

AN INTRODUCTION TO LEARNING IN THE METAVERSE

April 2022



WHAT'S INSIDE

The Metaverse 101	2
The Metaverse for Education	5
Getting Started in the Metaverse	13
Final Reflection	16
About Us	17
References	18
Appendix	21

Letter from the Authors

You've likely seen the word *Metaverse* in the media. The opportunities for this "next iteration of the internet" are exciting, especially for learning. In the Metaverse, we imagine students building skills and exploring in shared virtual spaces without the boundaries of the physical world.

As we bring the promise of new technologies into education, however, history is our greatest teacher. We've seen patterns of poorly implemented, underused technology in learning environments, so how can the Metaverse be different and fulfill its potential?

To address the range of needs among learners, educators, and other stakeholders, we must understand the limitations of emerging technologies – as much as their affordances – and engage diverse perspectives and areas of expertise. Bridging divides between designers of cutting-edge technologies and educators who will use them is imperative. We need everyone who is eager to advance learning in the Metaverse to draw on evidence-based strategies as we pave the way forward.

You might be an educator, a caregiver, a museum designer, or an administrative decision maker wondering how the Metaverse might affect your work and your learners. Or, you might be a technology developer who wants to apply their skills and products to learning environments. We are a team of educators, scientists, and entrepreneurs who believe in the power of technology for intellectual, professional, social, and emotional growth. We created this document to provide a useful overview of the Metaverse, its components, its potential for education, and for those wanting to dive in – a starting point.

Our work and this conversation is ongoing, so please reach out with feedback and ideas (we are particularly interested in hearing how you use immersive technology for learning). You can reach us at xrlearning@meridiantreehouse.com.



Daniel Pimentel



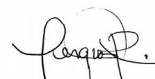
Géraldine Fauville



Kai Frazier



Eileen McGivney



Sergio Rosas



Erika Woolsey

What is the Metaverse?



Imagine standing in your living room but feeling as though you are exploring the ocean floor alongside a friend who lives on the other side of the world. This is possible in the Metaverse.

Meta is Greek for beyond, and *verse* represents the totality of something. In this way, the Metaverse alters the human experience, using technology to go beyond our physical reality. The term was originally coined by science fiction author Neal Stephenson in his 1992 novel “Snow Crash”; in it, he describes the Metaverse as a virtual world composed of unique environments, each with a specific purpose: to entertain, socialize, educate, and more.¹ Using head-mounted displays (HMDs), smartphones, and other media technology, people could enter these shared spaces and engage with one another regardless of their location.



A decentralized network of computer-generated worlds where users feel a genuine sense of being in these spaces for work, leisure, and learning.

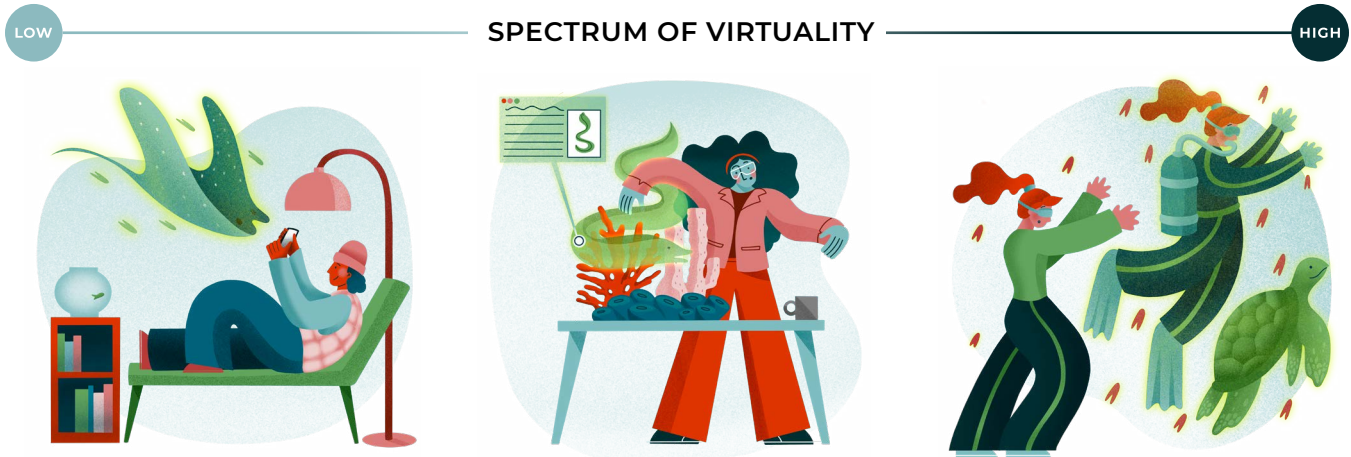
Three decades after Stephenson’s social allegory, advances in computational science and communication technology are making the Metaverse more of a reality.²

In plain terms, ***the Metaverse is the next iteration of the internet***; a decentralized network of virtual spaces where users can socialize, learn, and play. Leveraging other emerging technologies (5G, blockchain, artificial intelligence), and shifting from 2D graphics on flat screens to 3D graphics in

HMDs, the Metaverse will enable the creation of an interactive and virtual equivalent of our physical world (in terms of people, places, and things) that we will be able to explore through extended reality (XR) platforms.³

What is XR?

XR, which stands for “extended reality,” or “cross reality,” is a catch-all term for immersive technologies used to access the Metaverse: augmented, mixed, and virtual reality. XR also represents a spectrum where each of these technologies is situated between a completely computer-generated virtual environment (high *virtuality*) on one end and the physical reality on the other (no *virtuality*).⁴ Physical reality constitutes any sensory experience naturally available to us in an environment. When such environments are perceived or processed in real-time using audiovisual hardware like smartphones or headsets, users are then placed along the XR continuum based on the degree of virtuality, or the ratio of virtual versus physical content being experienced.⁵



Augmented Reality (AR)	Mixed Reality (MR)*	Virtual Reality (VR)
<p>Tool: Mobile device or see-through head-mounted display to superimpose digital content onto the physical world from the view of the user.</p>	<p>Tool: See-through head-mounted display to merge virtual content with the user’s physical environment.</p>	<p>Tool: Head-mounted display to enter and interact with a computer-generated virtual environment.</p>
<p>Description: Interactions between virtual and physical objects can be limited. For example, 3D objects may be semi-transparent and cannot hide behind physical objects.</p>	<p>Description: Interactions between physical and virtual objects are more natural. For example, virtual characters can hide behind physical objects, and vice versa.</p>	<p>Description: Audio and visual stimuli from the physical world are replaced with those of the virtual world.</p>
<p>Scenario: Two students in the same room use smartphones to scan an image of a fish, which then overlays text information and an animated 3D model of the species. A person in an AR head-mounted display can view that same 3D model from their perspective.</p>	<p>Scenario: Two students in different rooms use an MR device to scan their unique physical space and embed a virtual coral reef onto it where a virtual fish can swim around the furniture and each learner.</p>	<p>Scenario: Two students in separate rooms put on a VR device and are now on a virtual coral reef. They look down at their new virtual body of a scuba diver (avatar) and can interact with the fish and one another in that space.</p>
<p>Hardware: Smartphone, tablet, AR head-mounted display like HoloLens, Relear devices, Magic Leap 1, or ThinkReality A3</p>	<p>Hardware: HoloLens, Magic Leap 1, Varjo XR3, Lynx</p>	<p>Hardware: Meta Quest 2, HTC Vive</p>
<p>Application: Snapchat, Instagram, Pokémon Go</p>	<p>Application: Destination: Mars, Undersea</p>	<p>Application: theBlu VR, Human Anatomy VR</p>

* While there is collective ambiguity around the difference between AR & MR, we rely on conceptualizations and distinctions provided by industry and academic practitioners in the field of human-computer interaction.

Shaping of the Metaverse

2021 saw the term *Metaverse* surge in awareness,⁶ sparking global discourse centered around simple albeit important questions: *What is the Metaverse? How will it impact us as humans? Is its impact grounded in reality, or is this just hype?*

Metaverse technologies are not necessarily new. Their origins trace back centuries to rudimentary sensory illusions and, more recently, to advancements in computing in the late 20th century. For decades, XR and 3D technologies have contributed to advancements in medicine,⁷ chemistry,⁸ and engineering,⁹ among other fields. Back then, these technologies were incredibly expensive, bulky, and served an industry-specific purpose. Today, with the availability of high resolution mobile screens, accurate motion sensing devices, and highly efficient mobile processors, XR is poised to make the jump from industry laboratories to our living rooms, offices, and classrooms. Put simply: ***XR is here to stay, and is transforming how humans work, socialize, play, and learn.***

EMERGENT TRENDS

Societal	Technological	Industrial	Legal
<p>Virtual Lives: Humans are spending more time in virtual environments than ever before, increasing the importance of their virtual identities (avatars). Popular platforms include Roblox (over 200M users), Snapchat (over 300M users), Fortnite (over 350M players), and Meta's Horizon Worlds.</p>	<p>Manufacturing: Costs of XR hardware to access the Metaverse has been steadily declining, meaning XR adoption is likely to continue to increase over time.</p> <hr/> <p>5G: The ubiquity of high-speed internet connectivity will improve accessibility to the Metaverse globally.</p>	<p>Corporate Investment: Companies are creating positions that require workers to understand how to leverage XR effectively. Roblox users spent over \$1B in 2020.</p> <hr/> <p>Non-Fungible Tokens (NFTs): Companies are increasingly creating and selling virtual goods, from virtual Nike shoes for your avatar, to unique digital paintings. In 2021, companies sold over \$24B in NFTs.</p>	<p>Cybersecurity: Local and national governments are investing in, and preparing for, legislation that will govern human activity within the Metaverse.</p>

In addition to these transformations brought on by the Metaverse, rapid societal change occurring in the 21st century is placing new demands on education systems. Many characteristics of education today are legacies of the 20th century system that emphasized the “three Rs” - reading, writing, and arithmetic - and prepared people for stable jobs performing routine tasks. In our increasingly complex and technology-driven society, however, the future of work is uncertain and requires people to be adaptive, lifelong learners.¹⁰ Other aspects of society are also in crisis, including increased globalization, persistent inequality, environmental degradation, public health concerns, and political turmoil.¹¹ For all people to thrive in the future of work and tackle these global challenges, they need skills like critical thinking/reasoning, creativity/creative thinking, problem solving, metacognition, collaboration, communication, and global citizenship.¹²

This points to an urgent need for education to prepare young people to thrive amidst rapid technological, economic, and social change. Metaverse technologies may be useful in re-imagining how learning is done, if grounded in the realities of what they can and cannot do. Collectively, a more informed community of educators, content creators, and developers will enable institutions of all sizes to broaden learning opportunities regardless of subject matter or teaching methodology and prepare our societies for what is to come.

