

Learning everything there is to know about immersive learning

to renew the pleasure of learning and
transmitting



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Executive summary	8	Chapter 7 – 7 challenges for 2030	200
Editorial	10	7.1 – Challenge no. 1: Creating shared resources and tools	203
Foreword	14	7.2 – Challenge no. 2 : Improving accessibility and inclusion	207
Chapter 1 – Introduction	18	7.3 – Challenge no. 3: Limiting physiological and psychological	211
1.1 – Why this book?	21	7.4 – Challenge no. 4: Defining a framework of trust and	
1.2 – Who is it for?	24	developing the logic of sovereignty	213
1.3 – What will I find in this book?	25	7.5 – Challenge no. 5: Environmental impact	216
1.4 – Technology evolves, transmission remains	26	7.6 – Challenge no. 6: Generative AI	220
Chapter 2 – Immersive Learning: a new teaching method	28	7.7 – Challenge no. 7: A French industry of excellence	223
2.1 – Our definition	32	Chapter 8 – Experts' corner (annexes)	226
2.2 – The benefits	33	8.1 – A brief history of immersive technology	228
2.3 – The levers	44	8.2 – Equipment	232
2.4 – Towards an immersive pedagogy?	48	8.3 – Software	242
2.5 – Equipment, software & adjustments	56	Chapter 9 – And now?	244
2.6 – A space for future possibilities	67	Acknowledgements	247
Chapter 3 – How immersive technologies work	68	Annotations	248
3.1 – The three types of reality	71		
3.2 – Interaction	74		
3.3 – The sense of presence and the three illusions	76		
3.4 – Environments	83		
3.5 – Degrees of freedom	84		
3.6 – The avatar	86		
3.7 – The Proteus effect	87		
3.8 – Multisensory integration	88		
Chapter 4 – 8 misconceptions about immersive learning	98		
4.1 – Misconception no. 1 – Immersive learning will replace instructors and teachers	101		
4.2 – Misconception no. 2 – Immersive technologies make people ill	104		
4.3 – Misconception no. 3 – Immersive technologies lack maturity	106		
4.4 – Misconception no. 4 – Immersive technologies are too expensive	110		
4.5 – Misconception no. 5 – Immersive technologies are reserved for young people and gamers	114		
4.6 – Misconception no. 6 – Immersive technologies are isolating	116		
4.7 – Misconception no. 7 – Immersive learning is reserved for certain topics	118		
4.8 – Misconception no. 8 – You need a headset, not everyone has the equipment	120		
Chapter 5 – Overview of uses and feedback	122		
5.1 – Introduction: a picture is worth a thousand words	124		
5.2 – A few cases under the microscope	126		
5.3 – Stakeholder testimonials	144		
Chapter 6 – Four steps to a successful Immersive Learning project	174		
6.1 – Step 1: Adaptation, documentation and training	177		
6.2 – Step 2: Setting the framework for your project	184		
6.3 – Step 3: Launching and managing the project	192		
6.4 – Step 4: Continuous improvement	198		

Table of contents

Education and vocational training have undeniably benefited from the contribution of digital technology for many years now, as evidenced by the increasing number of educational projects incorporating digital technology and the thriving EdTech ecosystem. More recently, a new category of tools and methods based on immersive technologies (augmented reality, virtual reality and mixed reality) have been deployed, including in education under the name immersive learning.

Many institutions including vocational training centres, universities, schools and companies have already adopted this new way of teaching, particularly in France. And yet, until now, there was no reference document that described, decoded and put this industry into perspective. This is the whole idea behind this book produced by France Immersive Learning, the first immersive learning association in France, which has been working for over 5 years on developing this ecosystem.

On the strength of many years of work and expertise, bolstered by a qualitative survey involving almost 200 institutions (universities, companies, schools, start-up companies), France Immersive Learning wrote this reference book for organisations and individuals who are interested in or work in the transmission of skills and knowledge. This book shares the fundamental principles, provides keys to decoding and understanding the concept, and highlights what already exists, while looking ahead to the challenges of 2030.

Throughout its chapters, this book outlines first the "immersive" methods applied to education, its principles and associated benefits, particularly in terms of information retention, quality of the simulations and learner safety.

Based on the feedback gathered within the framework of the survey, this book presents several use cases and testimonials of immersive teaching methods used in institutions as diverse as the University of Lyon to teach biology and geology, the BCPE to train their employees, the National Agency for Adult Vocational Training (AFPA) to train people in industrial and social service jobs, or even the CESI Engineering School to teach soft skills such as public speaking. This book also tackles the various misconceptions about the immersive technologies used for educational purposes, in order to unravel certain preconceived notions while highlighting the limitations and constraints related to these usages. The cost of these technologies, the role of the instructor, the impact on the learner - these are just some of the questions this book addresses in the context of technological development.

France Immersive Learning also wished to give a pragmatic dimension to this work, which includes a chapter dedicated to recommendations when embarking on a specific project and to allow teachers, educators and instructors to experiment with immersive methods in their educational projects.

Finally, this book provides an overview of the major issues and challenges that the immersive learning industry will face in the coming years, in terms of creating shared resources and interoperability, developing a programme of excellence, accessibility and inclusion, and creating a framework of trust.

So, the name of the game: popularise while remaining precise about the concepts covered and promote a reasonable and reasoned use of immersive technologies in order to make the most of what they can offer.

This work was carried out and published independently by France Immersive Learning, thanks to an unconditional donation from Meta.

Note: This book has been adapted after a French original publication released in 2023. We are aware a lot of French cultural biases (the concept of "error" among others), references and examples might not be relevant for international readers. We apologize for it. We hope we soon have the possibility of rewriting and updating this book, as well as integrating a wider range of companies, references, experts, user experiences, education examples...

Ethics: Some of the companies which are named in this book are active members of France Immersive Learning association but many others are not. They nonetheless all provide free information or resources for the topic.



The origin of the project

Portrait by Nicolas Dupain, The visionary man.

Nicolas has devoted most of his career to teaching via digital technology. He started as a school teacher, then moved to be an Academic instructor, then became a French Ministry of Education collaborator. He swapped from blackboards and overhead projectors to video projectors, from the first computer rooms connected to Internet, from the introduction of office suites (StarOffice, then Open and Microsoft Office), teachers' blogs, and was part of the battle of open source software and alternative operating systems to Windows and MacOS. He got from presential classes to e-learning and has always helped out his colleagues with the discovery and the use of technology.

The biggest shock he even encountered was his first immersive reality experience in one of the biggest European CAVE, a space that was 10 meters wide, 3 meters deep and high, where one could walk in virtual environment to scale !

He realized that with this technology you could move from a static, cerebral, 2D learning media situation to an active, emotionally involving, 3D environment ready for all kind of learning situations and experiences, with no limit of time nor space.

One could take a class to visit a pyramid in real scale, or the moon ! Technicians could fix a nuclear system with no risk, apprentices could test and try as many times as possible how to paint, to use any chemicals products or equipment which otherwise would be costly, dangerous, inaccessible.

" Letting go the 2D system (using stone or wax tablets, paper pages or screens) had considerable impact since the 3D actually meets the way our brain actually work. We have to learn to think and create learning situations in a multidirectional environment. What a challenge !"

Nicolas then felt the urge of creating a network that would provide a reference tool, including a usage observatory and a resource center, for those wishing to harness the remarkable power of these technologies in order to renew the pleasure of learning and teaching.

In early December 2018, after having spent a year meeting with hundreds of stakeholders in immersive learning (start-up companies, key accounts, public stakeholders), the French Immersive Learning Association (FIL) was created thanks to six French visionary organizations : the CNAM- represented by Thierry Koscielniak, former Deputy Chief Digital Officer Office - the Paris-East Créteil University (UPEC), Natixis, Orange, Défi métiers and the Fund for the Professional Inclusion of Disabled People (AGEFIPH).

In March 2023, Louis Rosenberg, distinguished pioneer of immersive technologies stated: "We have finally reached the point where low-cost VR and MR experiences can be so realistic and interactive that students can develop knowledge, skills and intuition that quickly become second nature. This is the future of education, and it's coming soon."

Today FIL is also co-founder of XR4Europe and the French National XR Council. It counts a couple of hundreds of members : companies, training centers, education organization, institutions all willing to acquire knowledge, share their experience and develop XR and AI use.

Nicolas' latest missions have been as a digital project and strategy consultant.



Editorial

Portrait by Thierry Koscielniak, President of France Immersive Learning

Thierry Koscielniak is significantly contributing to the field of immersive learning, notably as Executive Advisor on digital strategy and educational innovation at ENSAM in Paris, France, and as former Chief Digital Officer at Le Cnam in Paris. His work involves active research and implementation of extended reality (XR) for enhancing teaching and learning experiences. He promotes the concept of an academic Metaverse, termed “la Métaversité,” aiming to provide an open-source virtual world to teach and learn. His dedication to immersive learning extends beyond Higher Education. With Nicolas Dupain and other stakeholders, he founded France Immersive Learning professional network, highlighting his

commitment to fostering a national community around immersive learning technologies.

He is an expert member of the European Digital Education Hub and contributes to its Immersive Learning Squad. He is also involved with organizations such as the European association EUNIS, where he leads to a Special Interest Group on emerging technologies (XR and AI). He is also a member of the XR Community Group of the American association EDUCAUSE and takes part in its presentations at conferences, forums and meetings.

Thierry obtained his PhD in Computational Chemistry and Molecular Modelling at Sorbonne University in Paris.

France Immersive Learning international strategy:

France Immersive Learning has an international role to play in making proposals on specific subjects or areas in the field of digital education security.

For example:

- + Development of Best Practice Guidelines for XR in Education:
- + Ethical Use of AI and Data Analytics in XR
- + Training for Educators on XR Safety and Security:
- + Standards for Safe XR Content
- + Secure Development Practices for Educational XR Applications
- + Creation of a Secure XR Content Repository
- + Research on Psychological Impacts of XR Learning

France Immersive Learning will also contribute to the establishment of XR standards to label or certify Immersive Learning projects.

As a member of the XR4Europe federation, France Immersive Learning positions itself within the virtual worlds strategy to accelerate support for Europe’s virtual worlds ecosystem.

France Immersive Learning is a member of the Conseil National de la XR (CNXR), a federation of associations and groups representing all French players in XR technologies. The CNXR is also a vehicle for promoting a strategy towards the European Commission and the rest of the world.

Thierry Koscielniak



Daniel D Bryant Co-founder of Educators in VR
Director of Collaborative Realities

Over the past five years, I have had the immense privilege of immersing myself in the world of immersive learning thanks to virtual reality. It began with the founding of Educators in VR and the organisation of the largest international summit on education, which was an entirely virtual event. A little later, I had the honour of directing the Virtual World Society, founded by Tom Furness, one of the pioneers of VR. And nowadays, as part of my work with Collaborative Realities, I continue to be deeply involved in this transformative industry.

During these past five years that have been affected by COVID, I have had the pleasure of welcoming people from all levels of the industry, from CEOs to front-line teachers, and from every continent. I have collaborated with creators, students, instructors, pioneers and new users. I have been part of a global community of thousands of teachers who came together in virtual worlds to explore and collaborate on what learning, teaching and training in virtual reality really means. Nicolas Dupain is one of the remarkable people I met at the beginning of this

Foreword

exploration. As European colleagues in the world of education, we quickly bonded and embarked on several cooperative projects. Nicolas' energy and vision to enable French schools, universities, learners and teachers to become leaders in immersive learning is truly inspiring. The donation Meta made to fund this invaluable book, which contributes to the development of the global immersive learning community, is an acknowledgment of our collective efforts. It is a great honour and pleasure to write this foreword and share a few thoughts and encouragements for the journey that awaits you.

After spending hundreds of hours attending virtual workshops, conferences, courses and meetings, it seems obvious to me that immersive learning isn't just here to stay, but that it is also capable of bringing about a paradigm shift in education and skills development. Furthermore, immersive learning offers a learning method that is fundamentally more natural and more intuitive than anything I have come across in my forty years working in education. While books and screens remain essential learning tools, we are by nature spatial

beings, designed to understand our world in three dimensions and to live and learn in our environment, in our space. This space, whether real or virtual, adds context to the learning process, gives power to the learners, improves the understanding of abstract concepts and activates our brains and minds in a more direct and integrated way. This is immersive learning's promise, and we have a great adventure ahead of us to make it a reality.

As we embark on this adventure together in our classrooms or training rooms, let's take a moment to explore the origins of this technology and the pioneers who brought us to this point. Not many people know that the foundations of modern VR were laid down in the 1960s. We are building on the work of these visionaries who understood what this technology could accomplish and who devoted their lives to sharing this vision. While there is still a long way to go to harness the full potential of VR and immersive learning, it is just as important to recognise how far this technology has come and its real value in learning and training. This book embodies this realisation - VR is ready for your students!

Page by page, you will discover that VR produces remarkable results in a variety of contexts: from life-saving cardiopulmonary resuscitation simulations to "impossible" excursions to the moon for students, from promoting "good behaviours" to empathy training, and including immersive and collaborative projects in the fields of art, music and design. However, it is important to understand that not everything is "ready to use". The effective, reasonable and sustainable deployment of VR equipment and experiences in education and training requires meticulous expertise and planning. The industry is still in its infancy and the reliable methods and approaches need to be strengthened. If we look at how long it took for education to adopt information technologies, we are still at the beginning of immersive learning's journey, which requires a fundamental overhaul of teaching and learning.

But don't worry! This book is a big step in the right direction. Ambitious and pragmatic, it has come about just in time to be used as a map and guide when introducing immersive learning into your organisation. The time has come to go on a quest to revolutionise the learning and education system for future generations. Furthermore, with the imminent arrival of artificial intelligence (AI) in our classrooms, training rooms and lecture halls, it is crucial

to keep up to date. AI will accelerate and shape the VR and immersive learning industry, so it is essential to harness the potential of VR now.

This comprehensive guide will introduce you to the fundamental principles of immersive learning, teaching and training. It provides an overview of the advantages and risks, of what to do and what not to do, of appropriate use cases and of research findings. You will acquire the basic knowledge necessary to launch immersive learning projects within your organisation, make informed decisions in terms of equipment and software, and navigate the complexities associated with their deployment. Furthermore, it encourages you to enjoy this exploration while being honest about the challenges that lie ahead and providing you with practical advice and solutions. More than just a guide for your organisation, it gives access to valuable resources and support, illustrating what I imagined five years ago: a community of open-minded and adventurous educators, teachers and instructors, working together for the benefit of learners all around the world.

As the saying goes: "If you want to go fast, go alone. If you want to go far, go together". Collaboration is essential because, while we are individually responsible for the

results achieved within our organisations and classrooms, we have a collective responsibility, not only to our children, but also to the visionaries, pioneers and cultures who have paved the way for this technological revolution to be accessible to all. We must close the digital gap and make sure that each learner can benefit from immersive, spatial and collaborative teaching. That's the real promise of this technology.

I truly hope that Nicolas' work will encourage you to embrace the future of learning and teaching by becoming an ambassador of spatial learning for all.

May this book bring you new knowledge in this fascinating era.

Daniel D Bryant

Co-founder of Educators in VR
Director of Collaborative Realities

Introduction

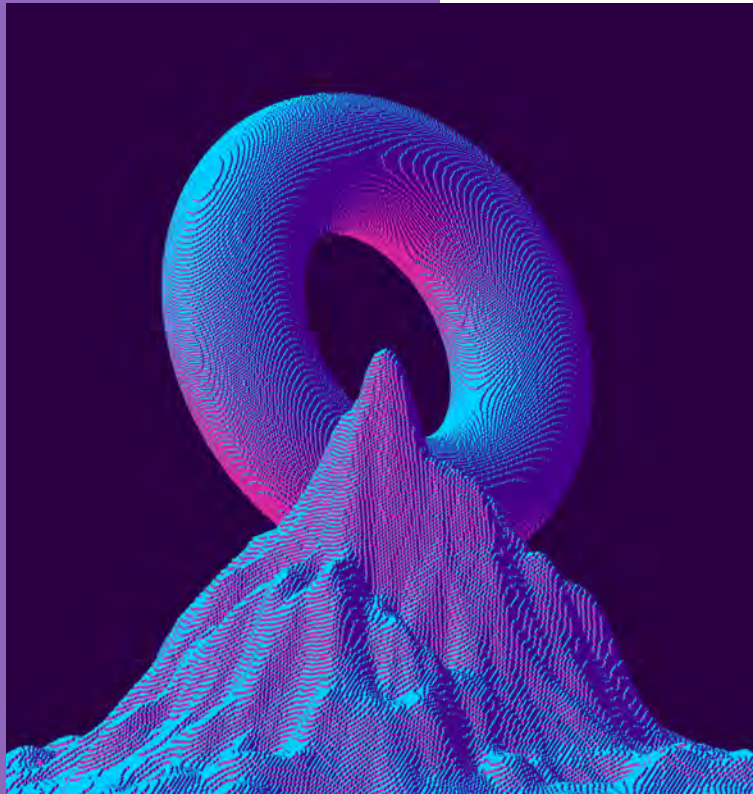
1.1– Why this book?	21
1.2– Who is it for?	24
1.3– What will I find in this book?	25
1.4– Technology evolves, transmission remains	26



chapter 1

Learning everything there is to know about immersive learning?

An enormous undertaking considering how quickly technology evolves and experiences multiply! This book was written to provide a comprehensive overview of the history of immersive learning, its potential, the perspectives it provides, the groundbreaking teaching methods it allows and the major challenges that must be faced to enable its democratisation.



1.1

Why this book?

The first immersive technology made its appearance in 1968 with the creation of the first augmented reality headset, which was based on a concept developed by Ivan Sutherland in 1965 at the University of Utah. Referred to as the "Sword of Damocles", this device used two cathode-ray tubes combined with optic elements to project computer generated images in front of the user's eyes, and this in real time, following the movements of their head.

We have come a long way since this experiment. During this past ten years, immersive technologies have slowly left R&D laboratories to reach the general public, popularised by largely recreational usages as well as the buzz created by the Metaverse in 2022.

These technologies have huge potential when used for training purposes, for what is called "immersive learning". The democratisation of this use represents a promising opportunity that will have a major impact in the coming decades, whether it's renewing the pleasure of learning and teaching or providing unique teaching methods.

Imagine exploring ancient history walking alongside Egyptian pharaohs, understanding geometry in

space by handling virtual 3D objects, or honing your professional skills thanks to realistic simulations! Immersive learning goes beyond the confines of traditional classrooms or training rooms and allows learners to interact with the content in a completely new way.

Introducing immersive technologies into learning paths could help put an end to physical limitations and open up new perspectives. For example, giving learners the opportunity to practise and repeat movements and situations, to broaden and vary the range of suggestions. Whether it's learning how to use a spray gun or responding to a crisis in a nuclear power plant, it is not always possible to physically recreate a learning environment identical to the real environment (too expensive, too risky, or quite simply impossible).

Immersive learning provides great added value by increasing the scope of teaching and learning situations, and better covering the blind spots associated with physical limitations. Thanks to virtual environments that partly reproduce real-world conditions, learners will be able to:

- + practise as much as possible, without cost or risk,
- + make every possible mistake with the only impact being a better command of the expected skills and procedures.

A veritable educational revolution!

The first-hand immersive experience provided by these technologies opens up an almost infinite range of possibilities, where everything is to be imagined and created. This is in itself a new way of teaching and learning, based on methods that require a fundamental rethink of the engineering of the teaching methods used today. Because immersive teaching methods are completely different to those used when you are in front of learners in a classroom, workshop and so on.

The aim of this book is to provide anyone interested in these new teaching methods with the means to identify the benefits they can draw from them, to understand their usages and to have a methodological approach to designing, implementing and deploying immersive projects in the right conditions.

It also aims to raise awareness to the challenges facing the immersive learning industry, in terms of digital sovereignty, privacy rights as well as the psychological and physiological risks associated with misuse.



1.2

Who is it for?

This book was written for those who act as "knowledge brokers" on a daily basis, and are committed to passing on knowledge in a lasting way and believe it's possible to teach differently by putting bodies and actions at the heart of the acquisition of knowledge, expertise and interpersonal skills.

If you are a teacher, instructor, head of studies or training, or a stakeholder in a corporate training project, you're in the right place. This book was indeed written for anyone involved in skill development, whatever their role and command of the topic.

You do not need any prior knowledge to read this book. It will however be easier to understand the examples we use if you are familiar with pedagogy¹. The vocabulary used is intended to be easy to understand, but a glossary is available at the end of the book if necessary.

If you don't know anything about immersive learning, try to read this book in order, chapter by chapter. We will progressively provide you with the keys you need to understand the next chapters.

If you have more advanced knowledge on the topic, you could undoubtedly dispense with this linear approach and use this book as a resource to browse depending on your current need.

1.3

What will I find in this book?

This book is neither an encyclopaedia of immersive learning, nor an academic history covering and detailing each topic exhaustively. It is a practical guide that aims to make immersive learning accessible to a wider audience, and enable more people to take the first step towards this new teaching method. We hope to update this book in the years to come with the contribution of members and stakeholders of the ecosystem.

Chapter after chapter, we will guide you through the fundamental principles of immersive learning, provide insights into its potential and identify the issues to

address if you wish to develop immersive learning projects.

The concepts covered in this book will come with examples, testimonials and views from experts, all in a pragmatic approach. This approach will provide the vantage point needed to understand the subject properly.

You will discover the many benefits of this method, such as improved learner engagement, better knowledge retention and optimised skill development.

1.4

Technology evolves, transmission remains

The transmission of knowledge has always existed. From the outset, we have learnt by imitation, trial and error, induction, deduction, association, repetition, explanation, etc. Furthermore, within the framework of what we historically call mass schooling, various approaches have been theorised, tested and adjusted...

These approaches, that we shall call "pedagogy" in this guide as a semantic shortcut, are based on various tools that can be used in teaching situations by an instructor, a teacher or a knowledge or skills broker.

Currently, the experimental method is the most commonly used; it places the learner at the centre of the learning process (action, reflexivity).

Whether it's in the form of overhead projectors with acetate sheets, televisions and video recorders, video projectors or even interactive whiteboards, technology has always had a place in classrooms and training rooms.

Ten fingers are not enough to count the technological tools invented over the last thirty years that were supposed to revolutionise and simplify transmission and acquisition. And the result? An accumulation of tools that remain confined to a fairly reduced functional scope: write information on a medium, whether wall-mounted or portable.

Paradoxically, the tools used in learning situations are becoming more and more complex. While they are based on technologies that can improve the learning experience, they can also have negative side effects on users (see chapters 3 and 6).

There is an obvious resemblance to the pharmakon of Ancient Greece and the vision of philosopher Bernard Stiegler, for who, all technology is pharmakon, i.e. both poison and remedy².

No one can deny that technological advances (modern computing, Internet, etc.) have opened up interesting opportunities for education. But, when we look closer:

- + the way we teach now is not so different from how it used to be. Imitation, trial and error, induction, association, repetition and explanation are still at the heart of current teaching methods, and they will continue to be so.

- + nor are teachers and instructors doomed to disappear, just as the French "compagnonnage" mentoring system cannot exist without a master craftsman.

Promoting immersive learning does not mean you seek to do away with teachers or instructors, quite the contrary. Using new mediums provides instructors and learners with new opportunities.

Join us and explore the revolution that is immersive learning and discover how this method can transform your practices. Ready to teleport?

Immersive learning: a new teaching method

2.1- Our definition	32
2.2- The benefits	33
2.3- The levers	44
2.4- Towards an immersive pedagogy?	48
2.5- Equipment, software & adjustments	56
2.6- A space for future possibilities	67



chapter 2

Immersion

Diving into or being fully immersed in a liquid and, particularly, in the sea³

Finding oneself in a foreign environment with no direct contact with your home environment (e.g. immersive language programmes)⁴.

Diving into or being immersed in a certain atmosphere, occupation⁵.

Fascination, captivation of the spectator for the atmosphere of the book, film, video game, etc. that they are viewing and into which they feel transported.



Over the past few years, immersive learning apps have become more numerous in schools, universities, vocational training centres and even companies, and many use cases have emerged:

- + Using 360° video to transport a user or a group of users to an inaccessible or difficult to access location, or even one that no longer exists,
- + Getting a close view of a watchmaker's movements using 180° stereoscopic video,
- + Attending a training course in mixed reality,
- + Learning a foreign language with learners from every country on a collaborative VR platform,
- + Learning about invisible disabilities in 360° video,
- + Handling scale models to learn the ropes of urban planning...

of reality is nothing new, technological advances now allow us to use devices that are far removed from those we know today.

Teaching devices such as technical platforms, hyper-realistic mannequins⁶, specially designed buildings⁷ and simulators⁸ will always be useful and won't disappear in the near future. They will, however, have to make room in teachers' and instructors' toolboxes for other devices based on new so-called immersive technologies (these technologies are described in chapter 3).

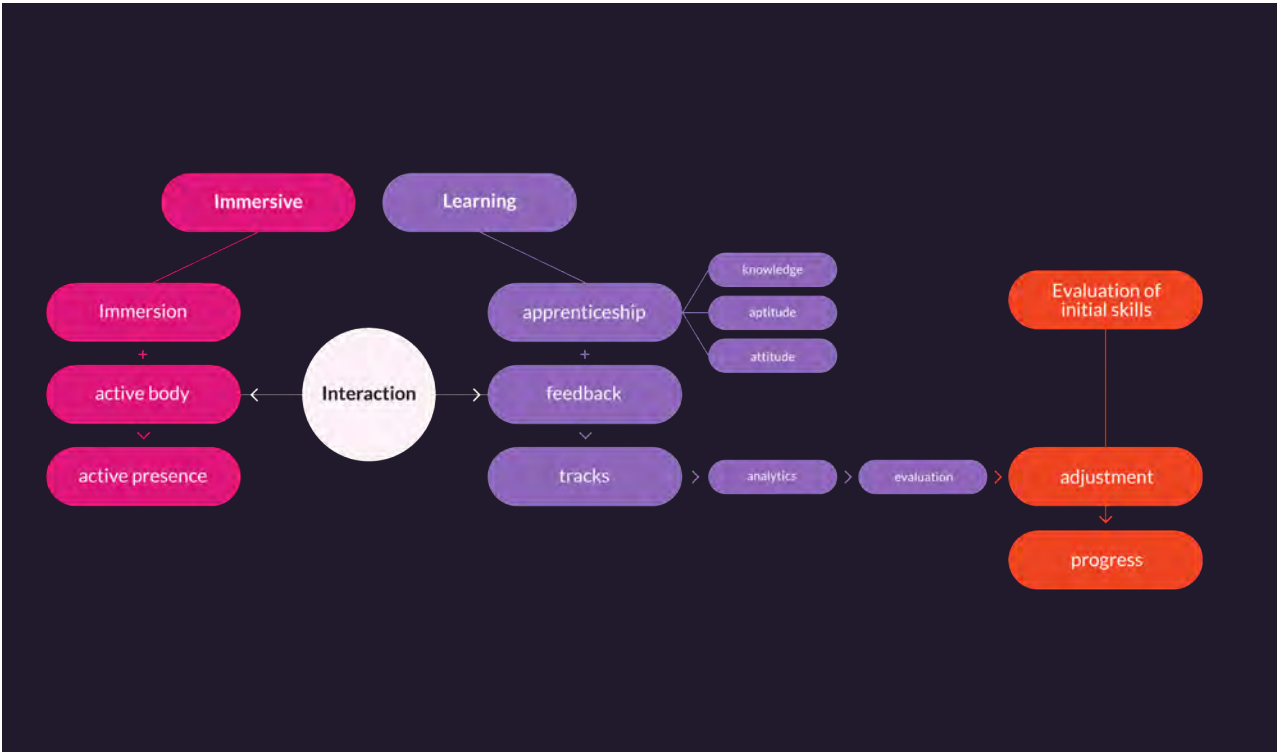
But what are the limitations of immersive learning? What characterises an immersive learning teaching device? How is this method different to existing methods? These are the questions to which we have tried to provide answers, to help you understand this new method and its benefits.

While the idea of immersing students in environments that are representative

2.1

Our definition

Our definition: Immersive learning is a teaching method that is based on immersive technologies (virtual, augmented and mixed reality), and uses various features of these technologies for learning, training and teaching purposes.



A representation of an immersive learning experience associated with a pedagogical process

On the left-hand side of this diagram is a list of what users enjoy when they put on a headset and are propelled into an immersive world. Their bodies are in action and users consider the environment around them and everything they see to be real (whether it is virtual, augmented or mixed reality, see chapter 3). This impression is amplified by the interactions they may have with the environment and objects that are present, if any. These interactions deceive the brain in a way, because they give it the impression of being able to "act" in the environment as they would in reality,

whatever the simulated experience's degree of realism. The ingredients associated with learning and training are represented on the right-hand side of the diagram in purple and orange, from the objectives to the assessment of learners' progress, via the knowledge to be acquired and the activities to perform to get there.

Immersive learning is the combination of these two worlds, through experiences designed according to a predetermined teaching scenario to meet specific teaching objectives.

2.2

The benefits

Immersive learning has many benefits: it improves learning and memory, reduces certain risks during and after immersive experiences, and it is even capable of handling objects that are impossible to handle in real-life conditions.

Over the past few years, an increasing number of scientific studies have shed light on and objectify these benefits. In particular, they enabled us to identify the main levers for action and the most effective immersive learning methods, as detailed below.

Mobilising the body to engage the mind

You have most certainly heard of the concept of "learning by doing". It is often used when referring to expertise and interpersonal skills, but this approach is rarely used for knowledge except at primary school. Indeed, children often handle objects in order to understand and learn abstract concepts.

Using experiences that involve manipulating or mobilising learners' bodies makes learning much more effective, because it places the learner in a state of embodied cognition. Here's a simplified summary: as the body is mobilised, the brain does not only record the knowledge in question, it also records a trace of the physical stimuli that took place. Later, when the person needs to retrieve the knowledge in question, their brain will reactivate this trace, enabling them to cognitively recreate the experience and thus gain access to the knowledge in question more effectively. This mechanism allows a complete mental representation to be recorded using working memory and long-term memory.

In an article published in the French review *Pour la science*, Remy Versace, Ph D, a cognitive psychology professor at the University of Lyon 2 (FR), wrote the following about embodied cognition:

Although embodied cognition is still largely unknown in the field of education, more and more teachers are calling on methods in which they use, without necessarily knowing it, the principles of embodied cognition. This is particularly true in mathematics; to learn abstract concepts, it is interesting to link them to sensory experiences, to movements or representations in space... In a way that memorised rules come from pupils' sensory motor experiences.

And this is precisely what immersive learning allows. Create enjoyable and engaging sensory experiences for specific teaching and learning objectives.

Concentration and engagement

A direct consequence of putting on a virtual reality headset is that the user is immersed in an entirely different universe that replaces the real world. The latter disappears and with it, all the distractions it provides. No more interruptions or untimely intrusions; no more looking at your smartphone for example. Living like this would be dystopian, but as a teaching experience usually lasts less than 15 minutes, the benefits are clear. Especially as the user is physically and mentally engaged. This is what neuroscience means by active engagement.

Scientific studies are starting to assess the impact that immersive technologies have on learner concentration. A recent study involving primary school pupils in Taiwan showed that using VR had a positive impact on the pupils' concentration compared to computers. It concluded that "VR training is more effective in improving participants' attention while reducing their learning anxiety and the cognitive load".

Improvement in concentration and the levers of engagement depend on the content design and may vary according to the technological choices made.

For engagement, it could, for example, be the storytelling prowess of a 360° video, or the ludic dimension of virtual reality content similar to a video game⁹. For concentration, depending on the experience, virtual reality can have a bigger impact than augmented or mixed reality, but we must not forget that the impact depends on the situation. In a mixed-reality fire simulation with the French company Baldr Innovation's FIRE kit¹⁰ for example, seeing your office catch fire before your very eyes naturally creates a heightened state of concentration and engagement.

Engagement can also partly be due to the novelty of these technologies: this is what we call the technology trap. Intentional engagement¹¹ with virtual reality content determines the sense of presence (for more information see chapter 3.3), which then encourages engagement when using the content: a virtuous circle.

Repetition and memorisation

While teaching content and the equipment needed to operate it are an investment, using them is inexpensive. Learners can practise as many times as necessary. And repetition is the key to learning. Repetition, combined with revision or remediation, is indeed an essential component of memorisation, particularly for long-term memory.

Let's use the virtualisation of chemistry experiments implemented at the Cnam¹² as an example. The VR experience is used in the

early stages of the experiments, especially for the safety instructions, and after in the laboratory. In this way, students can repeat the expected tasks in order to perfect their skills.



Did you know?

Studies in cognitive science and psychology took great interest in the effect that repetition has on learning retention and developed the notion of distributed practice. It is not just a question of repeating something as many times as possible in a short space of time, but managing to optimise the spacing effect which stresses the superiority of spacing repetitions out over time over massed repetitions, i.e. presented in quick succession ¹³.

Stanislas Dehaene also stresses that alternating sessions dedicated to learning and those dedicated to tests helps to measure what has been learned. Neuroscience tells us that it is the tests that count most, not the study time. Assessments give feedback and this allows learners to develop their metacognition, in other words, to realise what they know and what they do not know ¹⁴.

What of memorisation?

While many stakeholders in the field of immersive technology may claim that VR learning could increase the retention rate by 85%¹⁵, we must remain cautious.

More precise research has been carried out on the **impact immersive experiences** have on **memory retention**. A recent study that was published in *Science of Learning*¹⁶ highlighted the positive impact using VR has on memory when learning languages, but emphasised the importance of the context of the immersive learning environment. The immersive aspect is not everything.

Another field of study is that of **episodic memory**, another of our forms of **long-term memory**. In cognitive psychology, episodic memory is the process through which humans remember personal experiences, including information about the context (date, place, emotional state). S. Adam Smith published a literature review on the topic in 2019¹⁷. Even though he stresses that more studies need to be carried out in order to take into account the

differences in the protocols used in the various studies he analysed, he concludes:

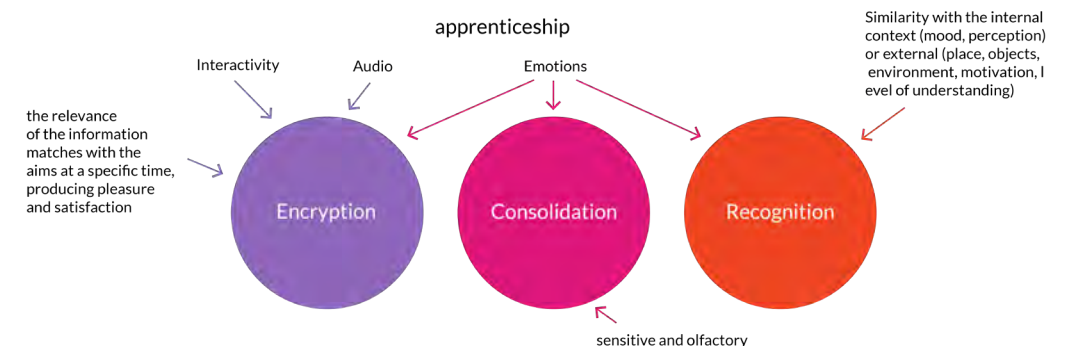
Despite the current gaps in our knowledge of how learning occurs within virtual environments, the potential offered by VR to increase the validity of tasks performed in the laboratory makes this methodological tool a prime candidate.

Our brains' memorisation mechanisms may be complex, but we do know **that memorisation**, also called **memory retention**, takes place in 3 phases:

- + **Encoding**, phase during which information is processed and transformed into a memory representation
- + **Consolidation**, phase during which memory representations are maintained and reorganised into long-term memory
- + **Recognition**, moment during which memory representations are brought back to a conscious level

Various factors influence memory anchoring and it is possible to take action on these factors when designing immersive experiences:

- + The relevance of the information (teaching quality and clarity, smoothness of the experience, ergonomics, playability¹⁸...)
- + Interactivity
- + Sensory stimuli
- + Emotions¹⁹
- + Situations of déjà vu (similarities in terms of context)



How memory works

But be aware that as the studies carried out on the topic are insufficient in number and robustness, there are no rules that can be followed to guarantee that your immersive learning content will be effective in terms of memorisation.

The right to make mistakes and the absence of judgement

In education, making mistakes had a negative connotation for a long time. As the authors of *Les neurosciences en éducation*²⁰ said: The popular image of a good student is that of someone who doesn't make mistakes. A mistake is seen as a failure, a deviation from a standard, from which a value judgement arises: "to have done something wrong".

This ignores the heuristic aspect of mistakes. According to Bachelard²¹: Mistakes are "a sign, as well as proof, that students are receiving an education worthy of the name". For cognitive science, mistakes play an essential role in the learning process: our brains constitutionally and constantly seek to predict the regularities of the world around us and to compare those predictions with environment based observations. **A mistake is just the gap between prediction and observation.**

So, let's forget about figures and focus on the multisensorial nature of the experiences, the ergonomics involved, and the relevance of the teaching objectives. In this way, participants will be in a state of embodied cognition and the emotions triggered will have a positive influence on the three steps of memorisation.

In other words, "our brain learns from its prediction errors, it detects them itself or via feedback from the environment. This is how knowledge is updated". Stanislas Dehaene's work confirms this: the learning process is triggered when an error signal shows that the prediction was not perfect. Nothing can be learnt if everything is predictable²².

This positive outlook of mistakes is in a way similar to a virtue seen in virtual reality experiences: alone in a virtual world, hidden from the gaze of others - their classmates/colleagues or their teacher/ instructor - learners don't feel judged and are therefore less inhibited. This absence of judgement is a factor that facilitates learning. This feeling can also be observed in collective VR experiences. Lowered inhibition comes from having an **avatar**, which allows learners to be present and represented, while feeling protected thanks to the distance it creates.

An example with English lessons in secondary school:

While lessons that follow the traditional format generate low learner participation, moving to the immersive method leads to a change in posture from the pupils and a transformation of their expressions and movements. The example of Michael McDonald, a member of the Educators in VR community who has completed more than 150 lessons given in AltspaceVR and Engage, is compelling²³.

The importance of feedback

If you wish to design an immersive experience, keep in mind that **without feedback, there are no "identified" errors**. Feedback is an essential part of learning, and immersive experiences are an ideal tool to create feedback in real time. Feedback must be thought through as early as the design stage and must produce two essential elements of the learning experience: provide the correct answer and encourage positive motivation even if that means using rewards. To go even further, it is also possible to use learning analytics²⁴ after the experience, during a private dialogue with the instructor or teacher, a remedial session for example.

The absence of risk

Did you know? An enormous amount of off-the-shelf training content concerning safety instructions has been created over the last few years in the fields of hygiene, safety and environment (HSE).

When combined with the right to make mistakes and *learning analytics*, virtual reality allows us to face all types of risks and learn how to deal with them or prevent them. Always with the same idea in mind: placing learners in a situation and expose them to the risks, giving them the opportunity to make mistakes so that they develop lifesaving reflexes when they encounter the reality of the job. And that's what makes virtual reality unique: do bad to do well, without getting hurt!

This approach to risk management can be integrated into any type of simulator where the goal is to learn both the technical manipulation of a physical device and the associated safety instructions. To give just one example: Mimbis' production line operator simulator²⁵.

