scan, sort, and move inventory without using handheld scanners or referencing paper forms. The integrated heads-up display overlays key information within the company's logistics hubs, scans barcodes, and relays instructions in real-time. Workers using the glasses are 15% more productive, according to DHL. The glasses could eventually be upgraded with object recognition.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar).
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• Can cut production time by 25% and lower error rates to nearly zero, while improving safety and enhancing the consistency of SOPs.

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	• AR can provide supplemental training for workers. These easily consumable training experiences can improve comprehension and retention.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://www.skoda-storyboard.com/en/press-releases/skoda-auto-tests-video-mapping-augmented-reality-helps-when-loading-pallets-in-logistics/ • https://upskill.io/landing/ge-healthcare-case-study/ • https://www.youtube.com/watch?v=z5HOHNECW20&feature=youtu.be
TECHNOLOGY PROVIDERS	• https://upskill.io/

	IMMERSIVE ANALYTICS
DESCRIPTION	**Better Visualisation Of Complex Analytical Data.**
USE CASES	• With growing volumes of data, 2D visualizations and manual processes limit companies' abilities to detect data patterns and derive actionable insights. • AR can provide new ways to visualize and make better sense of these complex datasets, providing real value to business leaders. Immersive analytics is the combination of immersive technology and Machine Learning. • Together, multiple departments can view, analyse, and collaborate by visualizing data in 3D.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar).
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• Bette visualisation of complex data sets. • Real-time interaction with date.

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	• More immersive experience. • Collaborative sessions facilitated remotely.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://medium.com/design-ibm/ibm-immersive-data-augmented-reality-for-data-visualization-898587b2a57c • https://medium.com/@alfredo.ruiz/bringing-data-to-life-with-ibm-immersive-insights-9423687c9ffe • https://www.youtube.com/watch?v=6WRNqdOMXmc&feature=emb_logo
TECHNOLOGY PROVIDERS	• https://www.ibm.com/cloud/watson-studio

MARKETING AND ADVERTISING

DESCRIPTION	**Better Marketing Through Interactive Brochures, Real-Time Demos And Product Visualisations.**
USE CASES	• AR experiences created in Vuforia Studio can provide service instructions and marketing information for the benefit of both customers and retailers/dealers. Customers and dealers can use the 3D in-context instructions to streamline the service of equipment. • Dealers can showcase features, help with service and parts inventory replenishment, and provide brand messaging to customers. • The AR experience also provides a key voice-of-the-product feedback loop for the team, in addition to differentiating the service experience.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar) or AR-enabled mobile devices (phones or tablets).
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• Better customer engagement.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change.

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	• Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://www.nextechar.com/advertising-ar
TECHNOLOGY PROVIDERS	• https://www.nextechar.com/

DESIGN, DEVELOPMENT AND MODELLING

DESCRIPTION	**Helping Designers Visualise Designs In Real-Time And 3D.**
USE CASES	• One of the major uses for AR in the customer experience journey is the ability to design spaces, experiences and products for customers virtually and be able to test, refine and enhance these at a much lower cost and quicker turnaround than testing physical prototypes. • AR is helping professionals visualize their final products during the creative process. • Use of headsets enables architects, engineers, and design professionals to step directly into their designs to see how their designs might look, and even make virtual on-the-spot changes. • Any design or modelling jobs that involve spatial relationships are a perfect use case for AR tech.
TECHNOLOGY USED	AR/XR Headsets (e.g. Microsoft HoloLens or similar).
COST	High. Development of software. Purchase of hardware (Microsoft HoloLens or similar).
PROS	• Quicker workflows. • Better understanding of physical size. • Better design and maintenance.
CONS	• Cost of hardware (Microsoft HoloLens or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.

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REAL WORLD EXAMPLES	• http://armeasure.com/?utm_medium=website&utm_source=archdaily.com • https://eonreality.com/portfolio/virtual-reality-industrial-planner/
TECHNOLOGY PROVIDERS	• https://upskill.io/ • https://eonreality.com/

VR USE CASES

	MAINTENANCE - WORKER
DESCRIPTION	**Maintenance Training On Equipment And Machinery.**
USE CASES	• Working together in one VR Training environment, up to dozens of trainees or users can communicate, interact, and collaborate in the same virtual environment from multiple global endpoints — anywhere, anytime. • VR offers a low-cost alternative to traditional methods of training by offering interactive and immersive 3-D simulation environments to train critical skills. Immersive training will result in better learning outcomes for training a procedural task than traditional computer-based training.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• By incorporating user interaction with the environment and content thanks to VR technology, companies can achieve three goals: train more people within a shorter period cost-effectively and interactively; enable people to learn about their workplace environment and machines without jeopardizing their life and safety; and help those very workers master using expensive machines before they try them out directly.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.

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REAL WORLD EXAMPLES	• https://www.youtube.com/watch?v=APYz8n2H9RY • https://eonreality.com/portfolio/vr-maintenance-training/
TECHNOLOGY/ PROVIDERS	• https://pale.blue/ • https://eonreality.com/

	ASSEMBLY
DESCRIPTION	**Assembly And Installation Of Complex Parts.**
USE CASES	• Interactive virtual learning program to train its assembly line workers while increasing worker motivation and attention. Using the HTC Vive, employees are immersed in their realistic virtual assembly line environment. Work equipment such as containers and other components are illustrated as 3D objects, which can be grabbed and moved using the controllers. During the training session, the employee goes through various step-by-step assembly processes. Hereby, employees learn required hand movements while getting familiar with the corresponding IT systems. They are going through several levels of difficulty which also require an increasing degree of independence and information retention.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Boost of self-confidence. • Fun, motivational. • Provide personalized training based on the skills or knowledge of the worker. • Intuitive learning, with instructions, instant feedback, and error support. • Different language versions. • The reduced need for space, and physical equipment. • Control of learning objectives. • Show the consequence of errors. • Increase training efficiency.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios.

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	• Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://eonreality.com/portfolio/engine-explorer/
TECHNOLOGY PROVIDERS	• https://eonreality.com

SALES - WORKER

DESCRIPTION	**Sales Conversion Tool. Salesperson Launches VR Models In Front Of Customers On An Enterprise-Only App.**
USE CASES	If you have an upcoming sales pitch, how would you prepare for it? You might practice with a friend, colleague, or even in front of a mirror. None of these methods fully prepares you for being at the actual pitch, in an unfamiliar office with an unknown audience. VR changes this. Virtual reality allows you to practice different sales techniques and strategies in a safe, realistic environment. You can practice high-stakes situations, such as selling to directors or at a trade show, as often as you like until you are confident with your approach. Practising in this way also allows you to receive feedback on your performance. Through speech recognition and motion detection software, you can receive feedback on eye contact, number of hesitation words used, pace of your voice and other metrics.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	Low. Only requires mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
PROS	• Load your presentation slides into the virtual room to practice with instant feedback on your sales pitch. • Eye contact feedback to help you engage with the clients. • Prepare with realistic environments and audience. • Practice high-stakes situations as often as you like. • Identify keywords you are saying and how often.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. Users' resistance to change. Wearing cumbersome headwear for long periods.

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	Battery life of the hardware. Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://makereal.co.uk/work/severn-trent-coaching/ • https://makereal.co.uk/work/lloyds-personal-vitality/ • https://takeleap.com/services/virtual-reality/porsche/
TECHNOLOGY PROVIDERS	• https://makereal.co.uk/ • https://takeleap.com/ • https://bodyswaps.co/

	CUSTOMER OR CLIENT INTERACTION TRAINING - WORKER
DESCRIPTION	**Better Understanding Of Customer Needs.**
USE CASES	In a popular 2015 TED Talk, VR executive Chris Milk labelled the technology "the ultimate empathy machine." Virtual Reality can assuredly be used to help workers better interact with customers and clients. The simulation of human interaction can facilitate many things — learning how to deal with specific situations, becoming more relaxed during interactions through repetition, and a better understanding of where the client/customer is coming from. By simulating high-stress and high-pressure environments in VR before the actual day, employees can be more prepared and relaxed for the actual day itself. The combination of simulation and repetition is extremely valuable in the training world.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Using VR-generated apps on how to avoid distractions and focus on the task at hand. • The theory is that by recognizing these potential auditory and visual distractions in VR simulations, the user will be more prepared and focused when interacting with scenarios.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing of cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.

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REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	• https://engagevr.io/use-cases/training/

	MARKETING AND ADVERTISING
DESCRIPTION	**Better Marketing Through Interactive Brochures, Real-Time Demos And Product Visualisations.**
USE CASES	• Brands are increasingly using VR- and AR-powered campaigns to immerse customers in their product lines and interact with their audiences in unique ways. • E.g. creating a virtual reality experience that can take people "flying" on a journey through a virtual showroom. • As consumer adoption of headsets increases, VR/AR will evolve to become less of a promotional novelty and more of a standard channel for experiential marketing and advertising.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	Low. Only requires mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
PROS	• Better customer engagement.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

	EMERGENCY PROCEDURES AND HEALTH AND SAFETY
DESCRIPTION	**Emergency Procedures Training Tool Using VR Systems Including VR Headsets Or VR CAVE System.**
USE CASES	• Fire extinguisher training. • Correct lifting procedures.

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	• Slips, trips, and falls. • First aid training.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Increased confidence and efficiency. • Can be placed in any number of scenarios and environments. • Real word visualisation and better engagement.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

MACHINERY OPERATION - WORKER

DESCRIPTION	**Training Employees On Machinery Operation.**
USE CASES	• Training employees on new or complex machinery for manufacturing etc.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Increased confidence. • No chance of breaking the physical model until confident in operation. • Cost and timesaving. • Better retention and engagement.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware.

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	• Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

MACHINERY OPERATION - CUSTOMER

DESCRIPTION	**Training Customers On Machinery Operation.**
USE CASES	• Training customers on new equipment e.g. service, maintenance, operation etc.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or VR CAVE System.
COST	Low. Only requires mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
PROS	• Increased confidence. • No chance of breaking the physical model until confident in operation. • Cost and timesaving. • Better retention and engagement.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

INDUCTION & ONBOARDING

DESCRIPTION	**Employee Induction And Onboarding.**
USE CASES	• Virtual induction of new employees including tour, meet the team, emergency exists, SOP, etc. • Likely the most popular VR for Training use case is new employee onboarding. Closely correlated, particularly in our world of fluid job functions, is employee cross-training. Both activities are geared towards educating

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	workers on something they are not likely terribly familiar with. • VR allows you to immerse a new employee in an environment and teach them (using features such as hotspots). This helps the new employee become familiar and comfortable with the environment before being thrust into it. The knowledge transfer potential is tremendous. As discussed above, recall is much better than say traditional 2D limited-width views. • Employee onboarding through VR is a great first touch point for many workers. It helps to calm the nerves and build confidence. Particularly in high-stress jobs, or ones that involve immediate client interaction, using virtual reality is a nice entry point for learning a job.
TECHNOLOGY USED	Mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
COST	Low. Only requires mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
PROS	• Increased confidence and engagement. • Reduced stress levels. • Inclusion. • Create consistency. • Standing out. • Dramatically cut costs in training new employees at field offices. • Cut the technology budget for training by 80%. • No need to have to fly trainers to the field office, but also reduce travel for new employees. • As the content is evergreen, they're able to re-use the training for each subsequent recruiting class.
CONS	•
REAL WORLD EXAMPLES	• https://virsabi.com/onboarding-and-training-with-vr/ • https://virsabi.com/ikea-is-using-virtual-reality-for-onboarding-and-training/
TECHNOLOGY PROVIDERS	•

STANDARD OPERATING PROCEDURES (SOP)

DESCRIPTION	**Digitising Standard Operating Procedures.**

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USE CASES	• Using VR Headsets, SOPs can be digitised and accessible by workers. This can apply to all situations where complex tasks need to be performed, and the working environment allows for it. • These can include machine start-up/shutdown procedures, safety precautions, emergency stop procedures, fire training etc.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	Low. Only requires mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
PROS	• Increased efficiency and reduced downtime. • Increased worker confidence. • Increased level of support.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

	DRIVER TRAINING
DESCRIPTION	**Advanced Driver Training For Field Operatives.**
USE CASES	• Training drivers. Objective testing, using advanced data collection, means you can train and test a driver's skill sets BEFORE they ever sit behind the wheel of an expensive vehicle.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar).
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Retention rates up to 70% better than traditional methods have been proven in academic studies.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios.

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	• Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://makereal.co.uk/work/vodafone-drive-safe/
TECHNOLOGY PROVIDERS	•

	CROSS-TRAINING
DESCRIPTION	**Cross Training Of Employees Between Different Departments And Skillsets.**
USE CASES	• Using VR scenarios, employees can be cross trained between departments using recyclable content. • Employees do not need to be physically present at the station for training.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Dramatically cut costs in cross-training employees. • Cut the technology budget for training by 80%. • No need to have to fly trainers to the field office, but also reduce travel for new employees. • As the content is evergreen, they can re-use the training for each subsequent recruiting class.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	• https://eonreality.com/

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TEST DRIVE - CUSTOMER

DESCRIPTION	**Allow Customers To Test Drive Equipment Before Purchase.**
USE CASES	• If users are in the market for a piece of machinery, VR technologies can enable them to test drive a piece of machinery before they take it home. • A VR app that allows the user to drive a piece of machinery through any chosen terrain. • More than just a marketing tactic, it is both a game and a point of reference for consumers.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
COST	Low. Only requires mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
PROS	• Simulate real-world and relatable environments. • Conversion tool. • Better engagement. • Allow remote customers access to equipment that can't be physically transported.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://www.youtube.com/watch?v=HEkGRUkqjTA&feature=emb_logo
TECHNOLOGY PROVIDERS	•

DESIGN AND DEVELOPMENT

DESCRIPTION	**Helping Designers Visualise Designs In Real-Time And 3D.**
USE CASES	• VR tools that will allow designers to not only sketch in 3D but also immerse themselves inside their sketches, streamlining the design process. • Streamlining the otherwise lengthy design process by allowing designers to skip hand-drawn designs and jump right into working on a 3D model.

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	• This cuts the process down from a few weeks to eight hours and enables them to anchor a driver at the centre of the 3D model and rotate the design to view from any angle. • This means faster design and innovation, and a more thorough experience.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Quicker workflows. • Better understanding of physical size. • Better design and maintenance.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

	MANUFACTURING
DESCRIPTION	**Enhancing The Manufacturing Process Through Good Design.**
USE CASES	• Using VR to enhance the design of equipment. • Before virtual reality, companies had to build physical samples of equipment to determine how they could adjust the design to improve functionality. Thanks to this new technology, however, companies can now make real-time adjustments using virtual representations of their equipment, and “try out” the adjustments as if they were using them before manufacturing even begins. • The ability to develop virtual prototypes has had a major positive impact on the manufacturing industry. Instead of investing exorbitant amounts of money and countless hours creating physical prototypes, designers and

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	manufacturers can now develop virtual examples and make any necessary adjustments to those examples.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Increased manufacturing times and efficiencies. • Troubleshooting before physical production.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

	EXHIBITIONS, TRADE SHOWS, EVENTS & CONFERENCES
DESCRIPTION	**Remote EVENTS AND CONFERENCES WITH SALES CAPABILITIES.**
USE CASES	• Since VR enables individuals to be placed virtually, it provides an avenue for organizers to welcome more individuals into in-person events. • VR can be used in a similar way to enable virtual conference attendance, but event-industry stakeholders are also using it to drive collective experiences among in-person audiences.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Less travel costs and expenses. • No travel restrictions. • Time and energy savings.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change.

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	• Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

MEETINGS & COLLABORATIONS

DESCRIPTION	**Remote Meetings And Collaborations Between Geographically Dispersed Teams.**
USE CASES	• Virtual reality (VR) has great potential to help users who are physically at a long distance. From the business perspective, it is particularly true in the enterprise and business world where information needs to be quickly and accurately shared. • Therefore, VR is optimized accordingly with the need to offer a tool to help the user in every aspect. Using the best and most accurate information along physical scale models gives the best impression of the final product. VR Meetings allow experts to use virtual space to jointly review models. This is an advantage in today's world where colleagues can be continents apart, the subtleties of this information can be hard to convey using a flat monitor screen and a voice on a telephone or Skype connection. • We can say the VR tools have tried to make the process easier providing an increasingly cost-effective option. The benefit of using VR is to create a shared meeting space seems to be accomplished. Areas such as design, engineering, construction, and architecture are taking advantage of VR. • It is a product that is to be believed will greatly improve the quality of meetings. The feature of VR Meetings is that they have integrated collaborative mark-ups, voice-over IP and synchronized cloud models to allow for easier sharing of information in a joint space. Apart from those meetings becoming a free-for-all where one person becomes designated as the Presenter among all. All participants can view the model. To move

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	participants to a specific location in the model, control the model scale and orientation and even mute others the control is given to the presenter. And if the presenter needs to direct the other's attention to a specific location it can be done easily.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Less travel costs and expenses. • No travel restrictions. • Time and energy savings.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

VIRTUAL SHOWROOMS

DESCRIPTION	**3D VR View Of Products In Your Personal Space.**
USE CASES	• Sales conversion tool - end users launch VR models in their locations. • In today's physical retail environment, shoppers are using their smartphones more than ever to compare prices or look up additional information on products they are browsing. • Companies can develop a VR app that customers can use at home to launch and view products. Users can also customize it using the app to see which colours and features they might like.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.

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COST	Low. Only requires mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
PROS	• Allows customers to see all products - no matter how large they are. • Customers anywhere in the world can view products. • Better immersion and engagement. • Callouts on product details
CONS	• Does not provide the same experience as seeing and touching physical equipment.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

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CASE STUDY

3D visualisation and interactive experiences

Audi creates a new dealership experience with Audi City

Audi is hoping its technologically equipped 'Audi City' stores will redefine the way customers shop for new cars, providing an exciting and engaging dealership experience. The stores focus on giving the consumer the ability to digitally explore and personalise Audi's line of vehicles. It is a new take on the conventional dealership, with virtual touchpoints able to present Audi's entire model range, while enabling millions of different possible configurations of the vehicles.

Audi has teamed up with ZeroLight to provide the real-time 3D visualisations. Multi-touch tables present a 3D virtual car to the consumer, which can be fully customised. The models that have been configured on these tables can then be viewed on a 'Powerwall', which presents a life-size scale of the car in large-format and 4K resolution, which can be explored inside and out. A member of the sales team is on hand to assist with the customer experience and journey throughout.

The level of personalisation that the technology allows for, creates a truly customer-centric experience, where the power is in the customer's hands to choose the right model, features and add-ons to match their tastes and needs, and help them create their dream Audi vehicle.

Without the need to stock Audi City stores with actual cars, the dealerships can be placed in key cosmopolitan locations, such as within shopping centres or airports. Current locations include Beijing, Berlin, London, Moscow, and Paris. In this instance, technology allows the customer to get the full Audi service experience and explore the complete spectrum of options, without needing to

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HAPTICS

DESCRIPTION	**Interacting With Digital Objects In A Physical Environment.**
USE CASES	• Interaction with objects (using gloves), viewing and scaling from different angles.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or VR CAVE System.
COST	Low. Only requires mobile devices (phones or tablets) with VR holders (Google cardboard or similar).
PROS	• Adds an element of realism to certain scenarios e.g. fire extinguisher training.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	• https://www.kat-vr.com/ •

PRODUCT TESTING

DESCRIPTION	**Testing Products For Defects Or Usability Before Expensive Production.**
USE CASES	• Using VR, users can test product designs for a wide range of metrics e.g. usability, size, colour, maintenance etc.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Detailed product testing before production to eliminate faults and usability issues.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware.

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	• Responsiveness of hardware.
REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

SCANNING & MONITORING

DESCRIPTION	**Scanning And Monitoring Large Geographical Areas.**
USE CASES	• VR have the potential to help farmers visualize the troves of crop data now available to them. • Commercially available aerial drones built with inertial sensors, GPS, powerful processors, and imaging sensors can give farmers and data scientists a look at what is happening in their fields. These drones, outfitted with 360-degree video capability, allow for virtual crop scouting, where farmers don VR headsets to scan through the field and assess crop response and damages. By caring for crops at the granular level VR and crop data allow for, farmers can increase yields, decrease disease, and improve costs. • Using a system of sensors, lights, and cameras that measure details of crop health., a solution can use AI to understand what each plant needs for the best growth. That data is wirelessly transmitted to a set of AR goggles, which farmers use to see what each plant should be getting, like more water, light, or fertilizers.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System or Drones.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Better data utilisation and visualisation. • AI integration assists.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios. • Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.