Building a Meaningful Learning Experience with XR

When designed well, technologies like XR can support effective learning that is difficult to achieve otherwise. Some features of XR that are especially important when applied to educational contexts are:

Immersion: XR hardware can leverage stereoscopic imagery and spatial audio to create the illusion of depth and space. Users can place 3D content (e.g., objects) in their environment from a first-person perspective, and feel as though they are sharing the space with the content itself.

Interactivity: XR allows people to actively engage with digital environments by enabling responses to users' movements and actions, making it an interactive medium that can invoke their full bodies and encourage creation and expression.

Invisibility: Because it uses realistic 3D imagery and blends the digital with physical, XR can visualize phenomena that are invisible to the human eye such as change over time or microscopic particles.

Together, these characteristics can facilitate a strong sense of presence, or the feeling of “being there,” in a place different from your physical location,¹³ as well as a strong sense of agency, which may be powerful for enabling learning.¹⁴ Additionally, the technologies can engender a sense of presence in a different body, known as *virtual body ownership*,¹⁵ and of being with other people, termed *co-presence*.¹⁶

Given these characteristics, XR is particularly good for certain learning goals and processes, and less effective for others. The affordances and limitations of XR for learning are described in the following lists.

Affordances: What Is XR Good For?

XR has some characteristics that align well with certain learning goals and processes because they enable learners to engage in certain tasks. We refer to these characteristics and their resulting potential for learning as *affordances*.

Increasing Interest and Motivation to Learn:

Studies consistently find that using XR learning environments increases learners' enjoyment, interest, and motivation to learn.¹⁷⁻¹⁹ Additionally, studies show that learners' self-efficacy, or their belief in their own capabilities, increases from using immersive learning environments by providing realistic hands-on or observational experiences.^{20, 21} These motivational constructs are important for facilitating learning, and are important educational goals in themselves.

Personalization: XR platforms can adapt to each user's environment for a personalized learning experience that situates their learning within

a relevant context.²² Using spatial mapping techniques, AR/MR platforms can create a 3D mesh of the user's space, where virtual content can interact with the environment.²³ Additionally, geolocation features can detect the user's location and display relevant content, such as 3D models of local biodiversity.

Visualization: XR can help learners see things that are impossible or difficult to see in the physical world. This can support learning more accurate spatial representation, such as understanding the structure of cells,²⁴ and making abstract concepts more concrete²⁵, like visualizing the theory of relativity.²⁶

Active Learning: XR can provide learners the opportunity to interact with real-looking objects and environments, which can enable them to actively participate in what they are learning, and connect their mind and body, too.²⁷ Learners can create with virtual objects in computer-generated and physical environments, facilitating new ways of learning-by-building.²⁸ XR is also useful for technical training and skill building, especially providing opportunities to practice high-cost, high-risk scenarios like medical dissections²⁹ or operating machinery.³⁰

Game-Based Learning: Gaming is perhaps the most prevalent application of XR.³¹ Games can engage learners by adapting difficulty based on need and proficiency, providing a scaffolded opportunity for repeated practice.^{32, 33}

Virtual/Augmented Field Trips: XR's immersive capabilities can support or facilitate learning situated in more authentic contexts than the classroom.³⁴ VR can transport users to places impossible to visit in real life, and AR can help provide information or context onto an environment during a physical field trip.

Limitations: What Is XR Not Good For?

XR has some characteristics that make it difficult to achieve certain learning goals, which we refer to as *limitations*.

Cognitive Load: XR experiences provide learners with a lot of visual and auditory stimuli which can increase their cognitive load as they process what they see, hear, and read.¹⁹ This may explain the mixed results of learning with immersive technologies in terms of what content knowledge is retained.^{39, 40} More research is needed to understand optimal instructional methods in XR to maximize learners' comprehension^{41, 42} and how it is best integrated into learning design,⁴³ something that is more well known with other materials like books, slides, and lectures.

Role-Play and Perspective-Taking: XR can also create a sense of virtual body ownership, or a sense of presence in a different body.¹⁵ This can facilitate role-play and perspective-taking, effective pedagogical tools for identity exploration which can help people learn social and emotional skills or develop their self-beliefs.^{35, 36}

Immersive Storytelling: Stories are powerful for learning, and immersive storytelling can put a learner "inside" a story to provide more context and deepen their understanding; for example, by immersing them in a news story.³⁷

Novel Social Interactions: Increasingly, XR applications allow people to interact with others through virtual meetings, games, and social networks. They open up the potential for collaborative learning, and connect people across distances that are difficult to orchestrate.³⁸



Accessibility: Current XR technologies are not easy to use for many people. For example, someone with limited mobility in their hands might struggle to use controllers. Even something as common as wearing glasses can make using a HMD difficult. Additionally, some technologies are not equally accessible for people from varied backgrounds and identities. For example, headsets often cannot be worn over head coverings or many hair styles, like religious headscarves and natural Black hair styles.

Affordability: XR technologies remain more expensive than other learning resources such as computers and books, and often require a high-speed internet connection. Additionally, content is more expensive to create, requiring specialized equipment and skills to create the interactive virtual environments necessary for effective learning.

Lack of Educational Content: There are not yet many programs for learning, nor is there a platform that makes it easy to search for content based on learning goals, subject area, or age

group. Additionally, few educators have the ability or capacity to create their own XR learning materials, much less teach learners how to make their own.

Privacy and Safety: XR technologies are being developed by corporations whose business models rely on collecting an increasingly detailed and wide range of data on every user. XR technologies have the potential to track people's movement and emotions, which can reveal personal and sensitive information about them,⁴⁵ raising the question of how to keep learners' data safe and their identities secure.

Difficult to Assess Learning: XR can afford a more individualized and unstructured learning experience, and is well suited to teaching skills, competencies, beliefs, and attitudes that may not be captured by multiple-choice learning assessments. And while XR offers the possibility of collecting diverse forms of user data (e.g., movement, eye tracking), this type of data has not yet been translated into meaningful learning assessments.

Note: The above lists of affordances and limitations are not exhaustive, and are intended to illustrate what we see as powerful (and not-so-powerful) applications of XR for learning. Also, while based on our understanding of the literature, research remains thin as the implementation of XR in educational contexts is nascent and the evidence base is likely to shift over time.

CASE STUDY

AR Reef is a mobile-based AR application that teaches learners about how their actions on land impact ocean health. Using a smartphone or tablet, the learner can “place” a digital picture frame on a vertical surface, from which the reef and its inhabitants emerge. This visualizes an underwater environment that is difficult to visit in real life, and animates coral biology and the impact of ocean stressors. Learners can move around the digital reef and view it up close from different angles. This interactive visualization was designed to support learning about the complexity of the ocean ecosystem, but data on learning outcomes has not yet been collected. Further, accessibility is limited based on the need to download an application onto the learner's device.



See the Appendix for additional examples of XR learning experiences.

Learning from the Past

In order to learn how to use XR effectively in education, we must first study the pitfalls that have hobbled past endeavors to revolutionize education with tech. By reviewing the sometimes unsuccessful history of tech in education, we can begin to understand why educators are oftentimes wary of new technology and the companies behind them. By building empathy with educators, we can better learn how to address their concerns with XR and optimize the impact that XR can have on the education space.

While learning is a complex and multifaceted phenomenon, XR has a lot of potential to contribute to formal and informal education. Yet, we can't overlook the fact that XR is not the first technology with promises of transforming education. History presents us with plenty of pitfalls to be avoided if we want to harvest the potential of XR for learning. A century ago, Thomas Edison enthusiastically argued that motion pictures would be a game changer for the educational system. He even suggested that this revolutionary technology would replace textbooks, and that videos would obtain one hundred percent efficiency for learning!⁴⁶ Now let's fast forward to 2021, when similar optimistic claims were made about the Metaverse, describing it as a place where anyone "could learn about anything in the world just by bringing it closer to them."⁴⁷ Of course, it is fair to wonder if these two examples are outliers, or if there is, indeed, a long history of utopic expectations concerning technology in education. Unfortunately, these two examples, a century apart, look nothing like outliers. However, by understanding these pitfalls, we can begin to build better moving forward.

CASE STUDY

One Laptop Per Child is a famous illustration of the hype cycle. In 2005, two MIT professors had an ambitious vision to build sturdy computers that cost only \$100 to be distributed in developing countries. The project received support from tech and design communities, as well as the United Nations. Despite the idealistic intentions, problems started piling up. The cost rose to \$180 while still cutting corners. Infrastructure was often inadequate, with lack of electricity or internet access rendering the computers useless for many students. Moreover, most implementations did not have technical or pedagogical support. As a result, most evaluations of these programs found no impact on students' learning, aside from their increased skills at using the laptops.^{56,57}

When we deploy technology for education, it cannot end when a piece of equipment is handed over to a school, teacher, or student. Instead, implementation should be done in accordance with the local practices, context, and culture.