Ubiquity and telepresence

Digital technology now provides many ways to reduce the physical distance between us, and to bring us together virtually to work, talk and have fun. By immersing the user in a virtual world, or by conjuring virtual objects in the real world, immersive technologies provide new ways of taking action on this distance and providing a feeling of ubiquity, the ability to be in several places at once.

By putting on a virtual reality head-mounted display, you are immediately transported elsewhere, in space as well as time. In a space station ²⁶, at the top of Mount Everest ²⁷ or on an oil rig²⁸: here are just some of the examples of how VR can make inaccessible locations, as well as times and situations, accessible: historical re-enactments ²⁹, extinct animals ³⁰ or worlds ³¹, a journey through the solar system ³².

Immersive technologies bring together learners and instructors from the four corners of the world in a same shared space, which can enhance teaching and learning abilities compared with video conferencing solutions.

Furthermore, virtual reality opens the door to the creation of artificial worlds which are not only "simulations of certain aspects of the world", but also "imaginary and symbolic" worlds³³. It is therefore possible to stand at the edge of a black hole ³⁴, go to the heart of matter, explore the tree of life and retrace the origins of life ³⁵.

Being present in a virtual or mixed reality universe via an avatar means being present for others. Zoom or Teams video conference may mean we are telepresent, but immersive technologies allow more advanced telepresence methods. Admittedly, our representations in virtual worlds are still far from our holographic dreams, but this doesn't stop children with mushroom avatars from chatting via VRchat.



Let's wait and see!

Research carried out by major companies like Meta, Microsoft and Apple, has announced that avatars will very probably look like their users very soon, in terms of mannerisms, facial expressions and even non-verbal communication. This evolution does contribute to a model of remote collaboration.

Autonomy

As with all forms of digital content, autonomous access to learning content is an essential part of the value proposition of immersive technologies, except for children and teenagers who need to be supervised.

In the industrial sector, remote collaboration tools are often used for project reviews and prototyping³⁶. In education, there are potentially many applications. Being together to talk, to visit any type of location, to carry out an activity together.

Let's use the example of two secondary schools in twin towns, one in France, the other in England. Bring together the language, art and technology teachers for the same project: that of creating, in the classrooms of both countries, a virtual world that resembles each of the two towns, enlisting the pupils' help, then meeting in either of these virtual world to speak English or French. A new type of language exchange programme!

The main obstacle has nothing to do with technical mastery. An autonomous head-mounted display is as easy to use as a smartphone or computer. The real obstacle to autonomy is equipment ownership and the associated costs. E-learning with a smartphone is straightforward: almost everyone has one (8.59 billion smartphones on this planet ³⁷). But there are far fewer virtual reality headsets: only 120 million people have access to this type of equipment, and some predictions mention 250 million in 2027 ³⁸.

To democratise access to learning content, we need to move toward mass use, or in the short term, ensure that certain institutions are able to make this type of material available to learners. According to Thierry Koscielniak, former Chief Digital Officer at the CNAM, Paris, this probably won't happen until 2030.

The ROI

This is the question asked by every organisation thinking of investing in immersive learning. Is it worth it?

The ROI of virtual reality may have been substantiated and documented for industrial output (prototyping and product design, optimising assembly lines and manufacturing process, remote collaboration), but this is not the case in education.

The ROI is clear for all training involving consumable items. From fire extinguishers for fire drills to large quantities of wood for carpentry training, not to mention the very expensive reagents in chemistry lessons, virtual reality could work miracles. Another approach to ROI is to compare employee involvement in a traditional training scenario and in immersive training. Here, immersive training has the advantage, as many case studies show ⁴⁰.

The initial investment is substantial, but it can be amortised over time, sometimes as early as the second year. However, ROI needs to be calculated on a much broader scale, taking into account what we can gain from immersive training. For example, employees at Intel are required to attend a training course each year in order to earn or update their certificate in electrical safety. Electrical accidents are considered to be one of the most fatal workplace accidents. Between 2015 and 2017, there were 24 electrical accidents at Intel. This cost the company over one million dollars. 90% of these accidents were due to non-

compliance with safety procedures. After introducing virtual reality training courses, the number of accidents fell significantly. Intel estimated a ROI of 300% over 5 years ⁴¹.

ROI as understood in the corporate world is difficult to apply to education, as education has such an impact on all aspects of society. It is above all a political issue to be approached with this sentence in mind: *"If you think education is expensive, try ignorance"* ⁴². For more information, read the report written by Julien Kleszczowski entitled "Education, quel retour sur investissement?" ⁴³.

Introducing immersive technologies in education is an investment that raises questions and even problems, even in the United States, as shown by the article "Metaversities Face Virtual Learning's Financial Realities" ⁴⁴. The floor is given to ten American universities experimenting with the "Metaversity" programme funded by Meta. In terms of educational opportunities, the feedback from the teaching community and students alike is very positive. However, these universities, including the iconic Morehouse College (whose yearly tuition fees are between \$39,000 and \$49,000) are worried about what comes next: how to fund the equipment at the end of the programme without increasing the

tuition fees? "The dilemma we have is the demand and interest is much higher than we can accommodate", said Daniel Mintz, Department Chair for Information Technology at the University of Maryland Global Campus.



2.3

The levers

Embodied cognition

In immersive experiences, interactions are pseudo-natural in an environment in which users are embodied.

Users are present, feel present and represent themselves as present, and they act. If the immersive experience has been properly designed and produced, users find themselves in a situation of embodied cognition, a concept that focuses on the essential role of the body and actions in the acquisition of knowledge.

According to this approach, acquisition via **memorisation** is not only based on **processing information in the brain**, it is also shaped by **the dynamic interaction** between:

- + the body
- + the environment
- + the mind

Embodied cognition highlights the importance of **bodily engagement**, **sensations** and **perceptions** in thought processes and problem solving. This perspective challenges the traditional idea according to which acquisition is essentially an internal and cerebral process.

Authors such as Francisco J. Varela⁴⁵ have developed **the theory of enactivism**, which focuses on the way acquisition and memorisation emerge from our interactions with our surroundings. They highlight the crucial role of the body in the generation of meaning and cognitive structures. For some researchers⁴⁶, enactivism is a fundamental paradigm of virtual reality in that it links sensorimotor and cognitive capacities.

Feedback

Feedback refers to the information provided to learners concerning their performance or actions to inform and guide them and help them improve their skills. Feedback plays an essential role in the learning process because it provides learners with the keys to understanding the consequences of their actions and making the necessary adjustments.

Feedback must be precise and relevant to the objective of the training course or lesson. It must provide

clear and specific information on learners' performances to enable them to understand where they were successful and what needs to be improved.

Feedback can be given immediately after an action or task. This way, learners can then quickly correct their mistakes and reinforce the desired behaviours.

Thanks to immersive technologies, feedback can become multisensory: visual, auditory and even haptic. For example, feedback can include visual indicators such as arrows or symbols of success/failure, while auditory feedback offers comments or spoken instructions. Haptic feedback is also an option to provide a tactile sensation in response to an action.

As with all types of learning activities, whatever the method, feedback can be adapted according to the learner's degree of mastery: explicit and detailed for beginners, but more subtle and focused on specific aspects or recurring mistakes for more advanced learners.

Remember that feedback is not just about pointing out mistakes. In virtual reality apps, it can also include positive reinforcement (virtual awards, praise, encouraging comments) to encourage correct and motivating behaviours.

Learning analytics

Learning analytics are an essential part of immersive learning. It is the collection, analysis and interpretation of learners'

actions in a virtual learning environment. By providing vital data to learners and teachers or instructors alike, learning analytics provide a framework to the learning process, while providing the keys to assessing and improving the effectiveness of the experience at the same time.

They are generally divided into 4 main categories:

- + **descriptive (what happened?)**
- + **predictive (what will happen next?)**
- + **diagnostic (why did it happen?)**
- + **prescriptive (do this to improve the results)**

Many learning analytics tools are only descriptive, but more and more of them are including algorithms allowing for prediction, diagnosis and prescription without human intervention.

Learning analytics involve **collecting data**, that we call **learner trace data**, from learners' interactions with the virtual environment. This can include information concerning the learners' actions, responses, decisions and performances during the simulation.

Virtual reality app designers often mention the sensors that need to be set up to collect this data. In this specific case, we are not talking about the sensors in the head-mounted display or controllers, but rather programming elements defined according to the teaching objectives that will analyse the learners' activity: Has this action been carried out? How long did it take? Was it carried out at the right time in a series of actions, etc.

However, learning analytics can also use data gathered by physical sensors, whether they are those of the head-mounted display or external ones: where learners look and what they focus their attention on, what their heart rate is, etc. Regardless of the type of sensor, what it measures has to be relevant to the teaching experience.

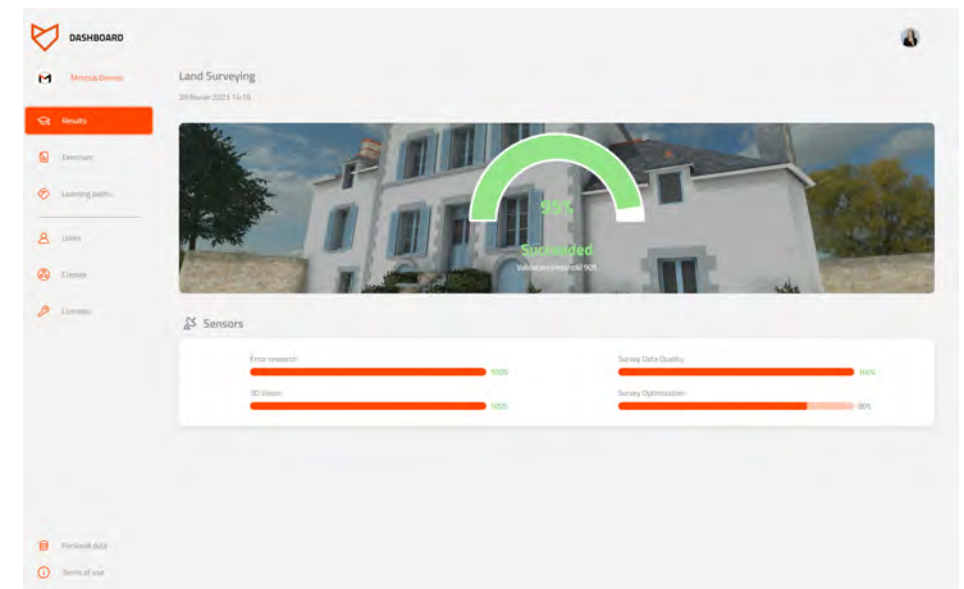
The data collected contribute to identifying learners' trends, patterns, frequent mistakes, gaps in knowledge and strengths. The analysis of learners actions and training data can be carried out in real time and modify the experience scenario. Learning analytics provide feedback adapted to learners according to their individual performance and needs.

For example, if the data show that a learner is having difficulties with a specific task, the virtual reality experience will automatically adjust the level of difficulty or provide additional instructions to help them overcome the obstacle.

There are two ways to **analyse this data**:

- + in the experience itself,
- + via a **Learning Management System (LMS)**.

In most cases, the second option is used. Using a LMS makes it easier to manage the learner profiles, learning paths and results for each sequence/module according to the granularity chosen.



Screenshot of the results page for Vulcan (Mimbus, 2021) ⁴⁷.

The results of the data analysis can be presented in various forms: dashboards or graphic visualisations, for example. They are used for:

- + easily visualising and understanding key performance and progress tracking information for each stakeholder (learners, teachers/instructors, employers, funders, etc.)
- + optimising the instructional design of the experience as part of a continuous improvement approach.⁴⁸

2.4

Towards an immersive pedagogy?

An immersive learning tool is above all an educational tool that serves specific and measurable teaching objectives. It must therefore be designed, from an educational point of view, using the same basic principles as any other method.

However, due to its very nature and the plethora of possibilities it provides, certain specific features that call for the formalisation of an "immersive" pedagogy must be taken into account. Let's take a look at a few basic principles to get a clearer picture.

Stanislas Dehaene's 4 pillars of learning

It is almost shocking to see the extent to which the use of immersive technologies is aligned with the 4 pillars of leaning⁴⁹ as developed by Stanislas Dehaene, neuropsychologist and professor at the Collège de France. Even though Dehaene's work focuses on children, it seems relevant to apply his concepts to adults.

Attention

Described as "the mechanism we use to select information and modulate its processing", Dehaene draws 3 consequences regarding attention in education:

- + A teacher's greatest talent is to channel and capture, at all times, the learners' attention.
- + The teacher must create materials that are attractive but don't distract learners from their main task.
- + The teacher must make sure not to create "dual tasks", especially for learners with specific learning disabilities or difficulties.

Active engagement:

A passive organism does not learn. Learning is optimal when learners alternate between learning sessions and repeated knowledge tests. In this way, they learn to detect when they do not know something (metacognition).

Feedback

Our brains use internal models to generate predictions on the outside world. The learning process is triggered when an error signal shows that the prediction was not perfect. Consequently, nothing can be learnt if everything is perfectly predictable. The error signal can come from an explicit correction (teacher/instructor) or the endogenous detection of a gap between prediction and observation (surprise).

Consolidation

The prefrontal cortex is actively involved at the beginning of the learning process (explicit, conscious and strenuous processing). Automatisation gradually transfers knowledge towards non-conscious networks, freeing up resources. While we sleep, our brains replay the neuronal discharges experienced throughout the day. Better sleep therefore has a positive impact on learning, as does the daily distribution of learning.

Lesson sequencing

The objectives

It is clear that teaching objectives must be defined for each immersive learning experience, otherwise the learning aspect would be nonexistent. To think about and define the objectives, we find it useful to refer to Bloom's taxonomy which enables us to clearly separate learning methods and to get an overview of them.

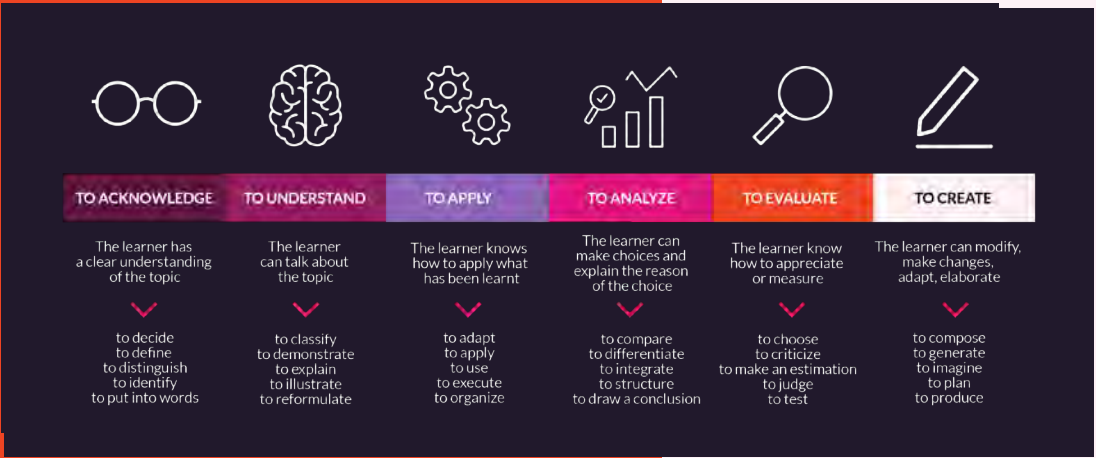
By referring to each skill level defined by Bloom, it becomes easier to formulate macro objectives. For example, "being able to": switch on a spray gun, explain how to spray paint, or even identify the protons and neutrons of an atom...

Immersive technology offers a specific approach to the notion of achieving objectives and to assessment. Thanks to learning analytics, teaching staff are able to refine the granularity when measuring the achievement of objectives.

For example, it is possible to weight the assessment by taking into account:

- + the number of repetitions necessary to correctly perform the task that has been assigned,
- + the accuracy measured by the sensors, etc.
- + the pre-defined maximum number of attempts to achieve an objective.

A small revolution!



Modules, sequences, sessions & activities

Three tools are frequently used to plan the various steps of a learning path aiming to achieve a specific teaching objective:

- + the educational staircase,
- + the zone of proximal development (ZPD),
- + the SAMR Model.

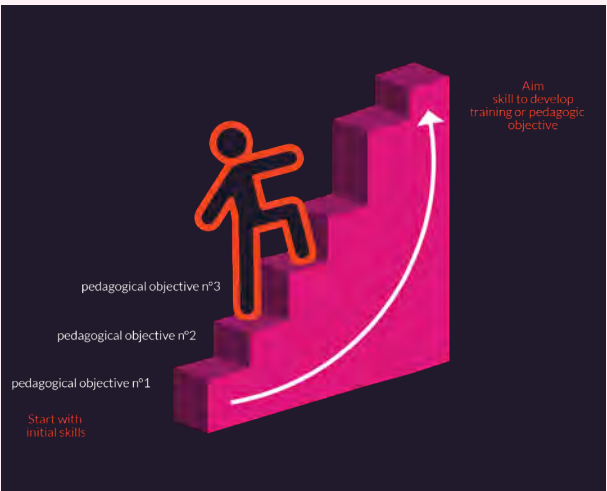
A simplification of Bloom's taxonomy

Benjamin Bloom, born in 1913, died in 1999, is an American psychologist and expert in education. He has long taught at the University of Chicago. He has chaired the program in Measurement, Evaluation, and Statistical Analysis (or MESA) and has created what is widely known as the Bloom taxonomy, which is a classification of skills according to their level of complexity

The educational staircase

Immersive technology has not yet changed the way the learning spiral is used. Remember that the educational staircase aims to define **the steps to be completed within a module**, activity after activity, session after session, sequence after sequence, in regular portions, increasing the difficulty level, to allow learners to succeed in each task without finding themselves in a situation of failure.

However, a specific feature must soon be taken into account with the development of predictive, diagnostic and prescriptive learning analytics (with a sprinkling of generative AI): the real-time reconfiguration of the learning path, based on the traces collected. The adaptability of learning paths will need to be increased, as opposed to linear approaches which are still anchored in practices.

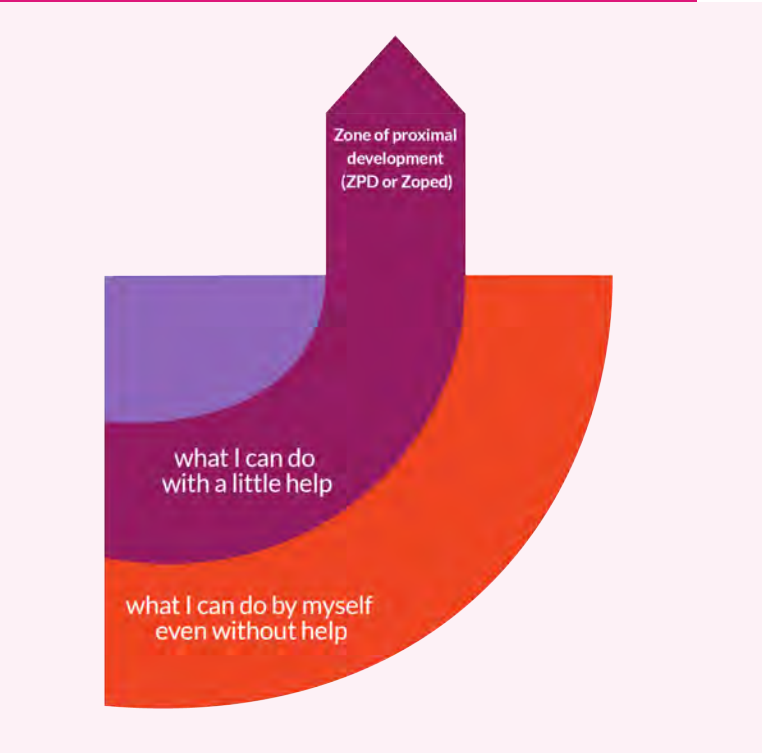


A representation of pedagogical progress

The zone of proximal development

Like the educational staircase, the zone of proximal development is not yet affected by the immersive method. It is still used in the same way as it is with other methods, and serves as a guide to the zone in which each learner can progress. However, here too, the arrival of predictive, diagnostic or prescriptive learning analytics, as well as AI, will force instructional designers to view this zone as protean.

To define it, the answers to the following questions should include factors calculated in real time, using measurements from the sensors that have been set up: Can the learner do this activity without help? Will they not be able to do it, even with help? Will they manage to do this activity with my help or that of their peers? In short, the introduction of a truly differentiated teaching method.



Vygotsky's ZPD

The SAMR Model (Substitution, Augmentation, Modification, Redefinition)

This framework is a reference in terms of digital integration in education. The aim is not to question the specific features brought by immersive technology in terms of use, but rather to highlight the fact that it is essential to use it when designing learning experiences.

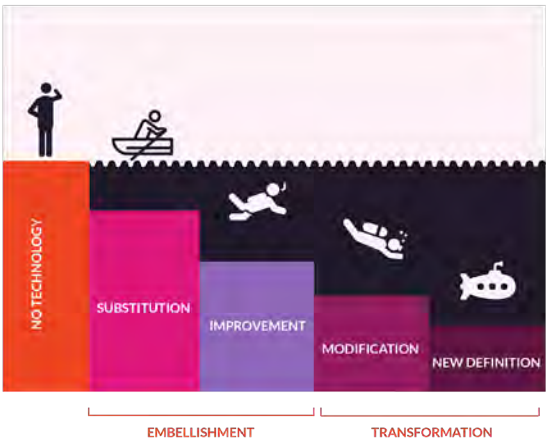
The SAMR Model suggests integrating immersive technologies thoughtfully and gradually, maximising the potential of this method for learners.

Let's go through the four levels of this model, using examples to illustrate them:

- 1. **Substitution:** At this level, immersive technology is used as a direct substitute for traditional tools, with no functional change. For example, learners can look at a painting in virtual reality instead of seeing it in a book.
- 2. **Augmentation:** Immersive technology is still a direct substitute, but with functional improvements. For example, learners can interact with elements of a painting in virtual reality, which is not possible with a book.

- 3. **Modification:** At this level, immersive technology allows learners to take significant action on the tasks. For example, using the previous example, several learners can work together and collaborate in VR on the same activity.
- 4. **Redefinition:** Here, immersive technology helps create new tasks that would not have been possible before. For example, learners could take part in ultra-realistic simulations which place them in environments or situations that would not be accessible or possible in the real world.

The first use case described later in chapter 5 as “making and manipulating prisms in secondary school” is a good illustration of the SAMR Model and the Modification/Redefinition levels.



The SAMR technology integration matrix

The ZPD is a concept developed by Lev Vygotski, born in 1896, dead in 1934, a bielorrussian psychologist and educator expert in early child development. He is known as the Founder of the Soviet psychology and has developed a history-cultural approach of human psychism. His most famous book “Thought and language” had a huge impact among educators and in the late 20th century.

Dr. Ruben Puentedura is a Harvard University Professor, also the Founder and President of Hippasus, a consulting firm based in Massachusetts, USA, focusing on transformative applications of information technologies to education. He is the creator of the SAMR model for selecting, using, and evaluating technology in education.

Assessment

A crucial step in ensuring the assimilation of knowledge, assessment looks a bit different in immersive learning, as described earlier in this chapter in the section on **learning sequencing**.

In addition to the completion of activities as seen in digital learning, or instructors' critical observations, immersive learning allows us to take full advantage of learning analytics. This new form of assessment makes it possible to continuously improve the effectiveness of the learning path offered to each learner, while providing a learning experience that is adapted to their specific needs. But please be aware that using learning analytics does not negate remediation which is still an important part of the learning process.

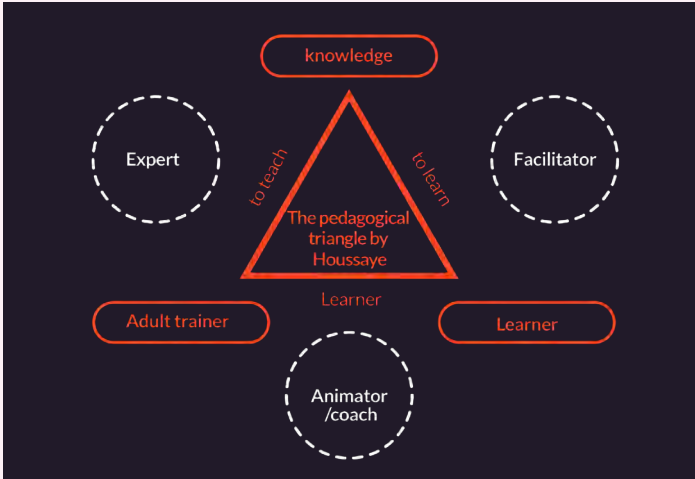
Place and posture of instructors

Using immersive learning technologies has a significant impact on the posture of instructors and teachers, as well as on teaching methods and the regulation of the learning process.

Instructors and teachers need to be given time to adopt and adapt to this technology. They need to familiarise themselves with the various functions of immersive technologies, understand the learning benefits and learn how to use them effectively in their lessons. This often involves attending an appropriate training course so that they can develop their understanding of this method and the associated skills. And this is all the more important if they are to take part in designing the learning content.

As for all new teaching methods, instructors and teachers integrating immersive technologies as a teaching method change posture: they move on from their traditional role of "conveyor of knowledge" to become learning facilitators.

A lot of research has been carried out on the topic; let's take a look at this diagram⁵⁰ of the educational triangle.



The pedagogical triangle by Houssaye

Virtual reality provides, for example, immersive experiences designed so that users can actively explore and discover content. Instructors and teachers generally **accompany** and **guide** learners, **encouraging them to experiment and develop a critical approach**.

Virtual reality fits into the multimodality of learning. Instructors and teachers use several methods to facilitate learning, including the immersive method. They must support the learning process taking into account the way each activity will contribute to the acquisition of the desired knowledge and skills. This may mean using adapted discussion, reflection, collaboration and feedback activities to reinforce the learning process in a multimodal environment.

The place of learners who do not participate in the immersive experience

It is also important to consider the place of learners who, for various reasons, do not directly participate in the immersive experience. They can be involved as active observers, benefiting from the communication tools used to interact with the immersed participants. They can also be asked to write summaries or share feedback to draw lessons from the immersive experiences of their peers.

Ensuring inclusivity and the participation of every learner, whether they are directly immersed or not, is essential to creating a learning environment that is effective, fair and contributes to a group dynamic.



2.5

Hardware, software & fittings

Immersive equipment

At the very least, an immersive experience requires a headset and controllers, sometimes supplemented by physical objects or accessories⁵¹.

Headsets

There are two types of headset: **tethered** and stand-alone.

Tethered headsets are connected to a PC with a latest-generation processor and a powerful graphics card. This category includes the HTC Vive Pro 2, HTC Vive Cosmos, HP Reverb, Valve Index, Varjo Aero and XR3, Pimax Crystal, and so on. With the exception of the Pimax Crystal, all require the installation of "outside-in" tracking to detect the position and orientation of both the headset and the controllers, and thus track your gestures and movements.

Stand-alone headsets can operate without a PC, i.e. wirelessly. This category includes the Meta Quest 2, HTC Focus 3, Pico 4, Microsoft HoloLens and, in the near future, the Apple Vision Pro (although at present there is a lack of information about its use in an Immersive Learning context). They feature inside-out tracking and function without transmitters: the headset itself takes care of its own tracking as well as that of the controllers. Their computing capacity is less powerful, but they use the same Qualcomm XR2 chip, which combines

a CPU and a GPU⁵². In other words, they cannot display 3D models in as much detail as tethered headsets.

That said, and therein lies their versatility, they can also be connected to a VR PC and take advantage of its computing power. If we compare an HTC Vive Pro 2 (tethered headset) to an HTC Focus 3 (stand-alone headset), there are very few differences: the former will benefit from better audio quality and slightly more precise tracking⁵³.

Controllers

The headset controllers are comparable to video game controllers with buttons and/or joysticks. They can also vibrate and create feedback when the user touches an object, which has proven useful and effective in a number of applications. Their use is not systematic in immersive learning applications, which are sometimes designed to mobilise only the hands, using a tracking system integrated into the headset. This is the case with Microsoft's HoloLens mixed reality headset and Apple's Vision Pro, designed to operate without controllers. However, with the exception of the latter, there is less gesture precision when headset controllers are not used. Controllers in the form of gloves are **also available**. They integrate haptic devices with feedback for even more realistic simulation. These gloves are able to simulate the hardness or softness of a material, giving the user the sensation of grasping a physical object. These include

the HaptX glove ⁵⁴, the Quantum glove from Manus ⁵⁵ and the Senseglove Nova glove ⁵⁶.

Aside from controllers, there is a whole range of haptic interfaces: from force feedback steering wheels in driving simulators to force feedback arms used for 3D design and modelling and high-precision interfaces used in surgery.⁵⁷

Haptic suits

While some are full-body suits, most are simple sleeveless vests that fit any body shape, and fitted with devices, often vibrotactile, that simulate a wide range of sensations (impact, rain, wind, splashes, etc.). They are sometimes fitted with sensors that provide information on the user's reactions. However, their use in training is very limited at present.

Skinetic from Actronika is a €800 entry-level model in the form of a sleeveless vest that fits any body shape and is equipped with 20 vibrotactile motors.

The Teslasuit is a premium full-body suit incorporating electrostimulation of the muscles, transcutaneous electrical nerve stimulation and biometric sensors to measure heart rate and pulse. It costs €12,000.

Omnidirectional mats

Comprised of a base on which you walk while staying in one place, and harness-like fastening systems to ensure you don't fall, omnidirectional mats allow you to move in the virtual universe without going anywhere in the real world. Usage in Immersive Learning is relatively rare, and these mats are still very expensive. The main ones are the Kat Walk, Omni VR and Virtualizer ELITE 2. They cost at least several thousand euros.

Immersive Learning platforms

There are many platforms where you can get together to learn in virtual or mixed reality. We are deliberately not discussing "general public" play platforms such as VRchat, or professional collaboration platforms such as Spatial, even though some people use them in ways that transcend this aspect⁵⁸. We'll focus on those designed for teaching and training.

The benchmark educational platform is Engage ⁵⁹ and offers a wealth of functions:

- + Cross-device (allowing users to switch from one device to another during a single use)

- + Session planning
- + 70 users per session
- + Group management functions
- + 70 3D environments with the ability to turn them into semi-infinite worlds
- + 3D asset library
- + 3D asset import
- + Personalised avatars
- + Room where you can watch 360° videos as a group
- + Display of 2D images, websites and videos
- + Creation of animations and, to a certain extent, interactions
- + Recording sequences for asynchronous use
- + GDPR compliance

However, Engage still seems a long way from what we have a right to expect in educational terms. The 3D object library is limited and closed, for example: no connector with Sketchfab, the interaction manager is not very powerful and, last but not least, Engage does not currently include Learning Analytics.

Less well known, but undoubtedly better suited to a one-on-one teaching or a group educational experience, 360° video interaction design platforms have seen some very interesting developments in recent years. These include Sphere, Uptale, Wixar and Wonda VR. Their use by major companies or Learning & Development

departments is testament to the presence of functions that are useful to the world of training and education, such as:

- + The fact that they are cross-device
- + Native integration of Learning Analytics
- + The ability to import your own 3D environments, as well as 3D objects for some of them
- + A wide range of interactions
- + Personalized avatars (including Ready Player Me avatars) for most of them
- + The opportunity to create collective experiences
- + The presence of an interaction manager, enabling industry-specific scenarios
- + Easy quiz creation
- + Voice recognition
- + The likely integration of AI-driven conversation agents

Immersive Learning is still in its infancy, and comparisons with the wealth of Digital Learning platforms and solutions are not to its advantage. Things are moving fast, however, and a number of projects are underway⁶¹.

Did you say Metaverse?

Invented by American science-fiction author Neal Stephenson in his book *Snow Crash* (1992) and popularised by Steven Spielberg in his 2018 film - an adaptation of another novel by Ernest Cline - *Ready Player One* (2011), the Metaverse created a buzz when Facebook's parent company renamed itself Meta.

The Metaverse doesn't actually exist. The Metaverse is a concept, a horizon of expectations and a technological and cultural convergence with multiple dimensions: literature and cinema, web, video games, virtual universes, virtual and augmented realities, blockchain and cryptocurrencies - fully documented in the government's 2022 report "Exploratory mission to the metaverse"⁶².

If we had to provide a definition, we could quote the EMRN (European Metaverse Research Network ⁶³), which sums it up thus:

"The concept of the Metaverse is that of a persistent, immersive and global 3D digital extended reality."

And to that we can add a quote from Matthew Ball, author of *The Metaverse* ⁶⁴:

"The Metaverse is a massively scaled and interoperable network of real-time rendered 3D virtual worlds and environments which can be experienced synchronously and persistently

by an effectively unlimited number of users with an individual sense of presence."

The emerging Metaverse is not just an archipelago ⁶⁵ of virtual worlds accessible in VR, disconnected from reality. For some, the Metaverse embodies the moment in the history of humanity when the real and digital worlds are converging in different ways, depending on whether we are using AR, VR or MR. It is meant to be accessible to smartphones and PCs, covering the widest variety of fields with a huge range of uses, maintaining highly diverse relationships with the real world.

Because AR by its very nature is highly adaptive, some people are already using the term "Metavearth" to describe the universe of data provided to users based on their geolocation. Google is way ahead of the curve here ⁶⁶ and Niantic has a great deal of experience. For the latter, the 'real' metaverse is augmented reality, not virtual reality⁶⁷.

Matthew Ball and Avi Bar Zeev ⁶⁸ agree on one thing: the creation of the Metaverse is reminiscent of the creation of the internet, a leap into the unknown that is in search of standards. Matthews Ball sees this as the necessary confusion of a creative process from which disruption can emerge, just like when the internet was built.

One of the key expectations of the Metaverse concerns interoperability. Utopia?

Crossing from the Meta universe to the Apple universe doesn't seem likely, but then neither does crossing from the American or European universe to the Chinese.

In any case, as with the W3C for the web, all the major players - except Apple - have come together in the *Metaverse Standards Forum*⁶⁹ (which includes the W3C) to establish the essential standards required for its development.

Another initiative worth mentioning is the UMI3D open source protocol ⁷⁰, which already enables the creation of large-scale collaborative applications that are interoperable with many different platforms, including openAR⁷¹.



Did you know?

Don't confuse web3 with the metaverse, the perfect example of which is Decentraland, which cannot be accessed with a headset, but only on a PC. We need to distinguish between platforms that are not accessible with a VR headset and those that are. The user experience and the associated benefits are not at all the same.

The promotion of the metaverse has to a certain extent blurred people's understanding of what immersive technologies actually are. The focus on generative Artificial Intelligence, particularly since 2022, has in some ways devalued the metaverse and immersive technologies with it.

Three key principles to remember:

1. The concept of the Metaverse is not dead and the development of virtual universes and the convergence of the real and the virtual are just around the corner. Meta's investment, Apple's entry into the race and the deal between Google and Samsung, as well as the hundreds of active or emerging start-ups in the XR sector, are strong signs of development in the years to come.
2. From the point of view of immersive learning, the Metaverse is not essential. There is already a wide range of possibilities to explore, including:
 - + stand-alone applications, i.e. applications that run locally and do not require Internet access
 - + as well as collaborative VR platforms, often referred to as the metaverse (with a small m), which can already be used to create content, operate synchronously or asynchronously, remotely and/or face-to-face, and use learning analytics.

We are going to have to integrate artificial intelligence into our daily lives, in both its dystopian and its generative capacities. ChatGPT but above all LLama 2 from Meta⁷², and Google's Gemini⁷³, are already disrupting teaching and learning, as well as questioning education and assessment methods. The upheaval will clearly have an impact on XR and Immersive Learning. Generating universes - their 3D environments, the 3D objects within them, their conversational agents, even their preceptors - will undoubtedly be less labour-intensive and will open up possibilities that we are already anticipating outside the realm of creative design.

Immersive content

Platforms may enable people to come together in a shared virtual space, but without content they are nothing. Immersive content is equivalent to e-learning modules, immersive activities that can be launched independently or with guidance from a trainer or teacher.

It should be noted that to date, there is no shared library of immersive content from which anyone can retrieve pre-existing building blocks to construct their own educational activities. This is one of the challenges listed in Chapter 6.

We currently differentiate between five types of content:

- + 180/360° videos/documentaries available on manufacturers' video applications or on YouTube VR that are

free, but rarely royalty-free.

- + The content, essentially demonstration content, available on educational metaverse platforms. Engage XR⁷⁴ offers an entire section of this type of content called "Lessons".
- + Paid content on manufacturers' virtual shops or via French, French-speaking and foreign publishers (mainly English-speaking, very rarely translated). There is no directory that lists this content, let alone one that assesses its educational qualities and user experience.
- + Content reserved for an organisation, and very rarely placed in the public domain or accessible outside the relevant organisation, including:
 - Self-produced content (often 180° or 360° videos, as the tools for producing immersive 3D VR content independently are still limited),
 - Customised content developed by external agencies (180/360 video, MR, VR).

Thanks to funding from DEFFINUM, a call for projects for the digitalisation of vocational training, digital or immersive teaching modules are also set to be developed this year, as well as complete or targeted hybrid training courses for blocks of skills and digital tools to facilitate trainer/learner interaction, peer-to-peer learning and remote tutoring. Not all of them will be open-source, but this will certainly help enrich the existing offering.

DEFFINUM is the name of a transformation and digitalization plan for education and professional training. It has been financed by Europe between 2021 and 2022. 100 millions euros have been invested to support innovative projects among which France Immersive Learning's.

Layout of the physical space

The layout of the physical space in Immersive Learning is a key factor that requires particular attention to ensure a high-quality transmission and learning experience. This goes beyond simple furniture and equipment arrangement. The orchestration of the space must be perfectly aligned with the teaching objectives, the transmission context, the type of learners, etc., while ensuring a secure environment conducive to immersion.

For example: a learner, alone in a virtual reality application with no restrictions on movement. Theoretically, they can travel through virtual space by walking through the real space in which they are located. Unless they have a real space that is bigger than the virtual one, they will quickly become acquainted with the walls of the real one.

We generally use metaphors to move through virtual space, using action buttons to either move or teleport through your avatar. This allows you to optimise your movements in real space while keeping one thing in mind: avoiding collisions with furniture, walls and other participants in group activities.

Whether the experience is individual (each person alone in their own experience) or collective (together in the same experience) makes no difference to what happens in the real space: everyone must remain in their own physical space, even though their positions in the virtual space may be completely different.

There is only one exception to this rule: co-located free roaming, a speciality of a company like Emissive⁷⁵. This type of experience, designed specifically for a given space and surface area, allows several users to walk around the virtual space without risk of collision, because real space and virtual space are aligned, and the positions of users in the two spaces are the same. In other words, if you touch the shoulder of another user's avatar in the virtual world, you are touching that user's shoulder in the real world.

What's important to remember is that once inside the immersive experience, learners quickly forget the real world and space, as well as any instructions they may have been given about where to go. Managing a group of learners taking part in a virtual reality

activity therefore requires an appropriate set-up of the space and vigilance on the part of the supervisors.

In this guide, we assume that the room used is dedicated to Immersive Learning and that its layout has been designed with this in mind. However, if your operational constraints make it impossible for you to have a dedicated room, the following advice is still valid but will certainly need to be adapted slightly.