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REAL WORLD EXAMPLES	•
TECHNOLOGY PROVIDERS	•

	HEALTH & SAFETY
DESCRIPTION	**Emergency Procedures Training Tool.**
USE CASES	• Where to locate emergency stops on machinery using Model Marker solutions. AR is showing promise in solving both pieces of the public safety puzzle. First responders wearing AR glasses can be alerted to dangerous areas and show in real-time individuals that need assistance while enabling them to still be aware of their surroundings. For those in need, geolocation-enabled AR can show them directions, and the best route to, safe zones and areas with firefighters or medics. • At the Safety and Health Expo Lloyds Register demonstrated their VR "Safety Simulator and gaming experience", developed with Polar Media. The user is placed in a virtual oil rig environment, where they are challenged to identify and fix safety breaches. The impact of failing to fix the problems is illustrated with crash-test dummies stumbling, falling from height, or being crushed. • For less hazardous environments, Walmart is using VR to train staff to deal with situations that would be difficult or dangerous to recreate in the workplace – like spills in the aisles or managing the Black Friday hoards!
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar) or mobile devices (phones or tablets) with VR holders (Google cardboard or similar) or VR CAVE System.
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	• Increased confidence and efficiency. • Can be placed in any number of scenarios and environments. • Real word visualisation and better engagement.
CONS	• Cost of hardware (HTC VIVE Pro or similar) and cost of developing scenarios.

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	• Users' resistance to change. • Wearing cumbersome headwear for long periods. • Battery life of hardware. • Responsiveness of hardware.
REAL WORLD EXAMPLES	• https://www.shponline.co.uk/safety-training-and-development/immersive-factory-launches-its-ehs-training-exercises-on-virtual-reality-standalone-headsets/
TECHNOLOGY PROVIDERS	• https://polarmedia.wistia.com/medias/beeljipet3 • https://immersivefactory.com/

	RECRUITMENT
DESCRIPTION	**Recruitment Based On VR Performance.**
USE CASES	• The advantage of introducing VR to a candidate assessment programme is that “seeing people in action is a better indicator of their potential”.
TECHNOLOGY USED	VR Headsets (e.g. HTC VIVE Pro or similar).
COST	High. Development of software. Purchase of hardware (HTC VIVE Pro or similar).
PROS	•
CONS	•
REAL WORLD EXAMPLES	• https://www.irishtimes.com/business/work/how-virtual-reality-can-help-real-life-recruitment-1.4269791 • https://vervoe.com/virtual-reality-recruitment/ • https://www.stereoscape.com/blog/2019/06/25/vr-in-recruitment-and-onboarding/
TECHNOLOGY PROVIDERS	• https://www.stereoscape.com/

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Appendix F

Interpret Studio

Institute of Art Design and

Technology

AR/VR Research Report 2020

Interpret Studio and IADT

Robert Griffin

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2020

About the Authors:

Robert Griffin from Dublin is a lecturer on the applied psychology course in IADT and also the chair of the MSc in Cyberpsychology. A graduate of the MSc in computer applications for education masters course in DCU and the MSc in cyberpsychology. Robert has been researching the field of virtual reality and user experience design.

Iva Bedzula Prebeg originally from Croatia where she graduated Psychology from the Faculty of Humanities and Social Sciences, University of Osijek. Currently living in Dublin and working on Masters of Science in Cyberpsychology at Institute of Art, Design and Technology. She is also a mother to two girls, a Cùdiu volunteer, runs a parent to parent support group and is a breastfeeding counselor in training. Her interests are cyber safety-especially with children, online support groups and different behaviors online.

Danijela Blazevic holds an MA in Psychology from the Faculty of Croatian studies at the University of Zagreb and currently studying Cyberpsychology at the Institute of Art, Design and Technology in Dublin. Currently working as a Safety Policy Operations Associate at Cpl for the German market. Her interests are user experience research and design, cyber safety and new trends in technological development as in virtual reality and artificial intelligence.

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Introduction

Interpret Studio, founded in 2018, is a technology start-up building a mixed-reality collaboration solution for enterprise use. The inspiration for setting up the company came about from the frustration with existing collaboration methods. "Our natural world provides endless cues and intrinsic meaning that as humans we understand without instruction yet our current forms of communication, particularly in the business setting, struggle to reach the same level of power as that, and so constrain the user and limit the outcome."

Within a corporate situation consulting, collaborating and communicating resorts to two dimensional forms whether paper, screen or even a wall full of post-it notes. The solution Interpret Studio is building looks to maximise the additional value of using 3D mixed environments to aid users in together analysing, building and communicating their strategies.

During development of the minimum viable product (MVP) of the software, we have noted that a new visual 3D language is emerging from our work, which provides significantly more semantic power then traditional 2D environments including computer screens, written reports, presentations, whiteboards, and sticky-notes plastered on walls.

As we continue to exploit this 3D language in our software product, we would like to capture best-practices and to draw on the recognised scientific evidence in the field. This report examines best practice, the latest research findings and the recommendations for developing and designing VR/AR applications.

Background

Interpret Studio have created a software product, with a working title of 'Exponent', deployed to traditional screen devices (PC and tablet) as well as on virtual reality and augmented reality devices. Users can join an online workspace with other users in a mode of their choice (2D, VR, AR). Interaction within each mode is tailored appropriately but all users can interact seamlessly with each other and the workspace irrespective of their

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chosen mode or the mode of the other users. A typical session may have up to eight users or may simply be a single person working together.#

Some product features include:

- Audio collaboration – users can speak and hear other users – the speakers will be visually highlighted
- Presence - Users will be represented in the world using 3D avatars as well data queues such tags on objects they are editing conveying information such as focus of attention, current actions, etc
- Tabletop surface - which is marked-up with user-defined zones which can imply meaning to objects placed upon them. E.g. SWOT analysis may divide the tabletop into four labelled zones.
- Objects – Objects can be created and placed onto the tabletop. The objects come from a palette of abstract shapes as well as scaled real world objects. E.g. sphere, cone, chess piece, dice.
- Object Modifiers – each object can be modified to add meaning. These modifiers include colour, height, textual description and emojis.
- Object Connections – objects are able to be linked together to imply a relationship and this relationship has modifiers such as a direction, strength and colour.

Definitions

Reality: the state of things as they actually exist, as opposed to an idealistic or notional idea of them.

Virtual Reality(AR): The computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors.

Augmented Reality(VR): A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.

Virtual Environments (VE):A virtual environment (VE) is not a single entity – it is a combination of multiple features. The more features it has the more realistic and thus the sense of presence is increased. Watching a 360 degree video in a HMD is often called VR but many people disagree on this. The environment should be interactive, enable the user to manipulate (touch, move, interact) and navigate (the user can move around within the space).

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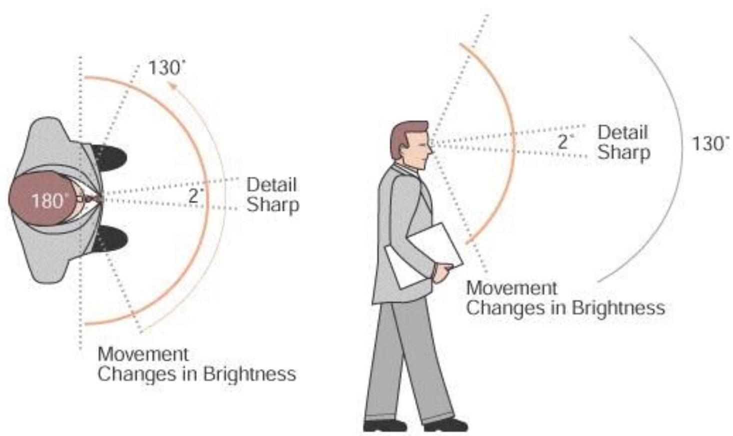
VR Hardware

Head Mounted Displays (HMD)

The principal hardware used for virtual reality is the Head Mounted Display (HMD). This is worn on the head and covers the user's vision. The HMD consists of two miniature display screens viewed through lenses . The display shows slightly different views of the virtual world simultaneously to create a 3d stereoscopic view. This can be disorienting because there is no outside information but this is essential for creating a feeling of presence and immersion.

Field of view (FOV) and Refresh Rate

The extent of the surroundings that we can view at a single instant is governed by the field of view (FOV) of our eyes. A total field of view is not required in order to feel immersed but it should be at least about 90 degrees horizontal.



The refresh rate of the screen must be high enough to allow our eyes to blend together the individual frames into the illusion of motion. FPS Frames Per Second also measured in hertz 90+ is needed for VR.

Sound

Vision is the dominant sense for people without any visual impairments. The second most important sense is sound. 3D sound increases realism by allowing the developer to include direction (where a sound is coming from to attract attention to it), distance (how far away something is and if it is coming towards you or away from you) and reacting in real time (drop or moving an object creating a sound increases immersion.

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Types of HMD

Handheld

Google Cardboard

Cardboard handheld uses a smartphone as a screen, a very cheap but basic entry level device.

Premium smartphone HMDs

Samsung Gear

Uses a smartphone as a screen.

Head strap and often have a remote control.

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Dedicated Headsets

HTC Vive

Focus

Oculus Quest

These are the top of the range headsets. There is a dedicated screen and built in speakers. They can be tethered (connected to a PC/Laptop) or stand alone.

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Motion tracking

The HMD Continuously measures the head position and orientation in order to generate the required image and to adjust the scene depending on the user's position. The HMD's that use smartphones as screens use the phone's accelerometer and compass for this. The other HMD's use two types of tracking. **Outside in** where a laser-based base station (Vive call them lighthouses) accurately tracks the position and orientation of the user's HMD and controllers in real time. **Inside out** where the camera or sensors are located on the device. Outside in means that the base stations need to be set up and calibrated, the user can't move out of a designated space without losing tracking thus limiting the area they can move in. The HTC Vive "playspace" is approximately 4.5m x 4.5m though this can be increased by using more base stations the standard setup has two. (HTC UK, 2016)

Inside out is becoming more popular and will be the new standard as it requires less setup and removes the restriction on how much the user can move.

Controllers

While the HMD is the most important and commonly used parts of a VR system there are additional devices which are becoming more common to make the experience more immersive. The most common one is the controllers, these are handheld devices that are tracked in the 3D space. They will have a trigger, a trackpad, squeeze functionality and buttons. These are used to interact in the VE and are discussed below.

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Forcefeedback and Haptics

In addition to visual and aural perception, haptics offer an extra dimension to the VR world by letting users feel the virtual environment via the sense of touch. External devices like gloves, shoes, joysticks, controllers etc,provide feedback in the form of vibrations. The most common version is with controllers which use electric motors to force feedback vibrations. Some data gloves use air bladders to harden and restrict your grip, so you can feel an object in virtual reality. They are particularly useful for medical training but can also be used in gaming and other applications.

A trainee surgeon using a HMD and haptic controllers to practice surgical procedures.

Haptic gloves allow the wearer to feel the shape, texture, and motion of virtual objects.

These are still very expensive around 5,000 euros and not commonly used for home purposes.

Haptic suits: A tactile suit, gaming suit or haptic vest which is a wearable device that

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provides haptic feedback to the body. Popular with VR arcades.

Can consist of just a vest or a full suit.

Other VR Hardware

There are many bespoke additions to VR which can also increase the sense of immersiveness. Treadmills allow for the sensation of walking and moving without physically leaving the space. Some VR arcades and experiences have gotten very creative with slides, bungee cords for a skydiving experience and moving platforms. (Nathie, 2019)

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AR Hardware

Unlike VR most people already own an augmented reality device which is their smartphone or tablet. Other devices consist of headsets or glasses. These are not readily available and tend to be expensive. The most well known one is made by Microsoft and is the HoloLens which costs €3,100. The HoloLens allows users to see digital holograms integrated with the world around them in Augmented Reality (AR). it is untethered as in it does not need to be connected to a laptop or pc. The headset contains similar computing power to a laptop. Sensors within the headset provide inside out scanning abilities joining the virtual and real worlds. (Microsoft, 2020)

Magic Leap have also developed a headset which they call spatial computing. The lightweight headset integrates virtual objects with the real world. (Magic Leap, 2020)

Software for VR/AR

Software for developing and disseminating VR/AR experiences. Gaming engines which are software-development environments designed for people to build video games are the most common method for creating VR experiences. They offer a 3D environment which can have virtual cameras to represent the view of the player. There is a full list and links to software for VR/AR in the resources section of this report.

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Unity 3d, Unreal engine and Cryengine can all make experiences for the different platforms such as Vive and Oculus. They work in a similar way by creating the environment out of models and programming interactions to allow for gameplay or tasks to be completed.

Unity 3d is the best known platform for VR development. It is used to make games for consoles, phones and PC's. It allows one to create interactive virtual environments in 3D.

Development Kits for VR

- OSVR/OpenVR the Open Source Virtual Reality hardware and software project with a focus on providing a solution for allowing headsets and controllers from all vendors to be used with any game or other VR software.
- WebVR is for developers working with Web-based solutions or JavaScript, the WebVR API provides a possible alternative for Virtual Reality development. The WebVR API provides the capability to target standard VR devices, including Oculus, Daydream, Windows Mixed Reality, PlayStation, HTC, and Google's Cardboard with applications embedded within a Web browser.
- SteamVR: The SDK for Unity to make VR experiences.

Development kits for AR

- Layar SDK was an augmented reality SDK for iOS and Android apps.
- Vuforia Augmented Reality SDK, formerly Qualcomm's QCAR, is a Software Development Kit for creating augmented reality applications for mobile devices.
- Wikitude SDK is an augmented reality SDK for mobile platforms originated from the works on the Wikitude World Browser app by Wikitude GmbH.
- ARKit, an Apple SDK, currently designed exclusively for iOS 11+ app creation. Formerly Metaio, purchased by Apple in 2015.
- ARCore, a Google SDK, currently designed exclusively for Android 8.0+ app creation

More development kits and SDK's can be found here:
https://bluewhaleapps.com/blog/top-ar-vr-development-tools-and-sdks-you-should-know-about

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A large part of the experience is virtual objects or models. These can be made with 3D modeling tools like Blender, Sketchup, 3D Studio Max and maya.

The game engines can create executable files which can then be shared via a website or a site like Steam the gaming website.

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VR/AR Market 2020

The Virtual Reality (VR) market was valued at USD 11.52 billion in 2019 and is expected to reach USD 87.97 billion by 2025, at a Compound Annual Growth Rate (CAGR) of 48.7% over the forecast period 2020 - 2025 (Market and markets, 2019). VR technology has gained widespread recognition and adoption over the past few years. Recent technological advancements in this field have revealed new enterprises. Numerous players are emerging in this market with the hopes to navigate it toward mainstream adoption.

VR and AR is available on the devices listed below. The entry point is very low as it can be accessed on a smartphone. Perkins Coie LLP and the XR Association survey 2019 predict that there is enormous potential for immersive technologies as prices of headsets reduces and quality increases. Smartphones which deliver both VR and AR are almost ubiquitous. The challenge identified in the report is the quality of user experience and available content offerings. (XR Industry Insight Report, 2019-2020)

The four main challenges identified which are facing VR/AR becoming mainstream are:

- **Content**: the lack of quality content limits consumer interest which hinders the business case for more VR/AR content development.
- **Education:** few members of the public have an accurate understanding of the technology due to a lack of first-hand experience.
- **Cost**: the cost of high-end VR/AR systems is still out of reach for the average consumer. This is less of a concern for enterprise.
- **User experience:** from both a software and hardware perspective, setting up and running high-end VR/AR systems and experiences is not a simple task.

The range of devices and operating systems is also identified as a challenge. Software that only runs on a particular hardware. Price Waterhose Coopers (PWC) predicts this will

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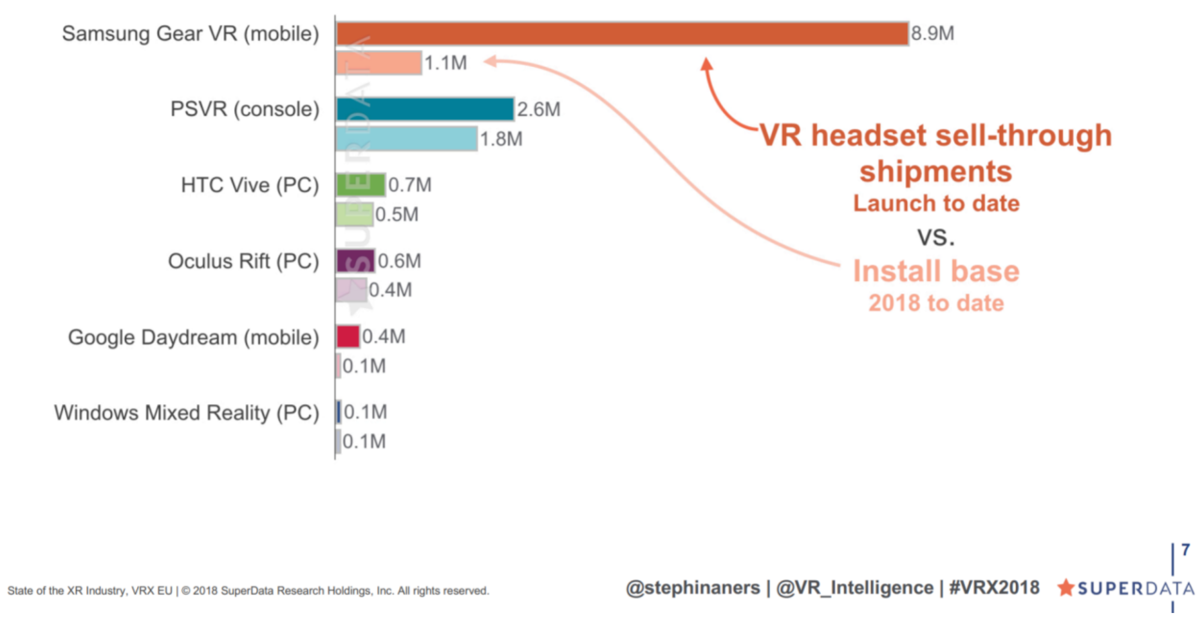
become less of an issue thanks to the OpenXR initiative, an open, royalty-free standard which works on all platforms. (Growing VR/AR companies in the UK, 2019).

Distribution platforms for XR

Samsung Gear is the most common platform for XR as of now with the Playstation VR headset coming second. The graph below shows the numbers of each device currently in use.



https://www.slideshare.net/StephanieLlamas/whats-in-store-for-xr-the-future-of-vr-ar-vrx-europe-2018?from_action=save

Virtual Reality experiences are distributed on Google Play, the Apple Store, Steam, Oculus Experiences, Microsoft store and VivePort.

Microsoft Store: https://www.microsoft.com/en-ie/store/apps/windows

Vive Port: https://www.viveport.com/infinity

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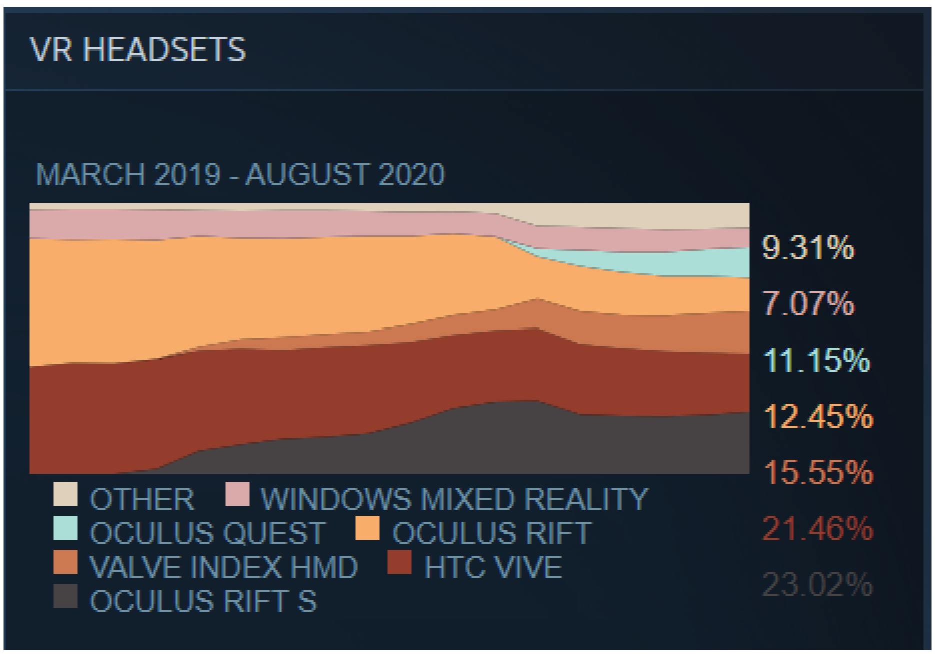
Steam Store :https://store.steampowered.com/

Oculus Store: https://www.oculus.com/experiences/rift/

Google Play: https://play.google.com/

Apple Store: https://apps.apple.com/ie/app/apple-store

Steam acts as the content store for HTC Vive users but it also supports Oculus Rift so anyone with either headset can download any of the VR games there. Steam conducts a monthly survey to collect data about what kinds of computer hardware and software their customers are using.It is a useful insight into which headsets are the most popular and their market share.