Education and Technology: A Tumultuous History

In the late 1980's, it was believed that "the educational system had a history of becoming a burial ground for new technologies."⁴⁸ Living up to this reputation, school systems in the 1990's and 2000's fervently adopted and integrated the latest technologies, from televisions and interactive whiteboards, to the iPad and other tablets. Even computers were supposed to "blow up the school",⁴⁹ though despite the prediction that computers would render schools obsolete,

the world's classrooms are still very much standing.

Put simply, *techno-utopians* have claimed that technology could be the ultimate solution to enhance academic performance and help fix some of the educational system's issues. Unfortunately, these predictions show a simplistic view of the otherwise complex phenomenon known as learning.

The expected measurable improvements in academic performance have not been as straightforward as many had hoped for. Moreover, technology has been proven over and over again to be an unviable strategy to fix problems in education. In fact, it has more often created new problems, especially around issues of equity.

Of course, we cannot deny that technology has transformed how we learn, both in and outside of school. However, the history of technology failing to live up to unreasonable expectations has repeated itself so many times that researchers have coined the term “rhetoric-reality gap”⁵⁰ to describe this phenomenon, doing so as a perpetual warning against blind support of technology in education.⁵¹⁻⁵⁴ But why does this keep happening? And how does it negatively affect learning?

The list of ingredients for this “oversold, underused” cocktail⁵¹ is long and complex.⁵⁰ The risks begin with unrealistic promises made by biased stakeholders with personal interest in the success of the technology.⁵¹ These false promises, made to buoy interest in the tech, then influence decision-makers with a naïve vision of the relationship between technology and education. Once implemented at great cost in schools, teachers face an uphill battle. Many are not provided with proper training or agency to acquire the technological, pedagogical, and content knowledge needed to successfully embed the technology in their teaching practices.⁵⁵

For teachers, time is also not on their side when implementing new learning tools. Teachers need

to adapt their lesson plans to accommodate the new technology. After the first implementation, teachers need to reflect on how things went and start an iterative process. This process requires time that most teachers, already burdened with heavy workloads, simply do not have. Thus, it is crucial that XR project managers and developers design and build the teacher’s user story into their product roadmap, and that any initiative led by a company to bring XR into the classroom has sustained teacher support built into marketing and launch plans.

The technology might also lack appropriate design to fit into the reality of the educational system, contributing to negative attitudes from the implementer and also impeding students’ learning. Simultaneously, poor initial planning can result in a lack of financial support to maintain the technology in working condition. This can result in the technology being abandoned, collecting dust on a shelf as the next hyped device joins the other obsolete pieces of equipment. This kind of vicious cycle can leave educators with feelings of resentment and frustration toward new technology implemented by decision-makers who, despite good intentions, lack expertise necessary to cultivate the soil on which technology is supposed to flourish.

Though the history of technology in education can be discouraging, vision and optimism for the future are crucial. When creators and educators are aware of the potential pitfalls in technology in education, they are better equipped to thoughtfully build and implement new tools in teaching practices.

RECIPE FOR SUCCESS — HOW TO AVOID THE “OVERSOLD, UNDERUSED” PARADIGM

- 1 Define your learning goals *then* see if XR could help you achieve them
- 2 Be realistic concerning what XR *can* achieve
- 3 Allocate time for educators to implement, experiment, and iterate their teaching practices with XR
- 4 Take into account the culture, context, and practice in which XR will be embedded
- 5 Make sure your budget includes all costs (e.g., maintenance, training) along with the cost of the XR platform(s) itself
- 6 Create or find high quality learning content in XR
- 7 Recognize that XR is a tool, not a panacea
- 8 Provide adequate training to your educators
- 9 And finally....***Don't use XR for the sake of using XR***

Tech as a Tool, Not a Silver Bullet

Teachers are often unfairly blamed for poor implementation of tech in the classroom. Technology is not the silver bullet to fix struggling systems of education. Technology is merely one of the tools available in the educator's toolbox. Moreover, a tool is only as good as its ability to serve a specific goal. After a century of this vicious cycle, propelled by naïve conceptions of the role of technology in education, it is time to change the course of history and break the cycle by learning from past mistakes.

Let's make sure that XR is seen for what it is; not a goal in itself, but a means to a carefully thought out end. In education, the goal concerns what needs to be learned. Once learning goals are clearly defined, then it is time to judiciously think about which strategy educators can use to achieve their objectives.

To give an example, let's say your learning goal is to inquire about the tidal zone ecosystem with your students. If you happen to live inland, XR might indeed be a useful tool that would allow your students to feel virtually immersed in this remote environment. On the other hand, if you happen to live close to the shore, benefit from safe access to a local beach, and can take students on a field trip, using XR would keep students away from an outdoor experience with nature, unnecessarily substituting it with a virtual proxy. In other words, if you can get your feet wet, do so; if you cannot, XR can be a valuable solution.

A rule of thumb is to use VR for experiences that otherwise would be Dangerous, Impossible, Counterproductive or Expensive (also known as the DICE acronym).⁵⁸

- ▶ **Dangerous:** Train how to put out a fire instead of risking injuries with real fires.

- ▶ **Impossible:** Walk on Mars even though this is probably impossible during your lifetime.

- ▶ **Counterproductive:** Cut trees in a virtual forest to learn about deforestation, something that in real life would go against what you are trying to achieve.

- ▶ **Expensive:** Become a diver in the remote location you have always dreamt to visit (but are still saving money for).

While VR can transport you somewhere you couldn't go otherwise by taking you away from reality, AR and MR add to the user's surroundings. With AR, you can clean a virtual penguin covered in oil in your own sink, or you can get help identifying the plants you encounter during an outdoor hike.

We know that XR and the Metaverse will not fix systemic problems in education, and might even create new problems. However, understanding the strengths and weaknesses of XR will allow for thoughtful reflection on how we use these tools for specific learning goals and contexts.

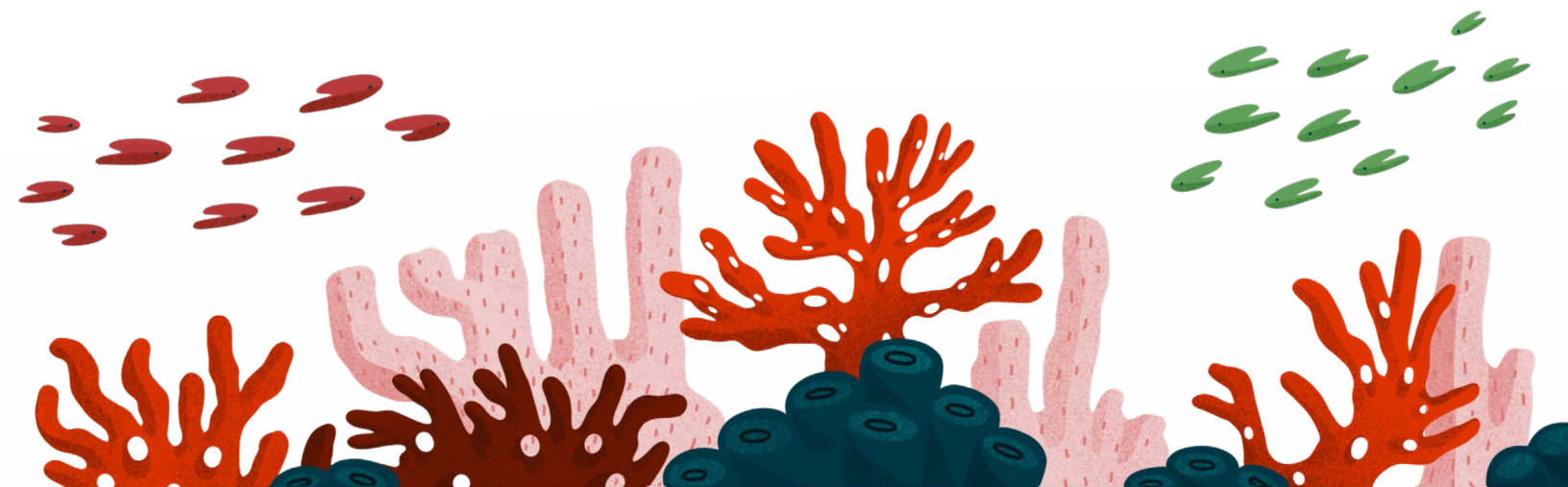


Inclusively Designing XR for Learning

The previous insights into XR's opportunities and challenges point to the importance of thoughtful XR design. To achieve this, we should ask:

- 1 What are the learning goals?** Educators and designers need to be specific about their goals, because while XR can help achieve some learning goals, it may hinder others. For example, XR-enabled learning experiences can support learners' spatial awareness by providing rich 3D representations that are not visible in real life. On the other hand, the rich stimuli can cause a heavy cognitive load that interferes with their ability to remember factual information. Frameworks for instructional design emphasize connecting the activities learners engage in with their mental processes that lead to learning,⁵⁹ and frameworks like Universal Design for Learning are helpful to ensure all media and activities are accessible for all learners.⁶⁰ Again, before any headset is donned, educators should articulate the goals and determine whether and how XR supports them.
- 2 Who are the learners?** When designing learning experiences and deciding which XR technology and applications to use (if any), it is crucial to consider who the learners are. Hardware and applications are not accessible or inclusive to every population of learners, in part due to who is designing them. Most XR content, as well as hardware, is created by a sliver of the world's population—typically by companies based in Silicon Valley, at the top of the world's income distribution, by people who have historically had the most privilege. Though diversity among XR developers, content creators, and leadership is increasing, representation skews male, able-bodied, and white.⁶¹⁻⁶³ This has resulted in XR hardware and content that is not equally accessible or beneficial for all. For example, several studies have shown that while in VR, women suffer more from motion sickness than men.⁶⁴⁻⁶⁸ One of the potential culprits seems to be the inter-pupillary distance (the distance between your pupils, a crucial measurement for comfort and vision in VR), which is generally smaller in women than men. Though most VR headsets have the option to adjust this distance, women and people with smaller faces are less likely to fit the headset to their eye morphology, resulting in motion sickness.⁶⁴