The room

The first point to consider is its size. There are two possible approaches: seated and standing use. For seated use, you can easily convert a computer room into a VR room.

However, for standing use, the space used per learner will not be the same. In fact, a minimum of 9 m² is required for each immersed learner's space, i.e. a 3m x 3m square, which can be called an "immersion zone", if the experience does not require the learner to move around physically.

Why is that? Quite simply because during immersion the learner may be required to move around, to make big gestures with their arms. And it is preferable that

they do not encounter any obstacles in their movements, as they cannot necessarily see the real environment. It is important to mark out these areas on the ground. Duct tape works perfectly here. Make sure you avoid anything that could become an obstacle for the immersion learner, i.e. raised edges or any other device that the learner could trip over or bump into.

Remember to leave sufficient space between the immersion zones so that trainers can move around the room and give help to the learners who need it, but also so that learners can leave the immersion zone once they have finished their activity. A one-metre corridor is sufficient for wheelchair access.



Don't forget to install one or more cable supports in the ceiling (for tethered headsets and stand-alone headsets used as a link). There's nothing more unpleasant than having to deal with a cable lying on the ground: this needlessly mobilises the facilitator and "breaks" the learner's sense of presence.

In addition to immersion zones, you'll also need one or more waiting or observation areas in your space, where non-immersion learners can wait and observe their classmates. Furniture and equipment for this area are set in the following paragraph. A surface area of around 20 m² will be . If you can add a "relaxation area", then do so. Learners prone to immersion sickness, also known as cyberkinesetosis, will be grateful.

Finally, if possible, also work on the lighting to avoid too bright a light which can disturb learners and lead to eye fatigue during the experience, but also when they take off their headset and return to the real world. The ability to lower the room's brightness (blinds, shutters) and use dimmed lighting are appreciated.

To define the size of your room, simply multiply the number of learners you plan to have working in immersion simultaneously by 9 m² ideally, adding the m² corresponding to the corridors between the areas occupied by the learners in line with your layout, and add the surface area you need for furniture and waiting or observation areas. On average, we estimate 90 m² for 6 learners, without taking into account the surface area required for furniture or waiting/observation areas.

Non-immersive furniture and equipment

As you will have understood from the above paragraph, the less furniture you have, the better. However, if you choose the right modular furniture and size your room accordingly, it is quite possible to have several different layouts (immersive room, room with tables and chairs, etc.) However, ensure you take all the constraints of each layout into account so that you don't get into difficulty when the time comes.

The most important furniture to think about when choosing stand-alone headsets: the recharging trolley for storing headsets and controllers and plugging them in to recharge until the next session. Do you remember when tablets arrived in schools? In many cases, the space taken up by the famous charging trolley had not been anticipated in room layout. You really do have to think of everything! Some players, such as Uptale, offer "all-in-one" kits with a transportable recharging unit and 6 headsets equipped with software^{71a}.

On the list of equipment to be integrated: **the screen** to get feedback on what the learners are seeing. Put it opposite the waiting and observation area, so that it is clearly visible to non-immersion learners. Don't put it behind their backs (no joke, it's happened before...) Whenever possible, opt for a large screen mounted on the wall rather than on wheels. If you can install several screens, that's even better. Avoid video projectors, which are far less practical to use. And consider the dongles⁷⁶ that allow the headsets to be linked wirelessly to the screens.

Don't forget chairs on castors, possibly with a retractable writing surface. They can be used when presenting the activity or remediation plan as well as during immersive sessions. For some people or certain applications (Google Earth VR, for example), it may be better to be seated.

And of course, pay particular attention to Wi-Fi connectivity and speed. This may not always be necessary, particularly when the immersive experiences are 100% embedded in the headsets. Nevertheless, an increasing number of immersive experiences take place in 'connected' mode so that they can be enjoyed by more than one person, and incorporate tools such as the conversational generative AI we discussed earlier. Ideally, having a dedicated Wi-Fi network in your immersion room is the best solution.

Cleaning headsets and accessories

Don't forget to bring something to clean the headsets between uses. Covid-19 pandemic or not, hygiene is important when it comes to Immersive Learning. Because they are worn directly on the face, as close as possible to the mucous membranes, head-mounted displays, headsets and other eyewear are an obvious vector for the spread of viruses, bacteria, fungi, etc.

So it's a question of taking the lead by applying basic hygiene and providing a controlled sanitary environment:

- + Provision of hydro-alcoholic gel
- + Surface decontamination using the Sinner principle⁷⁷
- + Use of specific disinfectant products (standard 14476)
- + Creation of clean and unclean areas to avoid cross-contamination

While headsets can be cleaned by hand, they can also be cleaned using special ultraviolet cleaning devices such as Cleanbox⁷⁸ (2 minutes for 1, 2 or 4 headsets), UV devices such as UVISAN⁷⁹ (2 minutes, up to 12 headsets), or ozone devices such as Hygizi⁸⁰ (4 minutes for 10 headsets).

2.6

A space for future possibilities

Immersive media and technologies can be disconcerting: the field of possibilities is immense and, like more traditional teaching methods, they challenge us to refresh our approaches. Technologies are evolving at an almost exponential rate and their penetration into the world of training, teaching and cultural mediation is progressing equally fast. Provided you have the means and a degree of control, you have an unrivalled transmission channel at your disposal. Almost anything is possible. However, you will still need to create, formalise and structure these experiences to make them accessible to as many people as possible, while anticipating the inclusive dimension so that everyone can benefit: people with disabilities and long-term unemployed in particular.

How immersive technologies work

3.1– The three types of reality	71
3.2– Interaction	74
3.3– The sense of presence and the three illusions	76
3.4– Environments	83
3.5– Degrees of freedom	84
3.6– The avatar	86
3.7– The Proteus effect	87
3.8– Multisensory integration	88



chapter 3

3.1

The three types of reality

Immersive technologies fall into three categories:

- + **Virtual Reality (VR),**
- + **Augmented Reality (AR),**
- + **Mixed Reality (MR),**

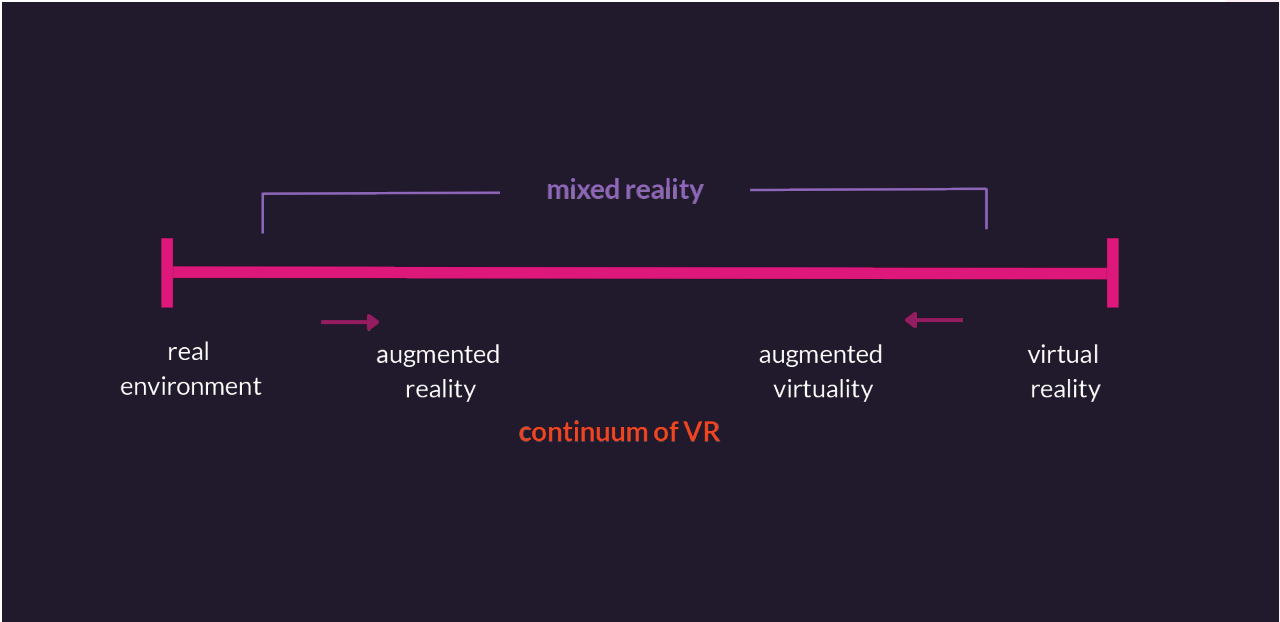
You will also hear about Extended Reality (XR), a generic term that has emerged more recently to refer to these 3 types of reality.

We can agree that defining them takes some effort. But rest assured, even "experts" and researchers ⁸¹ disagree on

how to describe these alternative realities. From a hardware perspective, some headsets can even be used for VR, MR or AR, depending on your requirements. It's enough to make your head spin!

The intention of this guide to be pragmatic, so we have opted for a simplification of concepts, even if it means offending the purists. Here are our definitions, based on the work carried out by Milgram and Kishino in 1994 and the notion of the "reality-virtuality continuum" that they formulated (see diagram below):





Milgram and Kishino and the notion of the “reality-virtuality continuum” (1994)

Augmented Reality

Augmented reality (AR) is a technology that superimposes virtual elements onto our perception of the real world. Interactions are either non-existent or extremely simple: for example, choose an item by clicking on it or looking at it for a few seconds. The superimposed

information consists of images, videos or text. While there are many examples of use for the general public, in the professional world its use can still be described as “niche”: industry and military aviation, such as head-up displays, which allow pilots to have numerous key indicators in their field of vision, without having to tilt their heads towards the instruments to read them.

They work via smartphones, tablets or special glasses featuring sensors and cameras to detect and track the environment. When we look at the real world through these devices, augmented reality adds virtual elements, offering an enhanced experience.

Many consumer applications have been highly successful, such as virtual fittings (make-up, glasses, accessories), with hundreds of millions of uses worldwide for Perfect Corp’s YouCam app, interior design with the IKEA app, and filters for Snapchat, TikTok and Instagram.

One example with a truly global impact is the game Pokémon Go, in which players try to capture Pokémon in the real world, with the Pokémon appearing on the screen of their smartphone as a superimposition on what is being filmed.

The most striking failure was that of Google Glass, the eyewear from Google that allowed all sorts of information to be superimposed, some more useful than others. Between privacy issues, cost and the lack of practical uses, these glasses never enjoyed much success.

Virtual Reality

Quasi-reality for some⁸², artificial reality for others⁸³, virtual reality consists of immersing one or more users in a multisensory simulation (visual, auditory, etc.): a digitally created, 3D world that can be “imaginary, symbolic or a simulation of certain aspects of the real world”⁸⁴, with which it can interact.

One important point: Virtual reality does not necessarily call for the use of a headset, as many simulators prove: a screen can be all you need. However, in this guide, our attention will be focused on the headset that allows the user to be immersed in the virtual environment replacing the real environment.

The best-known headsets are the Meta Quest 2 and the HTC Vive Pro 2.

Mixed Reality

Mixed reality involves a merger of the real and the virtual:

- + either by augmenting reality with virtual objects The most common usage case involves integrating interactive or non-interactive 3D models into the real environment. For example, in orthopaedic surgery, 3D medical imaging can be superimposed onto a patient's knee to help the surgeon perform the operation.
- + or by augmenting the virtual world with real objects (this is known as augmented virtuality). For example, the user is in a virtual kitchen where they have to prepare a dish. We can then integrate into this environment all their real kitchen utensils... while all the ingredients remain virtual.

For this merger to be effective and realistic, mixed reality requires peripheral devices capable of mapping the real environment and understanding its topology, whether with cameras or LIDAR (Light Detection And Ranging is a technique to measure distances based on light abilities). Some peripheral devices are opaque: the user can see the real environment thanks to the 2 high-resolution cameras in the headset, while others, such as the Hololens 2 goggles, offer a non-obscuring view of the real environment.

3.2

Interaction

When describing virtual or mixed reality, it is tempting to start with the concepts of immersion and sense of presence. As Fuchs puts it⁸⁵, these realities are characterised by the interaction they facilitate with the virtual world. Interaction is the basis of the user's agentivity⁷⁸ in other words their ability to act on, transform and affect the world and objects around them.

When users sense a high degree of agentivity, they feel they have real power of

action and control over the virtual environment, which helps their **sense of presence** and improves their **engagement** with the experience. Interactivity is thus one of the cornerstones of Immersive Learning.

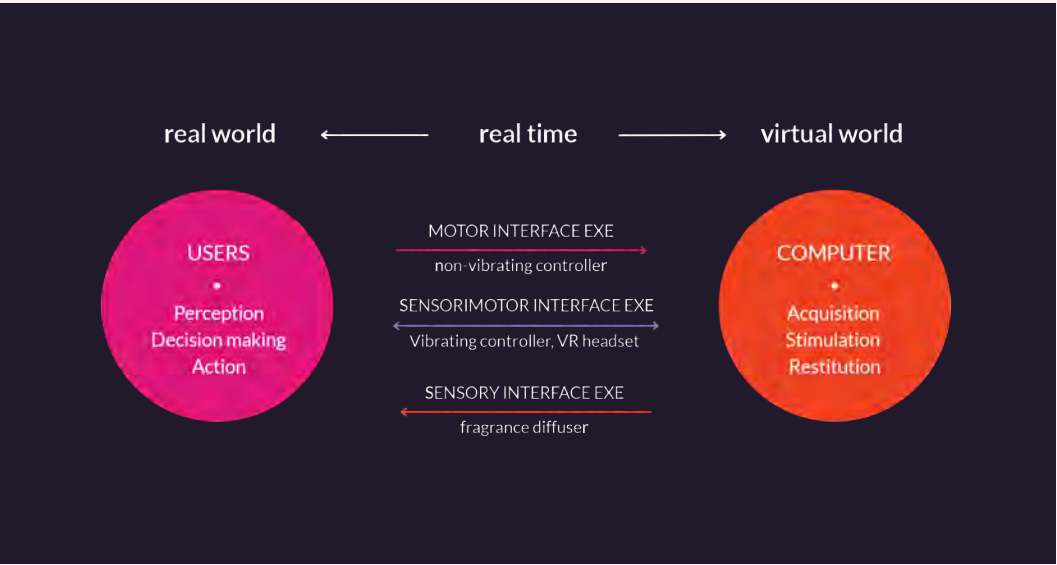
- + Sensory interfaces inform the user about changes in the virtual world from a sensory perspective.
- + Sensorimotor interfaces provide information in both directions.

In his book "Theory of Virtual Reality", Philippe Fuchs describes in detail the man-machine relationship of contemporary virtual reality devices.

What Fuchs refers to as the sensorimotor loop in an interactive virtual environment is fundamentally the transposition of the "perception, cognition, action" loop of human behaviour into a real mode.

This man-machine relationship is based on what are known as behavioural interfaces:

- + Motor interfaces inform the computer of human motor actions in the virtual world.



The man-machine relationship of contemporary virtual reality devices, after Philippe Fuchs

3.3

The feeling of presence and the 3 illusions

The feeling of presence is the sensation of really 'being there' in the virtual environment rather than in the real environment. It is strengthened when the elements of the virtual environment are perceived as reactive and consistent with the user's actions. It is subjective in that it is based on user perception. It is the direct result of immersion: that which fosters immersion fosters a sense of presence. It has four components.

Spatial presence: this is the feeling of being physically located and immersed in a virtual environment. Virtual reality uses display and motion-tracking technologies to create an illusion of a 3D space, giving the user the impression that they are occupying a real space. Spatial presence implies the perception of depth, distance and coherent proportions, which reinforces realism and the immersive effect.

Physical presence: this refers to the sensation of having a body or representation of oneself in the virtual environment. Body-tracking devices, which include motion sensors and haptic controllers, allow users to interact with the virtual world by mimicking real-life movements. This creates a correlation between the actions of the real body and reactions in the virtual environment, thereby strengthening the feeling of physical presence.

Social presence: this is the feeling of sharing the virtual environment with real people or virtual characters with artificial intelligence. Social interaction can take place with avatars, graphical representations of users or virtual participants. When social interactions are convincing and other characters react in a realistic way, this reinforces the feeling of social presence and can encourage greater commitment to the virtual experience.

Self-presence: This concept refers to the feeling of actually being in the virtual environment, of identifying with your avatar or virtual representative. When users feel connected to and emotionally invested in the virtual world, they can experience a stronger self-presence. This can be enhanced by elements such as avatar customisation, choices and consequences, as well as narrative factors that create a personalised and engaging experience.

To understand how virtual reality manages to play on our perceptions and create a quasi-reality with a strong sense of presence, an explanatory model is particularly appropriate: Mel Slater's 3 illusions⁸⁶.

Place illusion

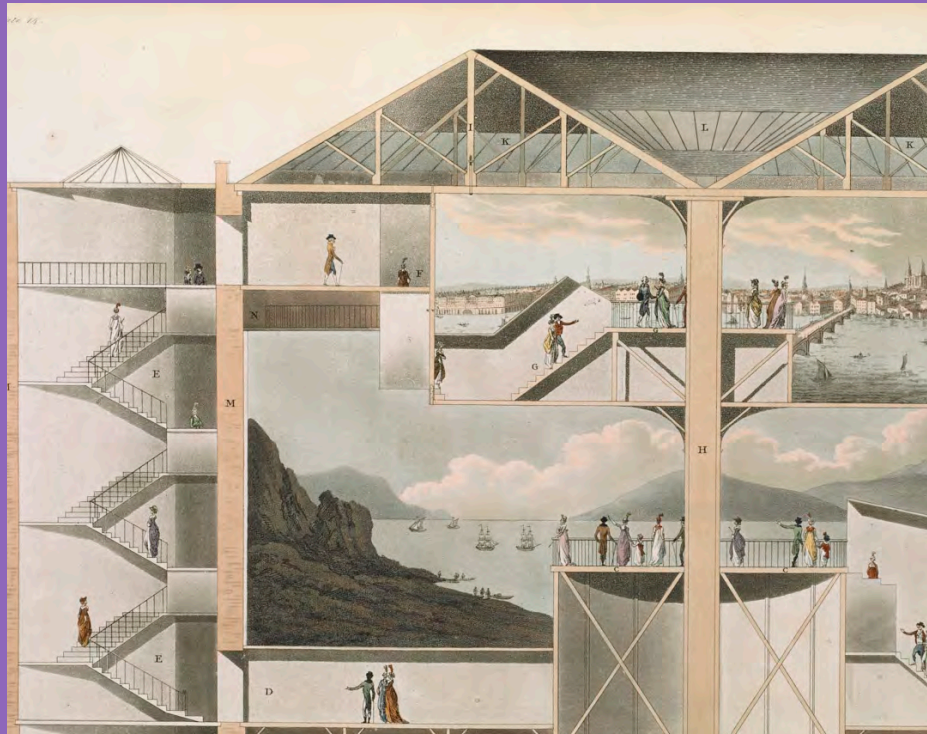
Donning a virtual reality headset means experiencing the inherently ubiquitous nature of the medium, being instantly transported to another place, with the illusion of fully being there.

In 1787, long before the advent of virtual reality headsets, Robert Barker invented a concept of 360° panoramic painting: the panorama. This nineteenth-century mass-medium, which fuses architecture and painting, drew hundreds of thousands of visitors to Paris, London and Berlin.

On the outside, it's a rotunda. But after wandering through a dark corridor, visitors arrive on a platform in the centre of Jerusalem or the midst of a naval battle. Everything is done to ensure that the architecture is obscured, leaving only a realistic painting of an imposing size (up to 18 metres tall) and so detailed that lengthy views are required to be able to appreciate it.

The panorama is the epitome of the illusion of place and is based on a characteristic that it shares with virtual reality: **non-mediation**. Everything is designed to ensure that the device itself disappears: a form of transparency for the user.

For its time, the proposal was radically innovative and produced real effects, like the Lumière brothers' "Arrival of a Train at La Ciotat Station". At the end of the 19th century, the short film scared spectators who were afraid of being run over by an oncoming train. Current immersive technologies, led by virtual reality, simply use this principle, but in a more advanced way.



Panorama Bourbaki

The plausibility illusion

This consists of deceiving the brain by giving it enough information to make the "virtual" situation seem plausible, so that it accepts it as "real". The plausibility of the experience is determined by a number of factors, from the realism of the environment to which we are transported and the interactions offered, to the credibility of the narrative and the being we embody. Multisensoriality and sensorimotor coherence are also significant factors⁸⁷.

Dynamic cinema uses this to make us believe that we are feeling the acceleration or deceleration of a car, the take-off of a rocket or any other simulation. By slightly tilting the seat we are sitting on backwards, gravity makes us feel as if we're being pulled backwards, and if at the same time, thanks to the illusion of place, our brain thinks we are in a speeding Formula 1 car, we consider the situation to be 'real'.

The Birdly immersive experience⁸⁸ is another interesting example. The user assumed the form of a bird and has to behave like one. You have to learn to fly between the skyscrapers of Manhattan or the mountain peaks of the Alps. At first, the body and brain don't know what to do. Then, after a few seconds, the reflex of mimicking the movements of a bird allows the user to fly and steer, climb, descend, turn right and left. It's child's play. The same logic applies to the experience offered by FlyView⁸⁹ of flying over Paris in a JetPack.



So if you find yourself in a virtual world in which you can pick up an object and throw it, even if you can't physically feel the object, the illusion of verisimilitude will encourage your brain, and with it you, to consider the situation, the action, the object as... "real". And sometimes it's the smallest details that reinforce this illusion. For example, the fact that every time you take a step in the virtual world, you hear the sound of your own footsteps, or that when you drop an object, it falls to the ground and makes a noise.

The embodiment illusion

The embodiment illusion consists of fooling your brain into believing that the body it sees is yours. This is why an avatar⁹⁰ is an essential vehicle in virtual reality for creating a sense of presence. The embodiment illusion occurs when the user has the feeling of personifying their avatar in the virtual environment, and perceives the virtual body as being their own body.

The embodiment illusion has been broken down into three dimensions by Konstantina Kilteni and her colleagues at the University of Barcelona:

- 1. Self-location, the feeling that you are located in the space defined by this body, inside this physical envelope.
- 2. Appropriation, the feeling that it really is your body and that it is the source of all your bodily sensations.
- 3. Agentivity, the feeling that you are in control of your avatar and that you are the source of its actions.

The first dimension, self-location, relates to the perception of the location of your virtual body. You believe that you are there where you see it, that you are located in the space defined by this body, inside the physical envelope. The second dimension, appropriation, concerns the perception of the sensory appropriation of your virtual body. It's your body and the source of all your sensations. The third dimension, agentivity, concerns the feeling of control over your virtual body. You move your virtual arms by moving your real arms, therefore they are yours. Your virtual "you" is thus real.



This embodiment is enhanced by synchronising the movements of the avatar and the user, as well as any form of tactile sensation added, such as the caress of a brush in the rubber hand illusion.

In this experience, one of the participant's hands is taken out of their field of vision and replaced by a rubber hand in a plausible position.

An operator strokes their fingers synchronously with two brushes: the visual argument for the rubber hand, the sensory argument for the real hand.

The operator then unexpectedly took out a hammer and tapped on the rubber hand.

The participant withdraws their (real) hand. The user has been tricked by the illusion of incarnation. This experience also works very well in virtual reality.



3.4

Environments

360° video

This consists of filming the environment in which you want to immerse the user with a 360° camera which, as the name suggests, films at 360° (i.e. it films everything around you). The video, edited and enhanced, will then be viewed using a virtual reality headset in which the viewer's can look in any direction. Interactions are very limited, and often just involve choosing between two videos.

360° video is not part of Milgram's continuum and is not always considered virtual reality. It is true that it offers no spatiality, the user has no visible body, it doesn't allow pseudo-natural interactions (grabbing an object, etc.), and that it isn't 'generative', in other words the only actions available are those that have been scripted and shot in advance.

However, it offers entry-level content based on real-life situations at a reasonable cost. Together with interaction design platforms (Uptale, Wixar, Sphere, Wonda VR, 3Dvista, etc.), it can be used to generate interactive content that can be

accessed from all terminals (headsets, PCs, tablets and even smartphones).

The possibilities offered by 360° video are limited, but can be very useful. A virtual visit in 360° video can be used as part of a teaching sequence to make observations, gain awareness etc. There are also many examples in the field of careers guidance and retraining to help introduce people to different professions.

Photogrammetry & lasergrammetry

Photogrammetry involves reconstructing an object or environment in 3D using multiple photos taken from different angles. Lasergrammetry works by using Lidar (Light Detection And Ranging) sensors to analyse thousands of laser points per second in order to produce a 3D object or

environment. LiDARs, for example, are used in self-driving cars.

Using these two techniques, it is possible to create what is known as a "digital twin", in other words a 3D model that is faithful to the original and can be used in augmented, mixed or virtual reality.

Other capturing technologies are emerging, such as Nerf (Neural Radiance Field), a reconstruction method using a small number of views (photo or video) and artificial intelligence. This technology is not yet mature enough to produce environments for VR, but it is only a matter of time.

CGI (computer generated imaging)

The idea here is to create an environment and the objects that populate it from scratch using 3D creation software. Structure, texture and all properties are computer-generated. It is this type of content that is found most often in explorable virtual worlds, the precursors of metaverses, the most common examples of which are video games (immersive or otherwise).

Advances in software, particularly in video game engines such as Unreal and Unity, promise to create realistic worlds in which pseudo-natural interactions can occur once the ergonomics of the experience are mastered. The scope of these worlds goes beyond Immersive Learning, but will certainly prove beneficial to it.

Please note: depending on the educational objectives, the level of training, etc., the level of realism of the rendering does not necessarily impact the commitment of the participants and their sensation of immersion.

Lastly, it is possible to integrate an object modelled using photogrammetry or lasergrammetry into a CGI virtual environment, and vice versa.

3.5 Degrees of freedom

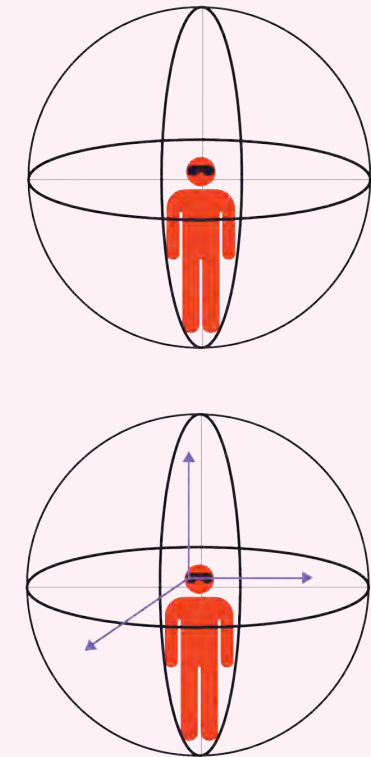
Depending on the type of environment used in an immersive experience, and the level of spatiality on offer, the user can move around it by walking, if the available real space is large enough, or more generally using controllers. This notion of spatiality is often

summarised in the Degrees Of Freedom (DOF) offered by headsets. The important thing to remember is that, depending on the technology used, your ability to move around and your associated experience will be very different.

Headsets with **3 degrees of freedom** (3DOF) allow you to look around yourself and are only capable of simulating head movements (up-down, left-right, sideways). They do not allow detection of your movements in real space and therefore do not allow you to move around in the virtual space. The user can teleport from one point to another, but no more than that.

Headsets with 6 degrees of freedom (6DOF), on the other hand, allow you to move around in the virtual environment and access its space. This means that your movements in the real world are taken into account in the virtual world. You can move forwards and backwards, left and right in a side-to-side style, and go up and down. This means you don't have to use the controllers to get around.

However, in practice movement is also restricted by the size of the "movement zone", which is generally around 3 metres by 3 metres. We often use controllers and teleportation (or translation) to move around in virtual space while remaining stationary in the real world. The ability to move around is used for micro-movements, turning around and exploring the space around us.



Immersive experiences offering freedom of movement and motion as close as possible to reality use headsets with 6 degrees of freedom (6DOF).

3.6

The avatar

What is an avatar in virtual reality?

It is both a body given to us that allows us to inhabit the virtual world and a representation of ourselves that we show to others.

Unless we have a virtual mirror, we are unable to see our avatar in its entirety: hands and part of the body, mainly the legs. However, in our own eyes this is enough to embody us in virtual reality.

A number of questions naturally arise: does our avatar need to be realistic? And can it be? Does it have to look like us? There is no single answer to these questions. This question of representation arises mainly in the context of multi-player experiences. Let's try to shed some light on the matter.

First of all, it's not always necessary for an avatar to be realistic, it depends on the experience offered. A collaborative prototyping application, for example. The focus is not on the relationship with other users, but on the object they are creating together. Here, a simple suggestion is enough here for users to be 'present' and situate them in the space.

In contrast, in an experience based on conversational exchange with other users, the need for realism comes to the fore. In this case, how realistic do we need to be?

We're used to interpreting the humans we come into contact with. It doesn't take much for an avatar to become grotesque, more 'repulsive' than attractive. This is the uncanny valley, well known in robotics. That's why it's sometimes better to have a cartoon-style avatar, like the ones in Ready Player Me⁹¹.

So what would be the holy grail of a realistic avatar?

- + A faithful representation of yourself with realistic movements. Poor reproduction of body movements can make a user suspect in the eyes of

other users⁹².

- + An accomplished facial expression⁹³.
- + For applications based on social and conversational exchanges, non-verbal communication is the holy grail. We're not there yet, but we're getting closer.

Does our avatar have to look like us?

Once again, it depends on the objective of the experience. If this requires you to project yourself into someone else's skin, it is preferable that the avatar does not look like you. On the other hand, for professional meetings in VR, looking like yourself is more advisable. Using an avatar modelled in your own image using photogrammetry or lasergrammetry is ideal, if possible of course.

3.7

The Proteus effect

Researchers such as Jeremy Bailenson and Mel Slater from Stanford University (USA) have shown that the identity a person assumes in a virtual environment changes the way that person perceives and acts in real life⁹⁴. This is known as the Proteus effect.

This research shows that when people are represented in the virtual form of a superhero, their confidence, prosocial behaviour and even cognitive performance are boosted. An experiment carried out by psychology researchers has shown that individuals embodying Einstein⁹⁵ in virtual reality found it easier to solve

physics problems than other participants who were just being themselves. Similarly, when participants see themselves with avatars of elderly people, they develop greater empathy towards elderly people in real life⁹⁶.

For example, Mel Salter and his colleagues conducted an experiment in which mothers took on the avatar of a child, and were asked to interact with a virtual mother whose attitude was either positive or negative. The result? Increased empathy between mothers and their children.

It is for this reason that these researchers have described virtual reality as a potential "empathic machine". This phenomenon opens up interesting possibilities for the use of virtual reality in areas such as education, awareness-raising, training, therapy and other applications where behavioural change is desired or beneficial.

3.8

Multisensory integration

The more an immersive experience mobilises all of our senses simultaneously, the more intense and profound the immersion will be. Sight, hearing, smell, taste and touch, as well as proprioception, thermoception and balance, are all ways of immersing ourselves in the experience and 'tricking' our brains.

This is also the observation that lies behind the paradigm of the three illusions and the feeling of presence. The combination of sight, proprioception and balance creates an illusion that is realistic enough for us to consider it as a form of reality.

We call this **multisensory integration**. This is how our brain combines information from different senses to characterise and recognise an object or an environment. The combination of information enables a

multimodal processing of perceptions, and influences cognitive functions such as attention and memory. The notion of sensory integration was introduced in the 1960s by Anna Jean Ayres, an American occupational therapist, who developed it into a therapeutic approach, used mainly to treat sensory disorders.

One of the first multisensory devices was the Sensorama, often wrongly thought of as the precursor of virtual reality. Among the six films made by Morton Heilig⁹⁷, the most famous simulates a motorbike ride by immersing the user in the streets of Brooklyn with a large amount of sensory stimulation: wide-angle colour stereoscopy, stereophonic sound, a fan, vibration, pizza and exhaust pipe smells.



Le Sensorama (1962)



Did you know?

Multisensory integration processes were widespread in the 19th century, culminating in the attractions at the 1900 Universal Exhibition in Paris and the Maréorama.⁹⁸

Vision

This is one of the main arguments in favour of immersive technologies: creating a vision. Since 2016, displays on headsets have continued to improve.

A brief overview:

+ Stereoscopy

Although there haven't necessarily been any significant improvements in this area, it's worth remembering that all headsets have two screens, one for each eye, to reproduce the way we see the world and access its depths.

+ Display frequency

A sufficient display frequency is essential to avoid eyestrain and cyberkinesia, which can cause nausea, discomfort and dizziness. Almost all VR headsets offer a frequency of 90Hz (some go as high as 120 Hz), which is the minimum to protect us from these unwanted effects.

+ Resolution

Achieving the resolution of the human eye is a priority for some manufacturers. To do so, the value of 60 PPD (pixels per degree) must

be exceeded. For now, only Varjo's XR3 can achieve this, and only in the central area of the screens. Most headsets on the market offer a resolution of around 21 PPD, a value that significantly reduces the grid effect: we no longer see the space between pixels.

+ Dynamics

Remember the Oculus Go: pasty images, devoid of black. Since then, progress has been beyond question: Expanded colour range, from the lightest to the darkest shades, increased luminosity and contrast. HDR (High Dynamic Range) rendering appears within reach.

+ Field of vision

The human field of vision is approximately 200°: 130° in the centre for stereoscopic vision plus 35° of peripheral vision for each eye. Apart from Chinese firm Pimax, all manufacturers offer headsets without peripheral vision, with a field of vision of between 95° and 120° - functional but ultimately unnatural.

+ Lenses

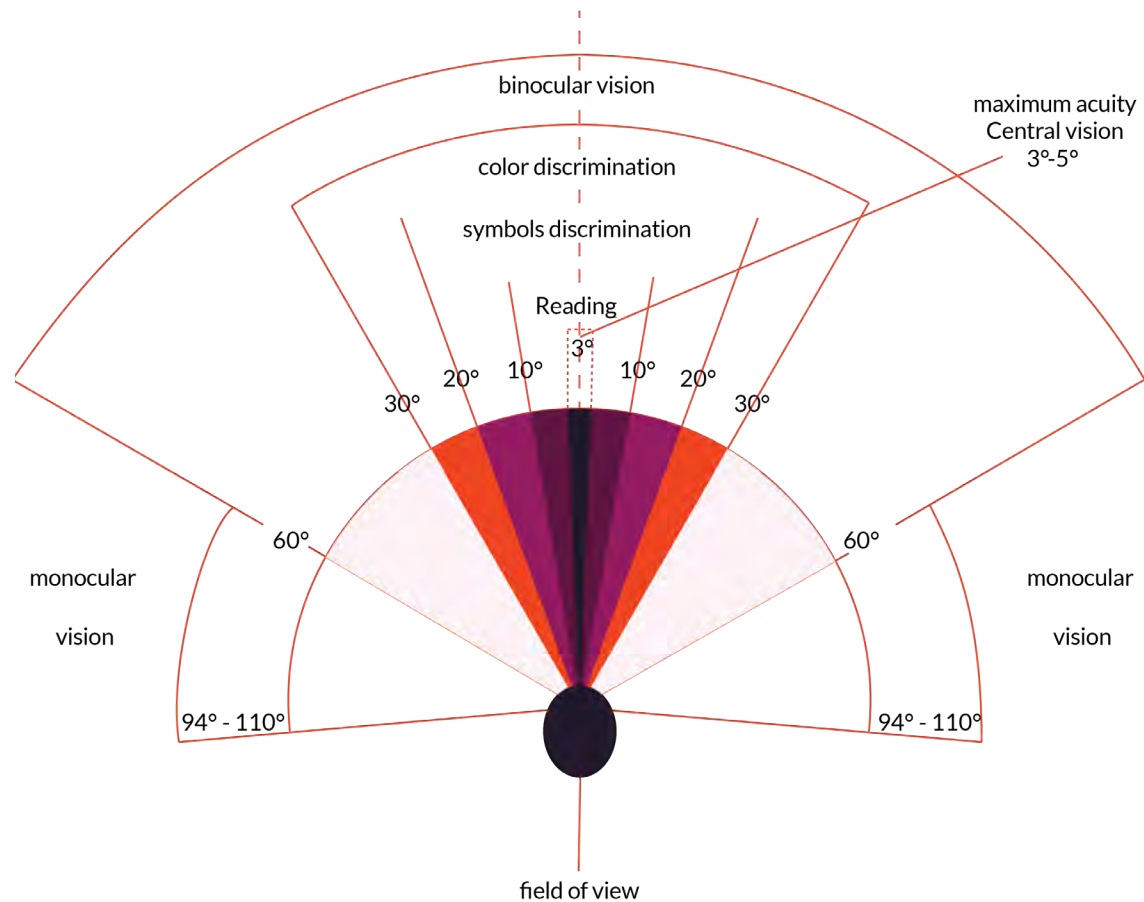
Used on a large number of headsets (Meta Quest 2, for example), Fresnel lenses are gradually being abandoned in favour of Pancake lenses. Their advantage: being thinner, they improve the headset's form factor and also reduce optical distortion.

+ Adjusting the (inter)pupillary distance

Interpupillary distance (IPD) varies according to age, gender and ethnic origin. In absolute terms, it should be possible to vary the IPD from 50 to 77 mm if we don't want to discriminate against women with a smaller IPD, and even down to 40 mm if we want to take children into account, which no headset does: whatever the manufacturer, the IPD varies from 58 to 70 mm, with manual adjustment (continuous or by range), or automatic and motorised, like the Varjo XR3. Let's hope that the trend will be towards greater user consideration for users, because an incorrectly set up IPD can lead to eye strain and cyberkinesia.

+ Varifocal display

This is still an area of research, particularly at Meta, but it's worth mentioning insofar as this display technology would make it possible to resolve the conflict between accommodation and vergence, typical of the use of a stereoscopic display on a screen; a conflict which leads to fatigue and oculomotor disorders (see chapter 8 for more details).



**Accommodation and vergence
in a human eye**

When we look at an object, two phenomena come into play:

- + accommodation, in other words the deformation of the lens to produce a clear image of the object on the retina;
- + vergence, which corresponds to the movement of the eyeballs as they converge to form a single image of the object.

With natural vision, the point of accommodation and the point of vergence are identical.

But in virtual reality, as in so-called 3D cinema (actually stereoscopic), they are different: the point of accommodation is on a fixed plane, depending on the optical system (screen and lenses), while the point of vergence is beyond this, depending on how far away the object is in the virtual environment.

This is known as the Vergence Accommodation Conflict (VAC). This conflict causes eye fatigue and contributes to cyberkinetosis.

Another parameter to take into account: the intra-pupillary distance. It obviously varies according to age. And for adults, it also depends on the individual, their gender and their ethnic origin.

It is between 55 and 70 mm, and lower on average for women. This has led some researchers to say that VR is sexist, made by men for men. In absolute terms, it would be necessary to be able to vary the IPD from 50 to 77 mm, which no headset does. For a Quest 2, the suggested ranges are 58-61, 62-65 and 65-68. They disadvantage women and children, resulting in an increased risk of cyberkinetosis.