Steam Monthly Report: https://store.steampowered.com/hwsurvey

Oculus Rift and Vive are the two most popular headsets. 23% of Steam users own a headset; this is an increase of 1.22% from the previous month.

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Killer App/Trends

A killer app is a piece of software so desirable that it proves the core value in a hardware device justifying it's purchase. For the early computers it was VisiCalc the spreadsheet and later PageMaker the desktop publishing software saved the Apple Mac. PWC report into VR/AR asks what the killer app in that space will be. The answer is not a single app but some uses for the technology. These are training, design, telepresence, smart information and entertainment. PWC predicts greater integration of VR/AR where the VR headsets will also be used for AR. In addition, they predict VR/AR will become an integral operational tool for most businesses. (Growing VR/AR companies in the UK, 2019)

AR and VR increasingly enhanced with AI

Smart, cognitive functionality built into apps. Technology which allows computers to recognise what they are seeing by using machine learning algorithms. This will allow for more sophisticated applications where objects in the field of view can be identified and labelled. As shown below inputting large amounts of data while in VR is currently laborious but improvements in natural language processing mean it will be an option in the future.

VR and AR will increasingly be used in training and teaching

Both technologies have obvious use cases in education. Walmart is using 17,000 Oculus Go headsets to train its employees (Venturebeat, 2018). Both systems help reduce risk and costs associated with training. In addition, it has been proven a useful tool for training in the use of dangerous tools/equipment or in hazardous conditions.

Consumer Entertainment

This has been predicted for a few years now and there still isn't a killer app which makes people want to buy a headset. Two barriers have been preventing it's take off. The high end of the market requires a powerful PC or laptop with a special graphics card.The lower end of the market using smartphones means limited graphics capabilities. Both of these issues are being addressed by stand-alone headsets incorporating powerful processors and the increasing abilities of smartphones. This will release consumers from the restrictions of

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tethered devices and wires. Headsets incorporating eye tracking can reduce the amount of processing power needed, increase field of view and allow users to interact and explore in more meaningful ways.

VR and AR environments becoming increasingly collaborative and social

Facebook's purchase of Oculus in 2016 showed that the social media giant believed virtual reality would become vital to the way we build shared online environments (Brian Solomon, 2016). The Covid19 pandemic has meant that many people are working from home and using video conferencing software. This may well change working practices in the future with less work related travel and more meeting/collaboration being conducted online. Two of the issues around video calls are immersion and presence which specialties of VR/AR as discussed below.

AR increasingly finding its way into vehicles

Two of the most significant trends in new vehicles are voice activated devices similar to Alexa or Siri and in car AR. Dashboard displays can overlay graphics onto camera footage around the car. Useful for parallel parking, pointing out landmarks and identifying hazards. This can improve safety allowing the driver to keep their eyes on the road.

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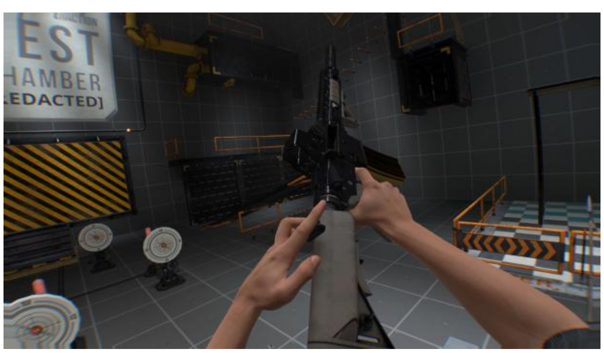
Applications

Entertainment

When the average person thinks about VR or AR it is most likely the person will think of some sort of entertainment experience or game. That shouldn't be a wonder when we know that 70% of owners of VR headsets bought them for gaming purposes (Insight, 2018). The trend of VR gaming is rapidly growing and it is expected that the VR gaming market size is going to reach USD 92.31 billion by 2027 (Grand view research, 2020).

Although VR gaming undoubtedly has great potential, it also has some issues hindering it from becoming truly mainstream. The first issue is with no doubt the priceyness of VR hardware making it unreachable for the average gamer. The same hardware is often described as clunky and uncomfortable reducing the perceived enjoyment of the gaming experience. As for the experience itself, VR games are often criticized for the lack of quality content making the consumer unwilling to dive into VR.

The lack of consumers, along with the expanse of development, leads to developers being reluctant to develop new content. Steam's list of top selling VR games for 2019 included Blade & Sorcery, Skryim VR, Arizona Sunshine, Gorn, VR Kanojo, Boneworks, Fallout 4 VR, Pavlov, Superhot VR, Beat Saber (Steam, 2019).



On the other hand, we have a completely different approach to gaming, AR gaming. AR gaming, contrary to VR, has been dominating the mobile game industry for several years. It

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made its way through in mobile gaming with the success of the world phenomena AR game Pokemon Go which is still holding 5 Guinness records in mobile gaming since it came out in 2016. Pokemon Go is also a great representative for the most popular AR games category, geolocation games which use real world maps and locations for their gaming environments. Other than these, popular AR games include strategy games, shooting games, sport games, table and card games and horror games.

Movies

When it comes to entertainment, cinema is also a category in which experts predict a bright feature for VR. This trend can already be witnessed in documentary filmmaking. The immersive characteristics of VR, the feeling of entering and being part of a world, relation and life that is usually inaccessible is why documentary makers, activists and journalists are particularly interested in VR (Nash, 2018). VR documentaries vary from environmental and nature documentaries to those tackling major societal issues like poverty and diseases.

Other than documentaries, using VR has become popular in animated and short movies granting even the first Oscar in 2017 for Carne y Arena (Virtually Present, Physically Invisible), a virtual experience by Alejandro G. Iñárritu. Virtual reality can be used as a tool in film making, as shown by the director of The Lion king, offering a first-person experience of scenes. Furthermore, VR has been widely used for promotion and marketing purposes in the cinematic industry.

The Jungle Book VR Experience 2016

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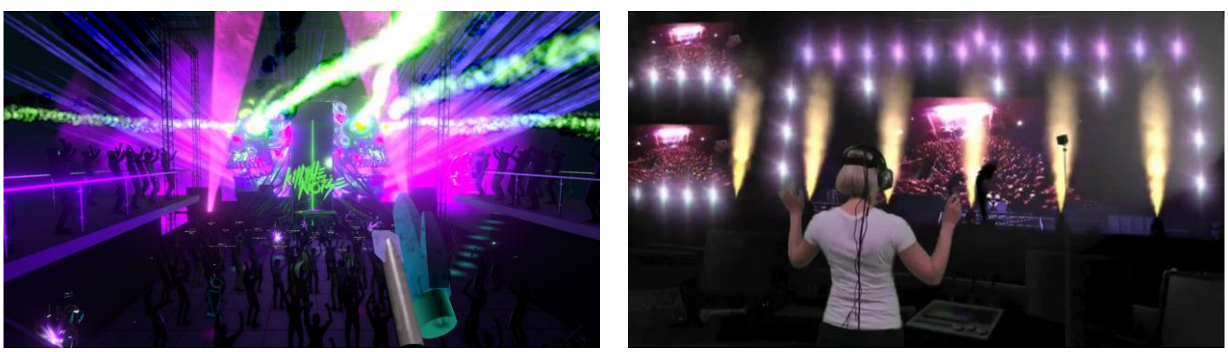
When it comes to short movies, research has shown that due to wider possibilities when immersed into a VR experience, the viewers tend to miss important factors of a storyline making it challenging for directors to guide viewers' attention (Syrett, Calvi and van Gisbergen, 2016). Another issue of VR experience movies is again priceyness. Some experts report that the process of stitching movies can cost up to 10000$ per minute (Hollywood reporter, 2016).

Nevertheless, the first feature length VR movie 7 Miracles has been released in 2019 and will hopefully start a trend in movie making.

Music

Another category of entertainment where virtual reality has been applied is the music industry. One of the most popular applications of vr in music is the development of vr music videos. Wear VR or even YouTube provide vr music videos of well-known bands like Gorilazz but also lesser known indie bands trying out new platforms. Aside from music videos, the idea of integrating VR in music or music in VR has been popularized through already mentioned rhythm games as Beat Saber.



Wave VR

There is a wide variety of platforms providing some sort of music experiences in virtual reality like Vinyl reality, a professional DJ vr application, music creation packages like The Music Room or even virtual reality musical instruments (VRMI). Another popular VR music experience are live concerts in virtual reality. Those can be virtual performances provided

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through platforms as Wave or real-life live performances of various musicians provided on platforms like MelodyVR. Some scholars argue that VR concert experiences have the potential to make a major change in that part of the music industry due to the growing immersiveness and feeling of presence (Charron, 2017).

Sports

Not only music events, but real-life live sports events such as the Superbowl or Olympics have been broadcasted as virtual reality experiences. When it comes to sports events, application of augmented reality as experience enhancer has also been proposed. Some describe development of AR tools which provide augmented information on participants in sporting events (Bielli and Harris, 2015).

Other than event broadcasting and enhancing there is a great interest in VR for trainers and coaches. VR can be used by them as a tool in various ways. Farley et all (2019) state that research findings on VR in coching showed good results in both coaching and skill acquisition. VR provides the possibility to immerse athletes in competitive situations, regulate the environment and develop their sensorimotor abilities in those situations. Faure et all (2019) also provide an overview on conducted research on VR in coaching, particularly in ball sports.

Although they conclude that vr is an efficient tool with great possibilities, they also indicate some limitations like cybersickness or technical limitations of vr tools as the limited field of view. Nonetheless, both Faure et all (2019) and Farley et all (2019) agree that virtual reality is a tool likely to become a standard of coaching and skill improvement.

Art, museums, galleries

Virtual and augmented reality are also providing a different experience of museums and art galleries. Some of the world's most popular museums like the Tate Modern, The Smithsonian or Louvre provide VR exhibitions or from home museum tour experiences. They also use AR to provide information or enhance visitor experiences. Furthermore, augmented and virtual reality have become artwork of their own. Platforms like Vrallart provide an overview to explore the world of VR and AR art in terms of galleries, artists, exhibitions, museums. When it comes to art, vr has also been implemented in art education. Researchers (Chen, Gao, 2019) claim vr can provide a realistic artistic

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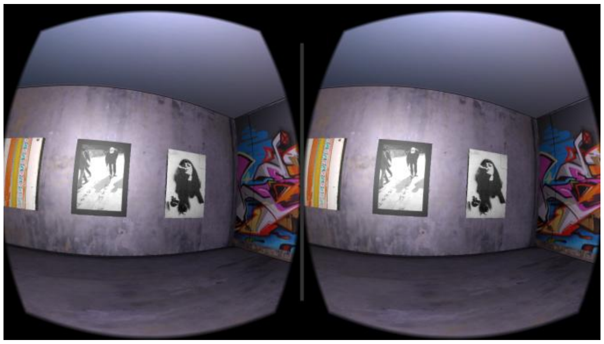
atmosphere for students to explore and eventually solve problems as insufficient funds, time risk and equipment loss for art education.



Education and Training

Aside from art education, vr and ar have been used in a wide variety of education and training environments, starting from preschool education all the way to college education and even further, education and training of professionals. Velev and Zlateva (2017) give an overview on challenges and benefits of vr in education. They argue that VR can be used as a successful tool in a wide variety of professions as well as it already being an important training tool in healthcare, drivers and pilots training or disaster and risk management. For these professions VR provides a safe environment removed from potential dangers which would be impossible without vr. Furthermore, vr and ar inspire creative learning and increase students motivation. Compared to basic online classes, collaboration in vr classroom provides social interaction and direct contact (Velev and Zlateva, 2017).

Kavanagh et all (2017) provided a review of VR in education and found that most frequently reported limitations of VR are linked to the cost, training as well as software and hardware usability. Other researchers (Makransky, Terkildsen and Mayer, 2019) have found that although VR education on lab simulations evokes more presence, it also leads to less learning and more cognitive loads, possibly meaning that the virtual reality environment was distracting for the students. VR environments have been successfully used for training everyday skills such as pedestrian safety skills in children (Schwebel, 2016) but are also being developed for unique tasks as space flight simulators for astronauts (Burugera, 2019).

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When it comes to education, vr and ar technologies are perhaps most widely used in healthcare education. VR applications for medical and nursing training immerse students in an actual hospital environment that simulates real-life experiences without representing a risk for patients. This type of virtual reality simulations provide a solid learning platform that works with the students to increase their participation and engagement with skills acquisition.

Researchers (Shibuya et all, 2019) have found positive evidence for the application of virtual reality for training and educating students of medicine and nursing. Students positively rated virtual reality systems as an incentive to practice skills and also to deepen their understanding. Reports of evidence regarding skills acquisition like tracheostomy care during training were also significantly positive. On the other hand, Bayram and Caliskan (2019) did not report significant differences in the knowledge level of students using vr as a learning method. Possible reasons for the disparity in literature might occur in the light of technical issues with mobile technology and VR technology. Another negative side of using VR for learning and training purposes is the slight discomfort and nausea reported by students.

References

Healthcare

When it comes to healthcare, vr has started rising mostly with Oculus Rift and similar technologies, due to their price and portability which was a major issue that couldn't be resolved with previous technologies. The most prominent areas of healthcare where growing interest in applying VR tools can be found are surgery, rehabilitation and pain

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management. The constant development of vr and ar technology allows current hardware and software to achieve photorealistic representations of the pathology and anatomy of the human body along with the properties of physical tissue and other physiologic parameters which provides a strong and safe basis for surgery planning and training. Invasive medical exams and procedures like neurological surgery, endoscopy, laparoscopic surgery and heart catheterization are in the focus of vr surgery tools development.

Furthermore, since these are surgeries with a high degree of complexity, having the live support of virtual reality during surgery could also improve the practical skills of surgeons and thus improve recovery outcomes for patients, and the costs underlying healthcare. VR simulations can aid healthcare practitioners through preoperative planning and image-guided surgery. Other more advanced VR applications in healthcare include developments that support remote surgery: a surgeon will simulate the procedure in the virtual environment which is transmitted to a robotic instrument or robot that mimics the actions in the patient.

Virtual reality applications in healthcare can also be used for both patient cognitive and motor rehabilitation to help patients regain skills by simulating cognitive tasks and body movement in virtual environments. This type of virtual simulation can be particularly beneficial for patients with strokes, acquired brain injuries, Alzheimer's, Parkison disease, and multiple sclerosis. It has been found that the level of realism of the virtual environment plays a crucial role: it has been found that the more realistic interaction with the virtual environment and its objects, the more it will be reported improvement of cognitive abilities in patients with strokes and other geriatric syndromes.

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Evidence of the positive impact of VR applications in pain management have also emerged. Chronic pain is an emerging issue to which healthcare systems struggle to answer as quickly and efficiently without using non-opioid interventions. In a study conducted Jones, Moore, and Choo supporting evidence have been found that patients can benefit from VR interventions in chronic pain versus control conditions in hospitalized patients. Nonetheless, more research is advised by Chi, Chau, Yeo, and Ta in their study conducted in 2019 since the clinical significance of the analgesic effect of virtual reality applications in different types of neuropathic pain is unclear, despite its potential to reduce it.

Mental healthcare

When it comes to virtual reality application in healthcare the most prominent area it is used in besides education is mental healthcare. The applicability of VR in mental health has been discussed widely, in academia as well as in business. One can find numerous types of VR relaxation applications on the market which are attracting a variety of users. Furthermore, virtual reality applications for self-guided therapy are being developed with the goal to make evidence-based therapy approachable to a wider audience. In the last decade, VR is also commonly used in therapy for psychiatric disorders like PTSD, phobias, schizophrenia, eating and weight disorders.

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In most disorder treatments, VR is used as a tool for controlled exposure to stressful situations commonly referred as virtual reality exposure treatment (VRET). VR has made it possible to present stressful situations as a realistic but safe and controlled stimulus while monitoring responses. Furthermore, with VR it has become possible to design these simulations on different difficulty levels, enabling tracking of progress. There are numerous studies and meta-analyses using VR as a tool in mental health issues. Most findings agree that the application of VR should be supported in the treatment of some disorders (anxiety disorders, stress-related disorders, obesity and eating disorders, and pain management) but further research has to be conducted. Still, results are mixed for the treatment of disorders like depression.

Furthermore, some meta-analyses suggest major flaws in studies on VR in mental health: the samples have been small in most part and validity and reliability have not been tested throughout.

Using VR/AR in Counselling and Psychotherapy

In the last decade there has been a huge rise in usage of VR/AR systems in treatment of clinical conditions. Chronic and acute pain management, phobias, anxiety disorders, PTSD, eating disorders, autism, OCD, rehabilitation and more. In early days Virtual reality therapy (VRT) was mostly used in treatment of agoraphobia (fear of certain spaces or situations) , gradually exposing clients to open spaces in a virtual environment leading to the final stages when clients were introduced to the physical environment. Graduate exposure similar to the one mentioned has expanded to other situations and objects that cause stressful situations. Virtual reality therapy uses emerging and innovative ways of exposing clients to similar situations as in the real world using computer generated virtual reality, hence a safe and controlled environment.

Treatment of posttraumatic stress disorder includes VR systems as a simulation of traumatic scenarios for war survivors but under the control of therapists to guide them through the traumatic experiences helping them to heal. In the study done by Botella, Serrano, Baños & Garcia-Palacios (2015.) using VR based treatment, mainly on war veterans, shows great success in reduction of symptoms and shows significant changes in post treatment check-ups.

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VR/AR has been widely used for pain management, for both acute and chronic pain. Mechanisms used in this area are mainly distractive. It has been used with success in managing acute pain for burn patients. Several studies explored usage of VR in treating phantom limb pain. Clients experiencing their virtual limb move had a form of relief in pain (Joshua Pate, 2016)

Treatment of eating disorders is using VR technology as a way to improve self body perception through education, visual feedback and simulations of critical situations.

Client is receiving virtual reality therapy treatment.

Technological efficiency of the therapist

In the last few decades there has been immense improvement in identifying and treating mental health problems. For example, if we take a closer look at cognitive behavioral therapy (CBT) as one of the leading psychotherapy directions. CBT is deeply researched and identified as highly efficient in treating adults and young people with mental health problems. The problem that arises is the extensive need of the professionals qualified in the field. Older methods such as didactic seminars, workshops and manuals just don't “produce” enough professionals at the high pace they are needed to provide treatment. Using technology in web provided training has shown more efficiency then training done while attending seminars or using manuals.

Research done by Richards, Simpson, Bastiampillai, Pietrabissa & Castelnuovo (2016) as one of the first studies done on the topic of computer based therapy sessions from the

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therapist point of view. Professionals participating in this study have reported that web based interaction with clients gives more autonomy to the clients to take responsibility within their treatments process, empowering clients, but also taking in consideration their personal needs and preferences. Using web based systems in treatment should be personally tailored for individuals and as such it has proven efficiency similar as face to face based one.

Psychological Research

Not only has vr been used as to access psychological well being it is also used as an important tool in psychological research. One of the primary advantages virtual realities poses is, as we earlier mentioned, the possibility to expose people to environments they usually could never be exposed to which is a great advantage when it comes to research. Among that, Pan and Hamilton (2018) specify other advantages of using this tool as experimental control, reproducibility and ecological validity. In their overview of virtual reality usage in psychological research they also mention challenges like embodiment, uncanny valley, simulation sickness, presence and ethics.

VR is used as a tool in social psychology research, perception research and clinical psychology research but with the development of better technologies it is expected to widen its usage.

Additional benefit above other technologies or treatments

Research done by Bouchard et al. (2017.) show treatments of clients with social anxiety disorder shows much better results using VR exposure then in vivo exposure through cognitive behavior therapy. Virtual reality treatments talk:

https://www.youtube.com/watch?v=J2uQ19baVYM

Architecture

The application of virtual reality in architecture and construction is based on providing a more realistic representation of design ideas to clients. Using VR, architects and designers can offer guided tours of their designs and their clients can investigate every aspect of those. The immersiveness of vr architecture tools offers the opportunity for both the designers and clients to experience the building as if it has already been built. Other than

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architecture design, vr tools have been implemented in engineering design which is an important milestone in developing products in engineering.

In his paper Wolfartsberger (2019) describes the development and evaluation of a VR engineering tool, VRSmart and concludes that the results indicate that a VR-supported design review allows users to see slightly more faults in a 3D model than in a CAD software-based application.