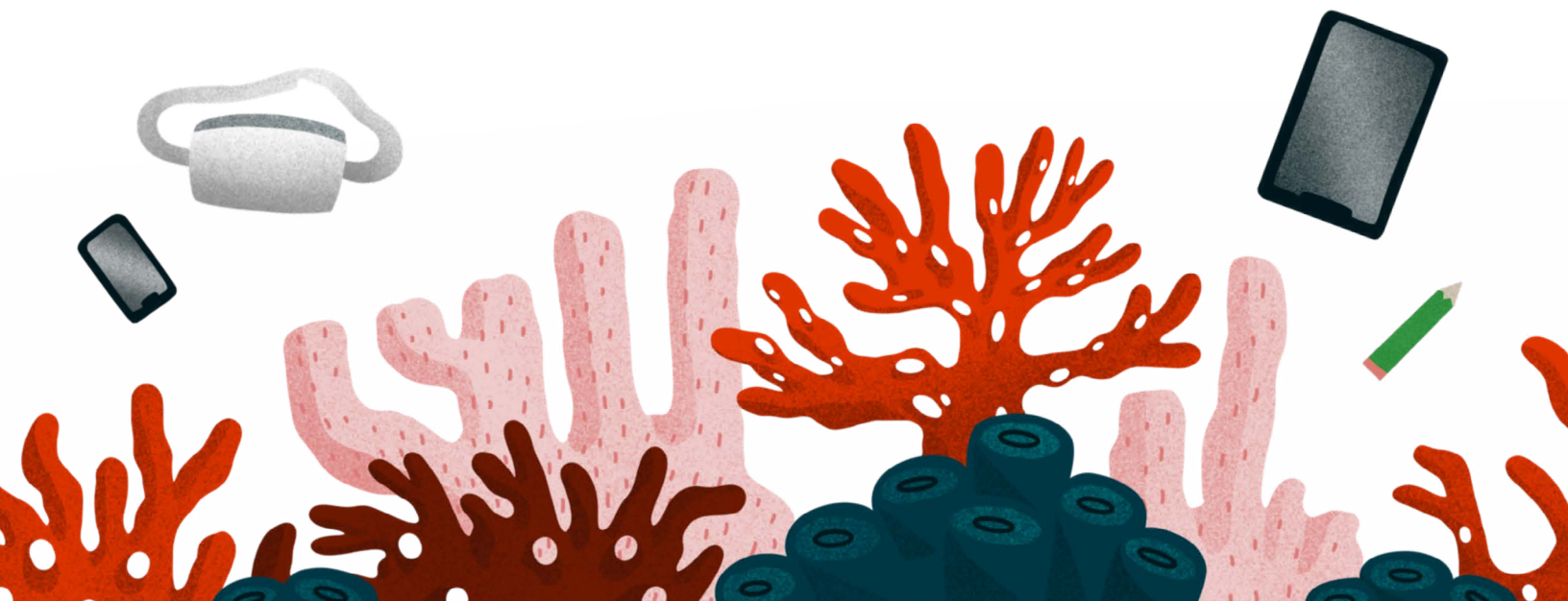
In addition, some VR experiences are aimed to highlight tragedies and difficult living conditions, which may be eye-opening and empathy-inducing for privileged populations, but could be triggering and harmful for those closer to the subjects.⁶⁹ We just don't know yet how learners from diverse backgrounds experience various types of XR applications, so designers must use caution and consider their audience carefully. Long term, the XR industry should also aim to diversify their ranks so the voices and talents of underrepresented groups are included from the beginning.



3 **What is the context?** XR technologies have not yet been designed with a range of potential learning contexts in mind. Some considerations include the skills and time of the educators who will be implementing the technology and learning experience, the infrastructure and characteristics of the space, the amount of time learners and educators will have, and the resources available to them. For example, designing a learning experience in a museum where individual learners engage in a brief, one-time experience is far different than designing an experience for a semester-long class with 30 learners. Choosing the right technology to deploy the experience also depends on the context, such as availability of electricity, internet, and devices.

CASE STUDY

KaiXR is a student-friendly platform of immersive experiences providing a safe pathway to the Metaverse with educator resources and implementation support. The platform contains over one hundred 360-degree virtual field trips ranging from the US presidential portraits of the Obamas to learning about CRISPR's DNA editing by a female Nobel Prize winning biochemist. The 360-degree videos are accessible on a range of devices including laptops, smartphones, and VR headsets, creating a low barrier to entry for practitioners and learners. The library prioritizes culturally-relevant content that can be hard to find. Although less expensive and easier to use, these 360-videos are not as interactive as more expensive and higher-end XR experiences, hence limiting the potential for hands-on learning. The company continues to research methods to demonstrate its effectiveness on learning outcomes across a wide range of learners.



Now that you have an understanding of learning in the Metaverse, you may be wondering if XR is right for your learning objectives and students.

What follows is a series of questions to help you think judiciously about embedding XR into your teaching practice. No matter your role in education, it is imperative to keep the students, your learners, front and center.

First, take some time to generate an initial learner profile that you will reference throughout the rest of this section. For instance, you can use the following worksheet to fill in the blanks:

_____ is _____ and lives in _____. He/She/They is _____, ,
Name Age Location Describe their background

enjoys learning about _____, and has trouble _____ .
Topic(s) Challenge(s) they are experiencing

Here are some sample learners we have used in the past:

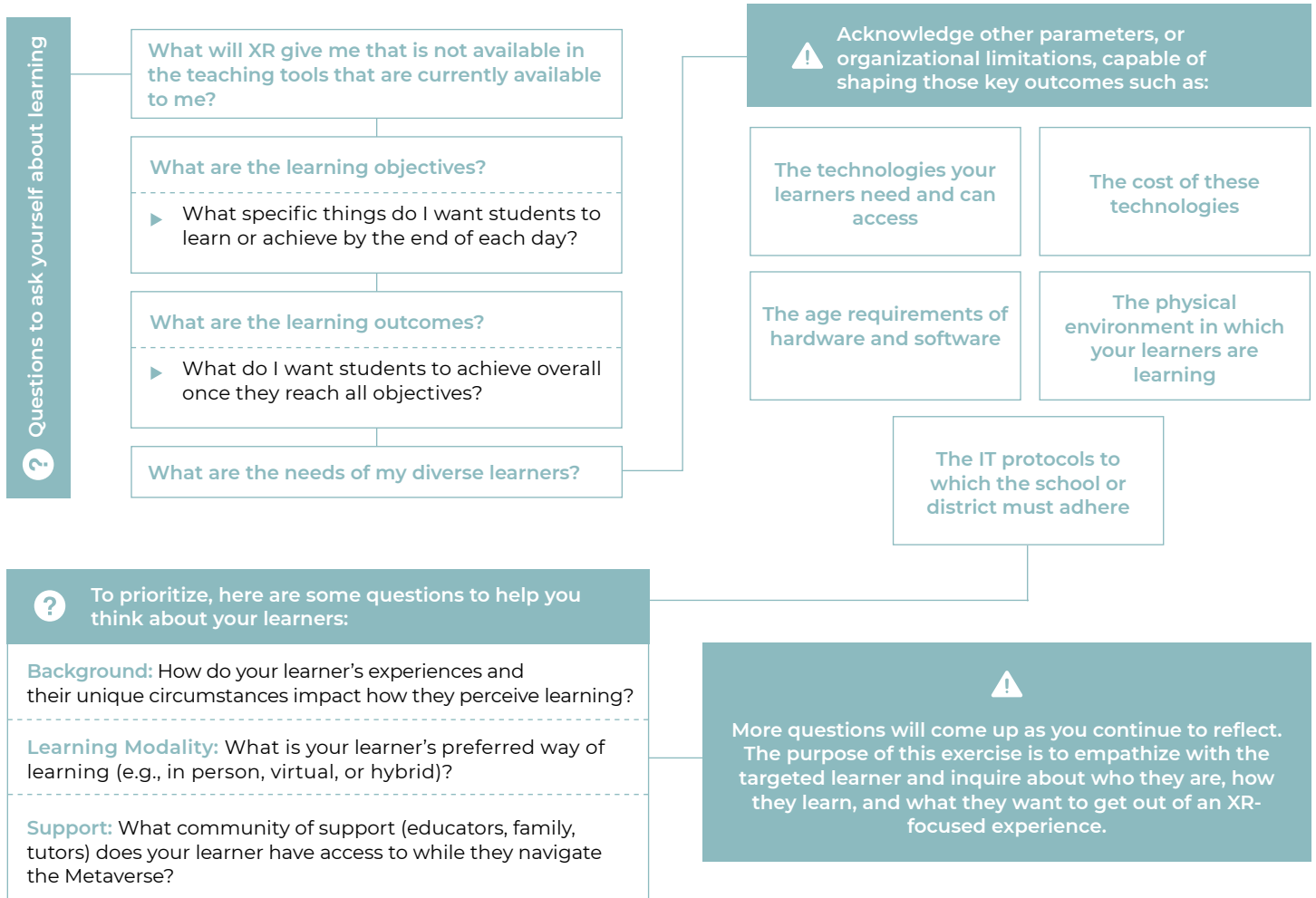
- ▶ **Ivan**, a first-generation, low-income student, attends a Title I school with limited access to technology. He has a strong curiosity but is unable to access libraries as his parents work two to three jobs to sustain their family.
- ▶ **Andrea**, a Spanish-speaking high school student in Panama, lives near the Smithsonian Tropical Research Institute and loves to snorkel. She is a woman of color who loves exploring, but fails to identify with the ocean researchers depicted in the media she's consuming.
- ▶ **Jessie**, who identifies as non-binary, is a college sophomore who is changing their major from social sciences to STEAM, is shy, and prefers small group learning. They are anxious about the future and wonder what careers are available to them.
- ▶ **Mia**, a millennial looking to work in tech, is searching for training programs that teach user research skills. However, she lives in a rural area in the southwestern U.S. and has limited opportunities to engage with experts in the field.