Hearing

Sound is 50% of the experience. Some of you will be familiar with this quote from George Lucas. And since almost everyone recognises the sound of a lightsaber and R2D2 in the Star Wars universe, it's fair to say that it's a pretty accurate one. While a picture shows the scene, sound and music are powerful tools that can tell us how we should feel about that scene⁹⁹.

Sounds do not affect us in the same way as images; they have a more direct and faster impact, and are closely linked with our emotions and memory.

Firstly, we now have extensive expertise in audio in VR, with the ability to produce a spatial audio environment in real time¹⁰⁰ or based on ambisonic recordings. This means that sounds are positioned with precision in the virtual space, depending on direction and distance from the user. This fosters immersion and a sense of presence.

Secondly, sound is more direct and immediate than images. While vision requires more complex brain processing, sound is perceived almost instantaneously. The use of sound stimuli therefore boosts reactivity in a virtual environment. Sound fosters an emotional connection to the content and, in so doing, memory, which we know is closely linked to emotions, both in the encoding phase (when we create the memories)

and in the recognition phase (when we try to remember).

Auditory and visual information are processed in separate areas of the brain. Sound is mainly processed in the auditory cortex, located in the temporal lobes, while images are mainly processed in the visual cortex, located in the occipital lobes.

Connections between the auditory cortex and the areas of the brain involved in processing emotions, such as the amygdala and the limbic system, are particularly strong. This allows fast, direct transmission of auditory information to the emotional centres of the brain. The triggering of an emotion by a sound is almost instantaneous, without the need for in-depth analysis. Sound also has the capacity to:

- + stimulate the imagination,
- + evoke memories more easily than images can,
- + occupy the space in a different way from the images.

Sound can come from a greater or lesser distance and from different directions.

Lastly, sound can also be a powerful tool for reinforcing the narrative in virtual reality. Structured dialogue, immersive music and strategically placed sound effects direct the user's attention and reinforce the narrative. Sound helps to create ambiance, indicate important events or provide contextual clues, while enhancing the overall narrative experience.

For all of these reasons, the sound design of an experience should always get our full and undivided attention, and above all: there can be no experience without sound. Some specialist agencies, such as Blanktone, focus their efforts on creating sound worlds¹⁰¹.

Sense of smell

Olfaction, on the other hand, is more complex to master: scents cannot be digitised. This means molecules need to be released. Devices do exist, but they are limited in the number of scents they can offer. Given that we can distinguish between millions of them, it seems a formidable task. It's nothing of the sort. Sometimes just one is enough. The sensory impact is powerful. Unlike images, smell perception does not pass through the frontal lobe and escapes our analysis.

Smell perception is not just a matter for the olfactory system. It activates

Touch, proprioception and thermoception

Tactile perception combines cutaneous, or passive, perception and tactilo-kinesthetic, or active, perception. Why active? Because, unlike the former, it integrates the movement of a body part and takes into account the action of muscles, joints and tendons.

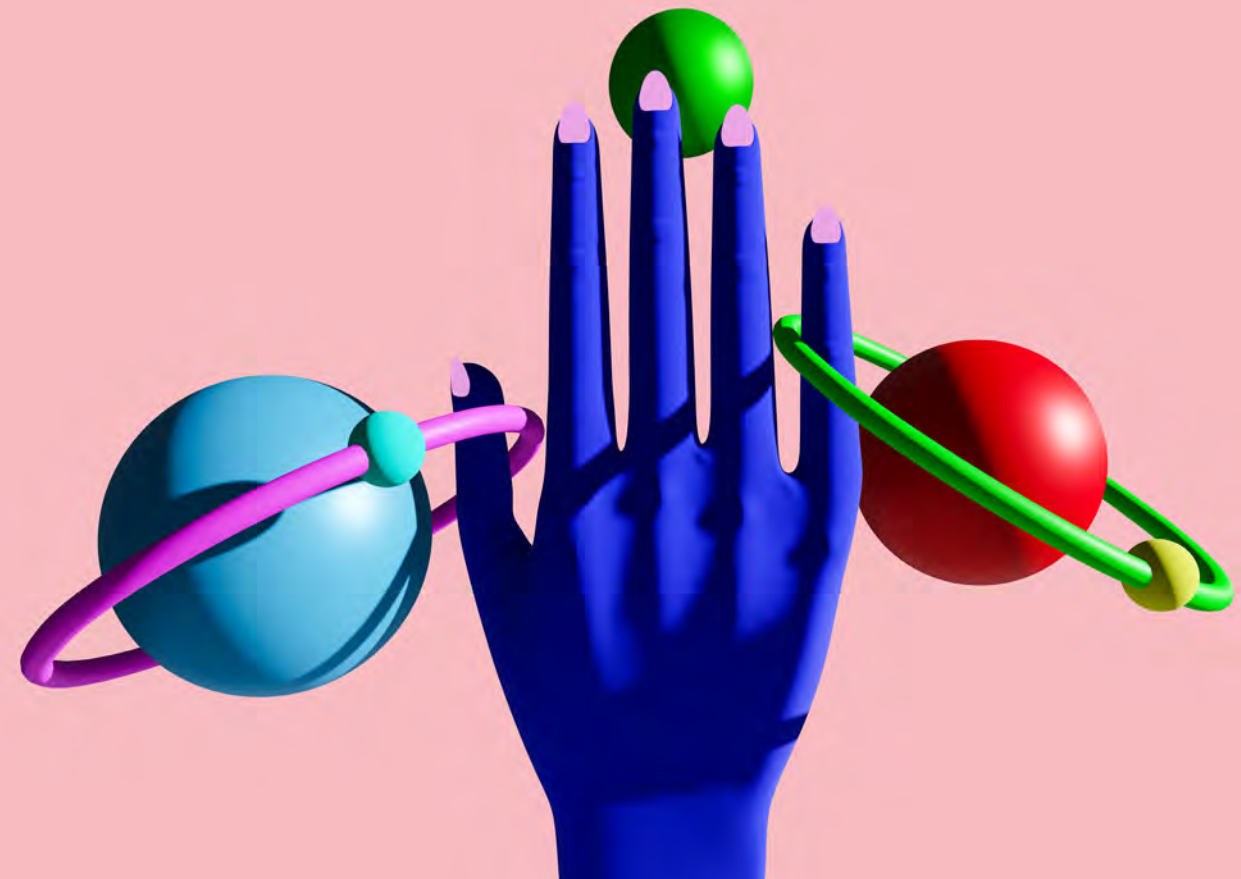
Immersive technologies use various devices to simulate different tactile perceptions: from the simple Birdly fan¹⁰³ to suits and numerous force feedback systems. While some are based on tactile perception and others on tactile-kinesthetic perception, they are generally referred to as haptic interfaces, from the ancient Greek haptomai meaning "I touch".

Among the best known:

- + VR headset controllers: can vibrate and create feedback when the user touches an object. It's certainly haptics at its most basic, but it proves useful and effective in many applications. Note that headsets do not vibrate, except for Sony's PSVR2.
- + There are a particularly large number of force feedback devices, including:

- Gloves that simulate the hardness or softness of a material, giving the user the sensation of grasping a physical object
- Steering wheels used in driving simulators
- Force feedback arms used in 3D design and modelling, surgical training, virtual assembly and other procedures that require a high level of precision (such as the Touch X¹⁰⁴)
- Haptic jackets

In short, while touch simulation is a powerful vector of the feeling of presence, the implementation of haptic devices concerns, for the most part, highly specialised experiences, especially in the industrial and surgical sectors (although, even in the latter sector, researchers continue to wonder about the benefit-cost ratio¹⁰⁵).



8 misconceptions about immersive learning

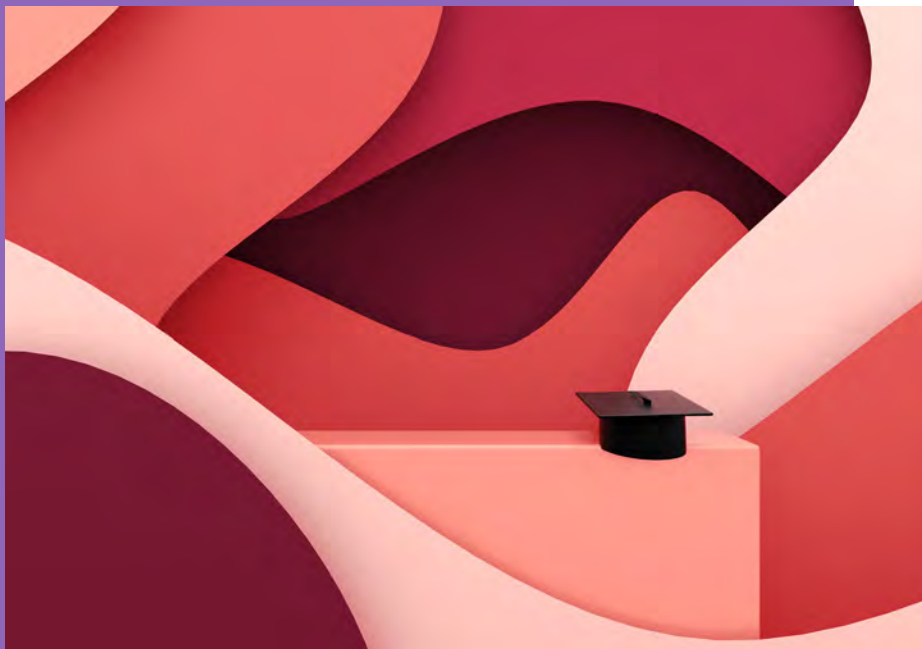
4.1- Misconception no.1: Immersive learning will replace instructors and teachers	101
4.2- Misconception no.2: Immersive technologies make people ill	104
4.3- Misconception no.3: Immersive technologies lack maturity	106
4.3- Misconception no.4: Immersive technologies are too expensive	110
4.5- Misconception no.5: Immersive technologies are reserved for young people and gamers	114



4.6- Misconception no.6: Immersive technologies are isolating	116
4.7- Misconception no.7: Immersive learning is reserved for certain topics	118
4.8- Misconception no.8: You need a headset, not everyone has the equipment	120

Like all innovations based on new technologies, immersive learning receives a lot of attention and generates many misconceptions. That its adoption is in its infancy is also an important factor, as are the sometimes excessive promises made by manufacturers or enthusiastic early adopters.

Let's unravel all this together!



4.1

Misconception no.1 – Immersive learning will replace educators, instructors and teachers

Do you remember everything we heard during the rise of MOOCs in the 2010s? And this prophecy cropped up again for immersive learning.

And this prophecy cropped up again for immersive learning. If MOOCs haven't replaced instructors, why would immersive learning? Firstly, teaching involves an essential human interaction that materialises

through the various roles of an instructor. According to Robert Kegan, a psychologist and professor at Harvard Graduate School of Education (USA), instructors are not just conveyors of knowledge, they are also hosts, coaches, guides, facilitators and mentors.



Instructors are versatile, they provide personalised advice, emotional support and motivation which go beyond what an immersive experience can offer. Their presence promotes engagement, teamwork and social learning.

Furthermore, instructors are able to adapt their teaching approach to the individual needs of learners. They can adjust the pace, explanations and teaching strategies in order to adapt to various learning styles. While immersive methods can offer modifiable and customisable scenarios, they remain at the service of instructors and are far from keeping their promise of a "real-time automatic adaptation thanks to AI". Only instructors are able to adapt to everything, even things they did not anticipate when planning the scenarios,

to answer questions, explain complex concepts and provide concrete examples in real time.

Thirdly, instructors play a crucial role in assessing learners' progress by providing constructive feedback and advice on how they can improve. Of course, learning analytics can be used to assess certain learning outcomes, in the same way as with digital learning, with, for example, scenarios based on an increase in the level of difficulty of the experience to allow the learning process to be regulated. However, we are still a long way from remedial sessions with an instructor

which are invaluable. This is in fact a recurring topic in most of the testimonials collected for this guide.

Finally, training courses are not just about transmitting knowledge. Instructors play a key role in the development of skills such as creativity, teamwork, communication and problem solving. These skills are essential in preparing learners to succeed in a complex and rapidly evolving world. They require authentic human interactions and continuous support.



Key points

Immersive methods require teachers and instructors to change their role and take on roles of facilitators and coaches. In short, learner support is one of the keys factors of success when using immersive methods.

And to be able to provide proper support, you need to be well trained yourself! This is where this misconception comes from. Nowadays, too few instructors and teachers have received proper training in these technologies and the associated educational developments. And even before being trained, too few have been acculturated.

Like all change, adopting a new method requires agility and curiosity. To master virtual spaces, apps and equipment for example, but also to identify the relevant existing resources. Or even to imagine how to lead a session in virtual reality and all the ancillary activities related to its implementation, or to design specific assessment tools, based on the collection of "traces".

There are therefore many biases related to immersive learning, many of which have led to this misconception. They will disappear as more and more people understand how this method works and what is at stake.

4.2

Misconception no.2 – Immersive technologies make people ill

Of all the misconceptions presented here, this one should be handled with caution. It's not enough to think that "it's because we put people on a roller coaster with Google Cardboard in 2015 that people think that immersive technologies make people ill".

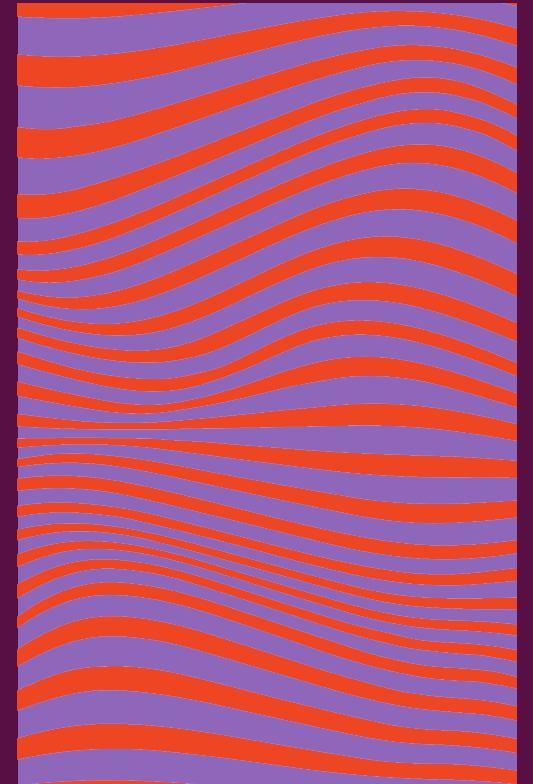
Cybersickness, the scientific term for "technology-induced motion sickness", is a question of equipment performance and particularly display latency and refresh rate (90 Hz is a minimum). It mainly occurs when the latency between visual display and movement is higher than

20 milliseconds and is therefore clearly perceived by the brain.

Today, most latest-generation equipment offer a sufficient latency and refresh rate to avoid this type of problem. A large proportion of users who have tested older and newer generation terminals confirm that they no longer, or to a lesser degree, feel this discomfort.

Many researchers are studying VRISSE (Virtual Reality Symptoms and Effects).

The French Charter of VR recommendations, published par the French VR Ethic Committee in 2019, and the 2021 report published by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES) both pointed out some negative effects of VR.



Key points

As the equipment available on the market improves, cybersickness will gradually disappear, or at least decrease significantly. The industry is still young, and consumer equipment is not always representative of the equipment used in immersive learning. While immersive technologies can make people ill, it is less and less the case.

4.3

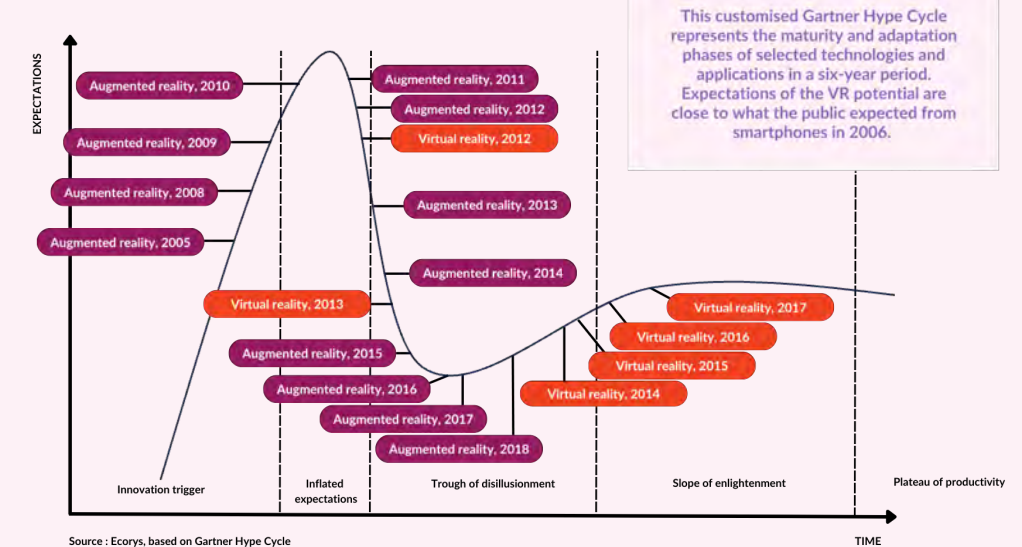
Misconception no.3 – Immersive technologies lack maturity

The first laser printer, the Xerox Star 8010, designed to be used with a personal computer, was launched in 1977. 50 years later, this technology is definitely mature. But who doesn't still encounter printing issues today?

Let's not be more demanding of immersive technologies than we are of printers. Immersive experiences can "crash" due to hardware or software issues. These technologies have however already achieved a sufficient level of maturity to guarantee functional stability.

When speaking about technological maturity, the Gartner Hype Cycle¹⁰⁶ is commonly used. This graph is the representation of the market's interest in a new technology and is generally thought to be a reliable indicator.

Gartner Hype Cycle for VR and AR



This graph is a representation of the successive phases of the adoption of technologies:

+ Innovation trigger

A potential technological breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. There is often no usable product and commercial visibility is unproven.

+ Peak of inflated expectations

The initial publicity produces many success stories - often accompanied by many failures. Some companies take action, many do not.

+ Trough of disillusionment

Interest wanes as experiments and implementations fail. Producers of technology bow out or fail. Investments continue only if the surviving providers improve their product to the satisfaction of early adopters.

+ Slope of enlightenment

More examples of how the technology can benefit the company start to crystallise and become more widely understood. Technology providers offer second- and third-generation products. More

companies fund pilots, conservative companies remain cautious.

- + Plateau of productivity
Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market accessibility and relevance are clearly paying off.

According to Gartner, virtual reality and augmented reality are mature technologies: the former came out of Gartner's cycle in 2018, the latter in 2019. In short: these technologies have been adopted by companies and, partly, by the general public as the equipment on offer is of sufficient quality and reliability.

Another approach in assessing the maturity of a technology is the Technology Readiness Level (TRL)¹⁰⁷. As its name suggests, it estimates the maturity level, or readiness, of a technology, right up to its integration in a complete system and its industrialisation.

Initially developed by NASA and the ESA for space operations, it includes nine levels:

- + TRL 1: Basic principles observed
- + TRL 2: Technology concept formulated
- + TRL 3: Experimental proof concept
- + TRL 4: Key components validated in a laboratory environment
- + TRL 5: Technology validated in a relevant environment
- + TRL 6: Technology demonstrated in a simulated reel environment
- + TRL 7: Technology demonstrated in an operational environment
- + TRL 8: System complete and qualified in an operational environment
- + TRL 9: System validated in a real environment

In view of the existing deployments and the uses the general public makes of them, immersive technologies have already reached TRL 9.



Key points

It is the lack of reference points and examples that makes us think that a technology is not mature, as well as the fact that our perception is based on the use of "consumer" equipment that does not perform as well. For the second point, acculturation and training are key to changing this perception.

For the first point, many enlightening use cases exist and are highlighted in this guide as well as on the FIL¹⁰⁸ website. For example, the French bank BPCE implemented a VR simulation of the evacuation of a tall building for its two high-rise buildings recently built in the east of Paris. The experience was deployed to 5,000 of their collaborators without technical issues or breakdowns. Sessions involving 8 people simultaneously immersed in the experience with a HTC Vive Focus 3 headset were set up and led by a trained moderator. Everything went smoothly.

4.4

Misconception no.4 – Immersive technologies are too expensive

Deploying an immersive learning project has a cost. And it can be quite high depending on the scope of the project.

Immersive technologies require adjustments and the purchase of equipment and software, which can be significant, but once again it depends on the magnitude and scope of the project, the desired number of users, the need to create specific content, etc.

In terms of equipment, things have changed a lot over the last few years. The prices have fallen drastically, making these technologies more accessible. In terms of software, many tools and platforms are now available to facilitate the creation of immersive content, without needing advanced programming skills. A lot of open-source content is also available, and many initiatives are being developed to create shared libraries. The French University of Lyon 1 (ICAP) is one example.

In terms of adjustments, in order to reduce costs, it is also possible to start out in "mixed" or "seated" mode. The major French adult training center AFPA, in its South of France site, chose a mixed (cross-device) system so that their immersive experiences could be used through headsets or on regular computers, in a browser. In this way, the immersive experiences are accessible remotely without equipment, and a simple computer room allows learners to begin, even without a headset. This gives organisations more time to get the equipment and gradually adapt their "immersive" room. "Seated mode", which helps organisations avoid totally rearranging a room, is one of the options at the CNAM where certain immersive activities were designed with inclusivity in mind taking into account

various disabilities, from dyslexia to visual impairments and motor deficiencies.

terms of risk prevention at work and safety training.

Every immersive experience can be used by wheelchair-bound learners, and movements such as "bending to pick up an object" are facilitated by a vertical line of light which allows learners to consider that they are able to pick up the object by touching it, however high the controller or the hand is. The inclusivity of immersive experiences allow them to be used while sitting down in a traditional training room.

Furthermore, for activities that require supplies, do not forget to compare the cost of the immersive method to that of the equipment or supplies that are necessary for a traditional lesson. Take the example of the immersive experience with the saw bench covered by Thierry Langouët, Deputy Head at the French Institut Agro in Dijon. More in chapter 6. Creating the real sawing conditions would require a small fortune, as oak trees are extremely expensive. The cost of an immersive experience which allows learners to acquire some of the skills necessary to perform these tasks becomes reasonable, as it is amortised in a few years.

In many cases, immersive technologies also allow learners to practice techniques that they would not have been able to see in traditional training courses, and that they would also not be able to learn in the workplace because they are either too expensive or too dangerous. Indeed, an employer will not put an apprentice in a critical situation just so they can acquire the ability to react correctly. This becomes possible in an immersive environment, just look at what French company Immersive Factory offers in



Key points

Yes, immersive technologies are still quite expensive. But, this method can generate long-term economies of scale, thanks to the possibility, for example, of producing training scenarios ad infinitum at no extra cost. As is the case with all technological methods, costs will also come down as more people adopt them.

Finally, you have probably already faced, at least once in your life, the dilemma of the "risk of doing something vs the risk of not doing something". What risks are we taking by doing something, and what risks are we taking by not doing it? Is the second more important than the first? If it is, despite the risk (of doing something), it is certainly better to go ahead.

And it's the same thing for a budget. For an immersive project, it is sometimes useful to weigh the "cost of doing something vs the cost of not doing something". Keeping in mind that the cost of not doing something isn't always financial. It can focus on:

- + the quality of the training course, and therefore learner employability,
- + learner safety once in a working situation,
- + the cost for the company of any mistakes made by learners,
- + the appeal of the training course and its financial sustainability, etc.

4.5

Misconception no.5 – Immersive technologies are reserved for young people and gamers

Another common misconception about immersive learning is that it is just for young people or video game enthusiasts. Of course, younger generations may feel more comfortable with the idea of putting on a head-mounted display. As some already do so when playing in a private setting. However, immersive learning is not just for this type of audience and can be used effectively by people of all ages.

First of all, you have to bear in mind that the less "polished" result of an immersive experience compared to an ultra-realistic game can be a barrier for gamers, whereas non-gamers wouldn't question it. Next, the intuitive nature of immersive technologies can help overcome certain technological barriers, and allow people who are less comfortable with digital tools to enjoy these learning methods.

Immersive experiences "imitate" reality, so it doesn't necessarily take users a lot of time to adapt¹¹⁰. Of course, users must learn how to move around, grasp objects with controllers or their hands and so on. But, many behaviours and actions feel natural to users, even the least experienced of them: turn your head to look around you or to look down, move your arms to move your hands in the experience and pick up an object or put it on a surface, etc.

Finally, immersive learning training programmes can be designed with the specific needs of each learner in mind, however familiar they are with the technology. The user interface, the difficulty level and the learning pace are customisable to meet each person's needs and preferences. Guidance can be activated by learners if they get lost, the time given to complete an action can be adjusted, and so on.



Keys points

Like smartphones who, in just a few years, went from being used only by younger generations and technophiles to being used by everyone, immersive learning has the potential of improving the learning process for learners from all age groups.

Furthermore, this misconception is exacerbated by the "gaming" aspect of consumer-grade virtual reality headsets.

The arrival of Apple Vision Pro will probably change the way the general public sees immersive technologies.

4.6

Misconception no.6 – Immersive technologies are isolating

It's a well-established belief: immersive learning is a solitary activity and users are isolated in their headsets, cut off from all human interaction. This comes from a perception bias. When we see someone wearing a virtual reality headset, we have the impression that they are completely disconnected from their immediate surroundings because they don't seem to see us and that their experience is solitary. This is less and less the case thanks to two developments: the development of social experiences and platforms and the development of mixed reality technologies.

The parallel with video games is obvious here, as the same reproaches have been levelled at them. When someone is playing a video game, people think that it is a solitary activity and that the player is cut off from the world. But the video game is perhaps a multiplayer game. The player may be writing or speaking to other players, to coordinate, gather information and so on. This is also the case

for immersive learning which provides many opportunities for collective and collaborative learning, allowing, for example, learners to work together in a same virtual environment, collaborate on projects, solve problems together locally or remotely in virtual environments...

This is in fact one of the benefits of immersive learning. Pascal Miché, Head of the Engineering and Innovation Department at CCCA-BTP (an innovative training Center in French Building Industry) describes it further in chapter 5 which is dedicated to use cases. Each learner is assigned a certain number of activities and tasks; the experience allows them to acquire real teamwork skills that they wouldn't have been able to develop otherwise. Finally, who could believe that an experience in mixed reality is isolating?

Its very purpose is to project virtual artefacts and objects into the real space users' occupy so that they can manipulate them. The example of the fire training course offered by previously quoted Baldr Company is compelling. Users see their environment catch fire, and must move around to trigger the alarm, grab a fire extinguisher and put out the fire that has started on their colleagues' desk for example.



Key points

This misconception is mainly due to virtual reality headsets and their use that "cuts" users off from their direct environment by projecting them into another environment where other people might be.

The isolation perceived by people outside of the experience but in the same room as the user, is not really isolation at all. It is a perception bias. Immersive learning is far from being isolating, it can promote teamwork, social interaction and a feeling of belonging to a learning community, well beyond physical boundaries.

Acculturation and training are key to changing this perception. The more this method is used, the more those involved in teaching and training will be trained in these technologies and the less this misconception will spread.

And let's not forget that during remedial sessions, even if the activities are individual, the sharing and exchanges that take place "connect" learners!

4.7

Misconception no.7 – Immersive learning is reserved for certain topics

Of course, some topics are more suited to immersive learning than others. Technical, medical and safety training already include immersive learning sequences, insofar as they usually require manipulations or simulations that can be effectively reproduced in a virtual environment.

But this method can be used in other areas. For mathematical calculation or hard sciences for example, immersive technologies allow 3D visualisations or even the manipulation of objects which are very useful in gaining a better understanding of the theoretical concepts being studied. This is particularly the case for "intangible" concepts and interactions such as solid geometry, the manipulation of

the infinitely small (molecules, atoms) or the infinitely big (planets, black holes).

For history and geography, even though the benefits in terms of learning gain merit further scientific study, immersive technologies could help learners project themselves into the situations described, feel emotions and thus contribute to a better memorisation of the concepts covered.

Learning foreign languages, or finding a career path through the discovery of trades also benefit from the contribution

of immersive technologies. That use case of Nantes University (Fr) is described further in Chapter 5.

Philosophy, literature and even certain social sciences may not benefit as much from immersive learning. These academic fields often require debates, discussions, critical thinking and deep textual analysis. It may be more difficult to transpose them in a virtual environment.



Key points

Immersive learning is still in its infancy. Although relevant, effective and long-term use cases exist, the full range of possibilities has not yet been explored. The next few years are going to be exciting.

Chapter 6 of this guide provides a good preview of what the future of learning could look like if immersive methods were more widely adopted. You will find a wide range of examples and real-life feedback.

4.8

Misconception no.8 – You need a headset, not everyone has the equipment

The answer to this question is simple. Yes, we need equipment. But we can acquire it gradually.

With a headset, immersive technologies realise their full potential, obviously. But, as we have already said in this book, an immersive activity can sometimes be deployed in "degraded" mode, on a computer, in order to ensure wider technological accessibility. In this way, the activity can be completed remotely, and if there are not enough headsets available, learners can switch between experiences "in the headset" and "on the computer".

Furthermore, during a session, the learners who are not equipped are not necessarily passive spectators, it can be part of the teaching approach. It is absolutely possible to involve them in the

activity. For example, they can be given the role of active observer where they are in charge of part of the remedial period, or they can "guide" the learners completing the immersive activity.

Finally, as we have already said, the material costs are falling drastically. In a few years' time, equipment will no longer be an issue. Nowadays, no one questions the presence of video projectors, computers and so on in classrooms and training rooms. And this will also be the case for immersive technologies.



Key points

We promote a vision of immersive learning where learners do not train remotely from home, but continue to go to training centres, vocational training centres, schools, companies and so on. In this way, the burden and need for equipment is not placed on the shoulders of the learners but those involved in training (organisations, universities, companies, etc.).

The real-world feedback, collected in the overview of uses, confirms that learners are never asked to buy immersive technology equipment.

Overview of uses and feedback

5.1– Introduction: a picture is worth a thousand words	124
5.2– A few cases under the microscope	126
5.3– Stakeholder testimonials	144



chapter 5

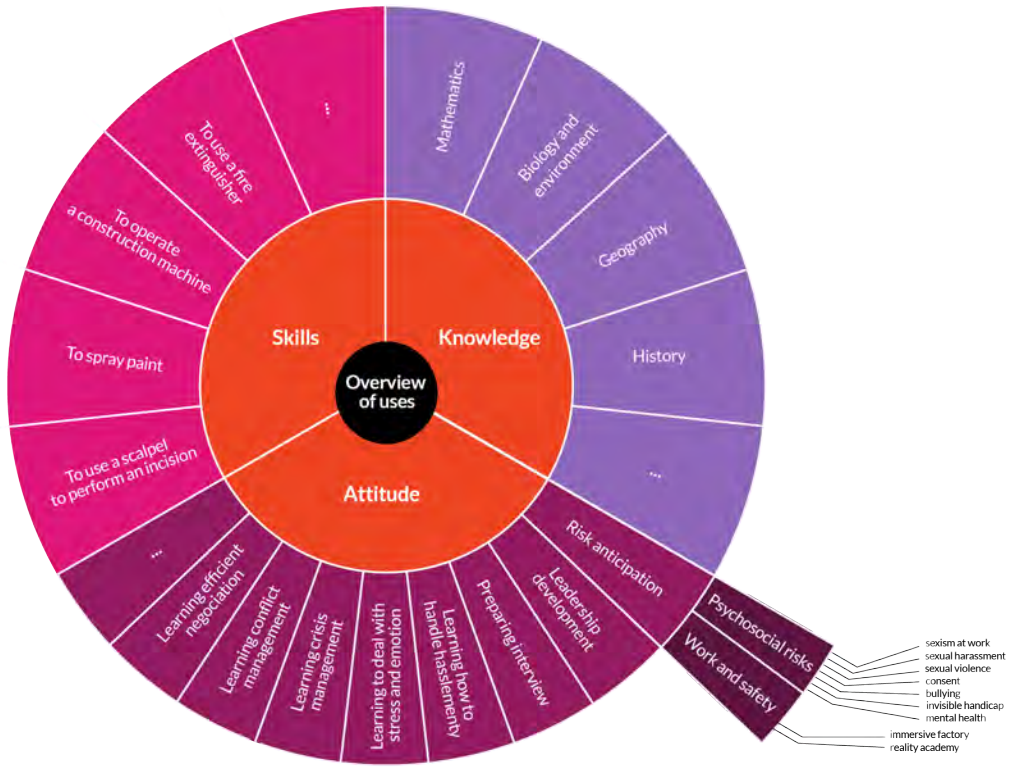


5.1

Introduction:
a picture is worth a
thousand words

Immersive technologies can be used in all types of organisations and whatever the level of learning provided that the activities offered have been designed to take into account the context, the specific characteristics of the target audience and the teaching objectives to achieve in terms of knowledge, expertise and interpersonal skills.

In order to provide an overview of the possibilities, we met many French pioneers of the industry such as secondary schools, higher education institutions, vocational training centres, companies or even a museum ! They all agreed to share their experiences about how they use immersive learning. We are aware many other interesting experiences exist all over the world. We hope to be able collect and report some in the future.



A wide panel of skills can be developed thanks to XR

5.2

A few cases under the microscope

Revisiting how solid geometry is taught in secondary school: an experiment carried out by the French Ministry of Education

- + **Level of education:** Secondary school
- + **Technology used:** Virtual Reality
- + **Organization:** National Education (FR)
- + **Context:** Mathematics lesson

Context and issues

Teachers and pupils often find teaching and learning solid geometry very difficult, mostly due to the teaching materials available. Parallel perspective drawings are difficult to read and create, and it is complicated to use them to solve a geometry problem. Wooden or plastic models make it easier to perceive three-dimensional objects but they cannot be modified and do not allow for reflective activities, which is the aim of secondary school geometry.

Solution

An experiment was therefore set up to meet this challenge using virtual reality (VR). The premise: a 3D model that can be created, manipulated and modified, thus going further than drawings and wooden models.

Method

The experiment lasted 2 years and used two types of equipment & software: HTC Vive with the Handwriter app and Oculus Quest 2 with the Gravity Sketch app. These tools enabled pupils to create and manipulate 3D geometric objects, making them easier to understand.

Benefits and impact

As well as their sight and hearing, the pupils' bodies are also mobilised via their movements. This reinforces the visual representation pupils have of

geometrical objects and their properties.

Another benefit of using VR: once pupils have created their prism or pyramid, and have spatially manipulated it by rotating it in all directions, they can enlarge it considerably. They can then look at it in two ways: go round it by moving about in the virtual space or observe it from the inside.

Teachers no longer simply replicate existing activities, they create new ones that take full advantage of the possibilities provided by the virtual environment. They are forced to change their teaching methods by including, among other things, movements and the physical aspect to a great extent.

Future challenges

The experiment revealed two main requirements:

- + The necessity of having a room dedicated to teaching in small groups
- + The need for apps specially designed for teaching solid geometry

In short



This experiment illustrates the potential of immersive technologies in education, whatever the subject, both in terms of benefits for the pupils and the teachers. It is also a good example of the redefinition of teaching opportunities, within the meaning of the SAMR Model, made possible by immersive technologies.

Recreating a chemistry lab in VR: when the Cnam virtualises Science

- + **Level of education:** Higher education
- + **Technology used:** Virtual Reality
- + **Organization:** Cnam Paris (FR)
- + **Partners:** Mimbus (FR)
- + **Context:** Practical chemistry work
- + **Scope:** 200 students trained in 2023

Context and issues

In 2020, the Cnam Paris, under Thierry Koscielniak National Head of Digital, launched a virtual reality app for practical chemistry work in partnership with Mimbus. Faced with a decreasing number of hours devoted to practical work but a still high number of technical skills students need to be taught, this initiative aims to optimise learning in the laboratory.

Solution

A chemistry lab was therefore created in VR, a true "digital twin" of the real lab. The project team driven by Maïté Sylla, professor at the Cnam, and which brought together a group of 16 teacher-researchers as well as the National Head of Digital then set up detailed teaching scenarios for each module. The app is connected to Mimbus' Vulcan platform and allows teachers to monitor the progress of each student individually.

Method

The app offers three levels of difficulty for each module, which allows gradual skill improvement. The modules are designed to be used before, during and after the practical work carried out in the lab. They cover aspects related to safety in the lab as well as specific practical work:

- + A module where learners "visit" the lab to learn how to use personal protective equipment (PPE),
- + a module where students learn how to identify and describe collective protective equipment (CPE),
- + three safety modules including simulation exercises on cut hazards, projection hazards and inhalation hazards,
- + several modules that focus on practical work and faithfully reproduce the expected processes and manipulations (weighing, making solutions, using reagents and various devices).

Benefits and impact

The app was well received by the 200 students trained in 2023 as well as the teachers. It allows for better student memorisation and engagement, while offering teachers a rewarding teaching tool. In addition, it takes into account accessibility for students with disabilities.

In short



Introducing this type of device enhances our teaching practices, increases the impact of our lessons and changes the way we transmit knowledge. It gives us a new type of pleasure in teaching and breaks down the barriers between subjects, which encourages the sharing of knowledge.

Maïté Sylla

MR supporting additive manufacturing: assimilating complex procedures in engineering school

- + **Level of education:** Higher education
- + **Technology used:** Virtual Reality
- + **Organization:** CESI (FR)
- + **Aline Becq**
- + **Partners:** Spectral TMS Solution (FR)
- + **Context:** Practical work in additive manufacturing
- + **Scope:** 50 previously trained students
- goal of training 30 students per year

The CESI

The CESI is a higher education and vocational training campus with over 28,000 students on its 25 campuses located all over France. It accompanies its learners in 3 sectors: IT and digital technology, industry and construction and includes a reputable engineering school.

Context and issues

The CESI, in partnership with a company specialised in mixed reality (Spectral TMS), offers a course to the learner engineers who chose to specialise in additive manufacturing. This course allows students to get to grips with the complex procedures involved in using industrial machinery, in addition to metal 3D printers.
The immersive experience was created to digitise and standardise the operation procedures of post-processing machinery that depend on an autonomous metal additive manufacturing unit. New

operators/learners learn how to operate the machines used to clean and finalise metal printed parts.

Method

This training course requires the use of mixed reality headsets (Hololens 2) and retransmission screens to guide learners through the various steps of the procedures immersively.

Length of the experience: 20 minutes
A session includes:

- + **Presentation of the mixed reality headset:** at the beginning of the course, students learn how to use a mixed reality headset. They learn how to manipulate it and use movements to interact with the virtual environment.
- + **Immersive guidance:** students are given mixed reality headsets and are guided through the steps of industrial procedures. The procedures are presented immersively, allowing learners to visualise and interact with real machines.

- + **Safety training:** learners also learn about the associated safety aspects, including wearing personal protective equipment (PPE) and managing the risks posed by industrial machines.
- + **Assessment:** although the training course doesn't focus primarily on a formal assessment, observations are made to estimate information retention and the effectiveness of the course. The solution allows the retrieval of data on how the sessions went (time it took to complete the scenario, steps that caused issues, etc.).

Note: the mixed reality training project is constantly evolving, constantly growing. Adjustments are made following feedback from students and instructors. The goal is to constantly improve the learning experience. This is why a no-code solution was chosen: to enable supervisors to modify the content autonomously.