As for construction, virtual and augmented reality are used to get a clear picture of how a final product will look in various stages of construction. In all three areas, architecture, engineering and construction virtual reality benefits both the providers and the clients by giving a most coherent experience of the final product and thereby a cost effective solution for all parties.

Retail

Virtual and augmented reality are also introduced to the shopping experience. Some retailers noticed the possibilities VR and AR open for a new approach to develop their business while others used these technologies for marketing while engaging the customers. For instance, Toms shoes company who donate a pair of shoes for every pair sold, provide their customers a VR experience of Peru and children getting donated shoes.

Other retailers engage customers by playing geolocation AR games in their stores. Some companies like Ikea and Sephora use augmented reality technology to allow their customers to virtually try their products before purchasing them. Ikea goes one step further and offers a whole vr experience of their kitchen allowing buyers to interact with the

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space. Similarly, car companies as Audi and Volvo offer vr test driving for the customers and online stores like Alibaba and Ebay offer vr store experiences.

Boardman et al (2019) states that ar technologies as magic mirrors used in clothing stores, can be both useful and easy to use, but the possibility and thereby the intention to use them may be limited due to availability. The same paper finds a similar disadvantage of virtual reality applications in fashion stores and adds common vr issues as motion sickness, priceyness and technology support for the vr hardware setup.

Marketing

Virtual and augmented reality are relatively new and trendy technologies and as such have already been in the spotlight of marketers. We already mentioned some applications of vr and ar marketing in retail businesses or in the music and movie industry but there are other examples. New York Times has delivered Google cardboard glasses several times to their loyal readers in order to enable them to have a vr experience of some short movies rewarding their brand loyalty.

McDonalds on the other hand delivered their own vr cardboard headset Happy glasses easily transformed from a Happy meal box which children could use to play vr games.

Researches (Scholz and Duffy, 2018) have found that AR mobile marketing can result in customers developing closer and more intimate relationships with brands. Another research (Rauschnabel, Felix and Hinsch, 2019) has shown positive changes in brand attitudes after using AR apps both for well known and lesser known brands emphasizing the importance of developing inspirational apps.

Barnes (2016) expects VR to transform marketing in the future as companies are expected to turn to developing downloadable apps for consumers rather than providing vr experiences in stores. The same article determines that a major disadvantage for the development of vr marketing, among motion sickness and availability, is lack of technical expertise in the marketing sector.

Tourism

Another area where augmented and virtual reality are used are tourism and travel marketing. There are simple AR apps developed with the purpose to enhance or simplify

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the traveling experience. App in the Air which allows customers to compare their own luggage to the airlines permitted size via AR. Transportation apps like Tunnel Vision or Bus Times London also use the benefits of AR to ease navigation through new cities. Furthermore, the traveling market also uses marker-based AR apps which work on the principle of object recognition and offering detailed information about that object. When it comes to VR in tourism and travel it can enhance the real-world experience, but it can also be used as a stand-alone travelling tool.

A research (Wagler and Hanus, 2018) comparing a real-life experience, a vr experience and a 2D experience of the same destination showed interesting results. Both VR and real-life conditions showed more spatial presence, emotional engagement and liking than the 2D video condition, there was no significant difference found between them. Such results imply that VR travel can generate the same or at least very similar experiences as real-life travel. Studies (Tussyadiah et al., 2018) have also found that VR can positively shape consumers attitudes and behaviours towards destinations via increased enjoyment and feeling of presence.

An overview paper (Nayyar et al., 2018) on VR and AR application in tourism suggested that both technologies have a unique potential to support the decision-making process in traveling experiences since it is an intangible product and thereby hard to represent in other mediums.

Military

The army adopted VR and Ar a long time ago, much earlier than commercial markets. Some argue that VR and AR technologies would be much different if there was not a huge investment by the military in the very beginning. The military has also developed the first headset, a.k.a. HMD. Currently VR is mostly used in light and battlefield simulations, medical training, vehicle simulation, and virtual boot camps.

VR training remains the most effective and widely used option and the greatest advantage of VR in the military is that soldiers can be trained without risk of injury for themselves or others. Similarly, AR usage started in the 1960s when it was used for fighter pilots' helmets. Displaying necessary information within the same focal length as the real world beyond, saving them the effort of constantly refocusing their eyes helped pilots to react

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more quickly in life-threatening situations. Today AR has moved to other branches of the army and is used as well as VR for training purposes thus providing great cost savings.

The factors affecting the effectiveness of military training in a virtual environment were identified and consisted of 3 factors: learner, teacher as well as tools and content. In military training implemented in a 3D environment, the design of the course is often restricted by detailed instructions, regulations, and operational procedures. Such training is based on the scenarios and activities involving the risk of loss of health or life. The uniqueness of the training requires identification and analysis of parameters that are important in the assessment of training effectiveness (Małgorzata Gawlik-Kobylińska, 2020).

Nonetheless, Virtual reality technology is still a relatively new thing for our military and has not been practiced too much. Strengthening the application of virtual reality technology in the military field should always focus on the theme of exploring the winning factors and winning mechanism of complex wars, strengthen the core technology research, and establish a standard system as soon as possible to achieve long-term benefits (Kang Wang 2018).

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User Concerns

Financial cost

Introducing a virtual reality or augmented reality system in corporate or any other industry has some financial cost at the beginning. Even with the price reduction of the VR/AR systems in the last couple of years, introducing a VR/AR into a company is still not a simple task. Detailed project documentation around the users needs and wants should be made before purchasing software or hardware, analyzing talents, equipment, space and similar should be done. Also time and effort for changing from one system to another and training for the employees should be considered.

There are many financial benefits for the companies using VR/AR. Training done in virtual reality vs. physical reality reduces travel expenses (reduced carbon remission) for the company. Property cost reduction as a major cost for most of the companies. Facilitation of the training done in virtual reality would also decrease the cost of human facilitators needed for the training and similar.

Limitations due to health conditions

Pregnancy was considered as a condition in which using VR systems should be taken with caution. But newer research, such as one done by Setiawan, Arsiwi & Agiwahyuanto (2019.) reported that using VR application for exercise while pregnant can help with the overall health status of pregnant women and is feasible to use. Also, using VR systems while giving birth showed decrease in pain.

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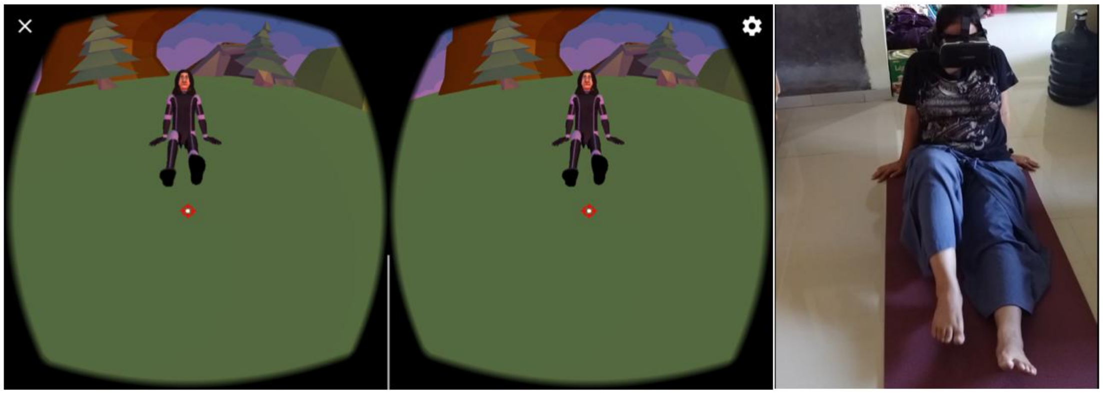

Research done on cybersickness and migraines shows that different types of migraines could trigger and increase cybersickness while using VR systems. Considering other triggers also increase cybersickness such as lack of sleep, not eating and hydrating, loud noises, caffeine this should be further researched. Also stress as one of the big triggers for cybersickness has limited research done (Paroz, 2017).

Epilepsy

People with epilepsy should contact their doctor and/or other specialist before using VR systems. Review done by Tychsen & Thio (2020) on assessing risk of photic-induced seizures in children and adults with epilepsy while using 2D/3D games or viewing videos on standard video display as well as using VR systems. Research showed no higher risk of seizures using VR systems then watching 2D or 3D movies on the normal video display. Some headsets even showed reduced seizures.

Vertigo

Vertigo is more a symptom than a condition where there is a discord between visual and vestibular systems which makes controlling movement and sense of the eye difficult. People with this condition have a hard time in environments where movement control and visual challenges are needed. In the last couple of years there have been developed an AR video game console and good results have been achieved with users experiencing vertigo.

Musculoskeletal disorders

Not a lot of research has been done on musculoskeletal disorders and usage of VR systems. Researchers have been mostly concentrated on using VR systems in treatment of relief and managing acute and chronic pain. But since musculoskeletal conditions are

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characterized by levels of pain and mobility limitations as well as functional ability there should be further research in the field soon.

Cardiovascular disease

VR systems have been used, not as much in treatment of cardiovascular diseases, but as a help in promoting and maintaining health status of patients. Taking into consideration patient needs and preferences VR systems could help improve overall health outcomes in patients after stroke when other therapies are not available or as comprehensive rehabilitation programs.

In the cardiology field VR Systems have been widely used in education, pre procedural planning, rehabilitation of patients and intraprocedural visualization.

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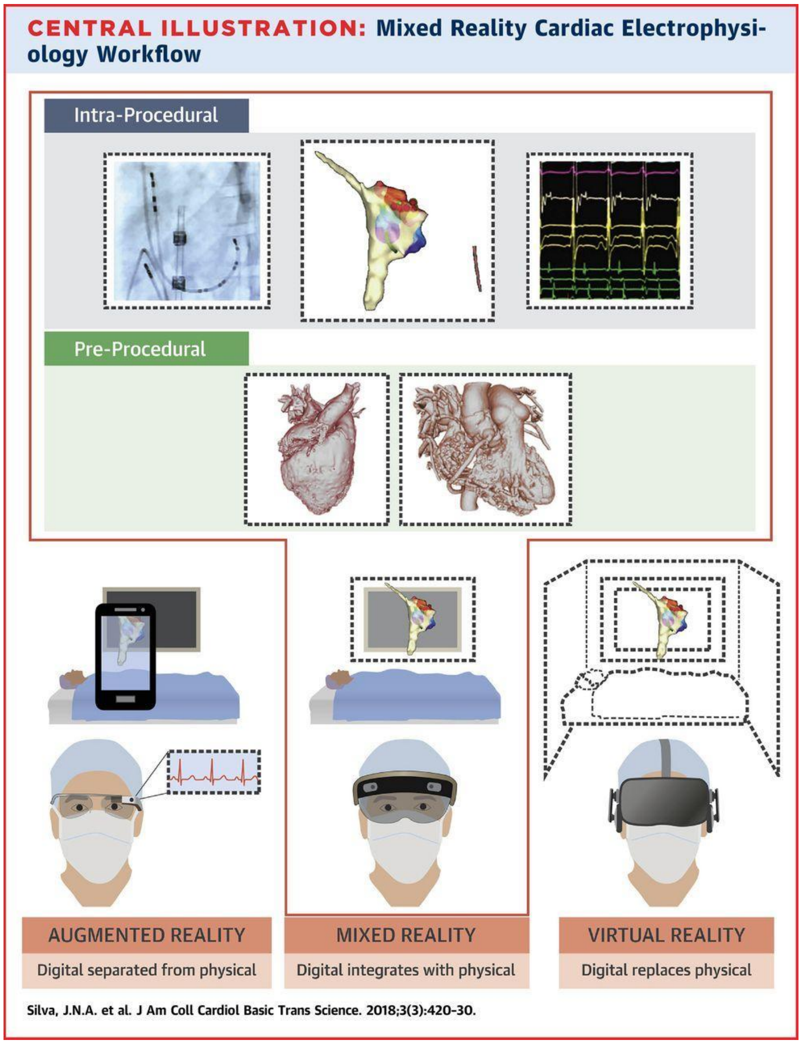

Obstructive pulmonary disease

Study conducted by Rutkowski et all (2020) compared the effects of inpatient rehabilitation programs comparing patients with chronic obstructive pulmonary disease when using traditional rehabilitation and non- immersive VR training. Results show that using VR enhanced with endurance exercise training is beneficial to the patients more than when only using traditional rehabilitation programs. Patients showed better physical fitness.

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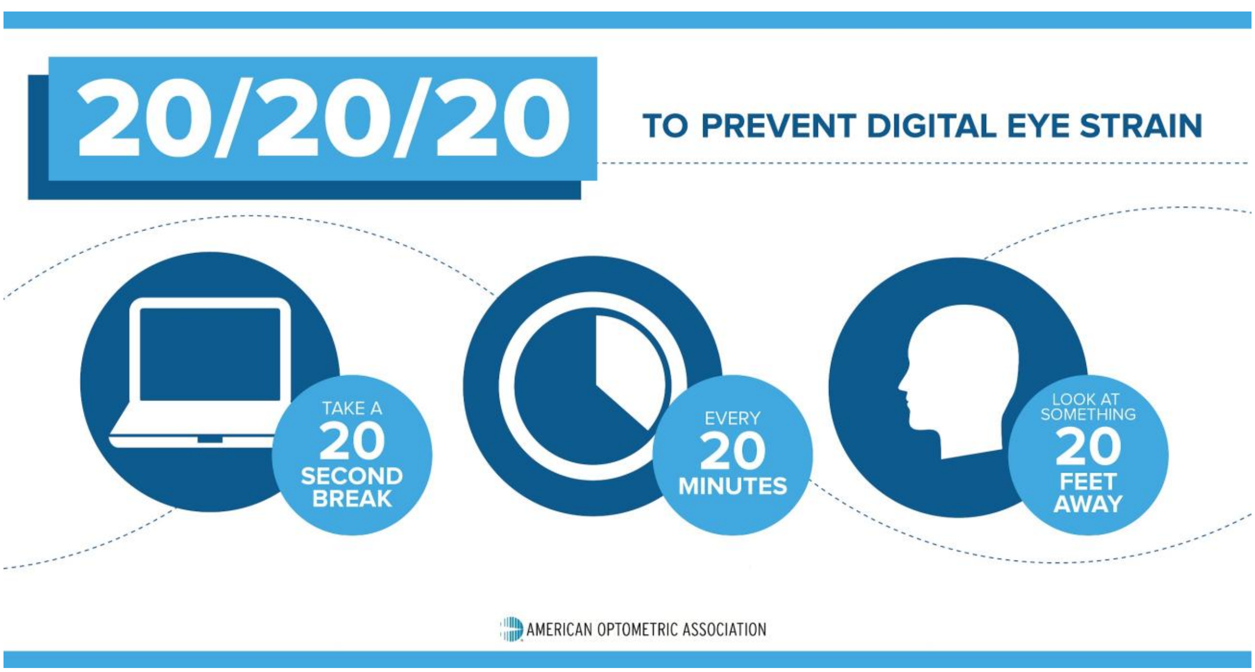
Main symptoms

Digital eye strain

Sight is one of the most important human senses. Using digital devices for work, social purposes, leisure and fun, usually many hours throughout the day, has now become new normal in this day and age. Digital eye strain (DES) is one of the conditions mentioned by ophthalmologists around the world. When talking about digital eye strain we are referring to a group of symptoms that include eye and vision related problems. According to the American Optometric Association mostly mentioned symptoms connected to DSE are: eye strain, headaches, dry eyes, blurred vision, pain in the neck and shoulders. One of the recommendations on how to decrease and help prevent these symptoms is the 20/20/20 rule. Meaning taking 20 seconds breaks after every 20 minutes of using digital devices and looking at something at least 20 feet away.



Digital eye strain can easily be prevented with using digital devices in a more ergonomically correct way. Location of the computer screen positioned in front of the person in a slightly

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downwards position, 15 to 20 degrees below eye level and at least 20 to 28 inches from the eyes. Materials used while working should be positioned beside the keyboard if possible or between screen and the keyboard. Lightning in the room can also prevent DES by positioning it to avail the screen glare. Anti glare screens are also recommended if possible. Comfortable seating position, with the chair adjusted to the table where the device is located is extremely important. Taking breaks (20/20/20 rule and if possible longer breaks) while using devices for longer and regular eye examinations are also highly recommended.

Computer "Eyegonomics"

Motion sickness

Motion sickness is described as an unwell feeling caused by motion. Usually connected with traveling but also with VR immersion. Some of the main symptoms of motion sickness include autonomic bodily reactions such as nausea, vomiting, sweating, pallor, hypersalivation and neurological disorder called sopite syndrome which includes drowsiness, lethargy and fatigue.

Motion sickness is caused by conflict between signals the balance system is sending to the brain. Balance systems combine information from different sources - vestibular system, visual system and proprioceptive system and when those systems get confused

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of what is happening as a result a person experiences motion sickness. While it is much easier to understand and work on the prevention of motion sickness it has been more challenging to explain and prevent cybersickness.

Cybersickness

Cybersickness is considered as a sub type of motion sickness connected to virtual reality. Difference between motion sickness and cybersickness (CS) is that the second one is usually triggered by visual stimuli. Both of these conditions share similar symptoms such as sweating, dizziness, fatigue and nausea. Women report more symptoms caused by CS then men but newer research shows it could be connected with the design of the VR headsets, not their previous experiences nor gender differences.

Although there are a lot of anecdotal reports of VR making people feel ill or cybersick the amount of literature that discusses it is limited. Cybersickness (CS) is described as a constellation of symptoms of discomfort and malaise produced by VR exposure (Stanney et al. 1997). A visually induced motion sickness (VIMS), which describes any sickness produced by observation of visual motion, symptomatically similar to car or sea sickness. The theories as to why some people experience CS are a mismatch between observed and expected sensory signals (Reason, 2016), self-motion (McCauley, 1992), visual display characteristics (Moss, 2011).

Cause of cybersickness is similar to the motion sickness one. Visual system is detecting movement, but vestibular and proprioceptive systems are not. While cybersickness is still being researched and possible preventions and treatments are being considered more we can come to the conclusion that if feeling any of the mentioned cybersickness symptoms while using VR systems a person should stop using until feeling better. Symptoms usually decrease in a short period of time. Professors Feiner and Fernandes (2016.) at Columbia Engineer University found a way to decrease cybersickness by strategically and automatically manipulating field of view. Usually decreasing field of view decreases sense of presence while using VR but this research showed that it is possible to preserve a sense of presence in the VR environment while making the VR experience more comfortable hence lasting longer.

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Research done by Kim, Park, Choi and Choe (2017) was aimed on developing and deriving a measurement index, a simple questionnaire to establish level of motion sickness in the specific environment such as VR.

According to Davis at al. (2014) cybersickness rapidly decreases after the age of 12 to 21, meaning older people are less prone to experience cybersickness while using VR systems.

Mitigating cybersickness

Sitting posture while using VR seems to be safer for users prone to cybersickness as it does not demand postural control. There are some suspicions, as already mentioned, that there are some gender differences while using VR but newer research shows they can be easily overcome with the different design of the VR headsets.

Cybersickness can also decrease/increase depending on the task the user is performing using the VR environment. Duration of the task and level of the control in the VR environment can also have influence on the possibility of cybersickness - less control over the environment brings higher possibility of cybersickness emerging. Using brief exposures to VR environments and giving more control to the user in the environment is more likely to improve the adaptation of the user and less likely to cause cybersickness.

Other symptoms connected to cybersickness like disorientation, sweating, pallor, drowsiness, nausea or even vomiting, fatigue have been reported by VR system users.

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Even with experiencing these symptoms and definitely before completely discontinuing the use of the VR environment users should consider taking breaks, using VR environment in shorter periods of time to allow adaptation. If the symptoms of cybersickness prolonged after use and persist, users should contact support services and their doctor to be sure there are no other underlying conditions.

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Cognition

When designing a VR/AR experience, as in any other designing process, it is desirable to keep the interaction between the user and the experience simple and natural, requiring a minimal amount of cognitive load for the user. This means intuitive designing. To develop an intuitive experience, learning how users perceive and process perceived information is substantial. Since VR and AR are a somewhat new and uncharted territory when it comes to perception and cognition processes, literature on these topics is fragmented and scarce. But conclusions can be derived in domains like colour, size and scale, animation, sound.

Vision

Understanding how we see and interpret visual information is useful when designing for VR. The retina at the back of the eye receives light information which our brain interprets into sight. Our field of view is 220 degrees but only a very small part of it is in focus 5% and the rest is peripheral vision. The peripheral allows us to see motion and key patterns but surprisingly very little color or fine detail. The eyes make up for this by darting around taking the view in small parts and creating a whole view. This has implications for combining a HMD with eye tracking capabilities which is discussed in the user concerns section. This video demonstrates how little of our field of view is actually in focus.