As you think about what your learners need (you know them best), remember that research in the field of XR and education can also complement your own experiences as a practitioner.

In order to effectively reflect about the role XR could play in your learning practice, progress through these four reflective levels, which we'll take you through below.

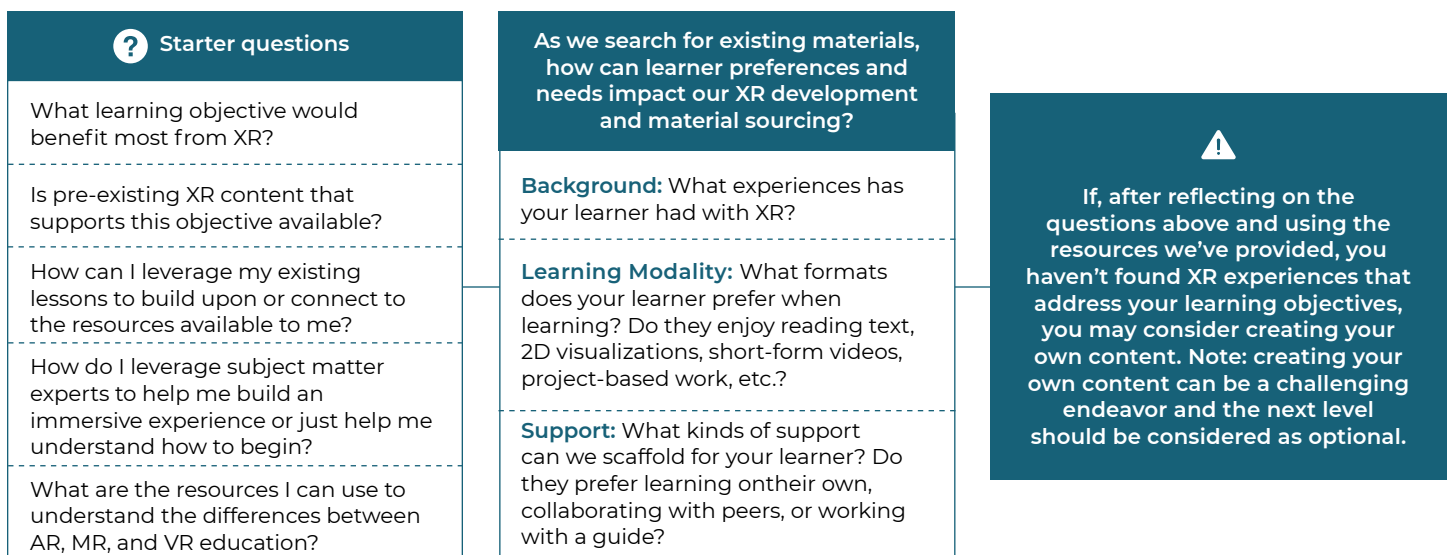


LEVEL 1: EXPLORE THE DESIRED LEARNING EXPERIENCE



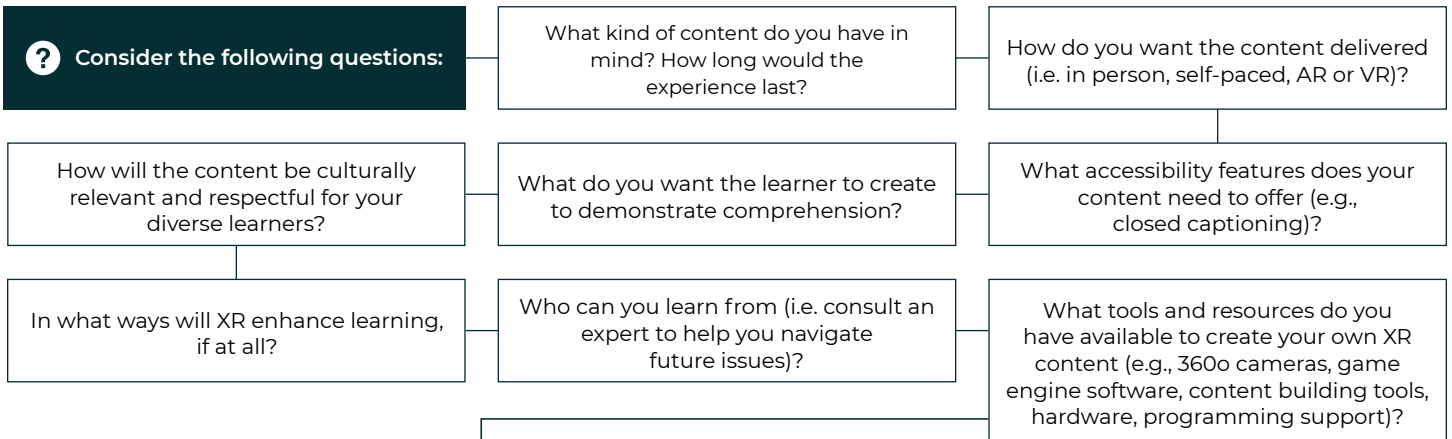
LEVEL 2: SEARCH FOR EXISTING MATERIALS

To avoid reinventing the wheel, be intentional about identifying existing resources. To get started, take a look at the **Appendix at the end of this guide for a list of educational XR experiences**. You can also check out the **Educational VR Apps database** by the Stanford Virtual Human Interaction Lab.⁷⁰



LEVEL 3: BEGIN DESIGNING NEW XR CONTENT, IF NECESSARY

Whether you build XR content yourself or outsource it to a third party, this section provides some questions to get you started.



? Consider the following questions when designing new content:

Background: What kind of content does your learner enjoy consuming (i.e. social media, entertainment)?

Learning Modality: What scaffolding does your learner need to develop and apply their learning (i.e. timing, artifact creation, etc)?

Support: What scaffolding does your learner need to develop and apply their learning (i.e. timing, artifact creation, etc)?

Inclusivity*: What elements can you incorporate into the experience to make learning culturally competent and relevant**?

*Inclusivity: A practice of building equal access to learning opportunities and resources for people who might otherwise be excluded or marginalized, such as those having disabilities or belonging to other minority or socioeconomic groups.

**Culturally Competent: Containing a range of cognitive, affective, and behavioral skills that lead to effective and appropriate communication with people of other cultures and backgrounds. Intercultural or cross-cultural education are terms used for the training to achieve cultural competence and relevance.

As you begin to sketch out your content, think about the potential of XR to enhance your learning outcomes. For example, if you are teaching how to construct a persuasive essay, does adding XR help the learner write better? If not, maybe this topic is not the best candidate for XR. Remember, **XR is merely one tool in your pedagogy toolbox.**

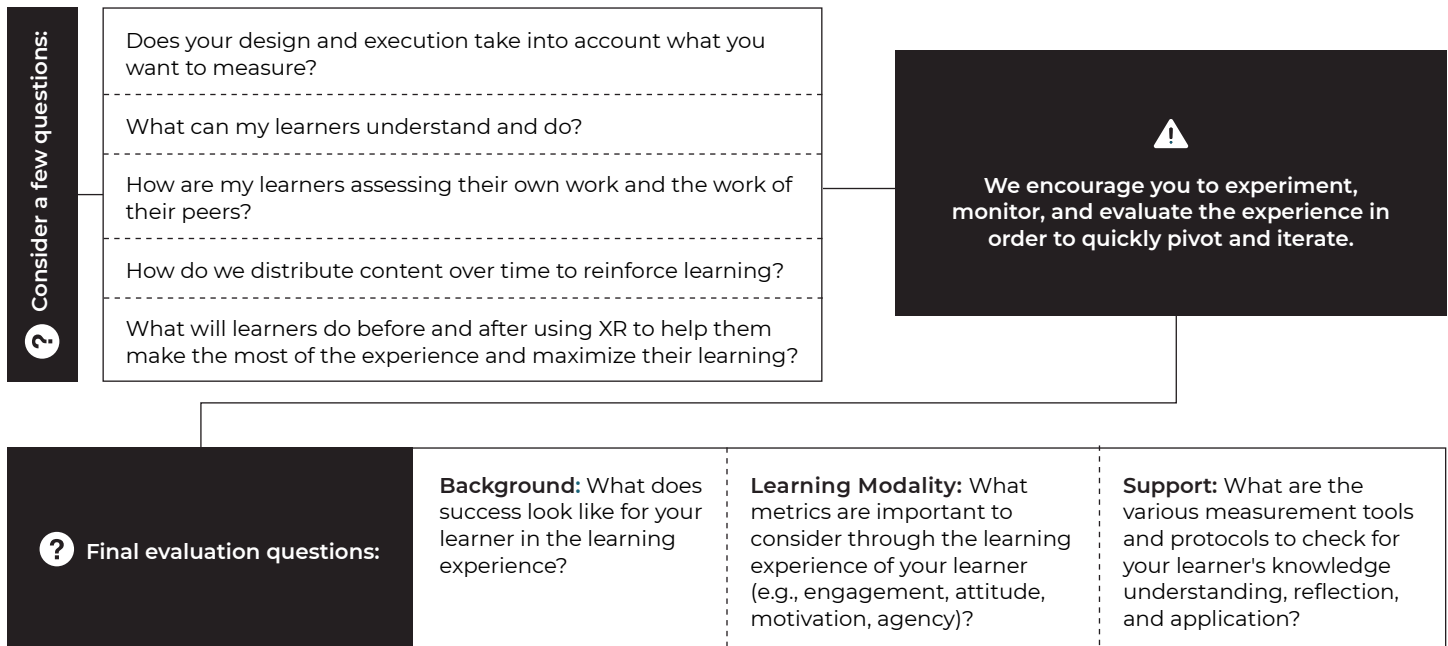
If you continue down this path, we recommend you test an early prototype of your learning experience with your targeted learners before investing further time in content development. **Receiving feedback on early prototypes will be invaluable.** The more targeted feedback you collect and reflect upon (and identifying what feedback to discard), the more effective the content will become.⁷¹