Benefits and impact

- + Improving information retention thanks to immersion.
- + Learning industrial procedures safely.
- + Possibility of reviewing the procedures at any time thanks to the smartphone app.
- + An innovative and motivating learning experience for students.
- + The training course requires less time compared to a traditional course.

Challenges

- + Managing the mixed reality headsets.
- + Variable fluidity of the virtual experience depending on the quality of the network connexion.
- + Adapting the training course to various types of learners, including "technophobes".

What's next?



The institution is also exploring other immersive learning scenarios and is investigating the complementarities with the use of digital twins in education.

Improve your English thanks to VR at Nantes University

- + **Level of education:** Higher education
- + **Technology used:** Virtual Reality
- + **Organization:** Nantes University – referents: Yannick Prié, Jérémie Coris, Sarah Rosenfeld
- + **Context:** English language lessons
- + **Scope:** from October to December 2022, 10 students in the 1st year of their Master's programme + 1 teacher + 1 observer

Nantes University

Nantes University is a public higher education institution with 43,000 students of which 5,000 are foreign. It is unique in France, it includes: a university, a university hospital (CHU de Nantes), an institute for technological research (IRT Jules Verne), a national research organisation (Inserm) and "grandes écoles" (Centrale Nantes, École des Beaux-Arts Nantes Saint-Nazaire, École d'Architecture de Nantes).

Context and issues

This research project was led by Jérémy Coris, a student in the 2nd year of his Master's programme. He is studying the use of the metaverse in higher education. His research topic focuses, particularly through this experience, on the use of collaborative, 3D and persistent virtual environments. Sarah Rosenfeld, an English language teacher also worked with Jérémy

Coris within the framework of her lessons at the university.

Solution

An experience on the use of collaborative, 3D and persistent virtual environments when teaching languages remotely. The platform "Spatial" was selected, rather than Engage, Shapes XR, or even Workrooms. The experience required a persistent, open and configurable environment which allowed elements to be imported, created, manipulated and modified. Ten students in the 1st year of their Master's programme were mobilised and each were given a head-mounted display that they used "at home". A teacher and an observer were also part of the team.

Method

The experience was co-designed in 3 stages:

- + Appropriation of the systems by teachers and students (onboarding)
- + Selection and appropriation of the environment
- + Environment co-designed by the teacher and the students

Its use is spread over 4 or 5 sessions in which several ludic simulation activities are offered.

Benefits and impact

The bodily "interactions" enabled by immersive technologies energised the exchanges and improved the quality of the debates. Using an avatar made it easier to play a "role" and helped learners debate and get involved more easily. Interactions were spontaneous and light-hearted where the same activity was laborious via Zoom. The environment kept track of the activities and this helped learners with the memorisation process and to develop the reference points that guided their learning. As the learners were involved in designing the experience, they were better able to assimilate the vocabulary learnt in relation to real-life situations.

What's next?



A second version is expected in 2023-2024 that we hope to be able to report soon. The VR sessions were reworked during a teaching workshop by teams made up of a teacher, a student who attended the lessons, a "teaching engineer" student and staff from the Educational Development Centre. This second version focuses more on teaching objectives and on behavioural and technical skills in a VR environment. And this through a combination of in-person and remote sessions (VR).

Let's focus on safety: BPCE's innovative approach to training its employees

- + **Technology used:** Virtual Reality
- + **Organization:** BPCE
- + **Partners:** I2L, Safety Bus, Emissive and Mocaplab
- + **Context:** Corporate safety training
- + **Scope:** 5,000 employees trained to date

Context and issues

BPCE, a French banking group, moved to its new offices in high-rise buildings in the 13th arrondissement of Paris in early 2023, with a major challenge: train 5,000 employees on the specific evacuation procedures of these high-rise buildings.

Solution

To meet this challenge, Pascal Aubert, Tools and Innovation Leader at Campus BPCE, launched an ambitious VR training project, via a virtual reality app which simulates the buildings' evacuation procedures. This app was developed with the help of several experts, including Immersive Learning Lab, Pierre Elizab  from Safety Bus, Emissive and the motion capture specialist Mocaplab.

Method

The VR app simulates the buildings' evacuation procedure, with a mentor explaining the steps to follow. The premises were recreated accurately, a true "digital twin". The characters, such as the mentor, are very realistic thanks to the motion capture process used to animate them. The teaching scenario follows the evacuation protocol precisely.

Benefits and impact

The app has enabled 5,000 employees to be trained efficiently in record time. The participants found that the simulation was so realistic that they had the impression they had already been to the premises when they moved in. This not only saved time but also resources, by avoiding the need for physical on-site training sessions.

In short



This project illustrates once again how immersive technologies can be used to overcome complex challenges in training. It is a good example of the alternative teaching possibilities, within the meaning of the SAMR Model's substitution level, that immersive technologies can provide.

[[G]host: glass art at Cerfav

- + **Level of education:** Apprenticeship (apprentice training centre, CFA)
- + **Technology used:** Virtual Reality
- + **Organization:** Cerfav
- + **Context:** Practical work manufacturing glass objects
- + **Scope:** second-year apprentices working towards their Certificate of Vocational Aptitude (CAP), each specialising in a glass craft

The Cerfav

The Cerfav (European Research and Training Centre for Glass Arts) is a training centre for apprentices preparing for their CAP in glass arts and techniques. The Cerfav covers the following specialisations: glassblowing - torchworking - stained glass art - glass decoration.

A summary of the [G]host experience: [G]host - Training cycle - Immersive modelling and advanced manufacturing for glass crafts

The objective of this immersive training course is to supplement traditional CAP training with knowledge and skills:

- + taking into account the development of technical creation tools (immersive modeller and tools, additive manufacturing, new glass making techniques, generative AI, XR, etc.),

- + developing, through information and usage, apprentices' critical thinking and creative spirit by covering concepts of technological fantasies,
- + giving apprentices the opportunity to experiment with these notions by studying the permeability between craftsmanship, digital technology and the manual production of real objects.

Organisational methods

The experience is part of a long-term learning path. The immersive aspect is integrated as follows:

- + 3 days of immersive modelling
- + 3 days of advanced digital prototyping
- + 3 days of coaching in the workshop for advanced production
- + 6 days for real production using the content from the previous days

15 days total

Profile of the participants

Second-year apprentices, each specialising in a glass craft.

Number of participants per session

4 (for the experimental version, which depends on the equipment available) + 2 instructors.

Example of a usage scenario

The training cycle includes a 3-day session to familiarise apprentices with immersive 3D models (VR headset) followed by another 3-day session producing (thanks to the generated 3D model) a 3D printing prototype which will then be used to create a glass object in the traditional manner.

Expected results

At the end of the training course, learners must be able to produce a real glass object that combines digital XR (virtual reality, etc.) design techniques and traditional glassblowing techniques, stained glass and the "pate-de-verre" technique.

Results observed

David Arnaud, the project leader, emphasises the great enthusiasm shown by learners in adopting these tools. Many suggestions for improvement, as well as novel usages, beyond glassblowing techniques, have emerged. David Arnaud: "In practical terms, we have already created glass objects thanks to these processes (Multiverre project). We have also seen learners refuse to use these technologies because some wish to move away from these tools".

What's next?



Cervav's proposal is an innovative organisational model in glass art techniques that could be replicated in other courses preparing students for artistic careers.

David Arnaud: "With this experiment, we hope to develop the practical aspect of new skills related to the use of immersive digital tools in constant dialogue with the traditional tools we have at Cervav. These new teaching and learning methods should allow a wider field of creative possibilities for apprentices in a social context of increasing digital development. This experiment follows the path from virtual to real, systematically encouraging the use of sensitive materials in the acquisition of skills, whether they are based on technical, digital or traditional systems".

Fire prevention and first aid at BlaBlaCar

- + **Level:** Skills training -
- + **Organization:** BlaBlaCar (FR)
- + **Context:** Creation of a training course
- + **Scope:** in the workplace

D'un Seul Geste

D'un Seul Geste is an impactful training centre, created with the aim of generalising prevention and first aid techniques. They offer two types of courses: fire prevention and first aid.

Context and issues

The COVID-19 pandemic shook up many companies, particularly in terms of employee training. BlaBlaCar (French community-based carpooling network), like many other companies, had to cancel all in-person training. Furthermore, the rise in remote working and the number of flexible work spaces doesn't make it any easier to set up safety-related training courses in the workplace. "D'un Seul Geste and Blablacar worked together to tackle several issues: setting up essential safety/prevention training on the one hand, and seizing this opportunity to reboot in-person training on the other", said Emmanuel Bourcet, co-founder at D'un seul geste.

Solution: virtual reality training

D'un Seul Geste designed a first responder course in virtual reality to provide workplace fire safety training, in one

hour, in the workplace. The solution uses virtual reality (a headset is necessary - HTC Vive focus 3) and a smart fire extinguisher, which provides a totally immersive experience. As it includes more simulations and realism than traditional training courses, this format has a greater impact and participants feel better prepared and are better able to memorise the techniques. Practising and repeating the techniques removes the fear of taking action.

Method

- There are two phases to these one-hour one-person sessions:
- + 30 minutes of virtual reality to learn how to use a fire extinguisher and what a first responder does in case of a fire
 - + 10 minutes, still immersed in the experience, to practice in a realistic scenario
 - + 20-minute discussion and debrief with the instructor

The training course is led by an instructor who has been trained in this innovative training method and the use of

virtual reality headsets. The one-hour sessions are held in groups of 2 to 4 participants (the number of participants can be increased depending on the company's needs). Participants wear virtual reality headsets and are guided by an instructor. The training course begins with a brief tutorial on how to use the headset, then participants are immersed into the virtual reality environment, where they learn and practice first aid techniques.

Test and deployment phases

D'un Seul Geste and Blablacar started by organising a pilot session which was met with great enthusiasm. The people participating in this session came from various departments. The objective was to test the training course on a population that was representative of the company. BlaBlaCar then decided to extend these training courses to its employees. The 1st year was devoted to first aid training, with an English version to cater to the company's multilingual staff. A training course on fire prevention was added in the 2nd year.

Assessment

During the training course, quizzes were provided to assess the participants' understanding, and they were awarded badges for correctly carrying out the activities. A final assessment, at the end of which a score is given, is used to determine the quality of their actions in a practical scenario in virtual reality.

Benefits

For BlaBlaCar, the benefits are clear: training courses adapted to the new constraints of working from home, a better quality of life at work and increased social responsibility. For D'un Seul Geste, working with a client like BlaBlaCar and carrying out a significant number of sessions allowed them to obtain useful feedback for the organisation's procedure of continuous improvement. New functions were added and others were adjusted to better meet BlaBlaCar's expectations.

In short



The collaboration between D'un Seul Geste and BlaBlaCar shows how virtual reality can be used to provide training flexibly, effectively and engagingly.

Professional immersion: an innovative initiative in career counselling

- + **Technology used:** 360 video
- + **Organization:** Campus des métiers Arts et design (FR), with the support of the Île-de-France Region
- + **Partner:** I2L
- + **Context:** Guiding young people towards professional careers
- + **Scope:** 500 learners per month (CMQE Industrie or Industry Job Campus)

Issues

Initiated in 2020 by Campus des métiers Arts et design, with the support of the Île-de-France Region, the projects aims to use 360° video as a tool in career counselling. The project was set up following several observations, including the potential of 360° video in discovering careers and the need to improve the quality of existing resources.

Solution

Royalty-free 360° videos, using Storyliving to encourage learner engagement, retain their attention and encourage their engagement thanks to a story in which they are directly involved. Under the Creative Commons licence BY-NC-SA-4.0, the videos can be used free of charge for non-commercial activities. They were created in collaboration with industry professionals, particularly when they are intended for secondary schools pupils.

Results and benefits

The project resulted in the production of 6 videos, rolled out in a few secondary schools and in CMQ Industry (French Campus of professions and qualifications). The feedback from learners was very positive. *Content was better assimilated when the sessions took place via the Innovation Centre, as the discovery of careers was then part of the process of discovering the industry – Sophie Uhl, the Campus Executive Operating Officer.*

In short



The project shows the unexplored potential of immersive technologies in career counselling. It also highlights the value of teamwork and sharing resources.

Journey into the heart of Evolution: a VR experience at the National Museum of Natural History

- + **Technology used:** Virtual Reality
- + **Organisation:** National Museum of Natural History (MNHN)
- + **Patron:** Orange
- + **Service provider:** Manzalab
- + **Context:** Scientific outreach
- + **Scope:** Cabinet of Virtual Reality, Gallery of Evolution of the MNHN in Paris

Context and vision

In 2016, the MNHN, with the support of Orange launched "Journey into the heart of Evolution", a virtual reality (VR) experience that focuses on the tree of life. Under the scientific direction of Guillaume Lecointre and digital project manager Stéphanie Targui, this initiative aims to challenge misconceptions concerning evolution, by presenting a more modern and scientific vision of the tree of life.

The technical challenge

The project aims to create a generative VR model of the tree of life, based on the phylogenetic nomenclature. The Orange Lab developed this model and integrated 469 species and their interdependent relationships.

The artistic and educational challenges

Representing the 469 species: the team chose illustrations rather than photos, in order to maintain artistic coherence. The illustrations were produced by Camille Desgardin and validated by the researchers of the MNHN.

Defining a scenario that meets the project's teaching objectives, i.e. to understand the unique origin of living organisms, to understand the principles of the phylogenetic nomenclature and the basis of kinship between species, to understand mass extinctions including the 6th for which we are responsible.

Providing an interactive and narrative experience with both a guided mode to understand the phylogenetic tree and an interaction mode to explore the tree and access 3D models.

Impact

Initially designed as an exhibit, this experience led to the creation of the first permanent space devoted to VR in a museum: the Cabinet of Virtual Reality, under the direction of Marie Wacrenier. The MNHN (France's Natural History Museum) has become a key player in the field of virtual reality and educational immersion.

In short



More than just a museum attraction, this project embodies a new form of scientific outreach combining rigour, teaching objectives and interactivity. It is an invaluable tool for addressing the evolution of species and humankind's place in biodiversity in a fun but serious way.

5.3

Stakeholder testimonials

As shown by the diversity of the use cases previously described, immersive learning has found applications in a variety of contexts. It has been rolled out in many organisations including universities, companies, training centres and start-up companies, and the feedback is enlightening.

We have interviewed 6 French project leaders from a variety of fields. Once again we hope to be able to report more international examples in a future version of this book on in our on-line Observatory of use cases. They agreed to share their thoughts on the benefits of immersive learning, the obstacles, constraints, opportunities, results, etc. Here are their testimonials!

AFPA – immersive technologies used in first-level qualification jobs – comments gathered in April 2023

Interview with Magali Sirerols, Regional Director of Engineering and Innovation at the AFPA for the PACA region – March 2023

Magali Sirerols, from the AFPA, the National Agency for Adult Vocational Training, provides feedback on a project that used virtual reality to revisit level 3 and 4 qualification training courses. As project leader, she describes the major steps and levers needed to motivate the stakeholders. She discusses the support required when adopting immersive technologies as well as the gradual integration of the "immersive" method.

+ Can you introduce yourself and explain what motivated you to set up a project using immersive technologies?

I am the Regional Director of Engineering and Innovation for the PACA region. I have an academic background as a teacher-researcher in cognitive science. My role involves deploying innovations in-house, as well as promoting the AFPA and its capacity for innovation on a regional scale.

The project we are talking about is special, because I was temporarily the director of the AFPA in Istres, and the aim was to reposition this centre to allow it to once more shine throughout the country.

We worked in partnership with universities and a laboratory called "Immersive-CoLab", which is associated with the National Centre for Distance Education (CNED) and research labs. We wondered how we could use immersive technologies to break new ground in training, particularly in 3rd and 4th level qualification jobs in industry, social services and catering.

We decided to reply to a call for projects within the framework of the Regional Skills Investment Plan and we obtained €400,000 in funding, for a project led by the national employment centre, Pôle Emploi, which aims to measure our ability to introduce immersive technologies. We understood the challenges this represented, especially in terms of complementarity with our existing digital tools, and particularly our METIS platform which is already effective.

Anxious to explore this method in its entirety, we worked with researchers who studied the Latour effect on avatarization. Avartarization is a concept that allows users to identify with an avatar in a virtual environment, which creates a unique immersive experience. We did not overlook the

potential risks of addiction for users, considering the sensory and emotional elements that do not exist in conventional interactions between humans and machines.

Our goal was to use immersive technologies to transform the learning process, starting with an initial stage of **experimental protocols on what we gain and what we lose**. We can see that learners are completely uninhibited. For example, when learning a language, when it's my avatar that's talking, I'm less embarrassed.

So we decided to use the immersive method.

We have committed to 20% of the total training course, because we have to go gradually to allow the instructors and learners to get used to the method. Furthermore, we chose a combination of in-person and remote sessions, to avoid total isolation.

The instructors worked with Immersive-CoLab to design 20% of their course using virtual reality. They reproduced training platforms, this was reassuring to start with. However, we believe that the real benefits of immersing technologies lie elsewhere.

We spent almost a year creating the spaces, training the instructors and mobilising the teams in charge of training and support. We also thought of how to mobilise job seekers and the training courses started in March 2023. We have to finalise the systems by the end of June.

+ Can you explain how you mobilised the instructors and what were their first reactions?

When we presented the project about a year and a half ago, the instructors embraced the idea.

We were able to get them involved by getting them to co-design the virtual spaces with Immersive-CoLab. They learnt how to work directly on the platform for the design part. At each step, they wondered how to word the instructions, what they'd observe and assess.

They chose to create technical sessions and cross-disciplinary sessions. They created spaces where they could interact with learners, moments where free expression and collective intelligence are encouraged. This type of activity is made easier by the use of avatars.

The virtual space itself would be of little use if the instructors hadn't thought of these different situations beforehand. It doesn't take long to see all there is to see of a virtual space, and if nothing happens, people don't come back. It's thanks to this

preparation and design work that we were able to make it their own.

In some cases, the systems were implemented by instructors with fixed-term contracts who did not take part in designing the spaces and need to adapt. The future will tell us how they adapted to these new environments.

Pôle Emploi chose which training courses to put in place depending on the local employment needs, particularly in social services and industry. Therefore, we did not choose the instructors. I was very clear at the beginning and explained that we were taking an experimental approach, that it could take instructors a while to get used to these new tools, that recipients might hesitate to use them, and that a certain amount of resistance could emerge. This is part and parcel of the experimental nature of this initiative.

+ How did the first experiences with learners go?

So far, it's going rather well. However, adoption is not spontaneous. If instructors do not assist learners in using the platform or encourage them to get involved, the platform is of little use. It takes on its full potential in a collective setting.

We encountered a few cases of technophobia, with people reluctant to use the tool. We had already seen this reluctance in the past, particularly with our METIS platform.

In a few months, we will have more data on these experiments.

Today, I can share our experience of the upstream stages, from preparation to launch. I know that people are rather intrigued by the idea, including those with lower level qualifications, because it allows them to work from home and test "blended learning". But the main question is how to encourage them to be actively involved.

If someone simply logs in and does nothing else, we risk losing them. By observing an avatar, we can see whether they are having difficulties and offer assistance. The platform takes on its full potential in a collective setting.

+ Which technologies did you use for this project?

The technology we use is adapted to and can be adapted to virtual reality headsets. However, we made sure that they can be used with computers that are not very powerful. This means that the quality of the graphics won't be as good, of course, but it allows learners to use them at home.

+ **Did you have to rethink your training spaces?**

For the moment, we have dedicated spaces with computers fully equipped for this new technology. But, we encountered issues related to security systems, some ports had to be opened. This has to be anticipated from the outset.

We didn't realise that this would be a problem, without this, we would have been able to let learners work from whichever computer station they wanted. It's important to reiterate that transitioning to a virtual environment can be done gradually, and you don't need to roll everything out online overnight.

We also noticed that some instructors tend to reproduce their habits and practices in virtual environments, even though they have access to many features. This reflects that fact that people tend to recreate their habits in order to feel comfortable, even in a virtual environment. We see that remedial spaces are gradually evolving towards more creative environments, and this will allow us to further explore the possibilities offered by immersive experiences.

+ **Can you explain the researchers' role in this project?**

The researchers are working closely with Immersive-CoLab, who is directly involved in the project. They came to the site and will work with the data collected. The

experimental protocol was developed with their input.

+ **What are your deployment prospects for this project?**

We plan to set up incubators to further explore issues related to the virtuality of learning and the necessary engineering. We hope to play an active role in this field, as do some of our instructors.

However, funding is a major challenge, because developing these technologies is costly in terms of engineering. The systems aren't yet mature enough for us to quickly integrate the necessary engineering and involve all the players. We were able to carry out this project thanks to funding from the Regional Skills Investment Plan, which covers one year's work for only 5 training courses, on the basis of 20% of the total length of these courses. We wouldn't have been able to implement this project without this funding.

In any event, I am convinced that we have to quickly move in this direction.

+ **In your opinion, what will the world of training look like in 20 years?**

I can already see significant change, especially in the diversity of formats, the multi-modality and reduced training periods. No profession will be able to do without these new technologies. I also think that companies will jump on board.

Virtual reality and workplace training can work together very well. Some things can be carried out by learners in the real world, without any risk to the tutor...

I think using immersive technologies is unavoidable. But it won't take off as quickly as we thought, it's still a revolution. When we see that learning platforms haven't yet been adopted by everyone, we have to be realistic about how far we still have left to go.

CCCA-BTP – immersive technologies to acquire skills

Interview with Pascal Miché, Head of the Engineering and Innovation Department at CCCA-BTP, a national joint professional association, in charge of coordinating the apprenticeship training policy in construction and public works – March 2023

Pascal Miché, of CCCA-BTP highlights the major role played by the CCCA-BTP and the Engineering and Innovation Department in vocational training in construction. The CCCA-BTP, on the strength of 82 years of experience, has evolved to meet the ever changing needs of young learners and training centres. The focus is very much on adopting immersive solutions, including virtual reality, to reinforce the link between theoretical and practical skills. In this interview, are mentioned the current challenges, such as the dissemination of immersive methods and the development costs, while highlighting the importance of training instructors and being collectively involved in shaping the future of learning in construction.

+ **Can you tell us about the CCCA-BTP, the Engineering and Innovation Department, and what led you to suggest immersive solutions?**

The CCCA-BTP is the joint body responsible for apprenticeship training policy in construction and public works. Its governing board consists of representatives

of professional bodies, trade unions, the government and the French Ministry of Education. It has existed for 82 years and was set up after the war to train the future workforce. It provides training materials that allow employees to train remotely. An avant-garde approach for the time!

However, it quickly became clear that distance learning was not enough. It seemed necessary to teach the future workforce the expected professional skills, and to do so, technical platforms were needed. The CCCA co-funded, with regional committees, the construction of joint training centres all over France, there are 76 of them today. These centres are designed to provide apprentices with work-linked training in construction and public works.

After the Avenir Pro law of 2018, the CCCA's role evolved. It is no longer the network leader, but it now provides services to all training centres that offer courses in construction and public works, which is around 450 centres. The CCCA assists these centres with the quality of their courses, the development of their instructors' skills and the accreditation of their courses.

As the Head of the Engineering and Innovation Department, I am responsible for

encouraging innovation in our sector. This is what has set us apart from our competitors in other sectors, and particularly in terms of the appeal of training in construction and public works.

Nowadays, young people have different expectations, their hobbies and habits have evolved. Training centres have to change their teaching methods. The "Avenir Pro" or "professional future" law introduced the possibility for young people to enrol in any training course at any time, and this until the age of 29, which was ground-breaking for training centres.

This is why the CCCA has been working on modularising training courses since 2018. This approach involves dividing courses into skill sets which are then divided into training modules. The more modular the course, the easier it is to take on an apprentice at any time, with a direct link to what they will be doing in the company. This approach with skill sets makes it easier to set up hybrid training courses and adapt to the heterogeneity of learners. The CCCA designed a process to facilitate modularisation. Incidentally, we have just released a guide "The Modularisation of Courses", presented in Cannes at the Université d'hiver de la formation professionnelle.

We also explored various teaching methods, including distance learning and the creation of a LCMS to enable instructors to develop training capsules and modules. Today, Aptyce has 50,000 users, instructors and learners.

This platform can be used for both enhanced in-person sessions and remote sessions. In enhanced in-person sessions, a youngster can follow a differentiated learning path. They do not take part in the session in the same way as others, and have access to a specific course on their computer or tablet.

Distance learning also provides opportunities. Between the first and second stages of the apprenticeship, learners can spend half a day, a whole day, or even two days working remotely. This approach aims to prepare future lessons or to go further with what has already been covered.

More recently, immersive methods have joined these ones, perfectly complementing traditional training.

Learners attending a course must now juggle between activities on a building site and those provided by the training centre. In a company setting, they are active; in a training centre, they acquire theoretical knowledge and skills. One critical element is missing: the acquisition of

autonomy. For this, they need knowledge and method.

Immersive learning has become a crucial tool to bridge this gap. This method allows instructors to put in place activities that would be impossible to carry out in workshops. After having asked them about activities that are carried out in the workplace and complicated, even impossible to reproduce due to a lack of space in training centres... Unsurprisingly, there are many, which enabled us to catalogue the modules that needed to be created.

Our starting point: no virtual reality module works if the scenario is not adapted to the target activity. The aim of training courses is to apply and acquire skills. So we must offer learners an activity, making sure that they will be able to carry it out and use their knowledge to achieve a defined objective. Errors are allowed, which is a considerable advantage, because in the workplace, errors can be costly. This way, learners can stop, think and start over in order to succeed.

At the end of each module, instructors can assess the tasks completed by learners and provide them with feedback, reinforcing the "learning by doing" approach. Virtual reality also increases learners' concentration when they wear headsets, which was an unexpected discovery.

The CCCA doesn't develop immersive modules itself, but it does promote innovation in the entire vocational training

sector. We also developed an augmented reality app, "RA by CCCA", in collaboration with Artefacto, to integrate elements into the training environment (stairs, furniture, etc.). They had the technical skills and we knew what was expected from an educational viewpoint. We also have a Building Information Modelling (BIM) team that develops interactive digital models for teaching purposes.

These examples illustrate our approach: offer simple, high added-value products to inspire and set an example.

In the framework of the DEFFINUM project, we are working on the interoperability of trades in the construction industry, because errors in this field are often due to the mismanagement of this interoperability. We are bringing 18 training centres representing 60 training sites with us on this project. We are aiming to develop 150 immersive modules within the framework of this project which is co-funded by the Caisse des Dépôts and the CCCA. The participating organisations are not contributing financially: they are focusing on the teaching aspect, i.e. designing and hybridising training courses... And all this for the construction industry.

+ What are the main obstacles?

The main challenge we are faced with today is the dissemination of immersive methods. Instructors find them difficult to download and implement. We are currently putting the final touches to a platform devoted to immersive methods, it is called "E-mersive BTP" and, like Netflix, will host all the immersive methods by sector. This project, developed with VR Connection, will facilitate the dissemination of modules and will allow each participant to benefit from this collective input.

The development cost of immersive modules is also a challenge. Scripting each course with the instructors is only part of the process. We also need to contextualise the environments and create the necessary elements (generally called "the assets"). We therefore integrated an asset library into our platform, which will allow instructors to create their own immersive modules in the future.

It is important to stress that this approach is not intended to replace what already exists, but to supplement traditional methods. It has proven to be an invaluable tool in improving teaching content and developing learners' skills in virtual situations, anchored in reality.

It is not our goal to provide a certification via this method. It can in no way replace real practical experiences or role-playing on-site situations. On the contrary, our main aim is to develop a solid methodology. We want to provide young people with a comprehensive understanding of the work they are doing. For example, when installing a window, virtual reality can help them save time, but the full experience on a building site is irreplaceable.

The true added value lies in the transition between theory and practice. Virtual reality bridges this gap by providing an environment where learners acquire knowledge and skills, while reflecting on and learning the method. This reinforces their ability to understand the overall work process.

Of course, there are costs associated with this approach, particularly related to the development of multiple scenarios to cover various aspects of the training course, from installing windows to wood and concrete construction techniques. Furthermore, we take into account learner diversity: it is absolutely possible to work with young people in vocational studies by adapting the complexity of the situations. The key to success is to have anticipated this from the outset, in terms of the expectations set out by the reference framework.

Virtual reality is also forcing us to rethink the organisation of our training rooms. The hybridisation of teaching methods is forcing us to adapt our facilities. We are actively working with instructors, management teams and education managers to rethink our training rooms. It's about providing learners with environments conducive to "gestelligence" - a term that refers to the combination of professional actions, informed choices and professional intelligence. These spaces must be bigger and better equipped to keep pace with these changes.

In terms of equipment, the very first thing to do is to work out how to store the PCs and data. We are investing in the right PCs, the right memory cards and the right VR headsets. The market is evolving to meet the material and human needs of this transformation. We are convinced that there will be many breakthroughs in this field in the coming years.

Finally, the CCCA put in place a teaching innovation accelerator, a concept and space that detects and identifies innovations. With it, we test new materials and equipment in a "pilot" apprentice training centre, we then roll them out to all the apprentice training centres of the industry if the field experiment is successful.

We are currently setting up a lab dedicated to innovation, a space where new ideas will come to life: a technical platform and TV studio to present innovative ideas and

projects. Our goal is to encourage the emergence of innovative projects and ideas for vocational training.

+ **How do you involve the instructors and do you support them throughout this process?**

With the advent of the Internet, the role of instructors has changed significantly. Learners no longer need instructors who only pass on theoretical knowledge, because they can easily access this knowledge online. Consequently, instructors have become facilitators.

We urge instructors to take on this role, which consists in encouraging a learning-to-learn approach rather than learning for the sake of learning. Learners must understand why they are learning and the context in which it takes place, which helps them better assimilate the information.

The instructor must help learners contextualise, understand and analyse situations. We are putting in place actions dedicated to developing instructors' skills, with a mirror effect, where everything we offer instructors is intended to be passed on to learners.

We are convinced of the benefits of reflective practices. The process of reflective thinking allows us to say "I did this activity, what effects did it have? Why? Did it have the expected results? Did I do it well? If I didn't do it well, how do I rectify that? What can I do better tomorrow?" Instructors have to encourage learners to think about their own learning process, to analyse the effects of their actions, to identify their mistakes and to think about how they can improve.

+ **You mentioned the importance of teamwork. How has this been integrated into the methods you have developed?**

Yes, teamwork is very important to us. We developed an inter-professional module called "Barbershop" where apprentices work together to build a hair salon. Each apprentice is given specific activities and tasks on the building site, and they can see what has been done before and after their involvement.

This type of project is a challenge for our developers, but it brings real added value. Our training courses are now designed to encourage this collective approach. At the beginning, we mainly offered individual activities, but we are now moving towards the interoperability of trades within our training courses, and therefore encouraging teamwork between apprentices in virtual professional environments.

Institut des métiers de la chaudronnerie et de la tuyauterie industrielle – immersive technologies to discover trades

Interview with Wilnick Piriou, Director of the Institut des métiers de la chaudronnerie et de la tuyauterie industrielle - the French craftsmen organisation "Les Compagnons du Devoir et du Tour de France" – March 2023

Wilnick Piriou, Director of the Institut des métiers de la chaudronnerie et de la tuyauterie industrielle within the French craftsmen organisation, shares his experience of immersive technologies in vocational training. He explains how his background as a metalmaker led him to take an interest in these technologies and how his institute developed a virtual reality tool to introduce metalwork to young people. He talks about the initial resistance of instructors and learners, as well as the positive impacts on learning and training. Finally, Mr Piriou envisions a future where immersive technologies could play a preliminary role in vocational training, while highlighting how important it is for instructors to adapt to these new teaching methods to prepare learners for the careers of tomorrow in a more immersive and effective way.

+ Can you introduce yourself and tell us what led you to take an interest in immersive technologies?

I am a "compagnon" metalworker, I completed all my training with the organisation, from secondary to higher education. I was an instructors and then decided to enter the world of business. Later in my career, I once again wanted to become an instructor, this time with at the ICAM (Institut catholique d'Arts et Métiers) in Lille.

I rejoined "Les Compagnons" two years ago as the director of the Institut des métiers de la chaudronnerie et de la tuyauterie industrielle. I am in charge of the management, project management, instructor support and deployment of new techniques and educational tools. I am also in charge of managing relationships with our partners, including the Ministry of Education, the Ministry of Industry and industrial stakeholders. I bring my professional expertise as a metalworker as well as a broader view of pedagogy to the projects to which we contribute.

A study carried out by the SNCT (French Boilermaking, Piping & Industrial Maintenance Union) among young people and industrial stakeholders revealed that, despite innovations in the sector, the professions of metal- and pipework lack visibility. As a result of this study, we decided to create a virtual reality (VR) tool to present our

trades to young people, whether they are in secondary school, doing an apprenticeship or in higher education.

We agreed to take part in this project and have designed various virtual reality scenarios. The result? An opportunity to discover our work environment and machines, with the possibility of clicking on them to watch videos explaining what they are for and how they work. All this comes with workshop sound effects and recorded dialogues, which creates a realistic immersive experience.

We then enhanced these virtual environments by incorporating even more realism thanks to our expertise. Scenarios put us on a building site, have us work on a fire permit, help us discover the methods office, or even have us work on a vessel.

The tool is now up and running, and we are constantly striving to improve it.

This project, called "**CTM Virtual Xperience1**", was supported by many industrial companies.

Furthermore, we were asked by the Ministry of Labour to work on the hybridisation of pipework training courses. We drafted proposals for this project, focusing on the use of augmented reality. We proposed solutions involving holograms to provide spatial representation. It turned out that this technology wasn't so easy for our learners to assimilate.

+ How did you get the instructors and young people involved? How did that go?

To talk about that, let's start with the obstacles, so we can end on a positive note. We encountered a certain amount of resistance to change and faced the paradox of "we don't like change but we like new things". When people are used to a method, they can be adverse to any kind of change.

However, we are fortunate to have relatively young instructors, most of them are between 22 and 30 and are from the field, the business world. We therefore invited our instructors to test these new tools.

For the modelling side, we called in a specialist company and gave them the scenarios and plans. Developing virtual reality tools requires specific expertise to ensure their integration, coherence and long-term sustainability, without becoming obsolete in a few years.

To train our instructors to use this method, we incorporated the approach into our annual seminars, designed to encourage people to monitor technological development and discover

new tools. We then invited small groups to test the immersive method, which quickly dispelled any misgivings. It is important to note that some scenarios were better received than others.

For our colleagues in the Ministry of Education, virtual reality experiences are particularly welcome, in terms of career counselling, because they allow young people to familiarise themselves with industrial careers without being directly immersed in a company.

For young people already doing an apprenticeship, there are two concrete points:

1/ they do not like visiting the workshops virtually as they already have real-life knowledge of the "field" as they're working in the company as part of their apprenticeship

2/ however, immersive devices are invaluable for those who do not get the opportunity to go on a building site, as not all companies offer on-site assignments, particularly for assembly.

We therefore encourage our learners to use VR as an additional tool, whether it's before or after a lesson. This allows them to explore situations that would otherwise be inaccessible to them. For example, visiting a site with a group of 20 learners would take half a day just to welcome them and talk about safety. With VR, we can cover sequences related to safety, wearing personal protective equipment (PPE), security codes, and even practical

activities such as climbing a ladder or welding parts using different processes. This approach is well received by learners. These tools also work very well at the end of the day, as revision or after the lunch break. We use small groups, usually 4 to 5 learners at the most. One of them wears the virtual reality headset, while another helps if necessary. The three other learners can follow the experience on a monitor. If there are any more learners than this, their attention wanes, which makes it harder for the instructor.

+ **How do the learners react?**

The learners all react differently. Some find these tools interesting, while others are unsure. There is a certain reserve, especially among the younger learners. However, students in higher education, who are slightly older, are more likely to express their opinions. They think these tools are useful, but also criticise the realism of some versions. For those who have had the opportunity to work on a real building site, manipulating the controller or a virtual device doesn't seem sufficiently convincing.

In some cases, we had to modify the scenarios in order to make them more realistic. For example, when an object falls to the ground in a virtual environment, it must really fall to the ground, forcing learners to bend down to pick it up.

+ **Did you notice any interesting results?**

On the site in Lille, where we have more information and perspective, we have noticed a few positive results. VR was a real revelation for some learners lacking spatial awareness.

In pipework, where we must position pipelines from 2D plans, VR simplified the task. In the past, in classrooms, instructors used folded paper to try to explain these concepts. Now, with these virtual reality tools, this operation is much easier, which was a nice surprise.

+ **Did you have to develop any new skills in-house to support these projects?**

Many people are involved in this project: the French Ministry of Education, companies, trade unions, UIMM (Union of Metallurgy Industries). The collective force allowed us to benefit from the resources needed to carry out this project, where everyone does their bit.

+ **One of the obstacles mentioned is the cost. What do you think? What do you think the future will look like?**

Yes, these projects involve significant costs. In our case, we didn't have to bear them

directly, as they were covered by other stakeholders. Furthermore, these tools will be put at the disposal of the Ministry of Education and training centres free of charge.

However, equipment-related costs remain high. We need gaming computers. In addition, virtual reality headsets are also a significant investment.

+ **What will training look like in 20 years? The use of immersive technologies?**

As far as training is concerned, in 20 years, I think immersive technologies could potentially partly replace in-person teaching, if we have enough resources and tools. Learners can practice at home before going out into the field.

Practical training will still be essential, but immersive technologies could play a role beforehand, before going out into the field. In certain sectors, particularly first aid training, associations have already started integrating compulsory distance learning modules. This

allows us to reduce the time spent in classrooms and offer better quality training courses. Learners who have done the training course remotely beforehand, focus on exchanges during in-person sessions, where instructors play a crucial role.

+ **Does this mean that the role of instructors will change?**

Yes, it will change. In the past, when I was an apprentice, the instructor explained how to do things and we followed their instructions, no questions asked. Today, we challenge everything, and instructors must always be on standby. They must correct any misinformation, encourage discussions and create genuine interactions with learners. They are no longer just experts.

The current generation, between 18 and 25 years old, are inclined to question everything they are taught. They want a deeper understanding of the topics they are studying.

In 20 years time, learners will probably begin their training courses with prior basic knowledge, and instructors will have to consolidate this knowledge while going further. Consequently, instructors must be more "expert" than they are today.

+ **Do these tools have an impact on the knowledge and appeal of these professions?**

It is too soon to tell. It will take time to bring about a change in attitudes and for these tools to be adopted across the board, especially as more training centres need to be equipped.

We cannot force the more "senior" and reluctant professionals to adopt these new technologies, because they have invaluable expertise. We have to support them in the appropriation of these tools. However, I am convinced that these technologies will help increase the appeal of our professions. They offer a simple and impactful way of discovering little known professions, like that of metalworker. And if they don't fundamentally change the appeal, they will help raise awareness of our professions.

+ **If you had to speak to a reluctant training centre, what would you say?**

Where's the harm in trying?

University Lyon 1 (ICAP) – immersive technologies for education

Interview with Nora Van Reeth, Head of Innovative Teaching Projects at the ICAP at the University Lyon 1 – March 2023

Nora Van Reeth from the University Lyon 1, goes over the "step by step" approach adopted by the university to integrate virtual reality (VR), focusing on the acculturation by teachers and students. She shares some examples a educational successes thanks to VR, while stressing the importance of "making sure that each VR resource brings true added-value compared to other teaching resources".