Shocking illusion - Pretty celebrities turn ugly: https://youtu.be/VT9i99D_9gI

Size and scale

The three-dimensional world of VR and AR has made size and scale an incredibly important factor. It must be kept in mind that when developing such experiences either 3d or 2d virtual objects are placed into the real world as with AR or whole 3d virtual worlds are being developed as VR making scale both important and difficult to approach. Although such technologies offer creative possibilities, most designs are required to mimic the real world and real-world perception and cognition principles.

The feeling of immersion that VR offers unlike any other medium is due to the sensory input of real-life sizes and scales when in an VR environment. When comparing avatar size and

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realism with perceived size of objects, one study (Ogawa, Narumi and Hirose, 2018) has found that perceived object sizes were underestimated when the avatar hand is enlarged. This finding also depended on depicted avatar hand realism. The more realistic the avatar hand was, the greater effect size of the avatar hand had on underestimating object sizes. This finding is in line with the assumption that realism is a great factor of immersiveness and that the VR design should mimic real-life experience.

Colour

With no doubt is colour one of the crucial aspects when perceiving the environment and that applies to VR and AR environments as well. The importance of colour characteristics like saturation, hue, brightness in human perception and decision making has been well documented, especially in digital technologies. When it comes to VR and AR development, although most of the well-known designing principles of colour apply to these environments the same as any other, there are some specific differences in colour perception. For instance, studies (Shin, Kim and Jo, 2019) have shown that people overestimate colours in VR compared to the same colours in real life meaning that the experience of colour is somewhat intensified in VR. Another interesting study (Siess and Wölfel, 2019) showed differences in colour temperature preferences depending on gender where women preferred colder toned VR environments compared to men. Not only was the preferred colour temperature gender specific it was also affected with other non-technological factors like time of the day or season in the year.

One research (Pardo, Suero and Pérez, 2018) has found the visual fidelity of generated images compared to the real-world image considerable, close to 4 on a 5-step perceptive scale. The fidelity of colour reproduction and the perception of material texture are the main factors related to this visual fidelity improvement. However, Pardo et all (2018) suggest this fidelity might be improved further. Since the graphic experience is connected to the device it is recommended to use graphic card compatible MHD rather than for example mobile devices which don't have the same capabilities.

Emotion

Expressing and interpreting emotions through nonverbal cues is a crucial part of human communication and often taken for granted. It is essential in everyday life and all interactions humans have, from casual conversations with friends to business meetings,

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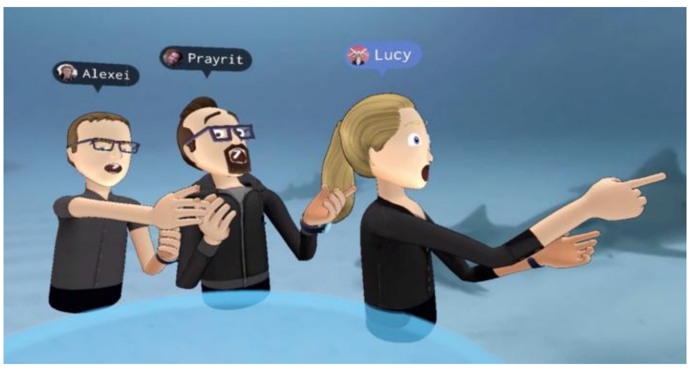
include encrypting and decrypting of emotions on a conscious or more often subconscious level. The importance of nonverbal cues for good communication is apparent in communicating via text messaging. This popular communication technique incorporated emojis to mimic face to face communication traits as facial expressions and gestures thereby helping to understand the underlying emotional tone of the message. It is theorized that emotion representation of avatars leads to more real life experience of VR and greater immersion.

As immersion is one of VR's greatest advantages compared to other 2D technologies, it is important to enhance the emotional experience in VR to make it even more life-like. Facebook was one of the first companies to understand this and develop Virtual emojis (Techcrunch, 2016). Virtual emojis are avatars whose eyes, eye brows, mouth and even hands change to mimic nonveral emotional cues in the real world. On Facebook they argue that social VR experiences have to incorporate nonverbal emotional cues if they want to maintain feelings of immersion and presence in their experiences. A lack of emotional response of an avatar in a social situation would most likely lead to breaking that feeling.



Providing emotional nonverbal cues to avatars requires development of animation processes for every cue required in the avatar which can be both time and money consuming (Vargas Molano, Díaz and Sarmiento, 2019). Vargas Molano et all (2019) proposed a workflow to adapt a face model called Candide into almost any humanoid avatar. This model provides an opportunity to simplify the process of emotional expressions development in avatars by replacing the original avatar face with the parametric mask resulting in emotional expression.

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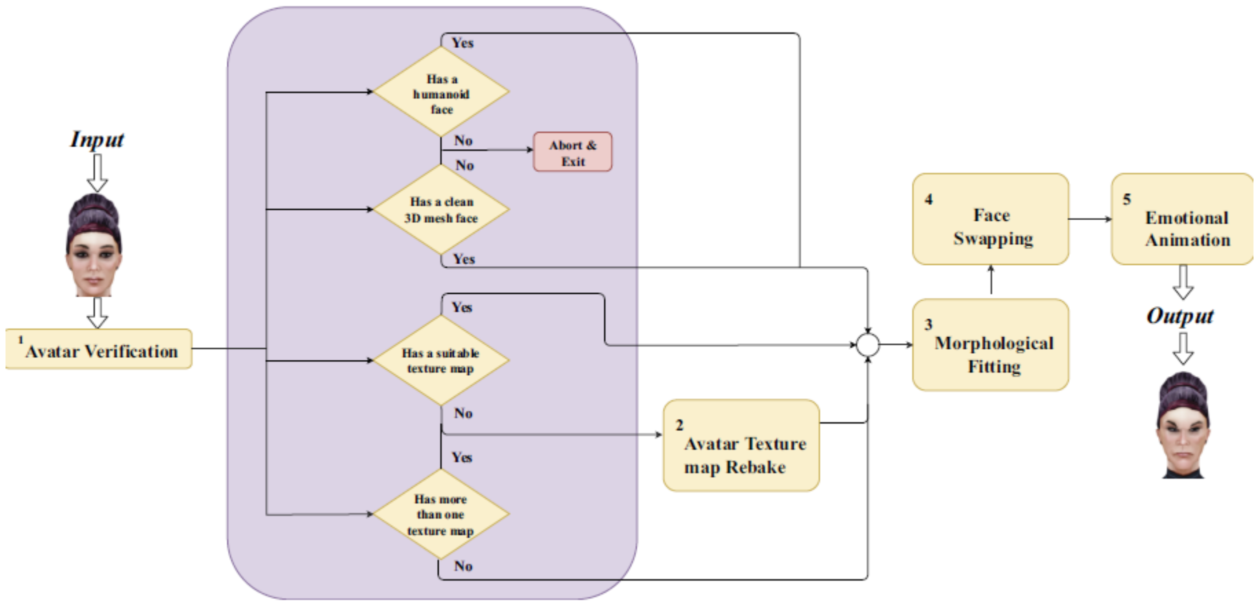

Time

Both real time and virtual time are important factors to consider when developing VR experiences. When it comes to real time and using virtual reality, most makers of VR headsets recommend taking a 10-minute break every 30 minutes. Prolonged usage time can lead to various consequences like loss of spatial orientation, dizziness and nausea which were mentioned earlier among other concerns.

Most findings on time perception in other technologies apply in virtual reality as well. In general, these findings show that time perceived is often different than real time. For instance, perceived time is longer then real time in tasks requiring greater cognitive load, in tasks with familiar and happy music and in immersive tasks.

Time cues that are used in virtual reality environments to create time perception are called zeitgebers. They can be natural like the sun, artificial like clocks and social. One study has found that manipulations of natural or artificial zeitgebers has a significant effect on time judgments of users (Schatzschneider, Bruder and Steinicke, 2016).

Novelty

Although VR in some form has been around for 30 years, only recently has it become commercial. Since the start of its wider usage it has been growing and developing rapidly and there is no stop to this development in sight. Market research predicts a rapid growth of VR market share and investment in all sectors of VR. Although gaming is still the most often mentioned sector of virtual reality development, education and training as well as healthcare follow close behind. The benefits that virtual reality offers compared to real life or even 2d technologies are overwhelming. Virtual reality offers countless possibilities in creative design of space, environment, embodiment and even physical principles without breaking the feeling of immersiveness, presence and real lifelike experience.

Various sources (Gebel, 2020; Forbes, 2020) mention this time of social distancing and isolation as a great opportunity for virtual reality in terms of remote working and learning. It is no wonder that tech giants like Facebook and Apple have accelerated their work in mixed reality technologies during the pandemic outbreak (Statt, 2020, Gurman, 2020). Due to forced remote working during the last months Facebook, among other companies, has recently announced shifting towards remote working in the future possibly creating a new trend in working environments, a virtual working environment while remote working.

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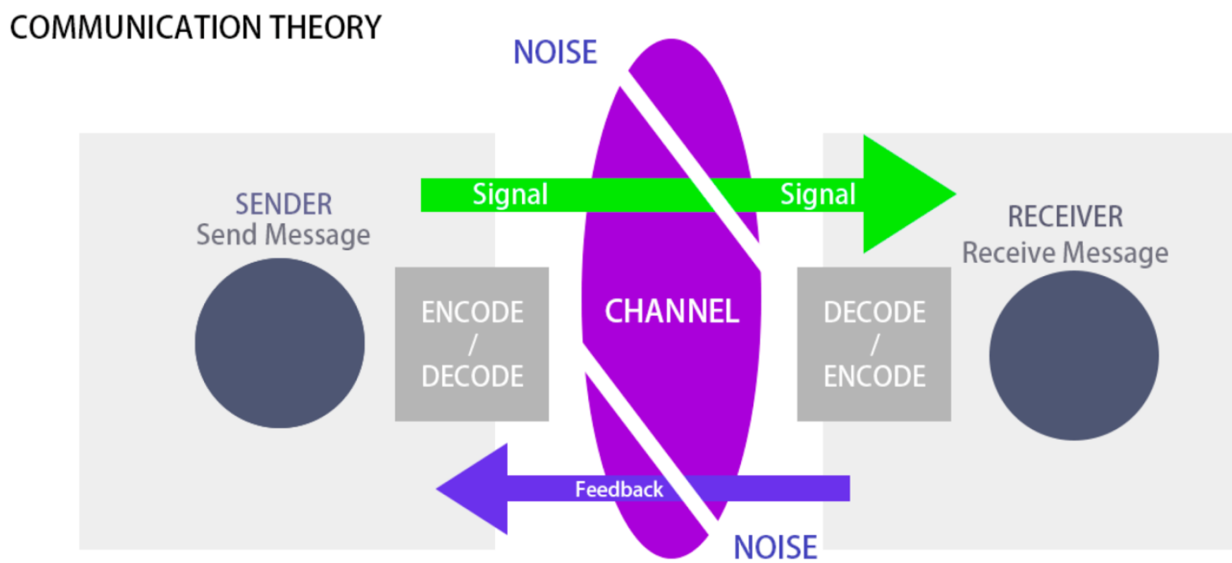
Communication

Computer mediated communication

Computer mediated communication (CMC) is defined as communication between two or more people using computers (or other technologies) as an instrument to achieve interaction (Herring, 1996). By Connolly, Palmer and Kirwan (2016) any use of technology to interact with other people, including messages sent through social media, comments of posts, emails, text messages or even voice messages is considered as computer mediated communication. A multi user VE can be considered a form of computer mediated communication.



In the last couple of years computer mediated communication has developed to a higher level. Virtual reality (VR) and augmented reality (AR) rose as a way of communication within different industries (such as recording, medical, communication, art and education industries) around the world. Using VR/AR in communication has been researched for decades but only with the advances made, regarding hardware and software, new opportunities have arisen. New technologies help people to communicate and collaborate

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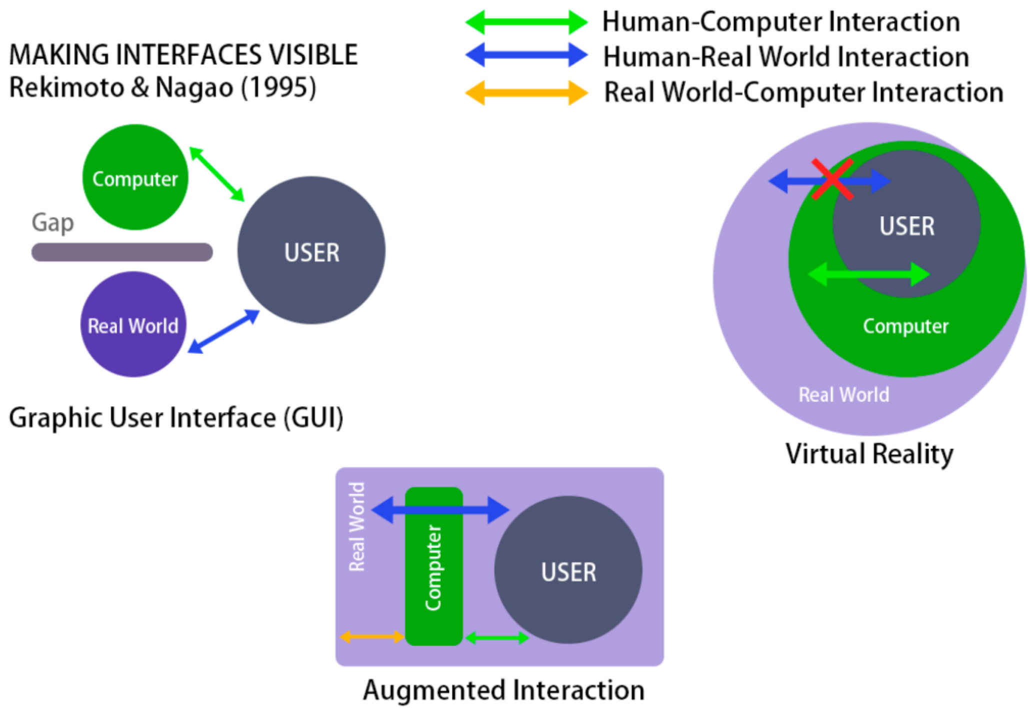
as naturally as possible but without necessarily being in the same room physically. Using VR/AR in corporate collaboration has given a completely new dimension of communicating in a way that is more memorable and more engaging and immersive for the employees.



VR is often seen as a solitary pursuit where the user is alone in the virtual environment. This is not always the case as there are also experiences which allow multiple people to be in the same VE at the same time. Popular CMC tools consist of text, voice, gestures, emoticons, avatars and other ways of communication. Biocca & Levy (1995) noted that VR "is likely to emerge as the next dominant medium - if not the ultimate medium" since it can provide all of these methods and much more. Facebook whose stated goal is to connect the world has invested heavily in VR as a communication tool.

Stasser (Stasser, 1992) defined interpersonal communication as a process by which a group of social actors in a given situation negotiates the meaning of the various situations which arise between them. Virtual environments can be designed to provide context for communications making the collaboration more effective. A work space compared to a play space for example. In addition 3d models can be imported giving the users a focus for

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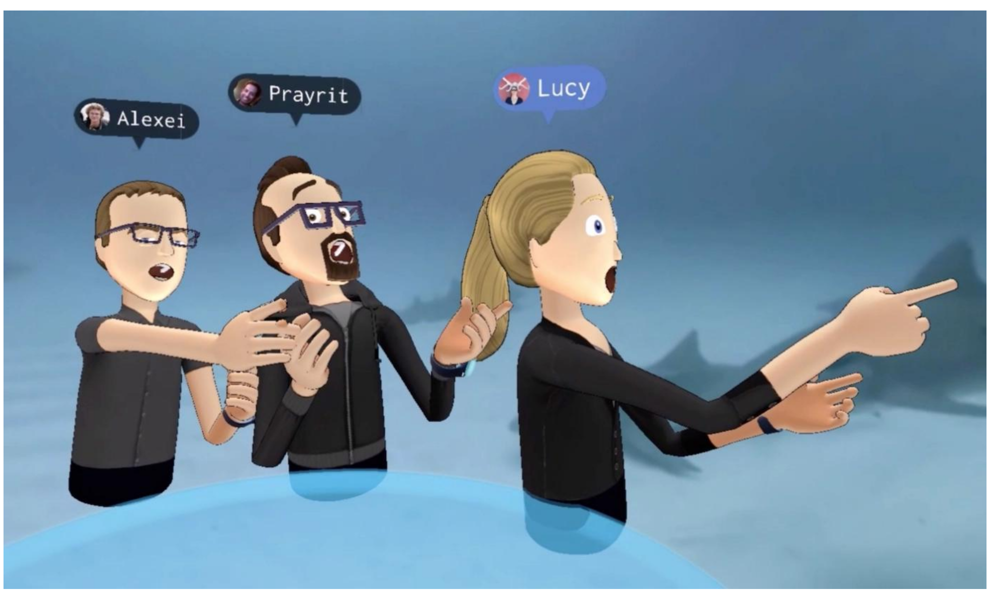
their communication. Virtual meeting rooms have features such as whiteboards, video screens and models that can be manipulated and moved.

Communication in VR

If a picture is worth a thousand words, a video a million what is a 3d scale model where the user can move about and interact with worth? In addition multiple people can be in the same VE simultaneously and communicate with each other. Other CMC methods lack nuance for example a text does not convey sarcasm. Tone and physical cues which provide context in face to face situations are lost. We can also tell a lot about the person we are talking to by their reaction, for example a confused expression if they don;t understand what you are saying. Because of this the users of these services have developed their own methods of converting emotion such as emojis and acronyms. In a multi person VE users will have headphones and microphones which allows for voice communication. The hands are tracked so gestures and body movements are visible, in addition the ability to manipulate 3d models in a VE allows for collaboration. Facial expressions and emotions can also be conveyed in innovative ways besides voice. Facebook's reality lab has created the VR Emoji where gestures will trigger facial expressions on an avatar. Shaking a fist for anger, hands beside face (Home alone style) for surprise, hand in the air for victory.



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Thes emojis make for a richer environment conveying information more efficiently between participants. Facebook allows users to create their own avatars to resemble themselves in real life. The have four good rules for avatar creation:

"You're comfortable with the way you look"

"Friends can recognize you at a glance"

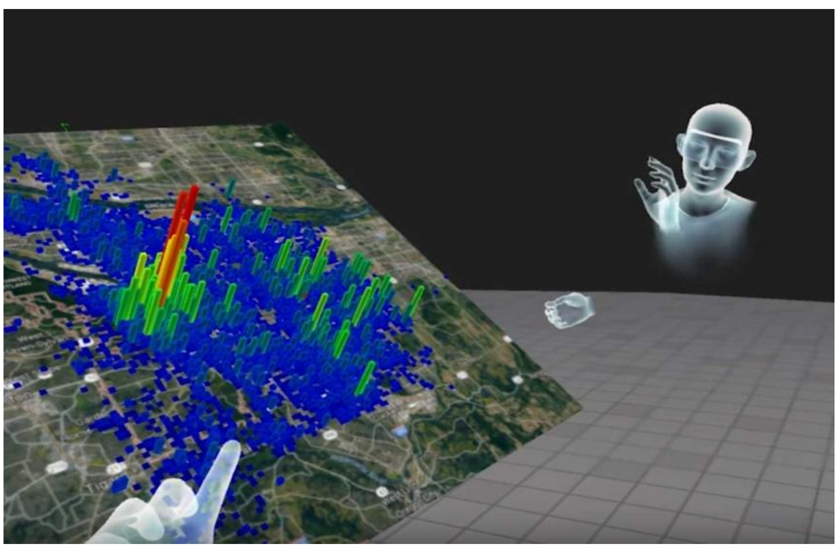
"It's not creepy and disturbing"

"Facebook can create avatars that represent each of its 1.7 billion users"

There are systems which will scan a person's face and body to make it into an avatar.

Communication in project management

A project requires a group of people to come together and execute a task to achieve predefined goals. Winch (2010) describes a project as a flow of information and therefore project management as the task to manage information. A task described by Kolltveit et.al. (2009) is something to be executed within a certain time frame, with a given limit of resource. A project will have given goals or a task to complete. The ability to create the environment, provide the tools needed and the context makes VR a useful tool for project management.



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Visualization is an important tool for communicating within groups. They can help improve the understanding of the group and provide a focus point for work. Consider someone describing the new app they developed to you compared to seeing a prototype you can hold in your hand and interact with. A regular meeting room will have devices such as a screen, whiteboard, flipcharts, prototypes etc these can also be created in a VE. A 3d model will also provide spatial and scale information in ways 2d will not. Data can be displayed and interacted with in interesting ways.