Want to learn more about the mechanics of creating content? We are in the process of building resources to help guide you through this. To receive them when released, contact us at xrlearning@meridiantreehouse.com.

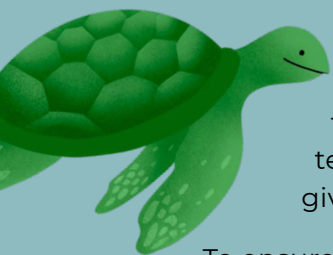


LEVEL 4: DELIVER A MEASURABLE EXPERIENCE

As you build out and make plans to deliver your curriculum, be sure to consider how you'll measure your learning outcomes. A recommended approach is to focus more on the process of learning, understanding, and reasoning instead of what content students know, do not know, or whether or not they reached a learning outcome.



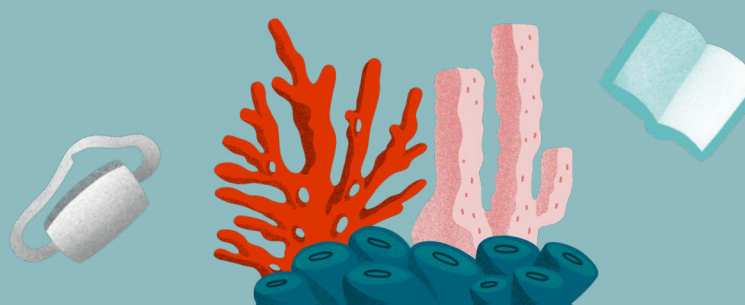
FINAL REFLECTION



This introductory guide is designed to serve as an onramp to learning in the Metaverse. Though you may have more questions than answers, we hope you feel confident to discuss and imagine the possibilities of XR in education. As new technologies emerge—impacting how people live, work, and learn—we are motivated to give every learner the opportunity to thrive in an increasingly complex world.

To ensure that learning experiences are impactful regardless of the tool or platform used, we need to understand the promise of these technologies and how they can fulfill their potential, instead of becoming another oversold and underused learning tool. If you remember one thing, it should be this: **rigorously prioritize your learners**—and their place in the future—as you build, implement, and evaluate immersive products. The Metaverse will continue to grow and evolve, as will the opportunities to create impactful experiences.

Learning with XR is still in its infancy. We hope educators, content creators, developers, and researchers will continue to work together to create high-quality XR learning experiences, experiment with them, build the evidence base, and share our discoveries. Our work and this conversation is ongoing, and we want you to be a part of it. Please tell us what you are taking away from this introduction, what you want to see next, and what you are doing with XR. You can reach us at xrlearning@meridiantreehouse.com.





ABOUT MERIDIAN TREEHOUSE

Meridian Treehouse is an award-winning nonfiction storytelling and experiential agency that cultivates multidisciplinary collaboration and innovation. Its team of scientists, educators, storytellers and technologists is committed to using the tools of today and tomorrow to build accessible and inspiring lifelong learning resources. The firm specializes in developing multi-platform experiences, content and partnerships that educate and entertain – all with the goal of fostering curiosity, free from outdated spatial and logistical constraints. Because exploration is for everyone, everywhere.

Learn more at:
meridiantreehouse.com

About the authors



Daniel Pimentel

As an XR creator and Assistant Professor of Immersive Media Psychology at the School of Journalism and Communication at the University of Oregon, Dr. Pimentel's work explores how immersive storytelling can help address prosocial and pro-environmental issues.



Géraldine Fauville

A marine biologist, ocean educator, and Assistant Professor in the Department of Education, Communication, and Learning at University of Gothenburg, Sweden, Dr. Géraldine Fauville studies how immersive technologies contribute to environmental science learning and ocean literacy.



Kai Frazier

A historian, innovative educator, digital storyteller, and Ed Tech entrepreneur, Kai Frazier inclusively applies new technologies in formal and informal learning environments. She is passionate about using XR to provide educational opportunities for underestimated communities.



Eileen McGivney

A researcher, instructor, and PhD candidate at the Harvard Graduate School of Education, Eileen McGivney's work looks at how people learn with immersive technology like VR, and how these experiences impact young people with diverse identities and cultural backgrounds.



Sergio Rosas

A first-generation immigrant, Stanford University graduate, human-centered designer, teacher, social entrepreneur, and founder of Next Shift Learning, Sergio Rosas is committed to economic mobility for historically excluded and underinvested communities of color through workforce training and upskilling.



Erika Woolsey

A marine biologist, National Geographic Explorer, XR creator, Visiting Scholar at the Stanford University Virtual Human Interaction Lab, and leader of 501c3 non-profit The Hydrous, Dr. Erika Woolsey is dedicated to inquiry-based learning and public engagement of science.

Citation: Pimentel, D., Fauville, G., Frazier, K., McGivney, E., Rosas, S. & Woolsey, E. (2022). *An Introduction to Learning in the Metaverse*. Meridian Treehouse.

ACKNOWLEDGEMENTS

Thank you to Monica Arés and Wesley Della Volla for your support and valuable insights into the future of immersive learning. Thank you to Nina Adjanin, Jeremy Bailenson, Will Carter, Ben Connors, Joe de Freitas, Chris Dede, Tessa Forshaw, Julie Gerdes-Becnel, Regine Gilbert, Alex Grady, Cortney Harding, Mitch Kapor, Peg Keiner, Freada Kapor Klein, Siddharth Kulkarni, John MacLeod, Guido Makransky, George Matsumoto, Dakota Ortiz, Xander Peterson, Anna Queiroz, Gabby Salazar, Mary Stephens, Pam Tambe, Jonathan Teske, Kevin Truong, and OnRaé Watkins for generously providing feedback on this guide.

This independent work was supported by Meta Education and Immersive Learning through a partnership with Meridian Treehouse and The Hydrous. The research team is committed to quality, transparency, and positive impact for learners and educators. The recommendations and viewpoints in this guide are those of the authors and do not necessarily represent the partners, reviewers, or funding organizations.

Design & Copy Editing: Exactly Agency

Illustration: Halsey Berryman

Photographers: Ryan Jones, Scott R. Kline, Johan Wingborg

References

The Metaverse 101

1. Stephenson, N. (2000). *Snow Crash*. Bantam Books.
2. Duan, H., Li, J., Fan, S., Lin, Z., Wu, X., & Cai, W. (2021). Metaverse for social good. *Proceedings of the 29th ACM International Conference on Multimedia*, 153–161. <https://doi.org/10.1145/3474085.3479238>
3. Meta. (2021). Meta. Facebook. <https://about.facebook.com/meta/>
4. Milgram, P., & Kishino, F. (1994). *A taxonomy of mixed reality visual displays*. *IEICE Transactions on Information and Systems*, 77(12), 1321-1329.
5. Ghazwani, Y., & Smith, S. (2020). Interaction in augmented reality. *Proceedings of the 2020 4th International Conference on Virtual and Augmented Reality Simulations*, 39–44. <https://doi.org/10.1145/3385378.3385384>
6. Jay, M. & Han, L. K. (2022). Everybody is talking about the Metaverse and I don't get it. What is this thing and why is it such a big deal? *Business Insider*. Retrieved from <https://www.businessinsider.com/what-is-the-metaverse-crypto-blockchain-gaming-vr-real-estate-2022-2>
7. Bajura, M., Fuchs, H., & Ohbuchi, R. (1992). Merging virtual objects with the real world: Seeing ultrasound imagery within the patient. *ACM SIGGRAPH Computer Graphics*, 26(2), 203-210.
8. Ihlenfeldt, W. D. (1997). Virtual reality in chemistry. *Molecular Modeling Annual*, 3(9), 386-402. <https://doi.org/10.1007/s008940050056>
9. Thabet, W., Shiratuddin, M. F., & Bowman, D. (2002). Virtual reality in construction: A review. *Engineering computational technology*, 25-52.
10. Dede, C., & McGivney, E. (2021). Lifelong learning for careers that don't exist. In *Reimagining digital learning for sustainable development* (pp. 36-44). Routledge.
11. Independent Group of Scientists appointed by the Secretary-General. (2019). *Global Sustainable Development Report 2019: The Future is Now—Science for Achieving Sustainable Development*. United Nations: New York, NY, USA. https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf
12. Vivekanandan, R. (2019). Integrating 21st century skills into education systems: From rhetoric to reality. *Education Plus Development*. Brookings.