+ Can you introduce yourself and explain your role at the University Lyon 1, as well as the immersive experiences you have developed?

I work at the University Lyon 1 in the ICAP department, which stands for "Innovation Design and Support for Education". Our department is composed of three units:

The Platform Unit which manages the university's LMS, with developers, people in charge of infrastructure, servers and user support.

The Teaching Unit with academic advisers and engineers who provide support and train users of the systems, and assess the learning experiences.

The Multimedia Products Unit, with ten or so people working exclusively to create teaching content, including 2D and 3D computer graphic designers, videographers, animators, photographers, etc.

My job as project leader is to oversee the functional activity of these three units. We have an in-house call for projects that is always open, allowing teachers to submit their educational projects. We reply by allocating resources depending on the labour and time required.

For example, a teacher who has noticed that students are struggling to understanding a specific concept covered in the lesson can submit a project, and we will work with them to develop solutions, like an animation or setting up a flipped classroom.

We support around 60 projects each year, which is impressive as Lyon 1 welcomes around 50,000 students each year, mainly in science, medicine and sports.

These projects can vary in length, with some only taking a few days to complete, while others can take several years, depending on the scale of the need.

In this context, our mission is both teaching and innovation based. We are currently exploring and testing new tools, teaching methods and new technologies.

+ How did you introduce immersive technologies, and particularly virtual reality (VR) into the university?

We were able to introduce immersive technologies, including virtual reality, thanks to funding over a 5-year period from the Auvergne Rhône Alpes Region. It was essential to get the ball rolling. It allowed us to progress more quickly and further in this direction.

Thanks to this funding, we recruited specialist staff, including real-time 3D computer graphic designers specialising in virtual reality.

We adopted a gradual approach, step by step. We knew from experience that the initial "wow" effect can be detrimental to what comes next. Even though we were convinced that VR had potential in education, we didn't want to rush things.

First, we organised events open to teachers on campus so that they could test VR experiences.

We were also able to set up a dedicated room, our "Virtual Lab", designed as a learning lab encouraging active teaching so that teachers could use the space freely, according to their needs. It has writable walls, desks in the middle of the room, ten computer stations each equipped with VR headsets, and an interactive whiteboard allowing the workstations to be projected onto a bigger screen. The Virtual Lab was opened to the whole campus and we held open days to showcase it.

We then started to develop our own virtual reality experiences in-house, starting with a scripted cellular biology experience.

The experience allows students to explore the different layers of skin, carry out actions and recover elements to understand the healing process. It was a success and is still used every year by 200 undergraduate students.

However, we quickly realised that developing virtual reality experiences in-house took a long time. So we started working with private companies to outsource the development aspect.

In any event, we are making sure that each VR experience brings true added-value compared to other teaching resources.

+ **How did you get teachers to incorporate these technologies into their lessons?**

The main lever we used is acculturation, i.e. introducing these technologies to the teachers. We're not trying to convince the teachers who aren't interested. Some teachers came to our demo sessions without really knowing how to integrate virtual reality into their lessons, and some changed their minds after having seen the educational benefits.

Students were also a driving force. Our dedicated room was often open, and at the beginning, many curious students came to see it and encouraged teachers to take an interest in virtual reality.

We set up an in-house training programme so that teachers could familiarise themselves with virtual reality and its potential. After the COVID-19 pandemic, we opted for a hybrid format.

Currently, we offer a 4-week training programme and the possibility of practical sessions in the Virtual Lab. This training programme covers the understanding of virtual reality,

augmented reality and mixed reality, as well as educational aspects like designing VR experiences and their benefits in terms of engagement, immersion and presence. This training programme is working really well and is contributing to raising teachers' awareness of the opportunities offered by VR.

+ **You mentioned that assessment was one of the missions of your unit. Can you explain what it involves and what the feedback has been from students?**

Assessing learning experiences is compulsory in every university, and this includes students assessing the content they were given. Our department is in charge of this assessment, which allows us to gain expertise in assessing the impact of virtual realities on learning.

However, it is much too soon to obtain significant data. To have a thorough assessment, we'd have to compare distinct groups of students.

We are currently carrying out informal assessments to get a general idea of the effects. The

feedback we have received shows that immersion and interaction offer an advantage in terms of learning.

+ **In your opinion, what will using VR in higher education look like in the future?**

I see two important aspects of the future of VR in higher education. From a technical point of view, technologies evolve quickly. Currently, we mainly use stationary solutions. We don't have much mobile equipment, but we are facing challenges such as monitoring users' screens, which is complicated in an educational setting. We have recently been working with autonomous headset kits to facilitate the logistics of it all, and an app management system to allow teachers to control the experiences.

In terms of software, some 3D virtual experiences have clear educational potential, particularly in fields like biology where they allow us to represent difficult concepts immersively. However, some 360° experiences are easier to produce and can be viewed on various devices. We are still exploring what the metaverse has to offer, especially authoring solutions, to see how they can be used in education.

We are also striving to share our knowledge and resources with other higher education institutions. We hope to create a shared resource library so that everyone can benefit from it. This project is progressing well, these are

the missions of action 5 of the Include project, Lyon 1's DémoES <https://include.univ-lyon1.fr/action-5/>

+ **And in your opinion, what will the university look like in 20 years?**

I think that the university will move towards increased delocalisation, with decentralised campuses to ensure that training is accessible to all. The University Lyon 1 has already opened delocalised courses, allowing students to pursue their studies away from the main campus.

My main hope is that we are able to maintain the balance between technology and education. I am sure that we will never be able to replace teachers, that they will remain essential, but that they must constantly learn how to use new digital tools and put in place new teaching practices. New innovations that we can't even imagine today might play a major role, let's come back and talk about it in 20 years...

Institut Agro Dijon - immersive technologies for technical actions and decisions

The Institut Agro Dijon, directed by Thierry Langouët, plays a major role by supporting agricultural education for the French Ministry of Agriculture. Their mission encompasses various areas, including IT, training and the creation of teaching resources. They developed immersive tools for agricultural education, such as simulators for forestry training and driving agricultural machinery. These tools allow learners to familiarise themselves with complex and dangerous situations. The goal is to improve training courses by offering realistic experiences and increase the appeal of careers in agriculture. In the future, the hybridisation of training courses could play a key role in improving the effectiveness of the learning process.

+ Can you introduce yourself and tell us a little more about Institut Agro's missions?

I am Deputy Head at Institut Agro Dijon and Director of the Technical Agricultural Education Support Mission at Institut Agro.

Institut Agro is one of the main operators supporting agricultural education for the French Ministry of Agriculture and Food Sovereignty via orders placed by its General Directorate of Education and Research. Support is provided to various areas, including IT, training engineering or publishing teaching or scientific resources.

Agricultural education concerns around 800 institutions, of which 175 are Public Local Establishments of Education and Professional Agricultural Training (EPLEFPA), private institutions (National Council for Private Agricultural Education, CNEAP, National Rural Union for Education and Promotion, UNREP) and the Rural Family Centre Network (MFR). There are also higher education courses in agronomy (engineers, Master's, etc.), forestry and veterinary training.

Overall, these training programmes go up to a PhD level and include apprenticeships and continuing education. Each year, around 220,000 people study in secondary or higher education institutions. There is also a distance learning centre at the Institut Agro Dijon which trains around 2,000 people each year.

In Dijon, we have a significant IT development component for agricultural education establishments, initially to support their management team, then for teaching purposes. We are, in a way, the Ministry of Agriculture's IT service company for agricultural teaching with more than forty people developing management, accounting,

learner monitoring software as well as teaching tools (LMS, etc.).

+ How do you use immersive learning?

The Institut Agro de Dijon has a science of education and training research team (Vocational Training and Learning Research Unit, UR FOAP), which focuses on vocational learning, i.e. the use of work analysis to design training devices. This team is interested in the benefits of simulators in vocational training.

For example, a few years ago, a public agricultural secondary school in Bourgogne Franche-Comté, specialising in forestry training contacted the team with several questions: when training foresters, we don't exactly know what the results of the actions and decisions we make in terms of forest exploitation will be. When we cut down trees, what are the results in 30 years? And more than anything, the stakes are high in terms of biodiversity and sustainability. Would it be possible to develop a simulator that allows learners to visualise the impact of what they do (planting, cutting, etc.)?

A collaborative project was developed to address these questions. It was selected following a call for projects issued by the Investment for the Future Programme (PIA). This project is called Silva Numerica. The consortium included agricultural and forestry education institutions, the ENSAM, French public schools, foresters, software development companies and the science of education and training team at the Institut Agro Dijon.

For 5 years, they worked together with foresters to describe and understand their profession. A simulator was then developed with IT specialists, instructors and researchers. This tool features a plant growth model of an area of forest, that can be visualised on a monitor or via a virtual reality headset.

One of the goals was to not focus on the visual conformity between simulation and reality. Our starting point: create a professional tool that should not look like a game. The tool immerses learners in a forest where trees of different species are displayed, as well as their age, characteristics and environmental attributes. The ultimate goal is to identify the long-term results of felling and clearing in terms of forest regeneration, biodiversity, etc.

In recent years, the use of these immersive tools has increased in agricultural education. Many institutions have agricultural and forestry machinery simulators, among other things. Mainly because

agricultural students are less often from an agricultural background, but also because safety regulations have been tightened. These tools place learners or professionals receiving training in situations they would rarely encounter in real life: a tractor on a slope, a high-clearance tractor in a hilly vineyard, degraded situations, or even accidents.

For example, the EPLEFPA in Beaune ("Beaune Viti Agro Campus") has 8 high-clearance tractor simulators and a teacher control centre which the instructor can use to inject teaching scenarios of different vineyard-related activities, adding a slope, a cant, and so on, which helps place young people in a variety of simulated situations. The sessions are recorded so that what happened can be analysed and feedback can be provided. Debriefing after a simulation session is essential, as we only develop a skill when it has been explained and understood, not just carried out in a real or simulated situation.

This type of equipment also exists in other agricultural education institutions, with the same hope of increasing the number of learning situations and making them as real as possible; these tools are of course not a substitute for real situations during an internship or a work-study programme. Another example, more recently, a company (Studio Nyx) submitted a project (VINUM), selected following a national call for projects, to finalise the development and deployment of their e-cab (driving simulator for machinery). This project also

includes the development of a vine pruning simulator.

The act of pruning is extremely engaging. With global warming and diseases, pruning is more crucial than ever in terms of the quality and quantity of the harvest as well as health consequences, and therefore risks. So it is hard to let a novice prune a real vine, given the various risks. To this we must add the fact that many wine companies, in Bourgogne Franche-Comté and other vineyards, often outsource the task of pruning vines. So we have to train employees, who may be novices, knowing that we can't always put them in real situations straight away.

So Studio Nyx is currently developing a new simulator using a plant growth model based on scientific research. Users of this type of tool intervene on a simulated vine, they can see the long-term consequences of their pruning, which is extremely complicated in terms of tool design.

A third future-oriented issue interests

certain agricultural education institutions specialising in agricultural equipment, particularly those used to maintain agricultural machinery. Agricultural machinery has become very sophisticated. It is therefore difficult for institutions to always have access to the latest technology. Furthermore, manufacturers may be reluctant to let a novice intern dismantle the gearbox of a combine harvester worth €400,000. Virtualising machinery and their components allows learners to be immersed in the equipment, for example in a gearbox or an engine, and to see how they work, to simulate and visualise malfunctions as well as the consequences of their interventions.

Similarly, it is not always possible to visit food processing plants for safety reasons or because of time constraints. Virtual tours of companies were therefore also developed.

Immersive technologies are also used to discover agricultural careers and training, to increase the appeal.

Generally speaking, by using digital technologies in training, we can encounter two hurdles: on the one hand, those who say that "digital technologies will solve everything", and on the other, those who are reluctant to use these tools at all.

In any event, these tools are therefore deployed successfully when they bring added-value to teachers and instructors. Using these simulators allows learners to learn, including safety training. Instructors can develop teaching scenarios. Both groups can benefit. This is how training teams adopt this type of tool, and school management teams are perfectly aware of this.

Specifically in training for adults and in apprenticeships, instructors have often had other professional experiences, and they are often even more aware of the added-value of these tools. In any case, these tools are not a substitute for lessons and work experience; they are complementary and can help learners develop their skills, quickly and safely.

Their deployment is similar to the moment when computers were integrated into education. The success of these projects depends on the ability of school management teams to get a group of instructors on board to tackle an issue or problem on which they have agreed, as well as on the way in which they are involved in designing the tools.

In Silva Numerica for example, in the "Beaune Viti Agro Campus" way, teachers and instructors have been involved in designing the tools which obviously increases

the number of opportunities and uses, as these instructors can then become ambassadors to other educational institutions and teams. When it's instructors who explain to other instructors, it works much better.

+ What is your immersive technology deployment strategy?

We can't say that we have a specific clear national strategy concerning the development of these immersive tools in agricultural education, even though we encourage the use of digital technologies in training courses, especially by promoting innovations and innovators. This type of project often comes from a more local level. Of course, we support project initiators when we can. Major calls for projects can co-fund these projects (Deffinum, calls for interest "skills and professions for the future", etc.), which are often quite costly in terms of development and instructor training. Personally, I also sometimes speak in front of collectives to explain the benefits of using simulators in training: use the context and the issues that instructors encounter, what immersive tools can do for them and how to use them.

With regard to learners, the goal isn't to please them or to assume that they will like "new technologies". The main reason we have to use these technologies is because professional situations are complex and it

is difficult to train someone without putting them in a real or near-real situation. These are complementary tools. In our institutions, we have farms and "mini food processing plants" which allow us to simulate real-life situations but not degraded or accidental ones. With immersive technologies, learners can be put in situations they will rarely encounter in reality, but that it is important for them to be able to handle (new or even dangerous situations, etc.).

It should also be noted that some learners have a "negative" reaction towards digital technology, this could be due to ecological issues or saturation. During the health crisis, the use of digital tools and resources obviously increased significantly, now we are realising that these uses are dropping, some are expressing their disappointment, especially if they found it easy to use.

It is difficult to know how the use of immersive tools will evolve

but I think that if we don't start from "teaching issues", i.e. the instructors, and if we don't base them on a clear and scientific approach, they won't be used much. Above all, it is necessary to demonstrate the effectiveness of these tools, to learners and all the other stakeholders in initial and continuing studies, and involve the "educators" in the design process.

+ In your opinion, what will the world of training look like in 20 years?

A lot of forward-looking studies have been carried out on digital technologies, but to our knowledge, very few on vocational training. Maybe because it is still heavily influenced by conventional schooling, but also certainly because innovations, much more numerous than we might think, take place in the classroom and are not very visible.

Through our discussions with instructors or management staff, it is clear that some social phenomena, for example the attention difficulties of "young people", can cause severe issues for teachers and instructors. They have to keep their teaching activities moving at a good pace, alternate learning situations, diversify their tools and resources. Digital technologies, including immersive technologies, can help develop and enhance practices. However, I don't think that in 20 years teachers and instructors will be replaced by an avatar in a virtual space! In 20 years, we can however hope to have made progress in the hybridisation of train-

ing courses. A very good study on higher education, Hy Sup, shows that the more we move towards hybrid models, the more effective the learning process.

The need to create a use case observatory

The feedback we have gathered from stakeholders in education and training are highly informative for the sector and for whoever wishes to implement an immersive project. It also reflects the fragmented knowledge we have of existing use cases. It is for this reason that the France Immersive Learning association has launched an immersive technology use case observatory with the aim of:

- + Showing the existing uses and showcasing the stakeholders
- + Identifying and capitalising on the good practices as well as the obstacles and solutions to overcome them
- + Producing an annual barometer of immersive trends
- + Monitoring local, regional and even national initiatives and projects, and interviewing stakeholders to produce impact studies and assessments
- + Creating user communities



4 steps to a successful Immersive Learning project

6.1– Step 1: Adaptation, documentation and training

6.2– Step 2: Setting the framework for your project

6.3– step 3: Launching and managing the project

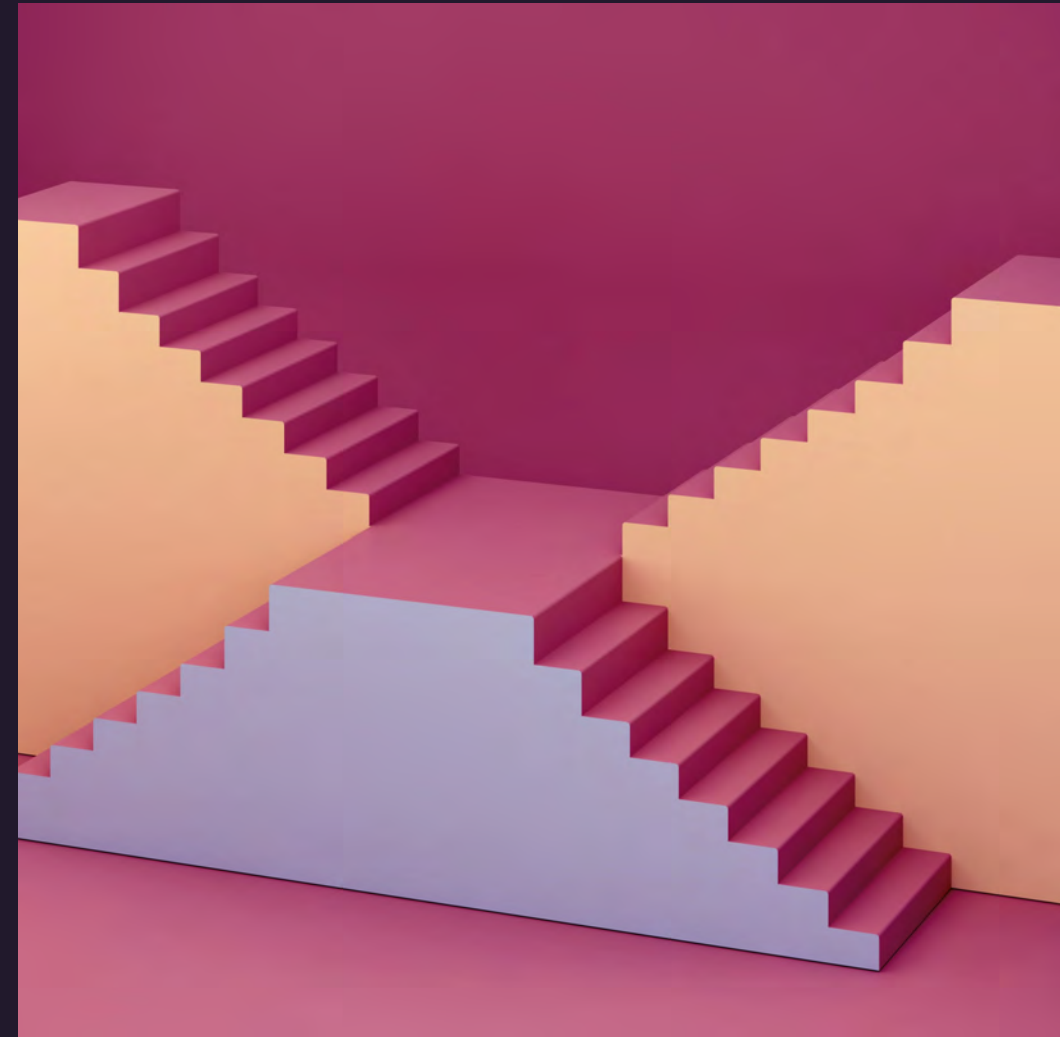
6.4– Step 4: Continuous improvement

117

184

192

198



chapter 6

6.1

Step 1: Adaptation, documentation and training

Whether this guide has inspired you to take action, or you're already convinced, let's not forget that an Immersive Learning project has its own unique characteristics and a degree of complexity compared to other methods you may be currently using.

For example, it's quite rare for a trainer or learning designer to be able to create an immersive learning experience from A to Z, as they would with a digital learning platform. This will become possible as design tools mature and content becomes more varied. We will expand on this point in Chapter 7, which discusses the challenges we face up to 2030.¹¹²

In this chapter, we have summarised the advice of experts and our ecosystem members to guide you step by step in your Immersive Learning project.

Please note: every project and every organisation is unique. Below is an overview of the key factors that need to be taken into account. Aside from the points highlighted, all the specific features of the development context and environment of the project must be taken into account. Unless you have the necessary skills and experience in-house, working with a specialist agency is highly recommended.

Whether you're a trainer, teacher or learning designer, one of the keys to understanding what immersive learning can do for your learners is your own acculturation. This will enable you to make realistic and relevant plans. It makes a lot of sense to train yourself, but also to exchange with your peers to get feedback from the field and learn from any mistakes they may have made.

Put on a headset and practice

This may seem obvious, but it's always worth remembering. The only way to understand what Immersive Learning can offer is to experience augmented, mixed or virtual reality. Whether they are learning experiences or not. Test and practice so you can plan ahead! One activity may seem just as effective as another on paper, but become less suitable once the headset is on. Practice as often as possible to develop your "immersive agility" - your sense of

ease with and mastery of all the elements that make up an immersive experience:

- + equipment (headset, controllers and accessories),
- + operating system (home screen, menus, app store, content library, settings, etc.),
- + interactions (menus, objects, ways of interacting, etc.),
- + movement and spatiality (i.e. the complementary nature of your

physical and virtual movements),

+ spatial arrangements (mix up the places where you practice to discover the subtleties of environmental configuration).

Discover, experience, feel and make up your own mind. This will help you become an expert user, with the ability to use the immersive modality with learners, participate in the design of immersive learning experiences, and effectively advise those around you on issues related to Immersive Learning.

In order to learn as much as possible, we suggest that you use the template opposite to document these immersive discoveries.



Type of Immersion	Experience category	Physical space	Movements	
			DOF	Scale
☐ AR ☐ 360 video ☐ XR ☐ VR	☐ Game ☐ Fun activity ☐ Virtual visit ☐ Discovering careers ☐ Training	☐ At home ☐ Equipped room (seated) ☐ Equipped room (standing)	☐ 3 ☐ 6	A little A lot
Equipment	Ease of use	Brief summary	The mechanisms I could use as teaching aids	
☐ Controllers ☐ Haptic gloves ☐ Haptic jackets ☐ Steering wheel ☐ Force feedback arm	Laborious Hyper intuitive			
What impressed me	What I didn't like			

Peer-to-peer learning

Practice is the first step in making immersive experiences your own. Practising with peers, meeting them and sharing feedback is another essential part of making rapid progress. Sharing pitfalls, feedback, tips and tricks are all ways of saving precious time and reassuring yourself as you explore an unfamiliar system.

How to identify them?

- + By asking your network
- + Researching on LinkedIn... the magic of networking!
- + By asking training organisations whether they have clients with similar use cases
- + By contacting the professional federations representing your industry: they very often have an employment/skills/training remit and may be aware of initiatives being carried out by companies in the same industry
- + By visiting the "Observatory" section of the FIL website

Here too it makes sense to document these exchanges so that they can be used effectively at a later date. We suggest you do this using the template opposite.



Organisation	Contact	Position	Date
Why was this project launched?		Time for implementation	Budget
Description of the immersive experience and its integration with other modalities			
Equipment	Facilities	Number of learners, supervisors, mediators?	
Measured benefits		Difficulties or pitfalls encountered	
Other notes			

Training

Immersive Learning is still in its infancy, so going through the training process to ensure that you have the knowledge base you need to implement an immersive project can be both useful and time-saving. Training sessions are also excellent opportunities to meet peers with whom you can stay in contact to discuss your respective projects.

While there are many providers offering to design and produce your own immersive projects, those that can teach you the fundamentals of Immersive Learning so that you can become self-sufficient are fewer in number. Here is a non-exhaustive list of French training organisations that can help you get to grip with the basics:

- + [Antilogy](#)
- + [Evol'Job](#)
- + [Immersive Ambition](#)
- + [Immersive Learning Lab](#)
- + [INA](#)
- + [Mimbus](#)
- + [Massive Immersive](#)

For teachers, this acculturation course offered by the Education Collaboration Innovation Technology Network (Récit), supported by the Ministry of Education of Quebec (CA) is also worth noting: <https://campus.recit.qc.ca/course/view.php?id=106>

MOOCs and training sessions on Immersive Learning are regularly run by our members, training organisations or agencies specialising in the design of immersive learning experiences, such as Speedernet MOOC¹¹³ or that developed by Pôle Leonard de Vinci¹¹⁴.



Useful info

FIL is regularly asked to put companies in the same sector in touch with each other. Being part of a network facilitates these links. If you become a member, you will gain access to the members' directory, which you can then use to contact other members. A number of interviews and case studies can also be found in the observatory section of our website.

We regularly post them on our Linkedin page, so be sure to subscribe now so you don't miss out > <https://www.linkedin.com/company/france-immersive-learning/>.

6.2

Step 2: Set the scene for your project

This is an essential step if you need to convince sponsors, financiers or stakeholders of the relevance of your project. Here are a few pointers to make sure you don't forget anything!

Defining the challenges

Why do you want to choose this option over another? This question of the issues behind an immersive project is often forgotten, even though it is of fundamental importance.

For example: you decide to launch an immersive experience project to reduce the cost of raw materials associated with a manual skill that your learners need to acquire (spray painting, using a sawing bench, etc.). Now let's imagine that, after a year's use, you carry out a review and

it reveals two things: that your learners who have used this immersive experience have a better mastery than those who have not, and that the cost of maintaining the hardware/software, once added to the cost of the project, means that it will take at least 20 years to break even with respect to the equivalent consumption of materials.

What conclusions do you draw? Does this represent a success? From an educational point of view, yes, clearly. But will the sponsors of this project, to whom you have 'sold' a reduction in costs, think the same?

This example is deliberately "simplistic", because in this case you will certainly have validated all of these budgetary elements as part of a feasibility study and monitored their development over time to ensure that they remain under control /appropriate over the course of the project, deployment and day-to-day use.

It does, however, illustrate the fact that it is essential to define clear, shared and documented challenges in order to get the sponsors, funders and other relevant stakeholders on board that you will need to successfully complete your project.

We recommend that you list one to three major issues at the heart of this project, and for each issue complete the document opposite, indicating the underlying facts, why it is strategic for your organisation and

the risks to be taken or not taken.

For example, reducing raw material costs, enabling learners to perform tricky technical tasks, reducing the risk of workplace accidents, being competitive with competing training organisations, etc.

Observation	What makes it strategic?	The risk I'm taking by launching a project	The risk I'm taking by not launching a project
Challenge no. 1			
Challenge no. 2			
Challenge no. 3			

Clarifying the educational aim

Immersive learning is just one of many approaches available to those involved in training. So before getting started, you need to make sure that this method will bring tangible benefits to learners compared with the methods you have used up to now.

Here are a few questions to give you some perspective:

- + Who is the target audience (the learners)?
- + What are the educational goals for learners?
- + What will immersive learning do for learners to help them achieve their goals?
- + What difficulties am I facing, or what could be improved?
- + For each goal, how can you quantify whether immersive learning is the right choice?
- + Could immersive learning be counter-productive in this case?
- + Can immersive learning create new difficulties for learners compared to the current approach? If so, which?
- + How could immersive learning help solve these problems?
- + Which teaching sequence will this activity fit into?
- + How do I go about this today?
- + Etc.

At this stage, it may be a good idea to draw up a requirements questionnaire and organise interviews with the relevant stakeholders you have identified. For example, trainers who are likely to use this method as part of the modules they teach.

Listing the planned equipment and facilities

Start thinking about the ideal room in which you want to deliver this immersive experience, and the facilities and equipment you will need, whether immersive or not. For example, you could ask yourself the following questions:

Activity

- + Are these activities performed while standing or sitting?
- + Do learners have to move around and make a lot of gestures?
- + Are learners alone in their activity, or are they immersed in a group?
- + Does the activity require full (VR), partial (MR) or video immersion (360°)?
- + Does the activity require an internet connection to retrieve online resources?
- + Does the activity require a "digital twin" of the room so that learners can move around as if they were in the real world?

Layout

- + Is there a dedicated room?
- + How many learners are practising at the same time?
- + Is the furniture fixed or moveable?
- + Does the room have curtains or shutters?
- + After use, is the equipment stored in the room or elsewhere?
- + Are the disinfection devices in the room or elsewhere?
- + ...

Equipment

- + Are they stand-alone headsets or are they tethered to a PC?
- + Besides headsets and controllers, are specific accessories required?
- + Are there any currently known constraints that will be imposed on the equipment as part of this project?
- + Who will be responsible for technical maintenance, in particular updating headset content?
- + How will the headsets (if stand-alone) be maintained and recharged?
- + ...

Platforms & immersive universe

- + Are there any known constraints on the V360 / VR / MR platforms?
- + Are there any pre-existing resources in content libraries (open-source or paid-for)?
- + ...

Estimating the resources required

At this stage of your project, it's normal not to be able to put a precise figure on it. However, the information gained from your peers or training courses should be enough for you to estimate costs, in terms of the activities you have planned. Based on your answers to the above questions, complete at least the following table.



Facilities	Equipment	Platform	Activities and content
Cost of room	Cost of headsets	Cost of licence or integration	Cost of project (design + implementation)
Cost of furniture	Cost of PCs		Cost of training
Cost of travel	Cost of screens		Cost of maintenance
	Cost of disinfection system		
	Cost of technical maintenance		

As far as the required budget is concerned, there is public funding that can be accessed, for example through calls for projects, grants or loans. Some suggestions:

- + [European funds](#)
- + [France 2030](#)
- + [BPI](#)

Identify the relevant stakeholders to be mobilised

Quickly identifying the relevant stakeholders you need to mobilise for your immersive project has a major advantage: it means you can bring them on board with you and put together a dedicated, motivated and effective team to bring this project to fruition. Also take the opportunity to draw up an inventory of the skills available around you, which will help you to better define your support requirements.

Here is a non-exhaustive list to help you consider your options:

Internal

- + Education
 - Industry experts
 - Educational managers
 - Teachers
 - Trainers / instructors
- + Digital
 - IT services
 - Innovation unit
- + Finance
 - Administration and Finance Department
- + Project
 - Leader / Project team

External

- + Equipment
 - Start-ups offering technological solutions
- + Project
 - Content producers
 - Specialist support agencies

- + Training
 - Training organisations
- + Other stakeholders
 - Competitiveness and transformation centres (such as [Cap Digital](#))

Define its KPIs

As with any educational project, defining indicators for monitoring the success of an immersive project is essential. These indicators are closely linked to the challenges you defined earlier. If educational efficiency was not one of the challenges, consider adding indicators to the KPIs to monitor this important point.

We propose the following framework for keeping track of these KPIs.



KPI	Indicator measured	Criterion for success	Acceptance rate
Challenge no. 1			
Challenge no. 2			
Challenge no. 3			
Challenge no. 4			
Challenge no. 5			
Challenge no. 6			

6.3

Step 3: Launch & manage the project

Existing project methodologies

There are many different ways of implementing an educational project, each with their own advantages and disadvantages. One of the most commonly used is the ADDIE model, with stages similar to those presented in this guide, but with a very general approach. Below you will find a brief description of each of these models, to help you make your decisions more clearly and guide your decisions.

There are advantages and disadvantages to each of these methodologies, and the decision to opt for one over the other depends in particular on the type of project, the needs of the learners and the available resources. It's up to you to choose the one that suits you best.

SAM (Successive Approximation Model)

This is an agile method for designing and developing learning programmes. Unlike linear approaches, SAM involves an iterative process that allows for continuous adjustments based on feedback from learners and other relevant stakeholders.

LXD (Learning Experience Design)

This is an approach that combines elements of interactive design, cognitive psychology and user experience (UX) to create effective, engaging and memorable,

learning experiences. The goal of the LXD? Focusing on the learner as a user, taking into account both the educational content and the overall learning experience.

ADDIE (Analysis, Design, Development, Implementation, Evaluation)

ADDIE is an instructional design model that takes a systematic, linear approach to creating learning materials and programmes. The five phases of the model are: Analysis, Design, Development, Implementation and Evaluation. Although this model has faced criticism for its lack of flexibility, it remains one of the most commonly used methodologies in learning and development.

MRK (Morrison, Ross and Kemp)

This is a learner-centred, problem-solving educational design methodology. Unlike more linear models such as ADDIE, the MRK model is circular, suggesting an iterative approach to the design of learning programmes. The model takes into account not only educational content, but also all the elements that affect the learning experience, including technology, management and learners' specific requirements. This model is often used for complex learning projects where several variables need to be taken into consideration. It encourages collaboration between the various stakeholders (learners, trainers, administrators, etc.) and places the emphasis on continuous assessment for progressive improvements.

Feasibility study

This is the first stage of the project, after you have established the framework and convinced your organisation to look at this opportunity to communicate differently. Its purpose is to assess the technical, financial and organisational viability of the project. This stage is critical to avoid costly mistakes later on in the project.

While the framing work proposed in the previous chapter can be considered the first stage of the feasibility study, we have chosen to isolate it in this guide as a stage of reflection before the project is actually launched.

This study covers several aspects: estimated costs, required human resources, technical compatibility and alignment with the organisation's strategic objectives. The study allows you to confirm whether the project is feasible in your specific context and gives you the opportunity to identify and address potential obstacles before they become problematic.

What you could do (*this list is non-exhaustive and depends on the context of your project*):

- + Draw up a detailed brief

+ Estimate total project costs (development, hardware, maintenance, licences) + Assess the required skills and human resources + Identify the technical limitations (compatibility, infrastructure) + Check alignment with the organisation's strategic goals + Consult the relevant stakeholders to assess the acceptability of the project + Perform a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) + Define detailed success indicators and KPIs + Draw up a shortlist of agencies to contact to help you implement the project + Create a small-scale prototype to test technical feasibility + Compile the results in a feasibility study report + Take a go/no-go decision based on the study results (including the choice of agency)	Educational design Educational design involves developing training content, defining methodologies and integrating relevant immersive technologies. Once the needs have been clearly established, the educational design revolves around the creation of the training content. This means opting for the most appropriate immersive technologies (VR, AR, etc.), if this has not already been done during the feasibility study, developing educational scenarios and creating or acquiring content. This step requires close collaboration between your project team, the selected agency and the relevant stakeholders involved. What you could do <i>(this list is non-exhaustive and depends on the context of your project):</i> + Choose the appropriate immersive technologies + Script the experience + Setting educational objectives + Formalising the educational sequence + Outline the user journey	+ Define interaction rules + List learning analytics + Consult business contacts or domain experts for validation + Adjust according to feedback Production of immersive content The production of immersive content is where the educational scenario comes to life. It involves creating the 3D elements, 360-degree videos, or any other form of immersive content required for training. Once the educational design has been finalised and its feasibility confirmed, it's time to move on to content creation. This step involves close collaboration between educational designers, developers, graphic designers and content experts. This is when the interactive elements, 3D environments, simulation scenarios and other multimedia content are developed that make the experience immersive. Special attention must be paid to the interactivity, plausibility and coherence of the virtual world created. The process can be iterative, requiring constant adjustments based on feedback from testers and experts.	What you could do <i>(this list is non-exhaustive and depends on the context of your project):</i> + Select or validate tools and software for content creation + Put together a skilled production team (developers, graphic designers, educational designers) + Define precise production stages and deadlines + Create content prototypes or drafts for validation + Integrate interactive, audio and visual elements + Configure the selected immersive learning platform + Test the compatibility and performance of content on the platform + Conduct trial sessions with a small group of learners or trainers + Gather feedback and adjust the content accordingly + Have the final content validated by instructors, teachers or experts in the field
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- + Integrate the content into the immersive learning platform

Deployment

Once the immersive experience has been produced and integrated into the immersive learning platform, the project still not complete. High-quality change management is crucial to successful adoption. It's about onboarding and training the teachers or trainers to use your immersive experience and the associated equipment. Some of the training in the use of immersive technology and running an immersive learning session can also be performed in advance, to ensure greater commitment to your project and reduce the workload during deployment.

What you could do (*this list is non-exhaustive and depends on the context of your project:*

- + Lay the groundwork and generate interest by showing extracts, working on teasers, etc. (right from the start of the project)
- + Communicate with relevant stakeholders to avoid gimmickry (and if necessary make sure that managers are on board too)
- + Anticipate feedback and remember to ask for it to improve your experience and the support you provide (getting started, what would have helped, etc.)

- + Formalise headset management instructions and make them easily accessible
- + Organise training sessions for trainers and anyone likely to use this method
- + Set up technical and user support
- + Launch pilot sessions to collect feedback from users and improve the experience

Taking stock

Taking stock is a critical stage in the life cycle of an Immersive Learning project. It enables you to capitalise on your successes and take corrective action on any challenges encountered. Here, the success indicators and KPIs are analysed to understand the project's successes, challenges and areas for improvement.

The evaluation can include satisfaction surveys, skills tests and metrics analysis such as completion rates, time spent on training and user engagement. It also involves bringing the project team together for a full review, in order to

discuss the successes, challenges and lessons learned from the project. This information will be essential when it comes to improving future projects and establishing best practices in Immersive Learning.

What you could do (*this list is non-exhaustive and depends on the context of your project:*

- + Collect tracking data (completion rates, time spent, engagement, etc.)
- + Distribute satisfaction surveys to learners & trainers/trainers/teachers
- + Conduct post-training skills tests
- + Organise a stocktaking meeting with the project team
- + Analyse the data and draft an evaluation report
- + Identify strengths and areas for improvement
- + Share results with stakeholders and sponsors
- + Archive all project materials and data
- + Plan milestones for future projects or updates to current content

6.4

Step 4: Improve continuously

Having taken stock and identified areas for improvement, the next step is to implement these improvements in a structured way. The aim here is to create a continuous improvement cycle that regularly involves learners, trainers and other relevant stakeholders in making adjustments based on data and qualitative feedback.

This is a proactive approach that doesn't just wait until the end of a session or programme to make changes, but implements them as and when data linked to success indicators and KPIs, as well as feedback from relevant stakeholders, is collected. This stage is crucial when it comes to ensuring that your project remains aligned with learners' needs and educational objectives, while optimising your return on investment.



7 challenges for 2030

7.1– Challenge no. 1: Creating shared resources and tools	203
7.2– Challenge no. 2 : Improving accessibility and inclusion	207
7.3– Challenge no. 3: Limiting physiological and psychological risks	211
7.4– Challenge no. 4: Defining a framework of trust and developing the logic of sovereignty	213
7.4– Challenge no. 5: Environmental impact	216
7.6– Challenge no. 6: Generative AI	220
7.7– Challenge no. 7: A French industry of excellence	223



chapter 7



7.1

Challenge no. 1: Creating shared resources and tools

Each country has its own policy regarding IA and VR. This is what has happened in France since 1997.

In 1997, France launched its plan for "new information and communication technologies in education"¹¹⁶, with the aim of connecting all educational establishments to the internet. In 2000, all secondary schools were online, and a few years later this was also the case for colleges and schools.

In 2023, this seems normal to us. It also seems hard to imagine higher education students not being equipped with laptops, especially after the Covid pandemic and the resources allocated by universities.