Immersion and Presence

According to Markowitz and Bailenson (2019) early work done by Pausch et al. (1997) and Loomis et al. (1999) state that the main goal of a successful virtual reality system is to make it as close to real life as possible. Two phenomena have been mentioned for achieving that goal : immersion and presence. Immersive VR systems obtain a higher level of user's presence by increasing virtual sensory stimuli and, at the same time, minimizing contact with real life around the user. Hence how well technology that has been used estimates movements and characteristics in virtual reality. Any irregular representation, both in desktop and immersive VR, can have a negative impact on the authenticity of the user experience in virtual space.

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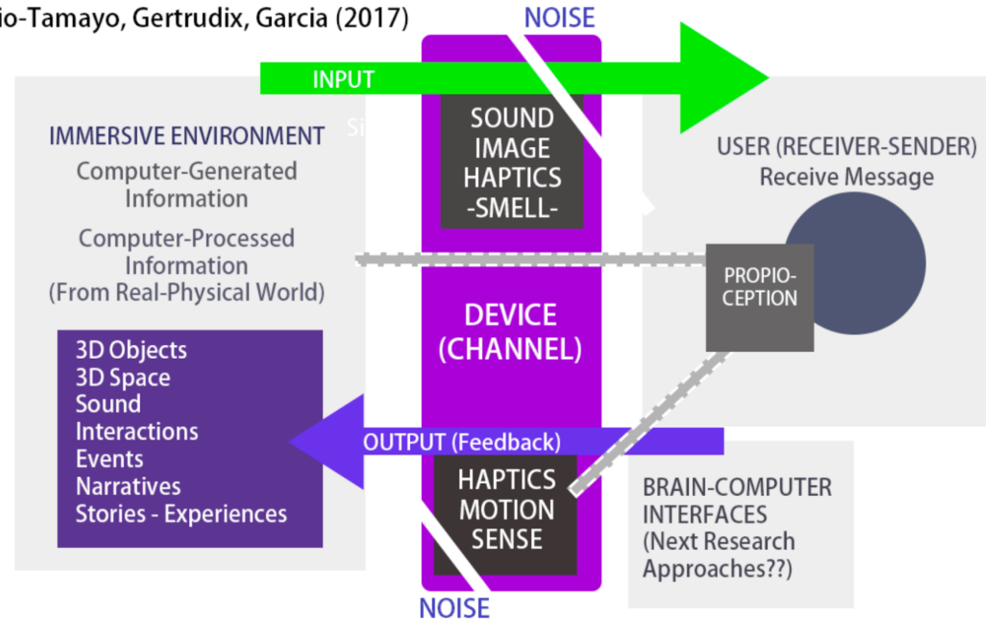
IMMERSIVE ENVIRONMENT-HUMAN INTERACTION
Rubio-Tamayo, Gertrudix, Garcia (2017)



Presence, used as a psychological term, is the subjective feeling of “being there” (Markowitz & Bailenson,2019). People using VR systems need to experience that their actions are perceived by other users and plausible as much as they would be in real life situations.

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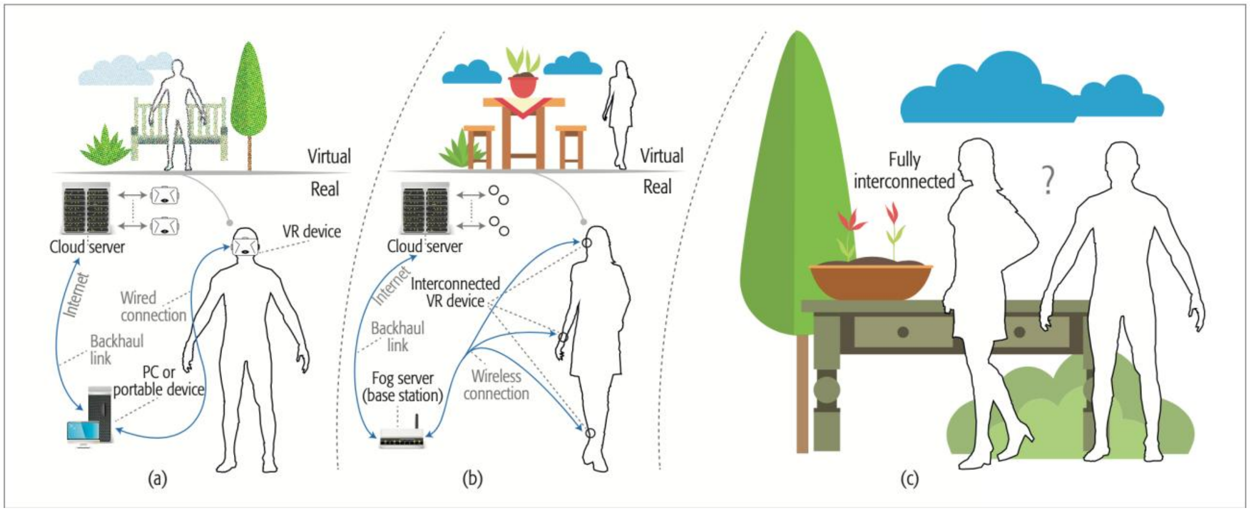

An illustration of virtual reality scenarios: a) current virtual reality systems; b) interconnected; c) ideal (fully interconnected) systems (Buttner,Mucha,Funk,Kosch, Aehnelt,Robert,Röcker,2017)

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VR/AR Interaction

Human-computer interaction (HCI) is a field of study focusing on the interaction between humans and computers. Interaction involves three parts, the user, the computer and how they work together. HCI is a well-established field and has been the main driver in making technology accessible and useful. Software is becoming cheaper, is often free and comes with little or no documentation. People expect to be able to download an application and start using it. They can do this because a language has developed during the development of traditional interfaces. The icons, locations and interaction types have evolved in such a way that there are a lot of similarities between applications. This means that when learning to use a new application we already know a lot even before getting started. The easiest products to use are those where the interaction feels natural, users can complete a task without needing to think about it. (Krug, 2005)

Previous sections of this report investigated how we perceive things such as colour, shapes, motion, the Gestalt principles can create a shortcut to learning how to interact and make an experience which is intuitive. A common term in interface design is "intuitive:" basically, knowing something without having to be told (Bruce L. Davis, 2015). Often, "intuitive" interfaces rely on some aspects of human instinct to communicate a purpose and encourage a type of interaction.

Using a 2D system the devices available are the mouse, keyboard, joystick, etc. providing a way to interact such as moving the mouse to indicate an x and y position for the cursor, clicking on icons and receiving feedback on the monitor. The keyboard remains very similar to typewriters, still using the same layout of the letters even though there have been many different redesigns the Qwerty keyboard is still by far the most used. These interaction languages take many years to develop and many mistakes were made along the way. VR/AR provides another way of interacting with technology.

Unlike the 2D environment, interaction in VR is far from settled. There are methods emerging but people are still finding innovative ways to complete tasks, for example Google cardboard has only one button and uses gaze control as its main input feature. Users can interact by looking at an option and after a predetermined time the option will

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execute. A dot on the screen operates as the cursor. Research into the best practices to create VR content are described below. By considering the context and capabilities of the user we can map out the optimum placement for UI elements.

Firstly, consider if the user will be seated or standing during the experience. This will inform where to place UI elements. Also note that using VR can strain the eyes after a while and people tend to use it for much shorter periods than 2D screens.

Input

Unlike the 2D environment, interaction in VR is far from settled. Google cardboard has only one button and uses gaze control as its main input feature. Users can interact by looking at an option and after a predetermined time the option will execute. A dot on the screen operates as the cursor.

Other smartphone based HMD’s use simple Bluetooth controllers

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For the high end HMDs hand tracking is not precise enough yet for detailed or intricate tasks so the preferred method is using controllers such as wands. Typically, the controller is tracked in the space, a trigger, buttons, grip/squeeze and a touchpad. In addition, there can be gaze control and voice commands.

Duration

VR has some physical requirements that make it different to 2D environments. The user is wearing a headset which has weight, though the HMDs are getting lighter with each iteration. They are often in a standing position and moving. VR sessions shouldn’t be longer than 20-30 minutes, Oculus and Vive recommend taking at least a 10 to 15 minute break every 30 minutes because people start to lose concentration after that time period. Longer sessions should allow the user to save their progress and be able to return back to the place they stopped. There is more about time in the cognition section of this report.

Content Zones

The physical orientation of the user allows you to determine where to place the content and make design choices. On a 2D screen we use the Gutenberg diagram which identifies the best position for screen elements. It uses our reading style where we naturally look to the top left of a document and read left to right ending at the bottom right hand corner.

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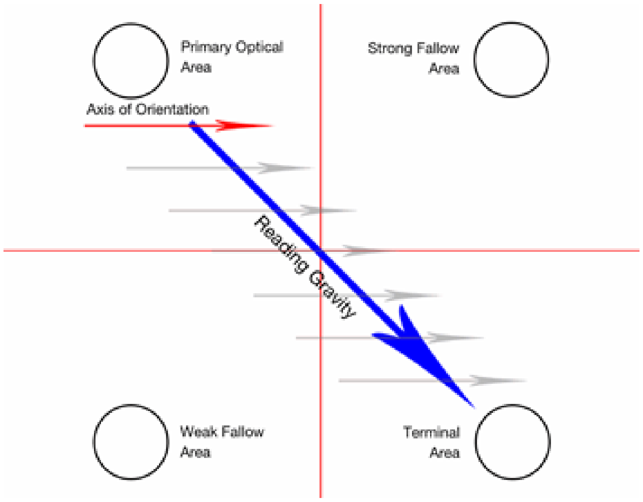

The Gutenberg diagram.

The primary optical area is the best place for logos and the website tagline as it is where people look first. They then will move right to the strong fallow area where login options are often placed. The bottom left is the least looked at part and the bottom right is where the scanning ends so is a good place for a call to action. This model can be used for designing user interfaces in VR where the user is making selections in a dialogue or menu box. The 2D designer has a limited space but in VR the space available is much larger 360 degrees and has the additional dimension of depth.

Mike Alger (Mike Alger, 2015) examined making a Gutenberg diagram for VR interaction design. Starting with where best to place elements where they can be viewed comfortably. HMDSs have different fields of view but generally someone looking forwards can see 94° comfortably without moving their eyes or head. We can move our eyes 30–35° without any strain and 55–60° with mild strain. This leaves an optimal area of about 60° where primary UI elements should be placed. Around that there is an area of 120° where secondary elements are best placed.

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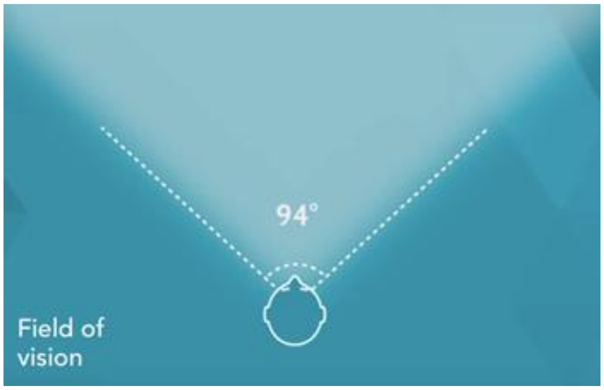
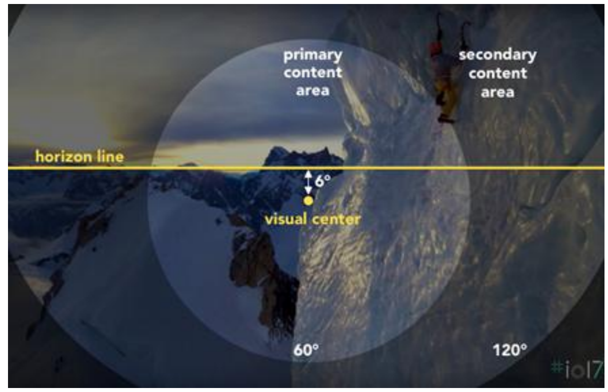
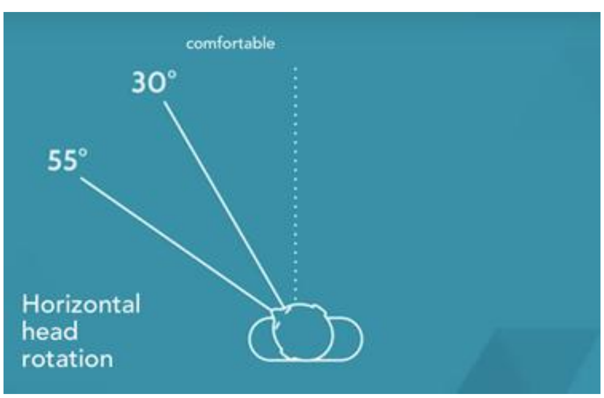


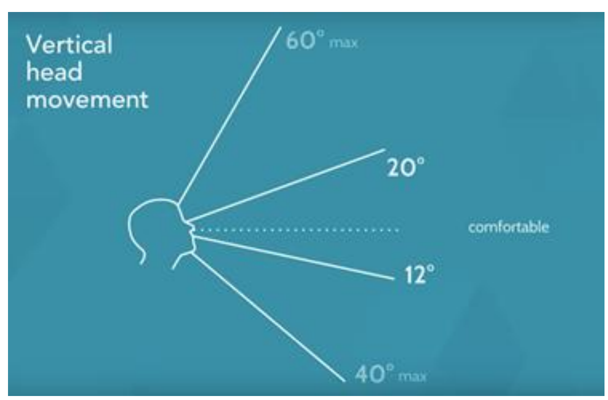


Mike Alger, 2015

Note we tend to look about 6° below the horizon line when looking forwards so the primary UI element should not be dead centre but slightly below the horizon line.

This is for someone looking straight ahead but VR also allows us to look around in any direction. Moving the head horizontally 55° left or right is comfortable for most people increasing the viewable area. Looking vertically 40° down and 60° up was found well within most user's comfort zone.





Mike Alger, 2015

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Mapping these movements creates the diagram below which can help inform where best to place UI elements within the virtual space. Within 0.5m elements will be too close for the user to be able to read or focus on, there is an exception to this which is “watch check” or menu’s based on the controllers which are explained below. Past 20m depth perception becomes less sensitive it is difficult to distinguish so UI elements there are best avoided if possible. The sweet spot is between 2m and 10m directly in front of the user. This is the best location for primary interactive features. Applying neck movement vertical and horizontal the comfort zone is 77°. Our peripheral vision is the area where one can still see but not focus without moving the head so not suitable for content you want the user to focus directly on.

The user can also turn around so the area behind them is called the curiosity zone. This is where elements which will be out of their view unless they specifically turn to see them are. This is not a place to put elements which you need them to view directly.

Mike Alger, 2015

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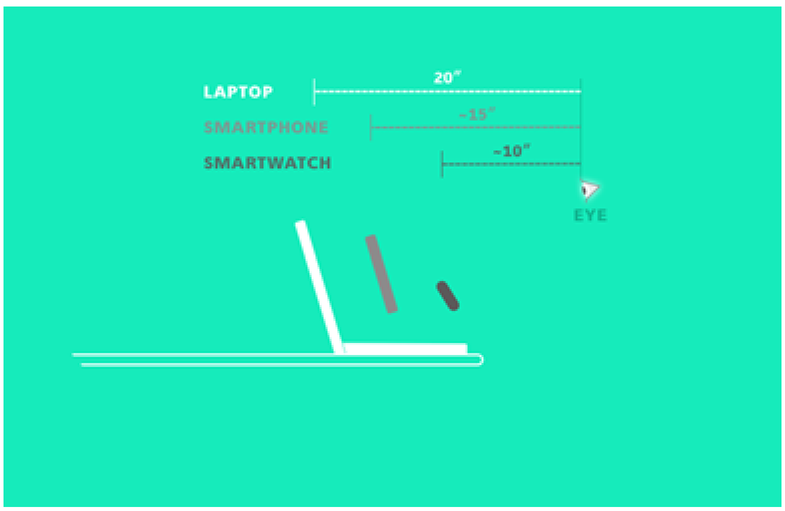
Scale and size

After deciding where to position UI elements one must decide on the size and scale of them. Since VR increases the possible workspace dramatically this provides challenges to designers used to working on a 2D screen. Using smartphones, tablets, monitors and laptops we know the screen dimensions and angle the viewer is looking at. The size and shape of menu options can be designed for the device. In VR these can change according to the position the user is in plus there is the added dimension of depth.



There have been several measurements suggested to calculate the size and scale of elements but the best and easiest to implement is Google's angular units. It is simple and easily understood. Angular units are used to set the size of text, buttons or any tools used for interaction. Too close and it can't be read or focused on too far away and it may be too small to read. Designers have been using angular units for designing text on smartphones and billboards.

How close or far away we are from an element determines how large text needs to be to make it readable, for example text on a phone can be small because we are close to it but a billboard needs very large text due to being far away.

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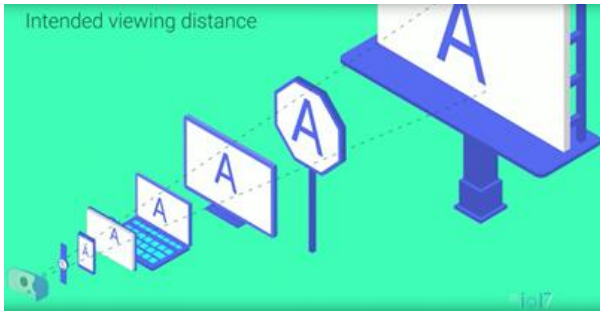
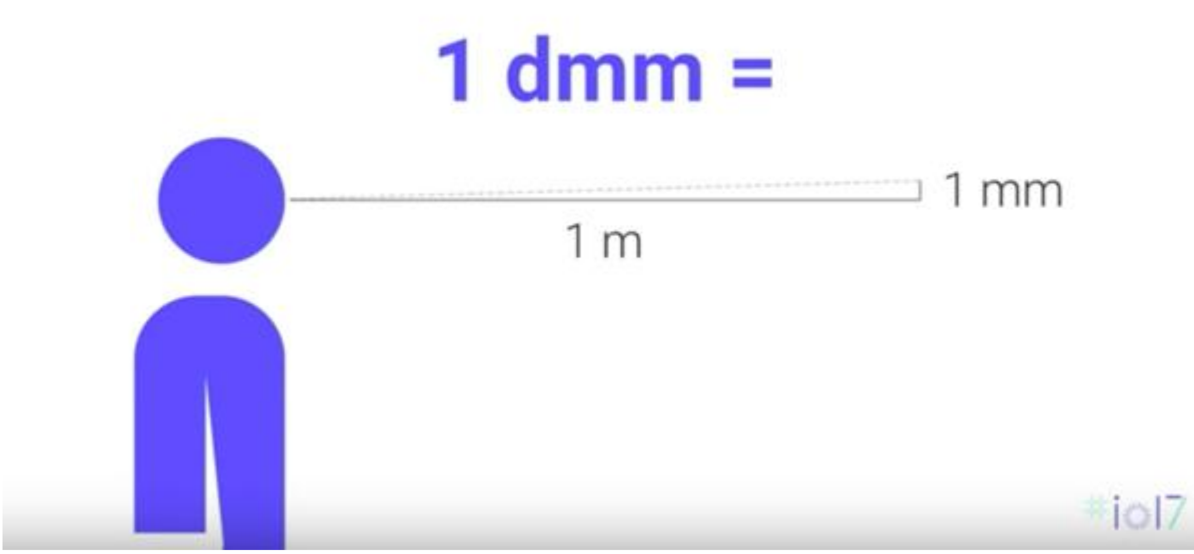


Google design lab

Google design lab uses the measurement distance-independent millimetre (DMM) pronounced DIMM. 1mm at a meter away. So 1 metre away should be at least 1mm in size. 2mm for text 2 meters away and so on. (Chris McKenzie, 2017)



Source: Google I/O 2017

This allows one to calculate the size of the screen based on how far away it is. It should be just as readable if it is up close to the user or far away from them. This allows the designer to create a screen size which will be readable from whatever distance it is away. The

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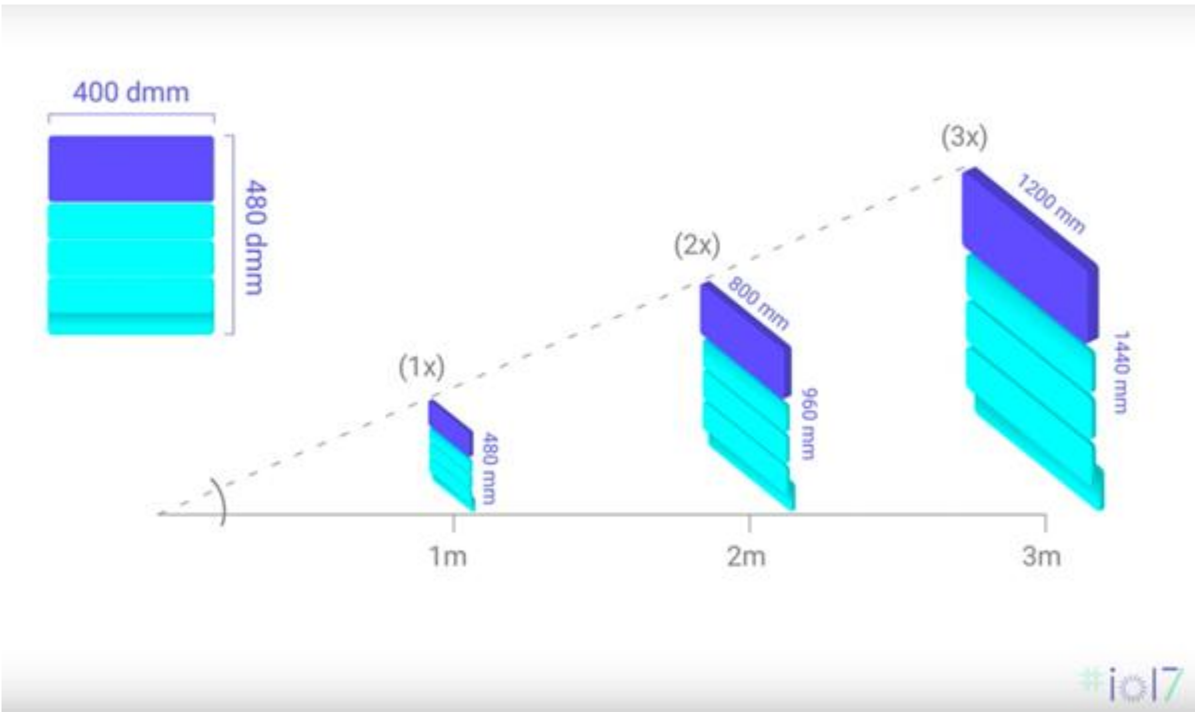
screen size doubles every meter allowing the designer to scale the screen according to its position.