The Metaverse for Education

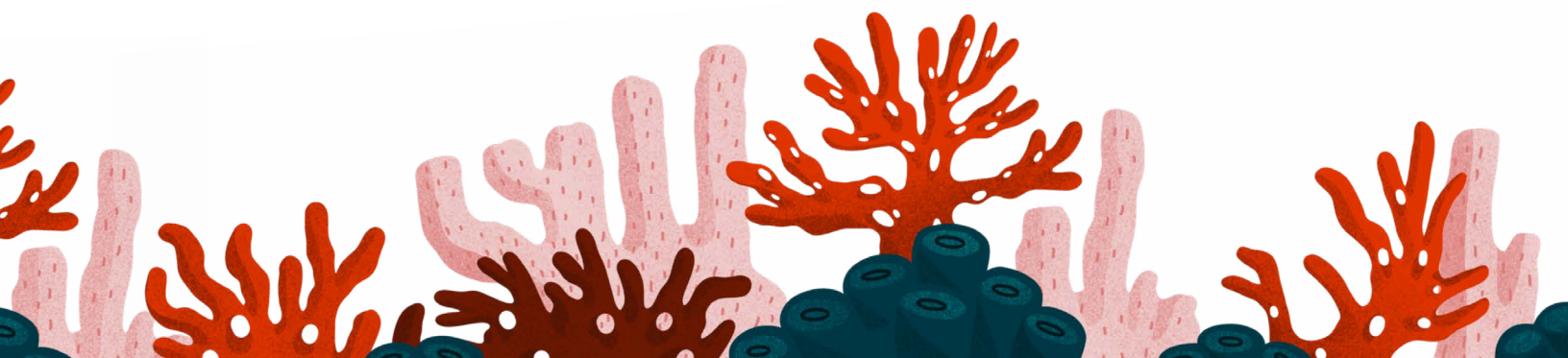
13. Slater, M. (2009). Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1535), 3549–3557. <https://doi.org/10.1098/rstb.2009.0138>
14. Makransky, G., & Petersen, G. B. (2021). The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality. *Educational Psychology Review*, 33, 937-958. <https://doi.org/10.1007/s10648-020-09586-2>
15. Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI*, 3. <https://doi.org/10.3389/frobt.2016.00074>
16. Oh, C. S., Bailenson, J. N., & Welch, G. F. (2018). A systematic review of social presence: Definition, antecedents, and implications. *Frontiers in Robotics and AI*, 5(114), 1–35. <https://doi.org/10.3389/frobt.2018.00114>
17. Queiroz, A. C. M., Nascimento, A. M., Tori, R., & da Silva Leme, M. I. (2018). Using HMD-based immersive virtual environments in primary/K-12 education. In D. Beck, C. Allison, L. Morgado, J. Pirker, A. Peña-Rios, T. Ogle, J. Richter, & C. Gütl (Eds.), *Immersive Learning Research Network* (pp. 160–173). Springer International Publishing. https://doi.org/10.1007/978-3-319-93596-6_11

18. Makransky, G., Borre-Gude, S., & Mayer, R. E. (2019). Motivational and cognitive benefits of training in immersive virtual reality based on multiple assessments. *Journal of Computer Assisted Learning, 35*(6), 691–707. <https://doi.org/10.1111/jcal.12375>
19. Parong, J., & Mayer, R. E. (2021). Cognitive and affective processes for learning science in immersive virtual reality. *Journal of Computer Assisted Learning, 37*(1), 226–241. <https://doi.org/10.1111/jcal.12482>
20. Lehikko, A. (2021). Measuring self-efficacy in immersive virtual learning environments: A systematic literature review. *Journal of Interactive Learning Research, 32*(2), 125–146. <https://doi.org/10.1016/j.rcim.2019.101887>
21. Reilly, J. M., McGivney, E., Dede, C., & Grotzer, T. (2021). Assessing science identity exploration in immersive virtual environments: A mixed methods approach. *The Journal of Experimental Education, 89*(3), 468–489. <https://doi.org/10.1080/00220973.2020.1712313>
22. Dawley, L., & Dede, C. (2014). Situated Learning in Virtual Worlds and Immersive Simulations. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 723–734). Springer. https://doi.org/10.1007/978-1-4614-3185-5_58
23. Park, K. B., Kim, M., Choi, S. H., & Lee, J. Y. (2020). Deep learning-based smart task assistance in wearable augmented reality. *Robotics and Computer-Integrated Manufacturing, 63*, 101887. <https://doi.org/10.1016/j.rcim.2019.101887>
24. Thompson, M., Uz-Bilgin, C., Tutwiler, M. S., Anteneh, M., Meija, J. C., Wang, A., Tan, P., Eberhardt, R., Roy, D., Perry, J., & Klopfer, E. (2021). Immersion positively affects learning in virtual reality games compared to equally interactive 2D games. *Information and Learning Sciences, 122*(7/8), 442–463. <https://doi.org/10.1108/ILS-12-2020-0252>
25. Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. *Personal and Ubiquitous Computing, 18*(6), 1533–1543. <https://doi.org/10.1007/s00779-013-0747-y>
26. Georgiou, Y., Tsivitanidou, O., & Ioannou, A. (2021). Learning experience design with immersive virtual reality in physics education. *Educational Technology Research and Development, 69*(6), 3051–3080. <https://doi.org/10.1007/s11423-021-10055-y>
27. Johnson-Glenberg, M. (2017). Embodied education in mixed and mediated realities. In D. Liu, C. Dede, R. Huang, & J. Richards (Eds.), *Virtual, augmented, and mixed realities in education*. Springer Nature.
28. Dawley, L., & Dede, C. (2014). Situated learning in virtual worlds and immersive simulations. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 723–734). Springer. https://doi.org/10.1007/978-1-4614-3185-5_58
29. Locketz, G.D., Lui, J.T., & Chan, S. (2017). Anatomy-specific virtual reality simulation in temporal bone dissection: Perceived utility and impact on surgeon confidence. *Otolaryngology-Head and Neck Surgery, 156*(6), 1142–1149. <https://doi.org/10.1177/0194599817691474>
30. Dede, C., Jacobson, J., & Richards, J. (2017). Chapter 1: Introduction: Virtual, augmented, and mixed realities in education. In D. Liu, C. Dede, H.-M. Huang, & J. Richards (Eds.), *Virtual, Augmented, and Mixed Realities in Education*. Springer Nature.
31. Foxman, M., Beyea, D., Leith, A. P., Ratan, R. A., Chen, V. H. H., & Klebig, B. (2021). Beyond genre: Classifying virtual reality experiences. *IEEE Transactions on Games, 1*–1. <https://doi.org/10.1109/TG.2021.3119521>
32. Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment, 1*(1), 20–20. <https://doi.org/10.1145/950566.950595>
33. Klopfer, E. (2017). Massively multiplayer online roleplaying games and virtual reality combine for learning. In D. Liu, C. Dede, R. Huang, & J. Richards (Eds.), *Virtual, augmented, and mixed realities in education*. Springer Nature.
34. Wang, P., Wu, P., Wang, J., Chi, H.-L., & Wang, X. (2018). A critical review of the use of virtual reality in construction engineering education and training. *International Journal of Environmental Research and Public Health, 15*(6), 1204. <https://doi.org/10.3390/ijerph15061204>
35. Herrera, F., Bailenson, J., Weisz, E., Ogle, E., & Zaki, J. (2018). Building long-term empathy: A large-scale comparison of traditional and virtual reality perspective-taking. *PLOS ONE, 13*(10), e0204494. <https://doi.org/10.1371/journal.pone.0204494>
36. Osimo, S. A., Pizarro, R., Spanlang, B., & Slater, M. (2015). Conversations between self and self as Sigmund Freud—A virtual body ownership paradigm for self counselling. *Scientific Reports, 5*(1), 1–14. <https://doi.org/10.1038/srep13899>
37. Kishore, S., Navarro, X., Dominguez, E., De La Peña, N., & Slater, M. (2018). Beaming into the news: a system for and case study of tele-immersive journalism. *IEEE Computer Graphics and Applications, 38*(2), 89–101. <https://doi.org/10.1109/MCG.2017.2801407>
38. Greenwald, S. W., Kulik, A., Kunert, A., Beck, S., Fröhlich, B., Cobb, S., Parsons, S., Newbutt, N., Gouveia, C., Cook, C., Snyder, A., Payne, S., Holland, J., Buessing, S., Fields, G., Corning, W., Lee, V., Xia, L., & Maes, P. (2017). Technology and applications for collaborative learning in virtual reality. In Smith, B. K., Borge, M., Mercier, E., and Lim, K. Y. (Eds.), *Making a Difference: Prioritizing Equity and Access in CSCL, 12th International Conference on Computer Supported Collaborative Learning (CSCL)*. Philadelphia, PA: International Society of the Learning Sciences.
39. Wu, B., Yu, X., & Gu, X. (2020). Effectiveness of immersive virtual reality using head-mounted displays on learning performance: A meta-analysis. *British Journal of Educational Technology, 51*(6), 1991–2005. <https://doi.org/10.1111/bjet.13023>
40. Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction, 60*, 225–236. <https://doi.org/10.1016/j.learninstruc.2017.12.007>
41. Meyer, O. A., Omdahl, M. K., & Makransky, G. (2019). Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment. *Computers & Education, 140*, 103603. <https://doi.org/10.1016/j.compedu.2019.103603>
42. Parong, J., & Mayer, R. E. (2018). Learning science in immersive virtual reality. *Journal of Educational Psychology, 110*(6), 785. <https://doi.org/10.1037/edu0000241>
43. Georgiou, Y., Tsivitanidou, O., & Ioannou, A. (2021). Learning experience design with immersive virtual reality in physics education. *Educational Technology Research and Development, 69*, 3051–3080. <https://doi.org/10.1007/s11423-021-10055-y>