Let's draw a parallel with immersive technologies: currently, only 120 million people worldwide have access to a virtual or augmented reality headset¹¹⁷ and this figure is even lower if we only include educational uses. The challenge is therefore to identify how we can develop the use of Immersive Learning in the context of progressive equipment.

The authorities have taken a clear stance on this issue on several occasions. The current government has launched a 200 million euro plan for immersive technologies and the metaverse, including 150 million euros dedicated to "immersive culture

and metaverse practices" and 50 million euros for the "technological building blocks" deemed essential to the sector¹¹⁸.

But if Immersive Learning is to move forward in France, Europe and the rest of the world, the whole sector needs to be structured and, above all, open-source resources and tools need to emerge, i.e. commons such as Wikipedia, to ensure that they are robust and as widely disseminated as possible.



Useful info

A commons is a resource created and/or maintained collectively by a community of heterogeneous stakeholders, and governed by rules that ensure its collective and communal nature. The European Commission's report on digital commons, initiated by France during its Presidency of the Council of the European Union and the European Commission, and resulting from work carried out by 19 Member States, states: "By relying on collective intelligence, knowledge networking and international collaboration,

digital commons challenge the lock-in strategies pursued by some governments and large digital service providers. At the heart of the digital value chain, they bring more security and drive innovation. Strengthening the digital commons is thus an essential lever of sovereignty for the European Union and all states¹¹⁹".

For people or organisations new to the field, the path to creating an initial library of usable content is a particularly daunting one, all the more so because of the inconsistent quality of productions and the absence of labelling to assess their level.

The challenge at this level is to have the human resources required to mobilise a sufficiently broad ecosystem of educational institutions, businesses and contributors. In this way it will be possible to create educational communities and make interactive learning modules, simulation scenarios, virtual environments, 3D assets and many other immersive resources available.

The development of collective immersive worlds dedicated to education and training represents an important step in this process. Indeed, these platforms are natively equipped with tools and resources that enable teachers to produce their own activities or sessions without having to master complex AR/MR/VR development tools - a recurring and justified demand from teachers/trainers.

France is well placed to make headway in immersive technologies with the same geopolitical soft power strategy that the USA has deployed with MOOCs that bring American university courses to every corner of the world.

With two conditions: don't leave it too late and use existing structures (La Francophonie, FUN, etc.) Bearing this in mind, here are the essential tools and resources for the widespread development of Immersive Learning:

+ A shared library of immersive content

A true immersive content distribution platform, wik'immersive'pedia, will facilitate access to free or paid-for content that organisations, universities, schools, training bodies, teachers and trainers can use. Everyone could draw on a shared catalogue of open educational resources (REL)¹²⁰ or Creative Commons¹²¹ to save time and reduce the cost of using immersive technology.

+ An immersive platform dedicated to training and education

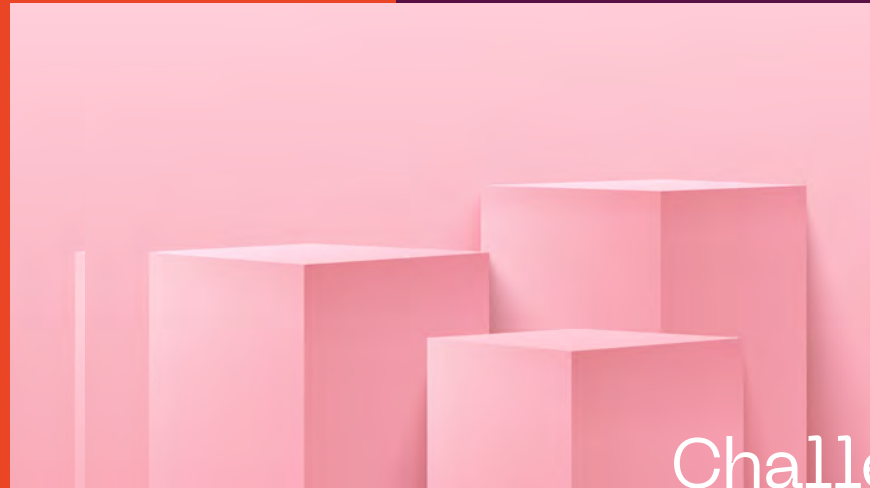
Following the example of digital learning platforms, it is essential that one or more immersive platforms specialising in education emerge, enabling learners to be brought together in 360° video, virtual reality or mixed reality. As we mentioned in Chapter 2, there is currently very little on offer, and there no specialised teaching platform exists in France. The Nexus project¹²² is meant to rectify this, but it will still be a few years before it is truly ready for large-scale deployment.

+ Session management tools for trainers and teachers

Hosting a session using 360° video, virtual reality or mixed reality is not the same as hosting a face-to-face session. This is because the teacher or trainer cannot see what the learners see, or what they are doing (except in mixed reality, but without having all the elements in front of them). What's missing today is a kind of 'back-office' that allows you to influence the immersive experience, or even intervene in it. Solutions are hitting the market, but we are still a long way from something sustainable, comprehensive and industrialised.

+ Fleet management tools

A fleet of immersive headsets cannot be controlled as easily as a fleet of PCs or smartphones. Without industrial asset management solutions, Immersive Learning cannot be deployed en masse. Players such as Uptale¹²³ are working on this, and we can be sure that this requirements will be met in the years to come.



7.2

Challenge no. 2: Improving accessibility and inclusion

Accessibility is a major challenge for Immersive Learning. While this method offers enormous potential, it also raises many questions in terms of accessibility and inclusion.

Firstly, inclusion...

We know the power of representation and example. Young women account for only 31% of students in scientific CPGEs (preparatory classes for grandes écoles), and 29% of engineering students, according to the 2020 statistics in the report on gender equality from DEPP (Direction de l'Evaluation de la Prospective et de la Performance - Directorate of Evaluation, Forecasting and Performance) published in 2022.

This under-representation is commonplace, both before and after the baccalauréat, but also in companies. The lack of examples and role models is one of the factors behind this under-representation. Another is the lack of inclusiveness in the examples given in textbooks and exercises.

The media are well aware of this. The television series and adverts of today offer much more inclusive portrayals, featuring people from minority groups (ethnic minorities, LGBTQIA+, senior citizens, people from disadvantaged or lower middle-class backgrounds, people with disabilities, etc.)

While the tools for creating avatars already make it possible to represent yourself in every way imaginable, it is essential that the immersive experiences on offer are as inclusive as possible in terms of representing human diversity.

First and foremost to avoid reinforcing stereotypes, as Katerina Bezrukova, lecturer at Buffalo's School of Management (USA), points out. Secondly, to prevent one of the benefits listed in chapter 2 - greater learner commitment - from being diluted or even cancelled out for some learners who find themselves disconnected from the image reflected by the proposed world.

Let's take another look at the power of empathy and immersive technologies to educate, inform and raise awareness of the challenges of inclusion and diversity, but also of what are known as psychosocial risks (PSRs¹²⁴) and occupational safety as in Quality, Health, Safety & Environment practices. Fortunately, a number of players are taking action on these issues, including two wonderful French companies: Reverso¹²⁵ for the first and Immersive Factory¹²⁶ for the second.

Then accessibility...

A not insignificant point: we're not starting from scratch! A standard has been defined by the W3C: XR Accessibility User Requirements (XAUR). It sets out a series of requirements for guaranteeing

the accessibility level of an immersive experience. XRSI and the Cyber-XR coalition have also published a set of recommendations called "Immersive Technology Standards for Accessibility, Inclusion, Ethics, and Safety"¹²⁷. The XRAssociation has published a guide called "Accessibility & Inclusive Design in Immersive Experiences". And since 2019, the XR Assist group, based at Cornwell University in New York¹²⁸ has been promoting inclusive design and accessibility in XR, supervising research and providing resources.

Manufacturers are also performing their own research, such as Meta¹²⁹ which provides a set of recommendations for developers¹³⁰ and implements accessibility features in the operating system of its headsets (mobility, colours, sound).¹³¹ For France and the Francophone world, proposing common standards would allow our values to shine through at standardisation bodies.

These functions are based on: adjusting colours to suit visual impairments, using voice commands for those who have difficulty with controllers, providing rapid access to a

safe space for people with cognitive difficulties, adjusting the time allocated to tasks, etc.

reminder: a colour on the interface assigned to a button to be used, represented by a ring on the finger activating the button.

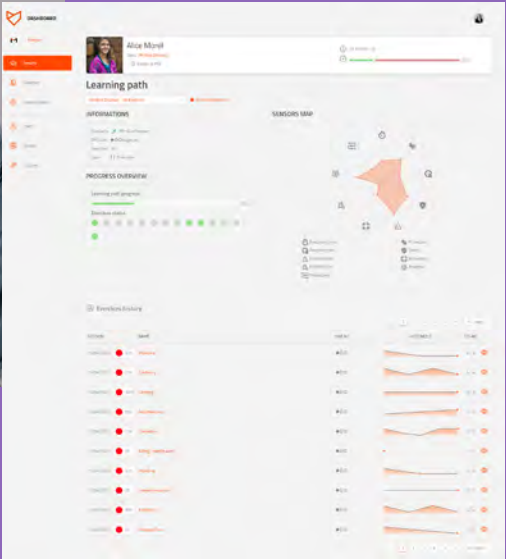
The first step would therefore be to:

- + translate and centralise this work to make it easily accessible to developers,
- + draw on this structured framework to introduce an awareness-raising and incentive-based approach, backed up by a working group to improve and add to it over time.

In addition, as pointed out by Christian Cousquer, educational engineer at the CNAM and immersive & accessibility project manager, it is important to:

- + take a look at **web and video game standards**. Indeed, these environments complement Immersive Learning and can be a source of inspiration when it comes to solutions;
- + **experiment**: beyond what we imagine and anticipate when we design the immersive activity, when we face reality it reveals blind spots that need to be addressed.

This is how we recognised the importance of offering textured floors to avoid the sensation of floating in the air, or how we discovered the solution of "magic rings" to help learners who couldn't remember the function of each button. A simple visual



The challenge here is to standardise the accessibility solutions provided by the various content and activity creators, manufacturers and, by extension, all the players in the sector, to ensure consistency of use for learners with disabilities.

They should not have to carry the mental burden of adapting the experience to their disability from one experience to the next, nor should they have to "relearn" how to use these accessibility solutions. This standardisation of commands is preferable for all learners and as far as possible for all experiences.

Finally, to round off the process and ensure that these accessibility solutions are relevant, monitored and developed: the definition of an **evaluation framework and a continuous improvement approach need to be formalised, defined, managed and promoted.**

There will once again be a need for a centralisation and coordination body capable of producing the recommendations and guides to good practice that everyone needs.

7.3

Challenge no. 3: Limiting physiological and psychological risks

We need to make it clear from the outset that all recommendations that apply to the use of screens, social networks and video games apply without reservation to virtual reality headsets and immersive experiences. This is the case with PEGI (Pan European Game Information) classifications, which require the minimum age of the player and the type of content to be indicated, as well as the initiative by the DILCRAH (Inter-ministerial Delegation for the Fight against Racism, Anti-Semitism and Anti-LGBT Hatred) to create a "Civic engagement in video games" moderation code¹³² to educate people on toxic behaviour.

However, immersive technologies have a number of specific features requiring complementary approaches. For example, in France the VR Connection Ethics Committee published a "Charter

of recommendations on the use of Virtual Reality"¹³³ in 2019. It stressed that VR "manipulates the psychological mechanisms involved in the experience of what constitutes reality" and "that create our sense of reality, of being in direct contact with our body and our environment".

According to researchers Madary and Metzinger (D), in extreme cases virtual reality is capable of modifying the phenomenological identification unit of the self. This is why they recommend a precautionary approach while scientific studies are carried out to increase our knowledge of the impact of immersive technologies on the mind and self-perception, and on:

- + content type,
- + duration of immersion,
- + repetition of immersion.

This is also what Kavya Pearlman (founder of XRSI¹³⁴, an organisation working towards immersive development that is inclusive, responsible and safe) describes as the "Phantom Timeline Syndrome". After spending a significant amount of time immersed (i.e. immersions of a long duration, repeated regularly), the human brain could end up considering reality as another version of the virtual world, causing the person to question themselves.

Is this my face, my body, my hands...? This phenomenon is already visible among people who misuse the TikTok / Snapchat / Instagram filters that change their face. The more they use them, the more they end up not being able to look at themselves, to accept themselves as they are.

We can only hope that these questions, and more generally the impacts, both positive and precautionary, will be explored in the future in greater depth in multi-disciplinary scientific studies that will refine our understanding and recommendations. The increase in the size and diversity of samples thanks to the growing number of regular users will also contribute to better documentation of the field.

On the other hand, these phenomena also explain the ability of virtual reality to contribute towards:

- + treating phobias using so-called *exposure therapy* conducted by a psychologist,
- + managing anxiety and pain during hospitalisation, and even replace certain anaesthetics during outpatient procedures.
- + Gaining self-confidence^{168b}

Several French companies are heavily involved in this field: C2Care¹³⁵, HypnoVr¹³⁶, L'Effet Papillon/bliss¹³⁷, Healthy Mind¹³⁸, My¹³⁹ rêve or Mist Studio¹⁴⁰. Virtual reality can therefore also help treat and heal, but this is beyond the scope of learning.

In summary, there is a clear need to centralise existing studies, to organise them and make them easily accessible, and to regularly update this knowledge by creating a network of involved players. Coordinated in this way, they will be able to respond effectively to the needs of private and public stakeholders and citizens wishing to document the developments underway.

7.4

Challenge no. 4: Defining a framework of trust and developing the logic of sovereignty

Whatever the headset you are using, the general conditions of use set by the manufacturer and its privacy policy will govern the data that may be collected. In some cases, a business contract may amend this framework and modify the rules. In short, it is not possible today to guarantee that no data will be collected and used, or even sold, by the manufacturer.

During an immersive experience, your movements are tracked more than 100 times per second. This means that spending 30 minutes or more in an experiment can lead to more than 2 million unique data points being collected, including posture and body shape, by deducing your 'agility'. The most powerful headsets also have eye and facial expression tracking (as standard

with the Quest Pro¹⁴¹, with the necessary accessories for the HTC Vive Focus 3 and XR Elite¹⁴²).

Soon iris recognition will be possible, according to Apple¹⁴³, followed by pupil activity reading, which starts with the HP Reverb G2 Omnicept¹⁴⁴, biometric data, such as connected watches, and brain activity, which is what Varjo and its partner OpenBCI are doing¹⁴⁵, as well as French start-up NextMind, acquired by Snap in March 2022¹⁴⁶.

XReality Safety Intelligence (XRSI) researchers¹⁴⁷, including Louis Rosenberg, found that tracking a user's hands and head could identify them with an

accuracy of 94.33% in 100 seconds among 50,000 users, and 73.20% in 10 seconds¹⁴⁸ (the logical follow-up to AI-based gesture recognition algorithms such as those in use in China since 2018).¹⁴⁹

This same researcher has also been warning for several years about the risks associated with "embodied conversational agents", personalised avatars brought to life by an AI. His recent articles "Metavers 2030"¹⁵⁰, published in November 2021, and "The metaverse will be full of elves", published in January 2022¹⁵¹, illustrate this perspective, its opportunities and risks.

Fortunately, Europe has already adopted some of the most protective legislation in the world: GDPR (General Data Protection Regulation). In theory, no personal data can be collected or transmitted without your prior consent, which you can withdraw at any time. But is this really true? And do you really have the means to verify this as a learner, a trainer or a company that provides its teams with an Immersive Learning system? Article 4 of the GDPR defines "biometric" as "personal data resulting from specific technical processing relating to the physical, physiological or behavioural characteristics of a natural person, which allow or confirm the unique identification of that natural person, such as facial images or dactyloscopic data"

This data makes it possible to draw conclusions about the psychological

profiles and interests of users, as well as identifying them precisely.

You might therefore think that it is not collected on a massive scale, as they are subject to prior consent.

But it is essential to the immersive activity. It is impossible to carry out actions in a virtual world without the video headset collecting, analysing and using data linked to the user's movements in the real world.

So what is the guarantee that this data will not be stored and used for other purposes? Therefore it should be forbidden to process this information without explicit consent. This is not currently the case.

In Immersive Learning, the issue arises in a slightly different way. Sufficient data on activity and behaviour needs to be collected to give the best possible support for learners' progress and to help them obtain certifications or diplomas. Beyond this, no personal or behavioural data should be collected.

In light of the proposed AI Regulation Act, the DSA¹⁵² and the DMA¹⁵³, the European Union will certainly have to develop GDPR to take better account of immersive technologies and close the associated data protection loopholes (data minimisation, transparency and notification obligations in AR/VR/XR environments, methods of gathering consent, etc.)

There is every chance that the Commission will take up this issue in the years to come, given the real security issues raised by this data. Today, public decision-makers and legislators are much more responsive than they used to be. For example, in July 2023, the European Commission published a strategic vision on the subjects we are discussing here (metaverse, AI)¹⁵⁴. The French government has asked Afnor to set up a standardisation committee in February 2023.

On a national level, it is more a question of coordinating the stakeholders in order to produce a set of operational recommendations, providing everyone with a common framework and objectives relating to learning data requirements.

As things stand, DPOs and data controllers find themselves in an "in-between" position, unable to 100% guarantee what data is collected by headsets, and unable to really oppose it. However, this is not normally the case for immersive applications marketed commercially or developed specifically.

The question of sovereignty also arises for Immersive Learning. Most of the equipment on the market is American or Chinese. How do you reconcile the Cloud Act and the risks of technological espionage? What should be done about companies bidding for public tenders where issues of sovereignty are contractual?

7.5

Challenge no. 5: Environmental impact



As the French consultant Lorraine de Montenay reported for Green IT at the conference “Assessing the impact of virtual reality” held at Laval Virtual 2023:

There are currently no studies that can tell us what the environmental impacts of the development of virtual reality and virtual worlds such as the metaverse are or could be. So it is unwise to put forward figures without an analysis of the lifecycle of the equipment used to offer the “virtual universe” product or service.

Although it is true that hindsight and data is lacking on this subject, it is important to stress that work is beginning to emerge and that we are very

likely to benefit from more concrete analyses in the years to come. For example:

- + Cornell University (USA) published a study on the possible impact of the metaverse in June 2023¹⁵⁵,
- + CEPIR¹⁵⁶, created in August 2022, aims to produce data and tools to evaluate the environmental impact of the French XR sector and to come up with recommendations.

From a pragmatic point of view, Immersive Learning, and more broadly the use of immersive technologies, currently represents a very small proportion of the digitalisation of our societies. Some key figures:

- + There are 8.59 billion smartphones in circulation worldwide¹⁵⁷, more than the number of people, compared with the 120 million people in the world who have access to a virtual or augmented reality headset (less than 250 million people by 2027¹⁵⁸)
- + A handful of players occupy more than 50% of the world's bandwidth alone, including Netflix (20%), followed by Google (YouTube in particular), Akamai, Facebook and Amazon, with no immersive use overall.¹⁵⁹

- + A virtual reality session can consume less bandwidth than a videoconference (which requires between 1.2 and 4 MB per second per participant¹⁶⁰) with a virtual reality environment pre-installed on a headset where only the voice and movement plus interaction coordinates are transmitted).

We should also note that the environmental impact of Immersive Learning does not really correlate with that of virtual worlds and the metaverse as presented in 2022. The vast majority of the platforms mentioned are not suitable for learning and education, have little chance of becoming so for a variety of technical or usage reasons, and only work on PCs or smartphones (Decentraland, Sandbox, Fortnite etc.) Reliance on NFT cryptocurrency and blockchain technologies is more than marginal in truly immersive content and platforms, and non-existent in Immersive Learning.

Also worth noting: at present, the majority of uses are disconnected, with content pre-loaded onto headsets. This situation is likely to continue until:

- + the integration of virtual reality headsets is standardised by IT departments,

- + and Wi-Fi networks are adapted to these new additional uses,

In addition, unlike a personal smartphone, an immersive device used in education or training is by definition shared and, usually, managed on a long-term basis. If we draw a parallel with transport, an immersive headset is at this stage closer to public transport than to a private car.

Finally, according to the ADEME - ARCEP (The French ecological transition organization - the French independant organisation to survey electronic communication) study on the ecological footprint of digital technology in 2020, 2030 and 2050 1, **79% of the carbon footprint of digital technology comes from the equipment.** Therefore this is where the bulk of the effort should be focused.

To start with, how many Oculus Gos and Quest 1s are lying unused in the cupboards of companies or training organisations? One avenue to be prioritised is potentially the organisation of a re-use/recycling channel for previous generations of headsets. So-called "first generation" equipment still has a real capacity to provide a service to organisations starting out in this field, and to enable all organisations with a social impact to integrate this approach into the lives of the people they support, in addition to the funding they would be eligible to receive.

In terms of software solutions, analysing their environmental impact is certainly necessary in terms of the design and

production of immersive applications or experiences, but to be 'complete', this work needs to be viewed against:

- + their duration of use,
- + their pooling,
- + their development and updates.

These software solutions also have an impact on usage, linked to the resources consumed, as detailed in the following paragraph. When it comes to design, consideration should be given to the creation of standards for the "responsible" production of content, along the lines of what is happening on the web.

Finally, in terms of servers and resources consumed, which represent only 16% for data centres and 5% for networks, the question arises of the logic of connected virtual universes compared with offline experiences.

In the first example, the impact is linked to the software solutions used. A dedicated SAAS-type immersive solution will have a very different impact from an immersive solution of the metaverse/connected virtual universe type. The lack of hindsight in analysing the impact of these technological choices should neither lead to Immersive Learning not being explored, nor lead to the area being avoided.

In the second example, there is of course a server and network impact to load the application into the headset, but virtually none when it comes to using it, until a new application is loaded (or updated).

The approaches when it comes to minimising the impact of the development of immersive technologies are the same as for digital technologies as a whole:

- + The second life of equipment deemed technologically obsolete when it could still be used for certain purposes by those who would really benefit from it,
- + Extending the life of equipment through eco-design and easier repair,
- + The greatest possible digital restraint in software design through providing developers with methodological guides and recommendations,
- + Gradual replacement of the most resource-hungry equipment as technology evolves, with careful calculation of the environmental impact over the following years.



7.6

Challenge no. 7: Generative AI

The generative AI are developing at high speed. From being capable of answering questions in natural language in a completely credible way¹⁶¹ to generating high-quality creations in a couple of seconds, be it texts, illustrations¹⁶², photos¹⁶³, videos¹⁶⁴, and slightly more time for novels or synthesis of documents over 100 pages long etc, the convergence between AI and immersive worlds is a veritable catalyst for innovation.

And this is just the beginning: the convergence between AI and immersive worlds is a veritable catalyst for innovation.

Combining the power of these two technologies could lead to four major revolutions, but also poses two major challenges. Read on to find out more.

Revolution no. 1: the generation of dynamic virtual environments

With AI, we can expect dynamic, personalised virtual environments that radically transform how we design immersive experiences today. Currently, for a learner to be able to move around and interact in an immersive experience, all the constituent parts need to have been designed and developed upstream. Whether it's the space in which the learner moves, the objects within the space, possible interactions with these objects... everything needs to have been anticipated, thought through, described and developed. Using AI, it becomes possible to generate a new object in the experience "on the fly" and make it available to the learner with complete fluidity. This opens up completely new possibilities in terms of scenario development.

Revolution no. 2: realistic, unscripted interactions

AI could boost the quality of user experiences in virtual environments tenfold, particularly when it comes to interactions between the learner and the virtual avatars in the experience. The learner could then speak to the "AI-powered" virtual avatar, which would understand the request, analyse the learner's non-verbal communication and respond with a perfectly adapted voice synthesis. This is obviously well-suited to training courses focusing on soft skills or simulated interviews, but it can

also be useful in any immersive learning experience, where the avatar is used as an 'assistant' by the learner.

Revolution no. 3: Real-time personalisation of the learner's learning path

AI opens up the possibility of creating dynamic and adaptive learning pathways. Content can be tailored to the individual needs of learners, measured in real time thanks to Learning Analytics. If the AI detects that a learner has more difficulty acquiring one particular technical skill than another, it will adapt the teaching scenario. In this way, the learner will be better guided to work on the gesture, while benefiting from a gradual progression in the difficulty so as to guarantee acquisition of the skill.

Revolution no. 4: advanced, real-time analysis of Learning Analytics

AI can provide invaluable analysis of user interactions and behaviour, which can then be used to create personalised recommendations. Remember that during an immersive experience it only takes 30 minutes to collect more than 2 million unique data points linked to your body and movements. Today, only AI is capable of absorbing such a vast amount of data and analysing it in real time to generate findings and recommendations. This opens up a whole new field for Learning Analytics.

Challenge no. 1: Biases and mechanisms of influence

By definition, an AI doesn't know anything. It is supplied with training data so that it can gradually learn to respond to requests and do what is expected of it. And therein lies the problem. Depending on what it is given to learn, biases may emerge in its model and therefore in its responses or what it produces. The best known are those regarding minorities in the recognition or generation of images¹⁶⁵. If we're not careful, these biases can influence learners through the answers they give, the representations of the world they generate, and so on.

Talking of influence, let's mention the work of Louis Rosenberg (him again), for the "AI Manipulation Problem" he drew our attention to in 2023.¹⁶⁶

In his view, if you combine the amount of data that can be collected for a user on an AI-enabled headset, it becomes possible to generate real-time stimuli capable of influencing the user to think or do what you want (for example, in a conversation with an avatar, when interacting with an object, etc.) How can you prevent this? There is no answer to this yet.

Challenge no. 2: Ethics and respect of private life

Gathering and analysing data on learners' behaviour and performance raises concerns about consent and confidentiality. In this regard, our view is that it is crucial to establish clear protocols to ensure the protection of personal data, including behavioural data collected during experiments. Considering how much can already be done with very little data, it is vital that the protection of learners' personal data is treated carefully and transparently. It is equally critical to guarantee the quality and reliability of AI algorithms, as bad design or biases built into models can lead to inequality or discrimination. Finally, design choices must follow a code of ethics, particularly in the case of real-time natural language interaction, to avoid "manipulating" learners without them being aware.

You will note that we have not listed the role of the trainer in the challenges, nor their replacement by AI. We simply don't believe in it. AI can be a wonderful assistant for trainers and teachers, but it cannot replace them. On the other hand, there is no doubt that as a trainer or teacher

the major challenge is that of monitoring¹⁶⁷ and training in order to understand, anticipate and make teaching choices. That's why you're reading this book on Immersive Learning, so you're on the right path :)

7.7

Challenge no. 7: A sector of French excellence

Contributing to the recognition and development of a sector of excellence has always been the primary objective of France Immersive Learning. This concern is also at the heart of the association's articles.

"However, the fact remains that there is currently no shared centre of expertise, open innovation or research in France, or probably anywhere else in Europe, capable of providing large-scale support to those active in these professional fields [...]. Nor is there any organisation capable of helping to structure and promote a French sector of excellence, despite the fact that the expertise is in place, but has not yet been coordinated."

According to various forecasts, the global market for immersive technologies is

expected to be worth well over \$100 billion by 2030, with the training and learning segment accounting for around 40%. The market will be dominated by the US, unless Lynx, a remarkable French headset, or other challengers establish themselves permanently in the ecosystem. The equipment will most likely be manufactured in China for American and Asian companies.

On the other hand, in terms of content and distribution, France and Europe have some serious advantages.

The expertise, talent and determination are there, but so far they have not been sufficiently coordinated. The representative organisations, federated within the National XR Council (CNXR)¹⁶⁸ since 2021, are associations with few resources, if any. The first challenge for these representative associations is to identify sources of financial support beyond the subscriptions they manage to collect. Without sufficient resources, it will be impossible for them to implement the large-scale projects required to structure the industry.

The second challenge is that they should have permanent regional contacts, so that they are able to lead and inform local ecosystems, where the vast majority of needs and reservoirs of growth are to be found.

The third challenge is that those wishing to do so should be able to evolve into professional syndicates, which can then be grouped together in a federation. A necessary structure contributing to the recognition of a sector whose actions will focus on:

- + The definition of an ambitious, realistic and achievable roadmap, supported by the authorities
- + Supporting the professionalisation of stakeholders by highlighting the existing training on offer (aimed primarily at teachers, trainers and educational engineers) and the

funding opportunities available to stakeholders in the ecosystem (all types of companies and structures operating in the field).

- + Developing an ecosystem and strengthening links with existing bodies and committees such as the National Digital Council, to name just one.

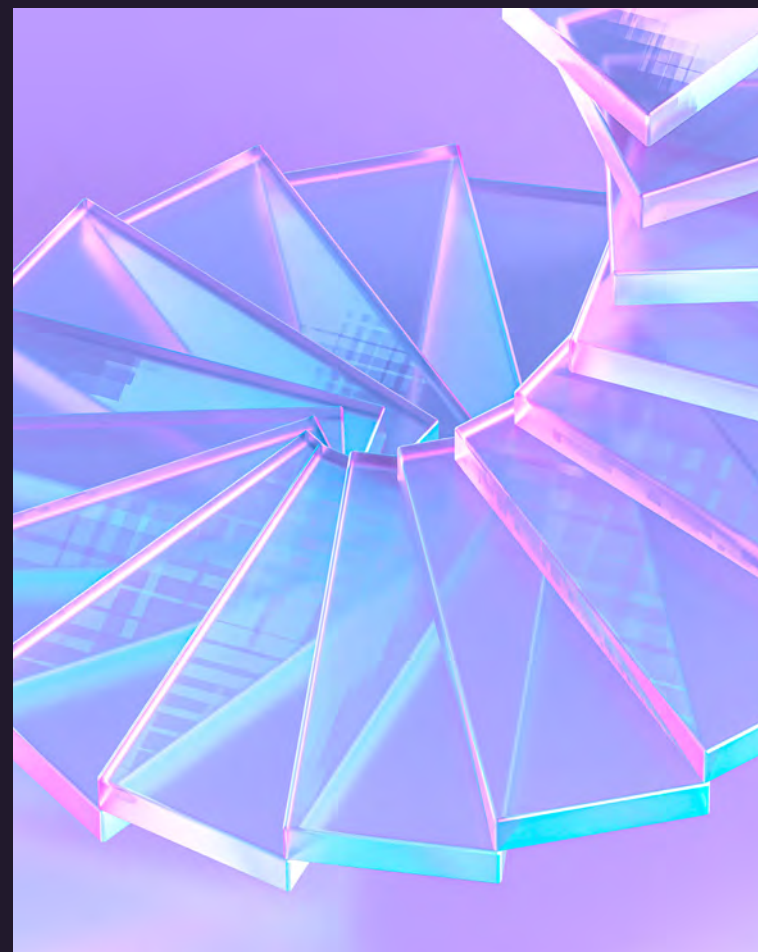
In 2013, Fleur Pellerin, then Minister for SMEs, Innovation and the Digital Economy, launched La French Tech. This initiative, which was designed to promote French start-ups on the international stage, has led to the emergence of a number of highly dynamic regional ecosystems, bringing together entrepreneurs, investors, incubators, accelerators, associations and public institutions. This movement has established France as a land of innovation and entrepreneurship, with many major foreign companies opening sites here: France's appeal is no longer in question.

Apple has just told the world that the future of screens will be those worn in front of our eyes. "This is a time of major construction projects, when everything needs to be built¹⁶⁹".



Experts' corner (annexe)

8.1– A brief history of immersive technology	228
8.2– Equipment	232
8.3– Software	242



chapter 8

8.1

Brief history of immersive



Prehistory

Cave paintings, which come to life in the flickering light and smoke of torches, are the first known form of immersive technology. A bit far-fetched, you might say? Certainly, from our perspective as humans surrounded by the latest technology. Nevertheless, it's safe to say that the impression these cave paintings could have made on cave people was not far removed from that left by today's immersive technologies: an "as if we were there" experience.

We already mentioned that at the Lumière brothers' first screening, a simple, non-immersive screen with low-definition black-and-white film seemed so real to the audience that they left the tent screaming. Immersive technology can sometimes be situational, just think of the panic caused by Orson Welles on the 30th October 1938 when he dramatized the "War of the Worlds" written By Georges Orwell on the CBS broadcast.

The 20th century

And the so-called 365° painted panorama patented by Robert Barker in 1787 and distributed and widely used throughout the 19th century, was actually one of the first immersive mass-media. We touched upon this in chapter 3. Hundreds of thousands of visitors to Paris, London and Berlin have walked it, and enjoyed this experience that was innovative for its time. In a rotunda, a gigantic realistic painting up to 18 metres high was on display. The architectural design of the rotunda gave visitors the sensation of being "immersed" in the scene being painted.

The 1950s

The Sensorama, also mentioned in chapter 3, is developed by Morton Heilig in 1956 as the first multi-sensory immersive device. It allows you to view a film in three dimensions by stimulating several senses (sight, hearing, touch).

The 1960s

The 1960s are a golden age for immersive technologies. A headset displaying what a remote video camera was filming is created in 1961 by Philco (a North American branch of the brand Philips), with the special feature that the camera orientates in real time according to the direction of the user's gaze. Then, in 1963, Ivan Sutherland at MIT develops the Sketchpad, an interactive graphics system for creating and manipulating precise engineering drawings. In 1968, the company founded by David Evans and Ivan Sutherland builds the first virtual headset: the "Sword of Damocles". A little later, Thomas Furness (inventor and professor, Seattle, USA) creates the "visually coupled system", another virtual headset. Finally, in 1969, Myron Krueger (USA) launches the "Glowflow" sound and light show, 100% controlled by a computer, during which spectators unknowingly interact via weight sensors sensitive to their movements.

The 1970s

Krueger continues to develop his shows, increasingly relying on computer technology. He eventually coins the term "artificial reality" in 1973. One of his shows, "Videoplace", allows audience members to immerse themselves in a computer-generated universe populated by avatars and other spectators.

In 1977, Kit Galloway and Sherry Rabinowitz (USA) create a virtual space connecting participants via electronic communication (a forerunner of the video-conference).

Then, in 1979, MIT researchers develop "spatial data management systems", a tool for managing, storing and manipulating 3D objects (and their data).

The 1980s and 1990s

DARPA (Defense Advanced Research Projects Agency, USA) creates a war game simulator called SIMNET (SIMulation NETworking) that allows hundreds of soldiers to train in manoeuvre tanks, helicopters and bombers in combat situations. In 1981, Furness develops a virtual flight simulator for pilots. The same year, Andrew Benjamin (MIT, USA) launches a hypermedia system and the "Aspen Movie Map", in which the user moves through a world representing the streets of Aspen, Colorado. In 1984, the American-Canadian writer William Gibson writes the science fiction novel *Neuromancer*, which introduces the term "cyberspace". In 1984, Jaron Lanier (USA) and Jean-Jacques Grimaud (FR)

founded VPL Research and a few years later coined the term "virtual reality".

In the 1990s, everything accelerated. The BOOM (Binocular Omni Orientation Monitor), a virtual headset mounted on a large motion-tracking device, is developed. NASA's work on liquid crystal displays helps reduce the size and weight of headsets. Numerous headset and equipment projects are launched. The cinema gets on board, as does the world of video games. The general public discovers it.

At the time, headsets were not very effective, and CAVE (Cave Automatic Virtual Environment) devices were preferred because they were much more convincing. These were virtual reality rooms in which the walls, floor and ceiling were used as projection surfaces for the content.

The 2000s

The gap between what is promised and reality is still too wide, and public enthusiasm gradually wanes. Virtual reality and immersive technology gradually make their way back into the realm of science fiction, boosted by a number of films (*Avalon*, *Existenz*, *The Matrix* etc.) In 2014, Google releases a project that seems experimental: the Carboard. A basic cardboard box with two "entry-level" lenses, into which you insert your smartphone. And the machine is off!

In 2013, a previously unknown company called Oculus launches its VR headset on Kickstarter. 7,500 headsets are pre-ordered and delivered. The story is well

known: the following year, Facebook buys Oculus for \$2 billion and launches its VR business. In 2015, HTC and Samsung follow suit. As does Microsoft in 2016.

Today, dozens of VR/AR/MR headsets are on the market, and new manufacturers continue to emerge, such as Lynx, the only French manufacturer in the race. The market has become more structured and the range of content has diversified.

8.2 Equipment

VR vs MR?

Few of the headsets on the market can be described as mixed reality headsets. It's not enough for the headset to have two cameras and a passthrough feature¹⁷⁰. Mixed reality requires powerful image analysis algorithms and LIDAR¹⁷¹ to map the space and the objects within it, and to be able to correctly insert virtual objects. In this instance, apart from the Hololens 2 and Magic Leap 2 goggles, the only mixed reality headset is the Varjo XR3 (€6,500 plus a subscription of €1,500 per year). The Quest Pro seems to be paving the way for mixed reality at Meta.

Power

There are 2 types of video headsets: tethered and stand-alone.

The former must be connected to a VR PC with a latest-generation processor and powerful graphics card (HTC Vive Pro 2, HTC Vive cosmos, HP Reverb, Valve Index, Varjo Aero and XR3, Pimax Crystal, etc.). With the exception of the Cosmos, which can be considered obsolete, all require outside-in tracking based on the use of a Valve tracking beacon system.

The latter can operate without a VR PC (Meta Quest 2, HTC Focus 3, Pico 4, etc.) They have inside-out tracking¹⁷² and do not need any external tags. The result is greater ease of use. Their computing capacity is lower (all stand-alone headsets use the same chip, Qualcomm's XR2, which combines a CPU and a GPU¹⁷³). Their display of 3D models is also less detailed than that of tethered headsets, as they cannot display as many polygons.

That said, and therein lies their versatility, they can also be connected to a VR PC and take advantage of its computing power. If we compare an HTC Vive Pro 2 (tethered headset) to an HTC Focus 3 (stand-alone headset), there are very few differences: the former will have better audio and slightly more precise tracking¹⁷⁴.

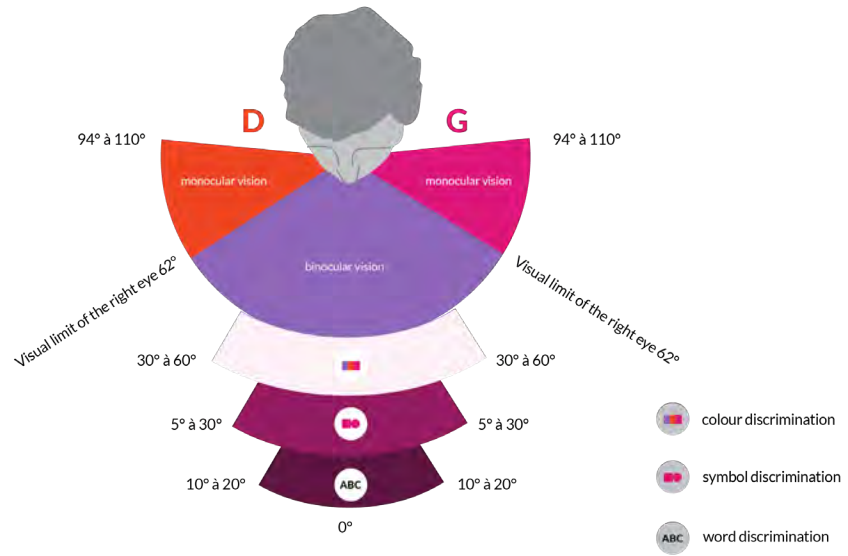
Optics

Field of Vision (FOV¹⁷⁵) & Resolution

Headsets from most manufacturers offer a relatively reduced horizontal field of vision (HFOV¹⁷⁶), between 93° and 110°¹⁷⁷. In other words, they offer a binocular field of vision (approximately 124°) and deprive the user of peripheral vision (32° to 48° on either side of the binocular field).