2D screens are flat but in VR they can be any shape you want plus there can be screens all around the user if they want. Flat screens follow the Gutenburg diagram described above. Curved screens can be used to indicate the importance of different elements and give clues to the user where their focus should be.

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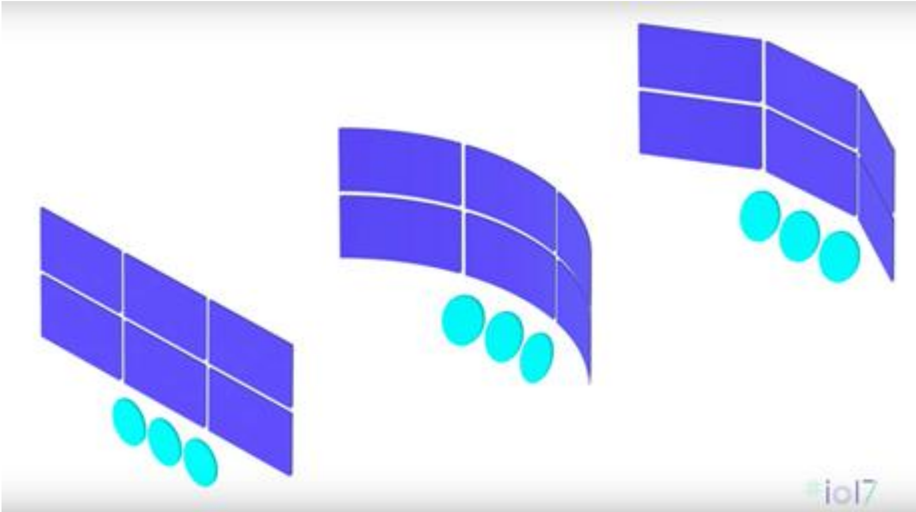

Source: Google I/O 2017

Interacting with UI Elements

VR devices come with different controllers and input methods. The most common methods are described below. Each has their own advantages and disadvantages so which to use depends on the context of use. In addition, mobile device controllers have three degrees of freedom, while the high end HMDs have six.

The controllers can be rendered within the virtual environment which means the user can see it with the headset on. In some instances, the controller can be replaced with animations such as hands particularly in gaming or as tools such as in Tilt Brush.

For the high end HMDs hand tracking is not precise enough yet for detailed or intricate tasks so the preferred method is using controllers such as wands. Typically, the controller is tracked in the space, a trigger, buttons, grip/squeeze and a touchpad. In addition, there can be gaze control and voice commands.

Interaction can be defined in two ways. There are interaction patterns which are high-level concepts that can be used consistently in an environment for actions such as pausing, saving, opening and closing. These tend to be completed using a menu and then

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interaction techniques which is a more specific one to complete a task such as drawing, picking up objects and locomotion. The most common interaction techniques are described below.

Hand-based Input

Using our hands is the most intuitive of the interaction techniques. It works by direct object-touching mimicking real-world interaction by reaching out to intersect with the virtual object and then selecting it by pulling the trigger or pushing a button. Using hands as input devices make this method the most intuitive and natural way of interaction. It gives freedom to the user to use different types of hand-based gestures for interaction with the virtual world. This method requires interactive objects to be within the hands' reach of the user in order to manipulate them. Picking up objects by placing the controller on them and pulling the trigger.

A visual cue such as a coloured outline works well to indicate it has been selected. The object can be dropped or even thrown away by releasing the trigger. Objects to be interacted in this way need to be within arm's length of the user.

A version of this which works very well and is mentioned above is the hand menu or watch check technique. One hand acts as the selection tool and the other provides the menu options. An example of this is using Tilt Brush. The dominant hand can act as the brush and for selecting options. The others contain the options which can be touched to select or a ray tracer will allow their selection. Tilt Brush uses an artist's palette as a metaphor.

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Tilt Brush, 2014

Other interactions we do in real life can be mimicked using this technique. Pulling levers, turning dials any interaction which fits with the desired applications.

Job Simulator, 2016

Ray-based Input

Pointing can be necessary when objects are outside of the users arm reach. Ray based input is used a lot in virtual reality as it is as intuitive as pointing with one’s finger. The user points at the object often with an indicator similar to a laser pointer. The point of the laser acts as the cursor does in 2D environments. The length of the laser beam indicates the depth and position of the element. This ray then allows them to make selections and combined with a trigger pull they can manipulate objects in the virtual environment. The size of the target should be big enough to allow for hand shaking as it is difficult to hold your hand out and still.

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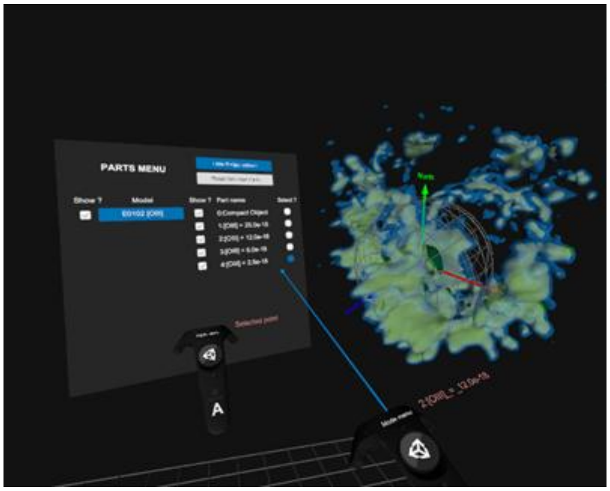
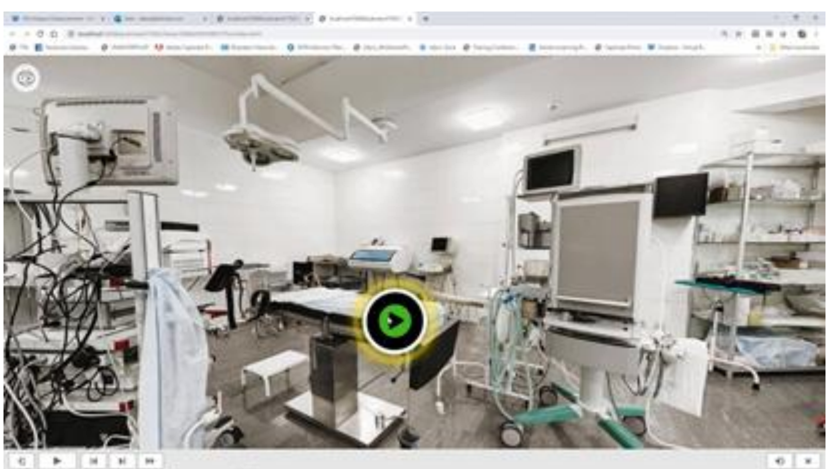


Gaze-based Input

Gaze-based input method assumes the constant gaze of the user on an object to be evidence of interest in that object. A dot in the user's eye line indicates to them where they are looking. By focusing for a predefined time on that area the user indicates they want to interact with it and an action can be triggered. This is often used in 360 degree tours, gazing at the arrow triggers a movement to the next image.



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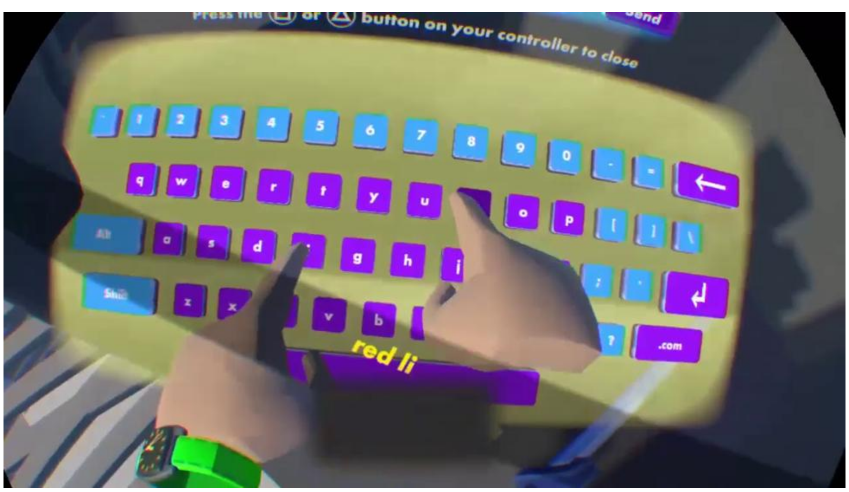
This method is good for devices that don't have controllers like smartphone based HMDs. It is not so common in the high end HMDs which have sophisticated controllers offering better interaction techniques like those above.

Text input

The above are the main input methods for interacting with objects by touching or selecting them. Another task one could need to complete in VR is inputting text. Since the user's vision is covered by the HMD there needs to be a virtual keyboard system to allow them to type. Typing large amounts of text is not desirable in VR as using the keyboard is a much more efficient way of doing it. Voice activated systems which will dictate from voice commands are still troublesome and not at the stage where they can replace a keyboard yet.

If the user needs to log in or send a text message while in VR there are some virtual keyboard techniques which can be used.

The most common virtual keyboard mimics a real life one. The users controllers turn into hands with the index fingers outstretched. They type using these virtual hands. As anyone who types with two fingers knows this can be laborious for large amounts of text but can be useful when there is a small bit of typing needed like entering a username. It is the most intuitive method but requires controllers.



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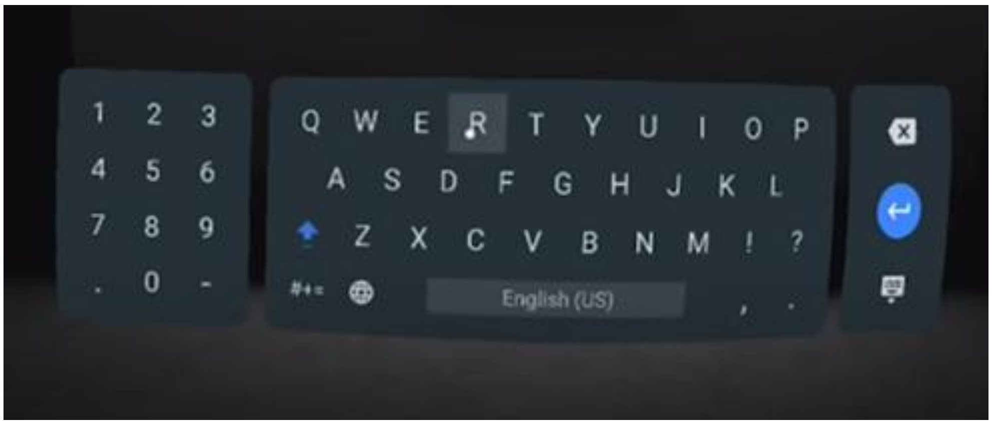
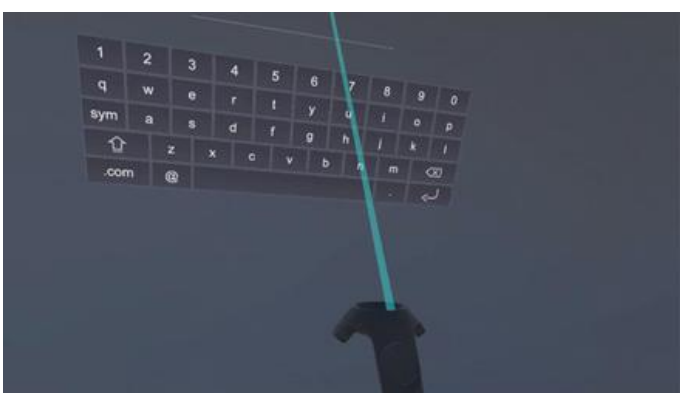
Gaze based keyboards use the gaze point as a cursor and allows keys to be selected by looking at the key they want to press. Holding the gaze selects it. This method works well for smartphone apps but there are better ways using the controllers for faster and more efficient typing.



Gaze based keyboard

Another method is to use ray casting style interaction, the user points the laser beam at the letter and presses a button to select it. With practice users report getting quite fast at typing using this method.



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A final and more fun method which can also be quite fast with practice is by having the keyboard within arm's reach of the user. They can type using projectiles from the controllers acting in a way similar to typing with drum sticks or playing a xylophone.

Locomotion

Moving within a virtual environment.

The user can move to a small degree within the playspace typically around 3.5 m x 3.5 m. To move outside that space a method of locomotion is required. Movement in VR is one of the main triggers for cyber sickness so it needs to be carefully considered. The user is moving in a virtual world but their physical body is not so this can cause a vestibulo-ocular mismatch similar to car or sea sickness. There is no one preferred method but the four most common are arm swinging, point-tugging, teleportation and trackpad. Each has their own advantages and disadvantages outlined below.

Arm swinging

Using this technique, the person in VR pulls the triggers on the controller and moves their arms in a walking motion without moving their feet. The faster they move their arms the faster they move in the environment. Direction is controlled by the orientation of the player so they are moving forwards, to change direction the user moves their body. The advantage is that this is a natural gesture and reduces disorientation. The speed is the typical human walking speed which is 1.4-3m/s but can be increased by swinging the arms more quickly. Allowing the user to control the speed means they feel more immersed and reduces the chances of motion sickness. A study by Coomer et al. testing different locomotion

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techniques found this one to be the preferred in that user group. A disadvantage is that the user can't do anything else while moving as their hands are occupied.

Point tugging

Similar to the arm swinging method, point tugging means the user will reach out and "grab" a space in front of them then drag themselves to that location holding down the trigger. It is best used in climbing style games where the user is reaching upwards and pulling themselves up. Another version of this is a grappling hook type locomotion where the player shoots the grapple and gets dragged to the position.

Teleport

The teleport technique requires the user to press down on the trackpad and point the handheld controller at the location they want to travel to. Upon releasing the trackpad, they are instantly transported to the desired location. This is done while preserving the eye height of the user in the y–direction. A visual cue such as a coloured arch is often used to help the user select the location.

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A variation of this technique involves a third person view where an avatar will move to the location. After releasing the trackpad, the person teleports to that position replacing the avatar. Teleportation is popular because it is less likely to induce motion sickness than other methods. Because movement is instant the view does not accelerate differently to their head position (CM Symposium, 2015).

The disadvantage is that even though it is very easy to do there can be a possible loss of immersion by doing an action one cannot repeat in life. Disorientation can also be an issue, an experiment by Evren Bozgeyikli (2016) compared two teleport techniques. One where the user could set their orientation before teleportation and another where the orientation mirrored their current position. The second technique scored better after testing.

Trackpad

Trackpad locomotion is performed on the controller's trackpad when the user moved their thumb on the pad they would move in that direction. The speed of movement resembles walking speed but by moving the thumb higher on the trackpad they can move more quickly. Similarly the Oculus knuckle controller has a small joystick controlled by the thumb which creates a similar effect.

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This method of locomotion causes the most disorientation; the user view is moving but their body is not. This can cause motion sickness particularly if moving quickly.

Which is the best depends on the context of use. They are all easy to implement, robust and require little instruction. Locomotion is a key decision when designing a VR experience which to use depends on the context and the target user group.

Most in control	Trackpad and point tugging
Most tiring	Arm swinging and point tugging
Most enjoyable	Arm Swinging and Trackpad
Most prone to motion sickness	Trackpad and point tugging

Small distances arm swinging and point tugging. For larger distances teleportation or trackpad.

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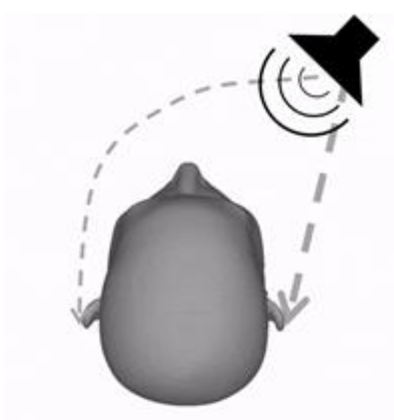
Sound

The more features of the real world a VE contains the more immersive it becomes so a VE should be a multi-sensory experience. Vision is the primary sense for a fully sighted person but sound comes a close second. The absence of sound can make a VE very unrealistic and break immersion. Good sound effects can greatly improve the quality of an experience. The user is isolated visually due to the HMD and aurally due to headphones. Nullifying outside sounds give the user a feeling of presence in the VE. It also provides a description of the space the user is in, it's size, and what is occurring around them.

Sound in the VE

In a 360-degree space our field of view can be changed by simply moving our heads and body, similarly sound can come from anywhere around us. This is called spatial sound, an enhanced immersive audio experience where sounds flow around you, including overhead. Sound can tell us what is happening outside of our field of view and the location it is happening in. Our hearing system allows us to locate where sounds are coming from, this is called localisation. This is done because of binaural cues, information about the level, timing and overall tone of the sound arriving at our left ear is compared to the sound arriving at our right ear. Differences between the sounds in each ear help us to work out where the sound is placed relative to our own position.



There are two categories of sound that can be used when designing a virtual experience. These are

1. Non-diegetic

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2. Interaction

Non-diegetic

These are sounds that have no obvious source in the visible world. Examples are narration or music. Narration can be an effective way for giving instructions while music can create the atmosphere. The mood of the experience could be fast and exciting or slow and relaxing. It is used in games to signal a coming event like when the music speeds up before an encounter with enemies.

Interaction

When driving a car, sound tells us how well the engine is running and alerts us if something is wrong. Replicating these audio features of the real world in a VE is a great way for making the experience more immersive and adding another layer to interactions.

Interaction sounds react to the user's actions and make the user's experience more pleasant. Unity3D and Unreal engine have features where sounds can be associated with objects and triggered when a defined action occurs. Throwing a bouncy ball can be set to make a bounce sound every time the ball hits an object which is solid like the floor. Because the sound is attached to the object it will lower as the ball bounces farther away from the player. This gives the sound depth and a feeling of being in a real space.

Interaction sounds can be useful to indicate if an interaction worked or not, a click when a button is pressed or some music when level is completed. Sounds can also be used to guide the user to where you want them to go, it is well established already in video games where the sound of footsteps for example is used to indicate an enemy is nearby.

Note: bad use of sound can be equally damaging though, remember repetitive music during video games which can become irritating. Sound needs to be used in a sparing way where it adds to the experience without becoming annoying or distracting.

Deciding how and when to include interaction sounds can be difficult and requires user testing to get the balance right. No one wants to be in an environment with a lot of distracting sounds. Only sounds that provide the user with information or enhance the experience should be used. Each of the sounds should provide some useful information indicating that the interaction was successful. The advice is to match sounds with the

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visuals, cartoon style sounds would work well in a children's game but not in a business application.