44. Dużmańska, N., Strojny, P., & Strojny, A. (2018). Can simulator sickness be avoided? A review on temporal aspects of simulator sickness. *Frontiers in Psychology*, 9, 1-14. <https://doi.org/10.3389/fpsyg.2018.02132>
45. Miller, M. R., Herrera, F., Jun, H., Landay, J. A., & Bailenson, J. N. (2020). Personal identifiability of user tracking data during observation of 360-degree VR video. *Scientific Reports*, 10(1), 1-10. <https://doi.org/10.1038/s41598-020-74486-y>
46. Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920*. Teachers College Press.
47. Meta (2021, October 21). *The Metaverse and how we build it together* [Video]. Connect 2021. <https://www.youtube.com/watch?v=Uvufun6xer8>
48. Murray, J. F. (1988). New technology and educational television. *Journal of Educational Television*, 14(1), 5-25. <https://doi.org/10.1080/0260741880140102>
49. Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basicbooks.
50. Sanders, M., & George, A. (2017). Viewing the changing world of educational technology from a different perspective: Present realities, past lessons, and future possibilities. *Education and Information Technologies*, 22(6), 2915-2933. <https://doi.org/10.1007/s10639-017-9604-3>
51. Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Harvard University.
52. Earle, R. (2002). The integration of instructional technology into public education: Promises and challenges. *Educational Technology Magazine*, 42(1), 5-13. <http://sites.harvard.edu/fs/docs/icb.topic87187.files/Earle02.pdf>
53. Oppenheimer, T. (2003). The flickering mind: *The false promise of technology in the classroom and how education can be saved*. Random House.
54. Säljö, R. (2010). Digital tools and challenges to institutional traditions of learning : Technologies, social memory and the performative nature of learning. *Journal of Computer Assisted Learning*, 26, 53-64. <https://doi.org/10.1111/j.1365-2729.2009.00341.x>
55. Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *CITE Journal*, 9(1), 60-70.
56. Yanguas, M. L. (2020). Technology and educational choices: Evidence from a one-laptop-per-child program. *Economics of Education Review*, 76, 101984. <https://doi.org/10.1016/j.econedurev.2020.101984>
57. Cristia, J., Ibararán, P., Cueto, S., Santiago, A., & Severín, E. (2017). Technology and child development: Evidence from the one laptop per child program. *American Economic Journal: Applied Economics*, 9(3), 295-320.
58. Bailenson, J.N. (2018). *Experience on demand: What virtual reality is, how it works, and what it can do*. Norton.
59. Gagne, R., Wager, W., Golas, K., & Keller, J. (2005). *Principles of instructional design* (5th Edition). Wadsworth/Thomson Learning.
60. CAST (2018). *Universal design for learning guidelines version 2.2* [graphic organizer]. Wakefield, MA: Author.
61. Golding, D. (2019). Far from paradise: The body, the apparatus and the image of contemporary virtual reality. *Convergence*, 25(2), 340-353. <https://doi.org/10.1177/1354856517738171>
62. Harley, D. (2020). Palmer Luckey and the rise of contemporary virtual reality. *Convergence*, 26(5-6), 1144-1158. <https://doi.org/10.1177/1354856519860237>
63. Stanney, K., Fidopiastis, C., & Foster, L. (2020). Virtual reality is sexist: But it does not have to be. *Frontiers in Robotics and AI*, 7, 4. <https://doi.org/10.3389/frobt.2020.00004>
64. Jun, H., Miller, M. R., Herrera, F., Reeves, B., & Bailenson, J. N. (2020). Stimulus Sampling with 360-Videos: Examining Head Movements, Arousal, Presence, Simulator Sickness, and Preference on a Large Sample of Participants and Videos. *IEEE Transactions on Affective Computing*, 1-1. <https://doi.org/10.1109/TAFFC.2020.3004617>
65. De Leo, G., Diggs, L. A., Radici, E., & Mastaglio, T. W. (2014). Measuring sense of presence and user characteristics to predict effective training in an online simulated virtual environment. simulation in healthcare. *The Journal of the Society for Simulation in Healthcare*, 9(1), 1-6. <https://doi.org/10.1097/SIH.0b013e3182a99dd9>
66. Hakkinen, J., Vuori, T., & Paakka, M. (2002). Postural stability and sickness symptoms after HMD use. *IEEE International Conference on Systems, Man and Cybernetics*, 4, 147-152. <https://doi.org/10.1109/ICSMC.2002.1167964>
67. Munafo, J., Diedrick, M., and Stoffregen, T. A. (2017). The virtual reality head-mounted display Oculus Rift induces motion sickness and is sexist in its effects. *Experimental Brain Research*, 235, 889-901. <https://doi.org/10.1007/s00221-016-4846-7>
68. Stanney, K. M., Hale, K. S., Nahmens, I., & Kennedy, R. S. (2003). What to expect from immersive virtual environment exposure: Influences of gender, body mass index, and past experience. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 45(3), 504-520. <https://doi.org/10.1518/hfes.45.3.504.27254>
69. Nakamura, L. (2020). Feeling good about feeling bad: Virtuous virtual reality and the automation of racial empathy. *Journal of Visual Culture*, 19(1), 47-64. <https://doi.org/10.1177/1470412920906259>

Getting Started in the Metaverse

70. Mado, M., Fauville, G., Jun, H., Most, E., Strang, C. & Bailenson, J. N. (2022). Accessibility of educational virtual reality for children during the COVID-19 pandemic. *Technology, Mind and Behavior*. See: <https://www.stanfordvr.com/edvrapps/>
71. Yen, Y.-C. G., Dow, S. P., Gerber, E., & Bailey, B. P. (2017). Listen to others, listen to yourself. *Proceedings of the 2017 ACM SIGCHI Conference on Creativity and Cognition*, 158-170. <https://doi.org/10.1145/3059454.3059468>



Existing XR Learning Experiences

This list is not exhaustive nor a form of endorsement, and is limited by the experience of the authors. We look forward to adding additional examples in future work.

- [AR Reef](#): an interactive AR experience about coral reef ecology and biology.
- [Anne Frank House VR](#): an interactive VR application of the Anne Frank House narrated by passages from her diary.
- [The Book of Distance](#): an artist's interactive VR experience telling of his grandfather's experience in Japanese internment camps.
- [Cellverse](#): a collaborative VR game that "shrinks" learners to fit inside a cell in the human body to identify cystic fibrosis.
- [CRISPR Field Trip](#): 360-degree video that shows how to edit DNA with CRISPR.
- [EcoMobile](#): a tablet-based AR app students can use when visiting a pond to hear from holographic park rangers and learn about the surrounding ecosystem.
- [The Enemy](#): an AR app that puts the viewer between people on opposing sides of conflicts to hear their stories.
- [ENGAGE](#): a platform for immersive learning, meetings, virtual events, company culture, training, and development.
- [Expedition Everest](#): a VR film by National Geographic about a team of scientists, Sherpa, and storytellers studying the impacts of climate change on Mt. Everest.
- [Explore](#): an interactive underwater VR experience that visualizes coral reefs from biological to global scales and teaches the learner to collect data as a marine biologist.
- [In Protest](#): 360-degree films from inside the Black Lives Matter protests of 2020 around the United States.
- [KaiXR](#): a student-friendly platform that offers over a hundred immersive experiences and provides support for educators.
- [Mission:ISS](#): a VR experience on the International Space Station.
- [Nanome](#): a VR platform to visualize nanoscale molecules.
- [National Geographic Explore VR](#): a VR experience where the user searches for a colony of Emperor Penguins in Antarctica as a National Geographic photographer.
- [Prisms VR](#): experiences that teach math through movement, experience, and discovery.
- [Sketchar](#): an AR app that helps teach drawing techniques by augmenting physical sketches and surfaces.
- [SMALLab](#): an MR multimedia laboratory that allows learners to visualize centripetal force with their bodies.
- [The Stanford Ocean Acidification Experience](#): a VR activity showing the process by which the ocean becomes more acidic as it absorbs carbon dioxide emitted into the atmosphere and its impact on marine life.
- [Strivr](#): VR training software platform to optimize workforce performance from procedural to soft skills.
- [Teacher's Lens](#): an anti-implicit bias training for teachers.
- [Traveling While Black](#): a VR documentary that immerses the viewer in the long history of restriction of movement for Black Americans and the creation of safe spaces in their communities.
- [Tree](#): a VR experience that transforms the user into a tree to experience its life cycle in the rainforest.
- [Wildevrse](#): an AR game creating a virtual forest where the users step into the shoes of scientists tracking apes and other wild animals and learn about what conservation organizations actually do.
- [Zoe](#): a VR app that helps learners build their own virtual environments without learning to code.

Additional Collections of XR Learning Experiences:

- [Educators in VR](#)
- [Educational VR Apps database](#)
- [XR Libraries](#)
- [XR Ecomap](#)

Resources on Kids and XR

Aubrey, J. S., Robb, M. B., Bailey, J., & Bailenson, J. (2018). [Virtual Reality 101: What You Need to Know About Kids and VR](#). San Francisco, CA: Common Sense.

Hirsh-Pasek, K., Zosh, J.M., Hadani, H.S., Golinkoff, R.M., Clark, K., Donohue, C., & Wartella, E. (2022). [A whole new world: Education meets the metaverse](#). Center for Universal Education at Brookings.

Reed, N., & Joseff, K. (2022). [Kids and the Metaverse: What Parents, Policymakers, and Companies Need to Know](#). San Francisco, CA: Common Sense.