Only two manufacturers are pursuing the goal of natural vision, i.e. a field of vision greater than 180°: Pimax and Xtal. These headsets are bulky and uncomfortable. While they offer real added value in terms of immersion, they are not very suited to use in a professional context, because the software development kit (SDK) does not allow an application developed for them to be ported to other headsets.

In terms of resolution, another goal is the resolution of the human eye. Here, the parameter to consider is the number of pixels per degree (PPD), which does not depend on the field of view covered. Usually, to match the resolution of the human eye, you need to align at least 60 PPDs. The PPD champion is the Finnish company Varjo, whose top-of-the-range headset, the XR3, offers 70 PPD over a central area of 27° x 27° and 30 PPD outside this area. To compare, a Quest Pro is 22 PPD, a Pico 4 21 and a Quest 2 20, while an HTC Vive Pro 2 is 24 PPD.



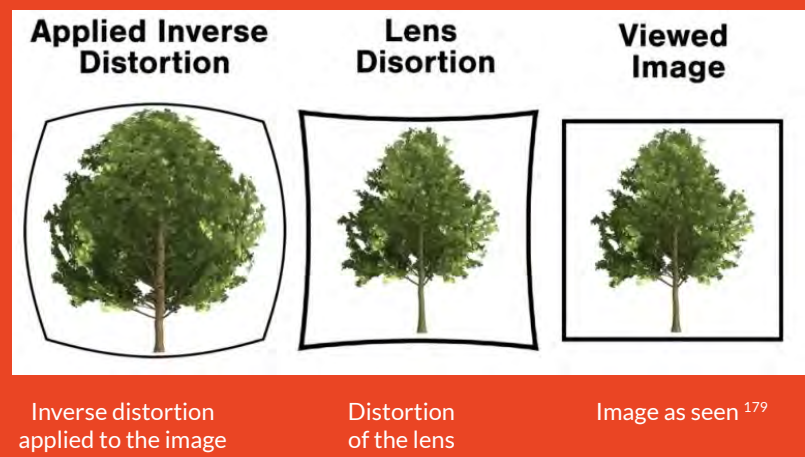
Human field of vision¹⁷⁸

Pancake lens

Until 2022, virtual reality headsets used Fresnel lenses to correctly reproduce the images displayed on the screens (one screen for each eye to produce stereoscopic vision). This type of lens has several disadvantages:

- + Their zone of sharpness is reduced: you need to adjust your headset so that your eyes are aligned with the sweet spot (the central sharpness zone).

- + They also need to be placed at a certain distance from the screens, which results in an unfavourable shape factor, i.e. a thicker headset. Because they distort the image (pincushion distortion), they require computing power to display a distorted (barrel-shaped) image on the screen.



Pancake lenses, which first appeared on the market in 2015, are gradually replacing Fresnel lenses. No more distortion, no need for precise adjustment of headset position, less distance from screens and a significant reduction in the thickness of the headset. These are the pancake lenses used in the Pico 4 and Meta Quest pro, and they are set to become the new standard.



Foveated rendering

Foveated rendering is a rendering technique used in virtual reality (VR) to concentrate computing power where the user's gaze is focused, known as the foveal zone.

The term "fovea" refers to the part of the retina of the eye responsible for central vision and the highest visual acuity. This is the area of the eye where details are perceived with great clarity. In contrast, the peripheral vision that surrounds the foveal zone is less sensitive to detail, but plays a vital role in detecting movement and changes in the surroundings.

In foveated rendering, the idea is to maximise the graphic rendering in the zone of the same name while degrading it in peripheral vision. To implement foveated rendering, virtual reality systems use real-time eye-tracking techniques.

to determine where the user is looking.

Interpupillary distance adjustment

As we already mentioned in chapter 3 (see 3.8. Multisensory integration), the interpupillary distance (IPD) varies from person to person and is on average lower in women, and even more so in children. Failure to respect this leads to eyestrain.

IPD adjustment is becoming standard for new headsets being launched on the market. Some offer manual adjustment of the IPD, either in increments (only three are available on the Quest 2: 58 mm, 63 mm and 68 mm), or continuously (between 55 and 75 mm on the Meta Quest Pro). Others, like the Varjo or Pico 4 headsets have automatic, motorised adjustment (between 62 and 72 mm).

Varifocal

All headsets currently on the market display VR content at a fixed focal length. This generates an oculomotor disorder: VAC, or Vergence-Accommodation Conflict. The promise of a varifocal display lies in eliminating the VAC. That's the challenge Meta is taking up with its Holocake lenses: being able to create 64 accommodation planes. However, this promising technology is not yet ready for mass production: "Holocake lenses have one major limitation: they require specialised lasers as a light source. LED backlights are not suitable. And these lasers are not yet available at a consumer product level of performance, size and prices, discounts or sales."¹⁸⁰

The problem of glasses

Should you keep your glasses on when you put on a headset? The answer is... not always. As a general rule, people with myopia and presbyopia should keep their glasses on. And it needs to be possible: some headsets, like the Quest 2, don't make wearing certain types of glasses easy. For hypermetropic people, it's best to try without glasses.

Only one headset offers native dioptric correction (HTC Vive Flow), however it's often possible to add a corrective lens to suit your eyesight. There are several manufacturers whose products can be adapted to a wide range of headset models¹⁸¹.

Tracking

Inside-out tracking

Inside-out tracking is based around the use of SLAM cameras located on the outside of the headset (four for a Quest 2 or Pico 4), which map the real environment around the user in the form of point clouds. These points serve as references for tracking the movement of the video headset (and therefore the user's head) and the controllers, in both real and virtual space. This tracking takes place in real time, using the headset's inertial sensors, controllers and a predictive algorithm.

The cameras are also used for passthrough, i.e. the ability to see the real environment, with each generation of headset offering better resolution, less distortion and a more dynamic display. It should be noted, however, that MR headsets do not use these cameras for passthrough, but two dedicated high-resolution cameras positioned on the front panel instead.



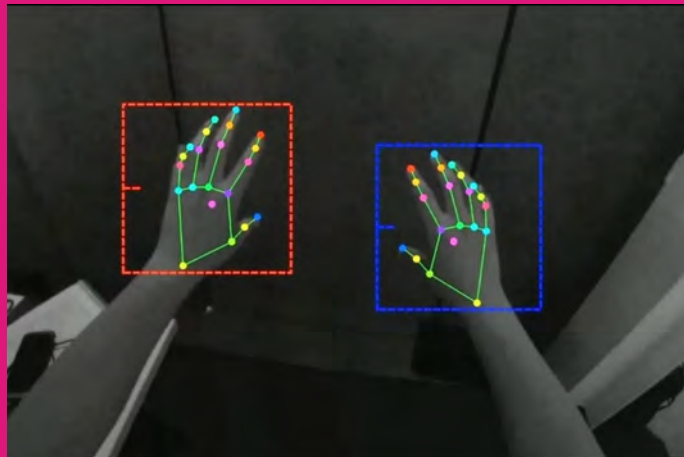
The Pico 4 with its four cameras positioned around the headset's perimeter



The Quest Pro and its two front-facing passthrough cameras, plus three cameras dedicated solely to inside-out tracking (one on the front and one on each side).

Hand tracking

Hand-tracking consists of following the movement of the hands and reproducing it in VR in real time. This function allows you to interact in a pseudo-natural way, without a controller. Meta declared that its researchers and engineers “developed a new method of applying deep learning to better understand hand poses when the device's cameras cannot see the entire hand or when the hand moves quickly”¹⁸².



Hand tracking is generally not the most accurate, which is why today headsets are mostly sold for use with controllers. The arrival of Apple and its Vision Pro, which does not use a controller and relies entirely on hand-tracking, should shake things up and lead to better tracking quality.

Eye tracking

With an XR headset, the eye-tracking components usually include cameras and light sources placed in a ring-shaped structure between the user's eyes and the screen. The principal machine learning algorithms generate a set of data in real time, such as pupil size, gaze vector and eye opening¹⁸³.

Eye tracking makes it possible to find out in real time what the user is looking at in the virtual environment, where they stop looking, for how long, and where they do not look: the entire visual pathway and pupillary reactions are reviewed. This information can be used, for example, to determine a person's ability to follow a stimulus, how they react to a situation, or even what they intend to do.

Not all headsets are equipped with eye-tracking technology, but all manufacturers offer one or more models that use it (or additional modules, such as the HTC Vive). In addition to the fact that eye tracking makes it possible to trigger interactions without the use of controllers (gaze), and is a prerequisite for foveated rendering¹⁸⁴ and the simulation of eye movement of avatars, it has many other applications.

Today, over 2,000 universities use this technology to understand human behaviour and psychology. How do we interact with others? How do we navigate in space? These are the questions that

fascinate researchers. Based on certain behaviours and responses, we can analyse a user's emotions and actions.¹⁸⁵

Eye tracking thus has many applications in the fields of neuroscience, psychology, industrial engineering, marketing and advertising. But what about training and education?

Here are a few ideas for application in this field:

+ Measuring engagement:

By observing the time spent looking at certain visual elements in the virtual environment, we can assess learners' level of engagement. Prolonged periods of fixation on specific elements may indicate high levels of interest or immersion in the training.

+ Assessment of understanding:

Eye tracking enables us to understand whether learners are focusing on key elements or whether they are having trouble identifying important information. This can be useful for adjusting training content and

providing targeted feedback.

+ **Study of cognitive processes:**

Eye tracking allows us to observe how learners analyse and process information in the virtual environment. For instance, we can study their decision-making, their search for visual cues or their action planning.

+ **Dynamic content adaptation:**

Eye tracking can be used to adapt training to the actions and attention of learners in real time. For example, if a learner appears to be having trouble focusing their attention in the right place, the content can be adjusted to offer additional explanations.

+ **Memorisation study:**

By analysing eye movements during a training sequence, it is possible to evaluate how well the information presented has been memorised. This can help identify areas that need to be repeated or reviewed.

Body tracking & face tracking

Body tracking involves capturing the user's body movements to animate their avatar realistically. The headset and controllers are usually supplemented by sensors positioned at the ankles and hips as a minimum.

However, with advances in artificial intelligence, this avatar tends to be animated solely by the movements of the headset and controllers, as this research from Meta Lab demonstrates ¹⁸⁶.

Face tracking, on the other hand, is more complex and is currently reserved for top-of-the-line headsets such as the Meta Quest Pro or Apple Vision Pro. A series of infrared cameras are placed inside the headset and a deep learning program controls the user's avatar. Not to mention the question of compatibility between models of headsets and cameras... which is not always straightforward.

In short, face tracking has not yet penetrated the mid-range market. It can only be used with top-of-the-line headsets... but watch this space!

By combining body tracking, face tracking and eye tracking, the ultimate aim is to have avatars that faithfully reproduce body movements, facial expressions and lip movements and that can make eye contact and fulfil the promise of non-linguistic communication. The challenge? Achieving a real social presence for users in virtual worlds.

Robustness

To measure the robustness of a VR headset, a use case is a good place to start. When it comes to robustness, tethered headsets, which have their own power supply, have no particular problems: connected to VR PCs, they can deliver VR content 10 hours a day without any difficulties.

However, this is not the case with stand-alone headsets, and for a very simple reason: they are battery-powered, so their autonomy is limited (1.5 to 2.5 hours, depending on the application used and the resources it requires). Our use case is provided by BPCE¹⁸⁷: Six stand-alone headsets with training sessions running all day long, for months on end. 5,000 people trained without a single breakdown. The secret? The HTC Focus 3, a headset designed for professional use with a hot-swappable battery.

8.3

Software

Standards

Every technological field is subject to the need to produce standards, which guarantee the pooling of research and the optimisation of solutions. Immersive technologies, like the internet before them, are no exception to this.

Until recently, the compatibility of an application with the various headsets available to buy and their SDKs ¹⁸⁸ was not guaranteed and in some cases required specific developments. A standard has emerged to facilitate this compatibility and the "maintainability of applications": **OpenXR**.

It is an open, royalty-free standard enabling access to virtual reality and augmented reality platforms and devices. It is being developed

by a working group managed by the Khronos group consortium ¹⁸⁹, which counts 500 members including major players in the industry such as Intel, ARM, Google, Apple, AMD and Qualcomm.

Another factor encouraging the standardisation of developments is Qualcomm's XR2 chip ¹⁹⁰ which features on most stand-alone headsets on the market and which encourages the unification of hardware and middleware solutions. ¹⁹¹. In contrast, for reasons of competitive advantage, certain technologies and functions, such as eye tracking and face tracking, have not been standardised (see 8.2. Hardware).

XRDMs

XRDMs are the updated version of MDMs ¹⁹² for stand-alone headsets. They enable the triangulation of users, a library of applications and a fleet of stand-alone headsets (VR) or glasses (AR). What do we mean by triangulation? This involves associating an application deployed on a specific headset with a specific user profile.

In practice, XRDM allows you to:

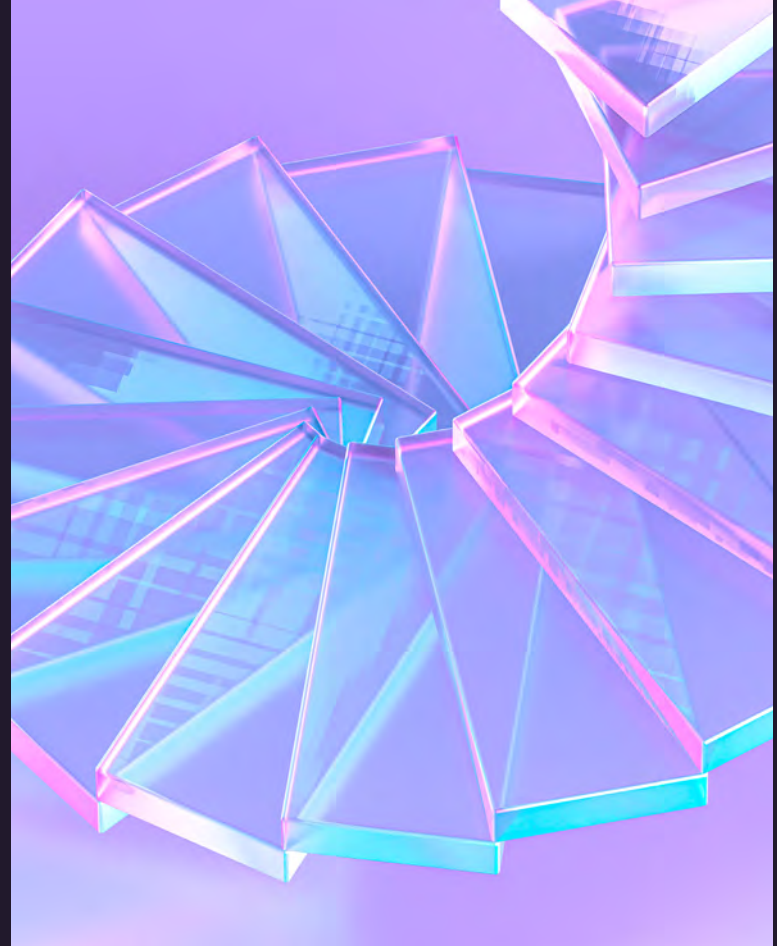
- + maintain each headset in your fleet (firmware updates)
- + install the applications of your choice
- + monitor the use of an application for a given user: open access, tracking of application use, or even kiosk mode, which allows users to go directly to the application they need when they start up the headset (so

that there's no need for navigation when it comes to launching their application).

XRDM is "tailored" towards large organisations that need to deploy on a massive scale. Imagine 10,000 employees, 15 applications and 250 stand-alone headsets. We agree that managing a deployment "manually" is not an option. XRDM is the obvious solution.

Few XRDMs are actually operational. Here are the two main ones: ArborXR ¹⁹³ from the US (formerly Springboard VR for aficionados) distributed by Matts Digital ¹⁹⁴, member and director of France Immersive Learning and Australian Snobal ¹⁹⁵.

And now?



Chapter 9

We hope that, like us, you are now convinced of the potential of Immersive Learning and that you will be part of the coming educational revolution. We also hope that reading this guide has made you aware of the importance of building this future together, by pooling our resources to create an industry of excellence capable of rising to the challenge of digital sovereignty!

France Immersive Learning works every day to raise the profile of all those involved in Immersive Learning in France, whether they are manufacturers, software solution providers, content producers, support agencies or end users (universities, schools, training organisations, companies).

This guide was made possible thanks to all the stakeholders and experts in immersive learning who agreed to share their knowledge and experience. You'll find a list of these people on the acknowledgements page.

We do not intend to sit back and rest on our laurels, it is time to make the uses of immersive learning more widely visible. So in the wake of this book being published, the association is launching a Use Case Observatory. Then, some time in 2024, you will discover the first Immersive Learning Awards ceremony, which will highlight and reward the best use cases in education and training. Finally, we have already started working on a version of this guide that is even richer,

denser and more immersive... So don't drag your feet on launching your immersive projects if you want to be included!



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Annotations

13
142
76
98
41
109
201

1. In this book the term education is used whether it concerns pedagogy (i.e. for children) or andragogy (i.e. for adults, which includes professional training, skill acquisition and so on)
2. The term pharmakon means both remedy and poison in Ancient Greek. (FR) <https://www.cairn.info/revue-psychotropes-2007-3-page-27.html>
3. A definition given par the French Larousse French dictionary
4. A definition given par the French Larousse French dictionary
5. National Center of Textual and Lexical Resources of the French National Centre for Scientific Research (CNRS)
6. <https://youtu.be/pKB5hI5hdmY?si=TPth4LPkEceHPIg3>
7. <https://youtu.be/pKB5hI5hdmY?si=TPth4LPkEceHPIg3>
8. https://youtu.be/pEjbsNRvLfM?si=gj0e_Hqx6k3jD0yV
9. <https://www.frontiersin.org/articles/10.3389/fnhum.2018.00047/full>
10. <https://www.baldr-innovation.fr/>
11. See chapter 3
12. See use case in chapter 5
13. Émilie Gerbier, Olivier Koenig. https://shs.cairn.info/article/E_ANPSY_153_0435?lang=en
14. In L'Année psychologique 2015/3 (Vol. 115), pages 435 to 462 <https://shs.cairn.info/journal-l-annee-psychologique1-2015-3-page-435?lang=en>
15. This percentage is an example, the figures quoted vary from one stakeholder to another without any source to back them up
16. <https://www.nature.com/articles/s41539-022-00147-6>
17. Virtual reality in episodic memory research: A review. S. Adam Smith. Psychonomic Bulletin & Review, 2019 <https://link.springer.com/article/10.3758/s13423-019-01605-w>
18. La relation comme forme. L'interactivité en art. Jean-Louis Boissier, Geneva, MAMCO, 2004. (FR)
19. La psychologie cognitive. Michel Denis (dir.) Éditions de la Maison des sciences de l'homme, 2019. Chapter 9. Les émotions. Martial Mermillod, Lætitia Silvert, Damien Devaux, Nicolas Vermeulen and Paula Niedenthal (FR)
20. Le Goswami, U. (2004). Neuroscience and education. British journal of Educational psychology, 74(1), 1-14.
21. Gaston Bachelard is a 20th century French philosopher.
22. English talk by Stanislas Dehaene, French expert in learning process and neuro-sciences" <https://youtu.be/MF5zOuNmdh4?si=hGIUfTiWaPZt6kt>
23. <https://educatorsinvr.com/2021/01/26/lessons-learned-from-over-100-vr-english-lessons/>
24. See chapter 3,3 for futher information
25. <https://mimbus.com/produit/pilote-de-ligne-de-production/>
26. Space Explorer, Studio Felix & Paul : <https://www.felixandpaul.com/?spaceexplorers>
27. Everest VR, Jonathan Griffith Productions <https://jonathangriffith.eu/everest-vr>
28. <https://engagevr.io/vr-training-solutions/>
29. Berlin Blitz 1943, BBC. <https://www.viveport.com/apps/b0d7eff7-abad-4de4-8a87-4db4316c4669?hl=fr-FR>
30. <https://www.mnhn.fr/fr/experience/revivre-les-animaux-disparus-en-realite-augmentee>
31. <https://www.mnhn.fr/fr/exposition-evenement/mondes-disparus>
32. Titans of space <https://www.youtube.com/watch?v=McrX1678uIE>
33. Théorie de réalité virtuelle, Philippe Fuchs, Presse des Mines, 2018 In French only so far
34. Directed by Eliza McNitt, by executive producers Darren Aronofsky and Ari Handel, narrated by Millie Bobby Brown, Jessica Chastain and Patti Smith.... And produced by VR studios, including Novelab and Atlas V, two members of the French Immersive Studio. <https://novelab.io/project/spheres/>
35. <https://www.mnhn.fr/fr/experience/voyage-au-coeur-de-l-evolution> (FR)
36. <https://youtu.be/6-DaWgg4zF8>
37. <https://www.statista.com/forecasts/1143723/smartphone-users-in-the-world>
38. <https://www.statista.com/statistics/677096/vr-headsets-worldwide/>
39. <https://er.educause.edu/articles/2022/5/xr-success-in-vocational-training-the-conservatoire-national-des-arts-et-metiers>
40. <https://www.smartvrlab.nl/roi-for-vr/>
41. <https://www.immersivelearning.news/2021/04/02/intel-enhances-corporate-training-process-with-vr-sees-estimated-5-year-roi-of-300/>
42. This saying is credited to Robert Orben or Abraham Lincoln
43. https://www.verslehaut.org/wp-content/uploads/2017/10/@20160628_rapport_e%CC%81valuation_impact_social_e%CC%81ducation.pdf Julien Kleszczowski, Ph.D. in Management Science, is specialized in the field of Management Control and Third Sector Organizations. He is Associate Professor, Lille University School of Management (FR) and at ISG International Business School (FR).
44. <https://www.insidehighered.com/>
- news/tech-innovation/teaching-learning/2023/07/11/metaversities-face-virtual-learnings-financial?utm_medium=social&utm_source=linkedin
45. The Embodied Mind: Cognitive Science and Human Experience, Francisco J. Varela, Evan Thompson and Eleanor Rosch, 1991
46. Réalité virtuelle et éducation. Pierre De Looz, Jacques Tisseau, LISyC - Centre Européen de Réalité Virtuelle – Brest Journal de l'Association Française de Réalité Virtuelle: www.afrv.fr – no.10 - 2011 (FR)
47. <https://mimbus.com/produit/vulcan/>
48. In France, professional as well as vocational training is regulated by quality assurance systems.
49. "The" 4 pillars of learning have been defined by Stanislas Dehaene, a cognitive neuroscientist at the Collège de France (Paris, France) [https://www.thelancet.com/journals/lanear/article/PIIS1474-4422\(20\)30229-5/abstract](https://www.thelancet.com/journals/lanear/article/PIIS1474-4422(20)30229-5/abstract)
50. HOUSSAYE, J (2000), Le triangle pédagogique. Théorie et pratiques de l'éducation scolaire, Peter Lang, Berne, (3rd Ed., 1st Ed. 1988)
51. For example, in the case of Baldr's FIRE kit, smart fire extinguishers are an integral part of the experience.
52. CPU stands for Central Processing Unit, GPU stands for Graphics Processing Unit
53. <https://virtual-guru.com/casques-vr/htc-vive-pro-2-vs-focus-3-quel-est-le-meilleur-casque/> (FR)
54. <https://haptx.com/>
55. <https://www.manus-meta.com/products/quantum-precision-xr>
56. <https://www.senseglove.com/product/nova/>
57. <https://builtin.com/articles/augmented->

- virtual-reality-surgery
58. https://www.linkedin.com/posts/ernest-l-nny-ribeiro-a33328227_vrchat-activity-7085566098166673408-kaCN?utm_source=share&utm_medium=member_desktop (FR). A project of film production within the VR.
 59. <https://engagevr.io/>
 60. For example: no connector with Sketchfab.
 61. Here we could mention ORamaVR's MAGES SDK to create our own training simulations with a low-code toolbox or even the open-source platform Nexus, currently under development, presently led by Inetum.
 62. This refers to a French exploratory mission on metaverses. <https://www.economie.gouv.fr/metavers-premier-grand-rapport-exploratoire> "The Concept Of The Metaverse is of a persistent, immersive, and worldwide 3D digital extended reality." (FR)
 63. The European Metaverse Research Network (EMRN) is a collaborative platform dedicated to advancing research and understanding in the field of the metaverse. Through interdisciplinary collaboration and knowledge exchange, EMRN aims to unlock the transformative potential of virtual reality for the benefit of society and beyond
 64. The Metaverse, Matthew Ball, 2022, Norton & Company
 65. Un Métaverse, deux visions, trois possibilités. Grégory Maubon, 2021. <https://maubon.info/2021/12/un-metaverse-deux-visions-trois-possibilites/> (FR). Grégory Maubon is a French expert on VR.
 66. Can Google Build an 'Internet of Places'? <https://arinsider.co/2023/07/25/can-google-build-an-internet-of-places/>
 67. <https://www.usine-digitale.fr/article/pour-niantic-le-vrai-metavers-est-en-realite-augmentee-pas-en-realite-virtuelle.N1158397> (FR)
 68. Beyond Meta — AR and the Road Ahead. <https://youtu.be/SVQ4h0b8HrA?si=vtXiXAcompM8gCnM>
 69. <https://metaverse-standards.org/>
 70. <https://www.inetum.com/en/press/umi3d-consortium-imagining-future-3d-media-open-source-gfi> Julien Casarin, Proposal for a web protocol for multi-support collaboration in 3D environment: UMI3D. University of Strasbourg, 2019 (in French only) <https://theses.hal.science/tel-02518604>
 71. <https://openar.fi>
 72. Llam is now an open-source model which is free to use even for commercial use. <https://llama.meta.com/>
 73. Google which was in favor of open models until now, has decided to lock down its searches in response to OpenAI's strategy (ChatGPT).
 74. <https://engagevr.io/>
 75. <https://www.emissive.fr/en/immersive-expeditions/> From Kheops at the Cité de l'architecture in 2019 to Eternal Notre-Dame in 2023 (and from October 2023, Life Chronicles at the French National Museum of Natural History).
 76. A dongle is a hardware device that can connect to input/output ports, to add WiFi connectivity for example
 77. <https://www.karcher.com/ge/home-garden/cleaning-and-care-agents/know-how/the-sinner-s-circle.html>
 78. <https://cleanboxtech.com/>
 79. <https://uvisan.com/>
 80. <http://www.hygizi.fr/>
 81. Term put forward by Jaron Lanier in 1989. It probably comes from the expression "virtual reality" used by Antonin Artaud to describe theatre in his book *The Theatre and its Double* (1938) and translated by Mary Caroline Richards (1958) who worked on this project with John Cage and David Tudor at Black Mountain College (<https://www.blackmountaincollege.org/4-11-david-patterson/>)
 82. Term suggested by Myron Krueger, artist and creator of "Videoplace", an artificial reality laboratory (<https://www.jstor.org/stable/1578043>)
 83. *Théorie de la réalité virtuelle*, 2018, Presse des Mines, by Philippe Fuchs, French expert in VR and AR. Head of the researchers team dedicated to VR and AR in Robotic Center of High education Engineer MINES ParisTech (Saclay, FR)
 84. Revisiting Milgram and Kishino's Reality-Virtuality continuum . Richard Skarbez, Missie Smith and Mary C. Whitton . *Frontiers in virtual reality*, 2021
 85. *Théorie de la réalité virtuelle*. Presse de Mines, 2018
 86. Slater Mel, Usoh Martin et Steed Anthony (1994). « Depth of presence in virtual environments ».
 87. *Introduction to Virtual Reality*, University of London. <https://www.coursera.org/learn/introduction-virtual-reality>
 88. See 3.2: Interactions - the sensorimotor loop is described in this section
 89. Birdly immersive experience. <https://birdlyvr.com/>
 90. Flyview immersive experience <https://www.flyview360.com/>
 91. We will describe the concept of avatars in more detail in paragraph 3.6.
 92. Ready Player Me <https://readyplayer.me/fr> is a French company which provides developers with an easy-to-integrate Avatar Creator and developer tools to give their users highly-personalized avatars to help increase retention and engagement
 93. *The Impact of Self-Representation and Consistency in Collaborative Virtual Environments*, (2021) by T. Collingwoode-Williams and co-authors to be read in full : <https://www.frontiersin.org/journals/virtual-reality/articles/10.3389/frvir.2021.648601/full> Tara Collingwoode-Williams, Zoë O'Shea, Marco Gillies and Xueni Pan (all Goldsmiths, University of London), *Frontiers in Virtual Reality*, 2021 <https://doi.org/10.3389/frvir.2021.648601>
 94. "For more information, cf chapter 8 "Tracking"
 95. *The Proteus Effect Implications of Transformed Digital Self-Representation on Online and Offline Behavior* (2009) by Nick Yee and Jeremy N. Bailenson. Full text : https://www.researchgate.net/publication/228445790_The_Proteus_Effect_Implications_of_Transformed_Digital_Self-Representation_on_Online_and_Offline_Behavior
 96. *Virtually Being Einstein Results in an Improvement in Cognitive Task Performance and a Decrease in Age Bias* *Frontiers in Psychology*, Volume 9 - 2018 | <https://doi.org/10.3389/fpsyg.2018.00917> Domna Banakou, Sameer Kishore Mel Slater
 97. <https://www.historyofinformation.com/detail.php?id=2785>
 98. <https://fr.wikipedia.org/wiki/Mar%C3%A9orama>
 99. 3D Audio - The Key to True Immersion in VR/AR. <https://medium.com/double-shot-audio/3d-audio-the-key-to-true-immersion-ff4d10330cea>
 100. Created digitally in real time in

- the app without using audio recordings. <https://dl.acm.org/doi/abs/10.1145/3441000.3441075>
101. <https://blanktone.com/>
 102. <https://olfy-official.com/>
 103. <https://birdlyvr.com/>
 104. <https://fr.3dsystems.com/haptics-devices/touch-x>
 105. Systematic Review of Virtual Haptics in Surgical Simulation: A Valid Educational Tool? Karan Rangarajan, Heather Davis, Philip H Pucher Journal of Surgical Education; 77(2):337-347, 2020. doi: 10.1016/j.jsurg.2019.09.006
 106. <https://www.gartner.com/en/research/methodologies/gartner-hype-cycle>
 107. https://en.wikipedia.org/wiki/Technology_readiness_level
 108. <https://fil-asso.fr>
 109. https://immersivefactory.com/fr?gclid=Cj0KCQjwn_OIBhDhARIsAG2y6zNSyp2oA4Rs-by mh4CbZxCab965EhEwV5BPU9ACCI f dt89viiiEk0QaAsp7EALw_wcB
 110. See chapter 4: the D'un seul geste use case - little time to enter into the experience
 111. <https://www.baldr-innovation.fr/>
 112. See 7.1. Creating common resources and tools
 113. <https://www.speedernet.com/mooc-sensibilisation-conception-pedagogique-immersive/>
 114. <https://www.devinci.fr/lancement-dun-nouveau-mooc-dedie-aux-pedagogies-actives/>
 115. For more information on competitive clusters: <https://www.entreprises.gouv.fr/fr/innovation/poles-de-competitivite/presentation-des-poles-de-competitivite> (FR)
 116. https://fr.wikipedia.org/wiki/Technologies_de_l%27information_et_de_la_communication_pour_l%27enseignement
 117. <https://fr.statista.com/infographie/28462/estimation-et-prevision-nombre-utilisateurs-casques-realite-virtuelle-augmentee-dans-le-monde/>
 118. <https://www.usine-digitale.fr/article/emmanuel-macron-annonce-200-millions-d-euros-pour-les-technologies-immersives-et-le-metavers.N2143877>
 119. <https://www.diplomatie.gouv.fr/fr/politique-et-rangere-de-la-france/diplomatie-numerique/actualites-et-evenements/article/le-rapport-sur-les-communs-numeriques-un-levier-essentiel-pour-la-souverainete>
 120. <https://www.unesco.org/fr/open-educational-resources>
 121. <https://www.sciencespo.fr/research/cogito/home/creative-commons-et-open-source-des-libertes-numeriques-a-rebours-de-la-proprietee/>
 122. <https://www.portail-ie.fr/univers/risques-et-gouvernance-cyber/2023/nexus-un-projet-de-metavers-francais-en-open-source-pour-doper-la-souverainete-numerique/>
 123. <https://www.uptale.io/technologie/comment-gerer-efficacement-ses-casques-vr-en-formation-presentation-device-management-sebastien-leang-co-founder-cto-uptale/>
 124. https://fr.wikipedia.org/wiki/Risques_psychosociaux
 125. <https://reverso.fr/>
 126. <https://immersivefactory.com/fr>
 127. <https://xrsl.org/publication/immersive-technology-standards>
 128. <https://xraccess.org/>
 129. How I build inclusivity as an accessibility researcher at Meta | Meta Research (facebook.com) <https://research.facebook.com/blog/2022/9/how-i-build-inclusivity-as-an-accessibility-researcher-at-meta/>
 130. Designing Accessible VR | Oculus Developers <https://developer.oculus.com/resources/design-accessible-vr/>
 131. Meta Quest 2 Accessibility Settings <https://www.meta.com/en-gb/help/portal/articles/settings-and-accessories/accessibility/>
 132. <https://www.dilcrah.gouv.fr/>
 133. VR Ethics Committee - VR Connection <https://vr-connection.com/en/vr-ethics-committee/>
 134. X Reality Safety Intelligence (XRSI, USA) | Helping Build Safe Immersive Environments <https://xrsl.org/>
 135. <https://www.c2.care/fr/>
 136. <https://hypnovr.io/fr/>
 137. <https://www.bliss-dtx.com/>
 138. <https://healthymind.fr/>
 139. <http://myreve.io/>
 140. <https://www.miststudio.fr/>
 141. <https://www.meta.com/fr/quest/quest-pro/>
 142. <https://www.vive.com/fr/product/vive-xr-elite/overview/>
 143. <https://iphonesoft.fr/2023/06/05/apple-vision-pro-qu-est-ce-optic-id-authentification-balayage-iris>
 144. <https://www.hp.com/us-en/vr/reverb-g2-vr-headset-omnicept-edition.html>
 145. <https://varjo.com/vr-lab/bridging-neuroscience-and-xr-insights-session-your-questions-answered/>
 146. <https://www.usine-digitale.fr/article/snap-rachete-la-start-up-francaise-nextmind-pour-ses-futures-lunettes-de-realite-augmentee.N1798912>
 147. <https://arxiv.org/abs/2302.08927>
 148. <https://rdi.berkeley.edu/metaverse/identification/>
 149. <https://techxplore.com/news/2018-11-chinese-gait-recognition-tech-ids.html>
 150. <https://medium.com/predict/metaverse-2030-ee59e4d4010d>
 151. <https://techcrunch.com/2022/01/12/the-metaverse-will-be-filled-with-elves/>
 152. The European Digital Services Act aims to modernise the current e-commerce directive, by regulating online intermediaries and platforms, including “online marketplaces, social networks, content-sharing platforms, app stores, and online travel and accommodation platforms”. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/digital-services-act_en
 153. The DMA (Digital Markets Act) of 14 September 2022 is, along with the Digital Services Act (DSA), one of the European Union’s (EU) major digital initiatives. It became applicable on 2 May 2023. It became applicable on the 2nd May 2023.
 154. <https://www.usine-digitale.fr/article/la-commission-europeenne-cherche-a-garantir-des-mondes-virtuels-sans-danger.N2152737>
 155. <https://news.cornell.edu/stories/2023/06/metaverse-could-put-dent-global-warming>
 156. Launched in August 2022, CEPIR is a French project that assesses the environmental impacts of XR (VR/AR/MR), 70% of which is funded by the government as part of the “Supporting green alternatives in culture” scheme (France 2030).
 157. <https://fr.statista.com/infographie/29769/evolution-nombre-abonnements-telephonie-mobile-et-population-mondiale/> <https://fr.statista.com/statistiques/1360012/taux-de-penetration-du-smartphone-dans-certains-pays/>
 158. <https://fr.statista.com/infographie/28462/estimation-et-prevision-nombre-utilisateurs-casques-realite-virtuelle-augmentee-dans-le-monde/>

159. Netflix pèse toujours plus sur les réseaux des opérateurs télécoms français | Les Echos
160. (Fr) <https://www.degrouptest.com/> for French inhabitants
161. <https://openai.com/chatgpt>
162. <https://leonardo.ai/>
163. <https://www.midjourney.com/>
164. <https://www.pika.art/>
165. <https://www.insa-lyon.fr/fr/actualites/l-inclusion-minorites-doit-etre-priorite-pour-l-ia>
166. https://www.researchgate.net/publication/371758473_The_Manipulation_Problem_Conversational_AI_as_a_Threat_to_Epistemic_Agency
167. For more information on AI and instructors: https://www.researchgate.net/publication/375138111_Artificial_Intelligence_in_Education_a_Systematic_Review https://www.researchgate.net/publication/370474286_Artificial_Intelligence_in_Education_Exploring_the_Potential_Benefits_and_Risks
168. <https://virtual-guru.com/astuces/les-meilleures-lentilles-de-prescription-vr-vr-wave-vs-widmo-vs-lens-lab/>
169. <https://www.uploadvr.com/quest-hand-tracking-2-1-fast-movements/>
170. <https://www.tobii.com/products/integration/xr-headsets>
171. See above, in the paragraph entitled "Optics"
172. The 2 types of tracking can be described
173. Meta Research: Quest 2 Body Tracking Without Extra Trackers. <https://youtu.be/Ql4aMf-244A>
174. See chapter 5 Focus on safety: large-scale deployment at BPCE
175. Software Development Kit
176. https://www.khronos.org/api/index_2017/openxr
177. This is a SoC (system on a chip) which includes a CPU (Central Processing Unit) and a GPU (Graphic Processing Unit).
178. Hardware refers to the electrical components while middleware refers to the software that bridges the gap between the operating system and the app.
179. Mobile Device Management, used in e-learning to deploy apps to smartphones
180. <https://arborxr.com/>
181. <https://youtu.be/LUry3BRpfJo?si=ZC0BoYHHzLLbgAlo>
182. <https://snobal.io/>
183. <https://www.tobii.com/products/integration/xr-headsets>
184. See above, in the paragraph entitled "Optics"
185. <https://link.springer.com/article/10.1007/s10055-023-00903-y>
186. Meta Research: Quest 2 Body Tracking Without Extra Trackers. <https://youtu.be/Ql4aMf-244A>
187. See chapter 5 Focus on safety: large-scale deployment at BPCE
188. Software Development Kit
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190. This is a SoC (system on a chip) which includes a CPU (Central Processing Unit) and a GPU (Graphic Processing Unit).
191. Hardware refers to the electrical components while middleware refers to the software that bridges the gap between the operating system and the app.
192. Mobile Device Management, used in e-learning to deploy apps for smartphones
193. <https://arborxr.com/>
194. <https://www.matts-digital.fr/arborxr>
195. <https://snobal.io/>