Manipulating objects

A VR experience often includes the ability to manipulate and interact with 3D objects, "manipulation" refers to any changes applied by/through the human hand. These can include : moving around or navigation, selection, rotation, translation, scaling, slicing and so on. Manipulating models have some attributes to consider when designing them: these are, how far away from the user is it can they reach it, the size/shape of it, the density (does weight play a role) and accuracy. Some parts of a VE may not be interacted with unless this is wanted, moving trees or walls for example. The goal in user interface design is to accurately and effortlessly translate a users intent into action. In VR, this is done by using gestures that feel intuitive and natural.

Manipulating objects in VR can be different on the different systems, factors to consider include degrees of movement, noise, latency and accuracy of the input hardware. Field-of-view, resolution, level of immersion and depth can also be factors. Research by Ferran 2013 notes that VR can be more physically taxing than other interfaces. The person is often standing and moving in a space. Fitts' law estimates the time required to perform an aimed movement considering only the physical properties underlying the acquisition task (the size of the target and the amplitude of the movement required to acquire it). Having objects that require manipulation close to the user is better than far away. Manipulating an object involves three steps: selection, movement, and rotation.

Selection

Selecting the object to be manipulated is the first step in the process. The most intuitive method is if the object is within reach of the user and they can reach out and touch it. People naturally reach out to touch objects in VR. The VR controller can either be digitally represented in the VE or as a hand. When moving close to the object a visual cue can alert the user that the object can be selected. Haptic feedback where the user feels a vibration can also be used to indicate that an object can be selected.

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If the object is outside of reach then a raycast can be used to indicate the object can be selected. In the case where there are no controllers for example when using a smartphone simply looking at the object for a few seconds can be used as a selection method.

Movement

Once the object is selected it can be moved. A gesture such as squeezing the controller or pulling the trigger allows it to be moved to the desired location. If it is within reach the user can simply let go of the trigger to indicate dropping it. If it is outside of reach a raycast can allow the user to move the object to the desired location and it can be released in the same way. This method can be used to pick up an object or even throw it. Objects can have physical properties including weight, the heavier the object the shorter the throw,

Rotation/Scale

In addition to moving the application may require rotation or resizing of the object. Once selected rotation can be easily applied by the user rotating their hand to the position

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desired. The scale of the object can also be manipulated to make it bigger or smaller. Once selected squeezing both controllers the user can move their hands closer or further apart, the object resizes in front of them. Once the desired size is found they let go. Best practice is to mimic real life as much as possible. Reaching out and grabbing objects is the most natural and intuitive.

Real objects in VR

Another exciting application is to attach a sensor to a real world object and render it as a digital model in a VE. These sensors can be attached to objects and tracked in the 3d space. The most common application is to have a model gun with the tracker attached. The trackers can be attached to any object though so if rendered in VR with the same size and shape it could be handled physically as well.

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Augmented Reality

Augmented reality (AR) also brings a lot of challenges and opportunities for designers in a similar way VR does. The templates and interaction types used on smartphones aren't always applicable for AR experiences. Both Android and iOS devices can drop virtual objects alongside real ones through the phone's camera. This makes augmented reality a more feasible option for developers.

An augmented environment combines a real-world image captured from a device's camera with virtual content, such as digital objects or information. The devices are either smartphones or headsets/glasses. The app builds an understanding of the environment as it tracks the position of the screen (smartphone or headset). As the user moves the camera around the space AR will recognise new features such as horizontal or angled surfaces which can act as planes for the virtual content. This process is called concurrent odometry and mapping, or COM.

Features which make virtual objects more realistic include.

- Ambient occlusion: Shadows on objects increasing detail and realism.
- Shadow planes: Shadows cast by the object onto the surface beneath them.
- Lighting: For objects to blend into the real world the lighting on objects is estimated by the app and adjusted to match the real lighting. It can change dynamically to adjust to surroundings.

These features also help create depth giving flat virtual objects the feeling of being solid and real.

Context

Since phones and headsets are mobile, the design of the app needs to work in many different spaces. It could require a small table or be used outside only for example. Consider the objects that may be in the space as well furniture or even traffic. Similar to

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VR we need to define the “playspace”. It can be a table top, a room or as big as the world in the case of Pokémon Go. A board game will require a table top but the size of the table cannot be assumed. Because of this AR design needs to be responsive and resize according to the space available.

Explain what the ideal space is before they download it or in the instruction. Also consider how the user is situated, sitting, standing or moving.

Note: Safety is important so if the user is looking at their phone or a screen while moving it will be easy for them to bump into objects in the real world and feel real world pain. Apps should have built in reminders to warn users to be aware of the environment around them and also don’t require them to walk backwards.

Duration

AR experiences won’t be as long as using a 2D screen so design them to have points where the user can save their progress and return to the state they were in. AR systems include haptic feedback the phone or headset can vibrate. Google do not recommend haptic feedback for AR experiences because as well as using it for the AR app the phone will also be sending notifications

AR Interaction

AR experiences start with the user moving their device in the environment they are in. The app finds planes like walls, floor and tables by finding surfaces that are part of the same flat surface. A visual representation of this works well indicating which direction to move and when a surface has been successfully detected. When a user successfully finds a surface, indicate this to them with a visual cue or animation then tell them what to do next. For example, place an object on the surface. Unlike VR the view is AR is limited by the screen size of the device being used. It generally does not take up all of the field of view. This view needs to perceive depth, scale, and distance. Minimum and maximum distances help place objects in the display in positions they are comfortably viewed.

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Selecting

The user will need to select an object in order to identify, manipulate, and interact with it. Interacting should be intuitive so colour, glowing outlines, or other visual highlights to let users know they can interact with it.

Moving the object can be done either by adding indicators such as arrows which the user drags the object or by pinning it to the centre of the view, moving the phone to place it and a tap to release it in place. As mentioned above boundaries limiting the playspace can prevent the user moving an object too far away or too close to the screen.

Objects can be placed in three ways:

- Automatically: Once a suitable surface it identifies objects are placed on them automatically requiring no user input.
- Manual: The user drags the object across the screen with their finger and releases in order to place it in the desired position.
- Tap: The user taps on a position to place virtual objects.

Once an object is placed it can be anchored, this is setting its position so if the user moves away and comes back it is still there. This is useful for pinning an object to a location.

Rotation and Scale

Similarly rotation and scale can be applied to the object. Once anchored it can be rotated by dragging in the desired direction. The pinch gesture first used on the iphone for zooming into photos is well established as a method of scaling. Two fingers moving further apart or closer together can make the object bigger or smaller.

Maximum and minimum scales are recommended to control the composition of the screen. The scale of objects depends on the desired effect, a small mouse could be amusing and cute while a seven foot tall one would be scary. Consider the size, proximity of objects to each other in order to make the selectable.

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Screen orientation

If the device being used is a smartphone the screen can be landscape or portrait depending on how the user is holding the phone. AR apps can be designed for both orientations so both should be considered by the designer. This increases immersiveness and comfort.

Interfaces

Moving , scaling, rotating virtual objects are just part of AR interaction; there also needs to be interfaces which lends itself seamlessly to the immersive experience. The advice from Google labs is to make the interface in a way that doesn't break immersion, this means as little interruption as possible. Menus that pop up, buttons and alerts can be distracting and break the feeling of presence. Less is more and a minimalist design works best. Make the controls as simple as possible which the user can trigger without having to think about it. Use visual cues, motion, and animation rather than text instructions which can take users out of the experience. Consider having an onboarding tutorial at the start of the experience. AR is not very common so some simple tasks at the start in the form of a tutorial can highlight the main interaction types quickly reducing the chances of the user getting frustrated.

UI patterns

Even a first time user or AR will come with previous knowledge of some familiar interactions such as tapping, dragging and pinch to zoom. Take advantage of this so they do not need to learn new methods. They can then get interacting without breaking the immersion of the experience.

Errors

There are some common and known issues with AR apps which will require notification to the user. These are a blocked camera, if the camera is blocked by an object like a finger when holding the phone it will not work. Dark environments where the camera cannot identify the objects in the room and moving too quickly indicate to the user to slow down their movement.

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VR and Eye Tracking

Eye tracker technology measures the point of gaze (where one is looking) and the motion of the eye relative to the head. Measuring eye movement has been used in the past for psychological studies, marketing and product design. Tracking a person's eyes when they are looking at a webpage for example can give insight into design choices. Tiny cameras in the headset pointing at the eyes can monitor the gaze. As well as movement though they can also measure eye opening/closing/blinking, eye status (watery or red), pupil size, eye colour and even wrinkles on the face.

Our eyes are the windows to the soul so the saying goes so what else can be extrapolated from eye tracking. Kroger et all 2020 analysed the literature and found that eye tracking data may implicitly contain information about a user's biometric identity, gender, age, ethnicity, body weight, personality traits, drug consumption habits, emotional state, skills and abilities, fears,

interests, and sexual preferences.

Implications for VR products,

A HMD with eye tracking has many advantages. The computing power required to render the VE will be greatly reduced if only where the user is looking requires high resolution, non tethered headsets could have very high resolution content without the need for high end graphics cards. People's eyes are unique so this could be used for verifying who the user is no more logging in as they can be identified instantly.

The privacy and data mining implications though are enormous. Oculus have recently required users to have a facebook account to use their HMD. In a business setting such a setup would mean it would be possible to track if participants were interested, excited, embarrassed, or bored during a meeting. Though eye tracking would make the processing issue any products that use this technology will need strict privacy policies. Avi Bar-Zeev makes some recommendations for such policies.

- Eye-tracking data and derived metadata is considered both health and biometric data and must be protected as such.

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- Raw eye data and related camera image streams should neither be stored nor transmitted.
- Derivatives of biometric data, if retained, must be encrypted on-device and never transmitted without informed consent.
- Apps may only receive eye-gaze data, if at all, when a user is looking directly at the app, and must verifiably follow these same rules.
- Behavioral models exist solely for the benefit of the users they represent.
- Companies must ensure that their users/customers are clearly aware of when, why and how their personal data is being used; that each user individually agrees, after a full understanding; and that the users can truly delete data and revoke permissions, in full, whenever they wish.
- Don’t promise anonymity in place of real security, especially if anonymity can later be reversed.
- Users must be given an easy way to trace “why” any content was shown to them, which would expose to sunlight any such targeting and manipulation.

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VR/AR Resources

For Developers

Unity Engine

Unity is a multi-platform development tool used to develop video games for PC, consoles, mobile devices, and websites. Unity 5.1 onwards contains built-in support for certain VR devices.

Unity3d Website: https://unity.com/

VR Developer Manual: https://docs.unity3d.com/Manual/VROverview.html

Asset Store: https://assetstore.unity.com/

Unreal Engine

Unreal Engine is also a gaming engine with VR integrations, an asset store, and great documentation.

https://www.unrealengine.com/en-US/

Asset Store: https://www.unrealengine.com/marketplace/en-US/store

Developer Documentation: https://docs.unrealengine.com/en-US/index.html

HTC Vive Developer

The Vive Developer portal includes tools and resources for developing immersive virtual reality experiences for the HTC Vive.

Developer Site: https://developer.vive.com/us/

Oculus Developer Center

The Oculus Developer Center provides access to the Oculus SDK, documentation, game engine integrations, and demos.

https://developer.oculus.com/

OSVR

OSVR is an open-source software platform for virtual and augmented reality. It allows discovery, configuration, and operation of hundreds of VR/AR devices and peripherals.

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OSVR supports multiple game engines and operating systems, and provides services such as asynchronous time warp and direct mode in support of low-latency rendering. OSVR software is provided free under Apache 2.0 license.

https://osvr.github.io/

Open VR

OpenVR is a software development kit (SDK) and application programming interface developed by Valve for supporting the SteamVR (HTC Vive) and other virtual reality headset (VR) devices. The SteamVR platform uses it as the default application programming interface (API) and runtime.[5] It serves as the interface between the VR hardware and software and is implemented by SteamVR.

Although OpenVR is the default SDK for HTC Vive, it was developed to have multiple vendor support. For instance, a developer can design OpenVR-based trigger button functions for controllers of Oculus Rift or Windows MR because these systems are both supported by the SDK.

https://github.com/ValveSoftware/openvr

AltspaceVR

The AltspaceVR Developer Portal provides resources for the AltspaceVR SDK, which enables the construction of holographic, multi-user web apps and experiences for virtual reality. The AltspaceVR SDK can be used together with three.js and other javascript libraries to create a variety of content that can be experienced with consumer VR hardware like the Oculus Rift or HTC Vive.

https://developer.altvr.com/

Amazon Lumberyard

Amazon Lumberyard is a free, cross-platform 3D game engine for developers to use to create high-quality games, connect games to the AWS Cloud, and engage fans on Twitch. Lumberyard Beta 1.3 introduces VR and HDR support.

https://aws.amazon.com/lumberyard/

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Cardboard VR

Google provides developers with two virtual reality (VR) platforms: Cardboard, the world's most popular and accessible mobile VR platform, and Daydream, a new platform for low-latency, immersive, and interactive mobile VR. The Google VR SDKs include everything you need to develop for these platforms, including libraries, API documentation, developer samples, and design guidelines.

https://developers.google.com/vr/

EasyAR

EasyAR is a free, open-source augmented reality engine. No watermark, and no limitation of recognition times.

https://easyar.com/

NVIDIA VRWorks

VRWorks™ is a comprehensive suite of APIs, libraries, and engines that enable application and headset developers to create amazing virtual reality experiences. VRWorks enables a new level of presence by bringing physically realistic visuals, sound, touch interactions, and simulated environments to virtual reality.

https://developer.nvidia.com/vrworks

Wikitude

Wikitude's augmented reality SDK is a library for location-based AR, image recognition and tracking for Android and iOS.

https://www.wikitude.com/

Vuforia

The Vuforia Studio Enterprise is a new tool for authoring and publishing augmented reality experiences for the enterprise. Vuforia Studio Enterprise is seamlessly integrated with PTC's Creo CAD visualization and illustration software and THingWorx Internet of Things platform to quickly and easily add an augmented reality component to connected things

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such as manufacturing and factory equipment to solar panels and medical devices. PTC completed the acquisition of the Vuforia business from Qualcomm in November of 2015.

https://developer.vuforia.com/

Model Making

3DS Max & Maya

These are Autodesk products for modelling, animation, lighting, and VFX. They don't have VR support by default but through pricey plugins instead. AutoCAD and 3DS Max are long-time standards in the architectural design industry and have some of the most precise tools in their UI. Like almost all GUI's for building 3D environments and drawings, these tend to be quite massive UI's with a lot of tools hidden behind menus, sub-menus, and toolbars.

https://www.autodesk.eu/

Blender

Free and open source software written in Python and is available for Windows, Mac, and Linux. There's a huge community of people devoted to this software and its use. Many websites provide tutorial videos, forums, and documentation.

Website: https://www.blender.org/

Documentation and tutorials: https://www.blender.org/support/

SketchUp

Google's SketchUp is a basic modelling application with a very low learning curve that can get anyone up and running in a short amount of time. The tutorials on the website are excellent, not only teaching the basics of the software but also as introductory lessons to basic 3D modelling concepts. You can quickly learn the basics of modelling with SketchUp and then move onto more advanced tools like Blender if you desire. It's really great for modelling, quickly learning the lingo, and then moving onto bigger and better things. There's a free trial version of this software.

https://www.sketchup.com/

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Podcasts:

Voices of VR Podcast

Portland, OR, Kent Bye interviews artists, storytellers and technologists driving the resurgence of virtual & augmented reality.

http://voicesofvr.com/

Research VR Podcast | The Science & Design of Virtual Reality

Research VR Podcast covers all things science and VR, diving deep into the cognitive science behind the new immersive technology industry.

https://researchvr.podigee.io/

Discover Virtual Reality Design Podcast

Immersive design, especially virtual reality.

https://discovr.design/podcast

Full Dive Gaming: a Virtual Reality Podcast

Gaming podcast

Full Dive Gaming: a Virtual Reality Podcast in VR

The Virtual Reality Podcast

All things immersion tech in education and business

https://anchor.fm/the-virtual-reality-podcast

VR Roundtable

UK / US: Virtual Reality news and discussion podcast

http://vrroundtable.blogspot.com/

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Journals

Virtual Reality

The journal, established in 1995, publishes original research in Virtual Reality, Augmented and Mixed Reality that shapes and informs the community.

https://www.springer.com/journal/10055

International Journal of Virtual and Augmented Reality (IJVAR)

The International Journal of Virtual and Augmented Reality (IJVAR) presents interdisciplinary research on the technological, social, legal, and policy implications of virtual and mixed reality integration and how the division between real and virtual worlds is becoming less distinct. Fostering interdisciplinary applied research and a unique forum for novel solutions for virtual immersion and mixed reality, the articles found within IJVAR are essential to the research needs of graduate-level students, researchers, and professionals interested in topics relevant to the digitization of everyday life.

https://publons.com/journal/74419/international-journal-of-virtual-and-augmented-rea/

PRESENCE: Virtual and Augmented Reality

The longest-established academic journal that is devoted to research into teleoperation and virtual environments (3D virtual reality worlds), PRESENCE: Virtual and Augmented Reality is filled with stimulating material about fundamental research into topics such as presence, augmented reality, haptics, user interfaces, and virtual humans, and applications that range from heritage and education to training simulators, healthcare, and entertainment.

Presence appeals to a wide audience that includes computer scientists, high-tech artists and media professionals, psychologists involved in the study of human-machine interfaces and sensorimotor/cognitive behavior, and mechanical and electrical engineers.

https://www.mitpressjournals.org/pvar?mobileUi=0&

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Cyberpsychology, Behavior, and Social Networking

The premier peer-reviewed journal for authoritative research on understanding the social, behavioral, and psychological impact of today's social networking practices, including Twitter, Facebook, and internet gaming and commerce.

https://home.liebertpub.com/publications/cyberpsychology-behavior-and-social-networking/10/overview

Thought leaders on Twitter:

Cathy Hackl (@CathyHackl)Magic Leap's enterprise team.

Clay Bavor (@claybavor) Vice President of Virtual and Augmented Reality for Google.

Tom Emrich (@tomemrich) Latest AR innovations daily, as well as videos showing off new technologies.

Paul Miller (@PaulMiller) Senior Analyst at Forrester covering AR

Ben Wood (@benwood) Analyst for CCS Insight covering smartphones, wearables, VR, and AR

Dr. Helen Papagiannis (@ARstories) AR/VR consultant

Charlie Fink (@CharlieFink) New innovations, and cool images created with AR.

Graham Roberts (@Grahaphics) Director of Immersive Platforms Stoytelling at the New York Times.

Lubomira Rochet (@ljubomira) Chief Digital Officer for L'Oréal.

Michael Ludden (@Michael_Ludden) Principal Augmented Reality Product Advocate for the Bose Corporation.

Steve Dann (@VR2AR) Chairman of Medical Realities.

Bryan Ma (@bryanbma) technology industry analyst for IDC covering mobility, AR, and VR.

Julie Young (@juliey4) CEO of SH//FT, an organization that promotes diverse voices in the VR/AR industry.

Galit Ariel (@galitariel) founder of WondARLands, a consultancy firm

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Palmer Luckey (@PalmerLuckey) Founder of Oculus VR

John Carmack (@ID_AA_Carmack) CTO at Oculus VR

Chris Milk (@milk) Filmmaker and founder of Vrse.inc

Jens Christensen (@jensbch) Founder and CEO of Jaunt

Alex Kipman (@akipman) Microsoft HoloLens

Kent Bye (@kentbye) Host of Voices of VR podcast

Alex Schwartz (@gtjuggler) Owlchemy Labs

Websites/Blogs

MikeAlger

http://mikealger.com/

Multidisciplinary designer with expertise in immersive computing.

VRScout

VR News Stories and Top Virtual Reality (VR) Content

https://vrscout.com/news/

Road to VR

Independent news publication dedicated to the consumer virtual reality industry.

https://www.roadtovr.com/

Upload VR

UploadVR is dedicated to bringing virtual reality technology to the consumer masses.

https://uploadvr.com/

VR Focus

VRFocus is a virtual reality specialist website covering all aspects of the technology

https://www.vrfocus.com/

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Reddit - Virtual Reality

A common ground for discussion relating to Virtual Reality and Virtual Worlds.

https://www.reddit.com/r/virtualreality/

Financial Cost

Financial cost for developers and buyers of VR systems

https://thinkmobiles.com/blog/how-much-vr-application-development-cost/

https://www.pwc.co.uk/intelligent-digital/vr/growing-vr-ar-companies-in-the-uk.

Pdf

https://games.jmir.org/2018/4/e10839/#ref18

Ethics

https://www.frontiersin.org/articles/10.3389/frvir.2020.00001/full

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